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Guide

SECOND
EDITION

Julian Walmsley

The Foreign Exchange and Money Markets Guide

WILEY FRONTIERS IN FINANCE

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Second Edition

Julian Walmsley



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Preface

This book is a revision of the 1992 edition, which many in the markets seem to have found useful. The updating was necessary because of three main factors: the arrival of the single European currency, the euro; and the rapid developments since the last edition in currency derivatives and risk management techniques. The introduction of the euro raised a number of technical issues, which are discussed in Chapter 6; it also meant that all the calculations in examples using DEM, FRF, and other “legacy” currencies had to be replaced with calculations using the euro. Recent developments in derivatives are discussed in Chapters 17 and 18; developments in risk management are covered in Chapters 19, 20, and 21.

Once again, I must gratefully acknowledge assistance: in addition to those who helped me with the previous edition, I must thank Trevor Cass of EBS and Dennis Nolan of ArbiTrain for their help; and once again, any remaining errors are my responsibility alone. Finally, I must again thank my wife, Jane, for her patient tolerance of lost evenings and weekends.

JULIAN WALMSLEY

London, England
February 2000

Preface to the First Edition

With the boundaries of the world opening, this book provides a simple practical guide to professional dealing in the world's money and foreign exchange markets. This expanded and updated version of an earlier, more limited book is as free of jargon as possible. The rapid growth of derivatives—futures, swaps, options, FRAs, SAFEs—made it necessary to update and expand the earlier book. There is also an increased emphasis on technical and charting trading methods, which are more common now than in the early 1980s.

Part 1 sets out a brief background framework introducing the basic nature of money and foreign exchange markets, the Euromarkets, the international framework in which these markets operate, and a brief guide to the prediction of rate movements. Part 2 explains basic money market calculations before looking at concepts of net present value, forward rate agreements, CD and bond calculations. Part 3 contains detailed calculations used in the foreign exchange markets: spot and forward calculations and cross-rates, broken date forwards, forward-forwards, cross-currency interest arbitrage, holiday and withholding tax adjustment calculations, and currency unit calculations (ECU, SCR). Part 4 discusses derivatives: financial futures, interest rate and currency swaps, and options. The latter topic, because of its complexity, is broken into two parts: a basic explanation of the theory including Black-Scholes and binomial models and arbitrage-free interest rate lattices, and a second chapter covering applications such as caps and floors, butterflies, bull spreads, and the like. Part 5 steps back from the detailed calculation methods to consider overall questions of risk and exposure—interest rates and foreign exchange movements—as well as the vital, but often overlooked, issue of settlement risk and procedures. The Appendices cover a number of secondary technical matters such as detailed EMS divergence indicator calculations, Islamic value dates, CME and LIFFE margin calculations.

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1 Money Markets

INTRODUCTION

There is much needless mystery about both domestic and foreign financial markets. But, in fact, the basics are very simple and can be summed up in two common adages: "Time is money" and "Nothing ventured, nothing gained." In financial jargon, the basics are the *time value of money* and the *risk/reward balance*. Net present value calculations, forward-interest rate differentials, cross-currency interest-rate swaps, binomial option trees—these notions sound complex, but they can be boiled down to simple concepts. I have tried to avoid needless jargon when writing this book; but sometimes, for the sake of brevity, it helps to use the correct technical term.

THE U.S. MONEY MARKET

The early part of this chapter treats *domestic markets*, markets in which a nation's money is traded internally. It concentrates on the United States because the U.S. dollar is the world's most widely traded currency. The latter part of the chapter brings in relevant comparisons to the United Kingdom (U.K.) and other countries where practices differ.

To begin with, *why is the money market important?* A slightly high flown answer might be that this is the market that calculates the price of time. The rate of interest set in the money market determines the time value of money, at least in the short term. This then influences spending, saving, and investment decisions throughout the economy, which in turn have an im-

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portant influence on the level of economic activity and also on the degree of inflationary pressure in an economy. Hence the central bank, which is the guardian of the currency and which has the duty of fighting inflation, will always be closely concerned with trends in the money market. In the United States, as elsewhere, the central bank intervenes constantly to steer the level of interest rates in what it believes to be the appropriate direction. Thus, understanding the money market is a key to understanding the operation of monetary policy.

What is the money market? A simple definition might be “the market in which short-term funds are lent and borrowed.” In reality, the money markets in each country tend to have a slightly different structure, involving different groups of participants and different instruments. Also, other markets overlap: for example, existing bond issues, as they approach maturity, are often used for short-term investments as a substitute for money market instruments.

The definition of *short-term* also proves slippery when examined. Most money market instruments have maturities of less than one year, and certainly by far the bulk of money market trading activity is for less than a year. On the other hand, Eurocurrency deposits are traded for maturities as long as five years. *Asset swaps*—bonds coupled with an interest-rate swap so that the combination appears to the investor like a money market instrument—typically have initial maturities of four to five years.

For most practical purposes, a reasonable working definition of the *money market* is “that market in which funds are borrowed and lent for less than one year using instruments such as bank deposits, repurchase contracts, Treasury bills or their local equivalent, commercial paper, bills of exchange (bankers’ acceptances), and certificates of deposit.” However, there might be times when this definition is unduly restrictive and a wider definition may be applicable.

Let’s now put the money market in its wider context, by looking at a flow-of-funds table for the United States (Table 1.1). This includes the flow of funds through the whole of the U.S. financial system, not just the money market, because the statistics do not separate the money market alone.

Here we can see that households borrowed almost \$487 billion, and corporations (nonfinancial companies) borrowed almost \$343 billion, whereas commercial banks and mutual funds were substantial net lenders. Mortgage pools were in balance, but government-sponsored enterprises were net borrowers. The rest of the world was a net lender of \$220 billion.

Table 1.1 Funds Raised in U.S. Credit Markets, 1998

U.S. Flow of Funds (USD bn.)	Borrowing	Lending
Federal government	-52.6	13.2
Households	486.6	-57.2
Nonfinancial companies	342.9	-3.5
Rest of world	21.9	249.1
Commercial banks	73.0	306.5
Government-sponsored enterprises	304.3	239.1
Federally related mortgage pools	192.6	192.6
Asset-backed securities issuers	317.0	275.2
Mutual funds	—	366.1
Others	404.7	509.3
Total	2090.4	2090.4

Source: Federal Reserve release Z1, March 1999.

An important channel through which money market flows are influenced is the foreign exchange market. This is less apparent in the United States, where the domestic money market is large in relation to the international market. But it can clearly be seen in the case of a country such as Switzerland. Inflows from abroad into a small country can swamp the domestic money market with excess liquidity. During the late 1970s, for example, foreign demand for Swiss francs was very strong because of the weakness of the dollar. The flow of money into Swiss francs pushed the Euro-Swiss franc deposit market into negative interest rates. One had to pay a Swiss bank for the privilege of placing money with it. Subsequently, the Swiss government imposed a 10% per quarter commission tax, meaning that foreigners were receiving -40% per annum on Swiss franc deposits. Yet because the Swiss franc appreciated by 50% during one year, such an operation was still worthwhile.

Conversely, if a currency is seen to be under pressure, funds will flow out of that currency into others that are perceived to be stronger. The authorities will often then raise interest rates to defend the currency. A classic example was the Exchange Rate Mechanism (ERM) crisis of 1992, when overnight French franc rates hit 150% per annum. In those currencies where exchange controls are in place, the effects can be spectacular. It was reported¹ that

¹Risk (October 1992).

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overnight, Irish punt rates reached 48,000% during the crisis. During an earlier crisis, the author was present on one occasion when Euro-French francs were lent at 5,000%.

A related effect arises when the central bank intervenes to support, or alternatively to lower, the value of its currency. If the central bank intervenes in support of its currency, it buys the domestic currency and sells foreign exchange. Thus, the amount of domestic currency in circulation declines, which tends to push up domestic interest rates. Conversely, if it intervenes to lower the value of its currency, it supplies domestic currency to the market. Thus the supply of domestic currency in the hands of the market rises, tending to push down interest rates. Because the U.S. dollar is the most widely traded currency in the world (largely because professional foreign exchange traders usually trade the U.S. dollar as one side of their deal), the net effect on the U.S. money markets is that there is a constant swirl of funds into and out of the Federal Reserve and the dollar holdings of other central banks, resulting from the ebb and flow of foreign exchange transactions. (The technical effects of these transactions are analyzed in more detail in Chapter 4.)

Another set of effects on money market rates can be the flow into and out of the accounts of other non-money-market participants. The Treasury has already been mentioned, but another example could be a major stock market issue. Again, this is less relevant to the United States. But in the United Kingdom, for example, large privatization issues such as British Telecom have occasionally led to significant money market effects. Investors subscribing to the issue wrote checks that then flowed through the clearing system to produce substantial short-term distortions in the marketplace.

Likewise, there are seasonal effects on the money market for holidays such as Christmas or Easter, when the public generally withdraws cash in the form of notes and coin from the banking system. This tends to drain funds from the money market—funds that then return after the holiday. Also, any interruption in the process of clearing checks for settlement can have money market effects. If the planes flying from Chicago to New York with checks for clearance are held up by fog, then the amount of float in the U.S. financial system expands briefly until the checks are finally cleared. This tends to push interest rates down, in the absence of countervailing intervention by the Federal Reserve.

SUBMARKETS: FEDERAL FUNDS, REPOS, COMMERCIAL PAPER, BANKERS' ACCEPTANCES, AND CERTIFICATES OF DEPOSIT

So far, we have talked of the money market as if it were a single entity. This is not, in fact, the case. In most countries, the money market consists of a series of interconnected pools of money.

The most important submarket in the United States is that for Federal funds (Fed funds). By definition, *Federal funds* are balances held at the Federal Reserve. A bank that holds such a balance can settle another bank's claim on it through same-day transfer. It can arrange for that other bank's account to be credited with immediately available funds. Therefore, Fed funds play a central role in the U.S. money market. They are the final means by which banks settle debits and credits with each other.

Another reason why Fed funds are so important is that banks are required by the Federal Reserve to hold a minimum average balance in their reserve account at the Federal Reserve over the week—Wednesday to Wednesday. The minimum average balance is based on the total deposits held by the bank or depository institution during the current settlement week.

Most Fed fund transactions are for overnight maturity mainly because the amount of excess funds that a given lending bank holds varies daily in an unpredictable way. Transactions for longer periods also occur, although more rarely. Fed funds traded for periods other than overnight are referred to as *term Fed funds*.

Because of the central role of Fed funds in the financial system, the interest rate payable on Fed funds is a key indicator of U.S. financial policy. The market watches the Fed funds rate like a hawk, to see if there has been any change in official policy. A change in the Fed funds rate is generally regarded as signaling a change in Federal Reserve (the Fed) monetary policy (unless it is caused by technical factors beyond the Fed's control, such as unpredicted changes in bank reserves).

Another important submarket is the market for repurchases, or *repos*. This arises primarily from the financing requirements of bank and nonbank dealers who are trading in government bonds, certificates of deposit (CDs), and bankers' acceptances. Much of their trading activity is financed by borrowing. The borrowings are secured by the assets purchased with the borrowed funds.

The normal technique is as follows: The dealer finds a corporation, a

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money market fund, or another investor who has funds to invest overnight. The dealer sells the investor, say, \$5 million of securities for roughly \$5 million, which is paid in Federal funds to the dealer's bank by the investor's bank against delivery of the securities sold. At the same time, the dealer agrees to repurchase these securities the next day at a slightly higher price. Thus, the buyer of the securities is in effect making the dealer a one-day loan secured by the obligations sold to him. The difference between the purchase price and the sales price on the repo transaction is the interest the investor earns on the loan. Alternatively, the purchase price and the sales price in a repo transaction may be identical; in that case, the dealer pays the investor some explicit rate of interest.

The Federal Reserve is heavily involved in the repo market as part of its open market operations (discussed in the next section). The Fed buys Treasury bonds from the key market makers—called primary dealers. The purchase is coupled with a commitment by the primary dealer to buy the bonds back the next day at a slightly higher price—the difference being effectively overnight interest. The repo is, in fact, a loan by the Fed to the primary dealer, but it is a loan secured on the Treasury bonds. Thus it is considered a very safe investment, and the Fed arranges repos not only for itself but also for its customers—other central banks whose currency reserves are held in U.S. dollars. (The use of repos as a tool of monetary policy is discussed in the next section, Open Market Operations.)

The Fed and the primary dealers are by no means the only players in the market, which is huge. Municipalities, banks, insurance companies, and other companies all use the market for short-term liquid investments. Current estimates of the aggregate size of the U.S. repo market are in excess of \$2 trillion. (*Note:* Throughout this book, *1 billion* means 1 thousand million, and *1 trillion* means 1 million million.) The Fed funds and repo markets are essentially for overnight money: longer-term Fed funds (term Feds) and repos (term repos) do exist, but they are much less common. For longer periods, investors use other instruments.

The primary market consists of trading in newly issued instruments, and the secondary market consists of trading in the instruments after the primary market is ended. The distinction is more important in the bond market, but it applies also to short-term money markets. The volume of secondary market activity varies from instrument to instrument.

A key part of the U.S. money market, which grew enormously during the 1980s (partly because of the troubles of the American banking system),

is *commercial paper* (CP). Commercial paper consists of a short-term promissory note, usually maturing in 30 days or less, issued by a large company. Because of its short maturity, CP is widely regarded as a very safe investment for short-term funds. Commercial paper is generally issued on demand in response to the needs of investors, on a continuous basis. To sell commercial paper, a company must agree to be "rated" by a rating agency such as Moody's or Standard & Poor's, which assesses the credit quality and rates the CP accordingly.

This is an expensive and time-consuming process, and for smaller sums of money many firms use the bankers' acceptance (BA) market. A firm shipping goods, say, from the United States to Germany might agree to take payment in the form of a bill drawn on the German importer. Once it has received the bill, it takes it to its U.S. banker who, in exchange for a commission, agrees to "accept" it: if the German firm does not pay, the bank will. Once the bank has accepted the bill, it becomes a high-quality instrument (assuming the bank's name is of high quality). The bill can be sold to investors. The BA is now backed by the German firm, the accepting bank, and, as a last resort, by the goods being shipped. Thus it is a very safe investment, and BAs usually trade at interest rates below commercial paper, which is backed only by the promise to pay of the issuing firm. However, the BA market has stagnated while the CP market has grown, as can be seen from Figure 1.1, which illustrates also the impact of the U.S. banking crisis of the early 1990s on the volume of time deposits.

An important short-term market is that for CDs, which are issued by banks and are available in maturities ranging from as short as 14 days to as long as five or even seven years. The bulk of the market is usually under six months in maturity. (If the bank wants to pay a floating rate, it will issue a floating rate deposit note, or it will do an interest-rate swap. It commits itself to paying a floating rate to someone in exchange for that party paying it a fixed rate. The fixed-rate income on the swap covers the fixed cost on the deposit note, leaving the bank paying a floating rate on the combined package of note and swap. Swaps are explained in detail in Chapter 16.) A related instrument to the deposit note is the medium-term note, which is really an extension of the commercial paper market to longer maturities.

The preceding discussion has been about trading assets and liabilities that will appear somewhere on a bank's or a company's balance sheet. There is another important set of influences on trading in the money market that comes from trading in off-balance-sheet instruments, commonly known as

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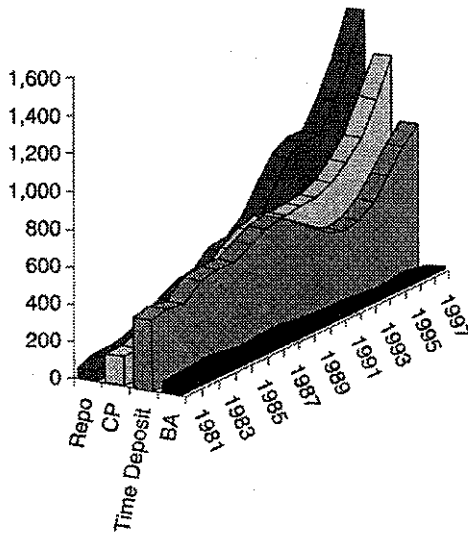


Figure 1.1 U.S. Money Market Instruments Outstanding 1981–1998 (billions of \$). *Source:* Federal Reserve.

derivatives (discussed in Chapters 15 to 18). As well as interest-rate swaps, derivatives include financial futures and interest-rate options. Trading in the financial futures markets, in particular, is of such volume that sometimes it will drive the “cash,” or on-balance-sheet, markets. United States trading in money-market-related futures is concentrated on the Chicago Mercantile Exchange, which has contracts based on Treasury bills and on Eurodollar deposits.

The interest-rate swap market (see Chapter 16) is closely linked with both the cash money market and the futures markets. The market for forward rate agreements (see Chapter 7) is another area linking the money markets to off-balance-sheet trading.

OPEN MARKET OPERATIONS

For many reasons, central banks sometimes want to adjust either the supply of money or the level of interest rates. They have available to them a number

of techniques to do this. Different methods are used in different markets. We will begin by describing those commonly used in the United States and then some of the techniques used elsewhere.

The simplest operation consists of a purchase of Treasury bills or government bonds from the banks. The banks' holdings of cash will rise, whereas their holdings of securities will fall. There is a permanent injection of reserves into the financial system. This might not always be desirable: the system might be only temporarily short of reserves. In that case, the Federal Reserve will use repurchase agreements (repos); and, in fact, repos are the main operating tool of the Fed.

The Fed intervenes on the "open market" to supply funds to the market or to drain funds from the market. The primary technique by which this is done is the daily "go-around," which for many years was at around 11:30 A.M. In 1994, the Federal Reserve began charging a fee for daylight overdrafts. Securities dealers began settling earlier in the day to reduce their daylight overdrafts. The Fed, in turn, sought to align its market entry more closely with the period of greatest market activity. In January 1997, it moved its intervention time to around 10:30 A.M., at which time the Fed decides whether it wants to supply funds to the market or to drain funds from the market. Having made this decision, it will do either a repurchase operation, in order to supply funds, or a reverse purchase, in order to drain.

The effect of these operations will depend on the reserve ratios on banks' liabilities. To see why this is so, consider an imaginary country called Home. Its currency is Home currency (HC). Assume that there is only one bank, call it Barclays, and the only other means of payment is cash. Suppose the government prints HC 1 million and pays it to Home Machine Company (HMC) in exchange for machinery. HMC pays the cash into Barclays, whose balance sheet now becomes (assuming nil balances to start with):

Liabilities	Assets
HC 1 million, HMC deposit	HC 1 million, cash

Suppose that the government requires Barclays to hold 10% (HC 0.1 million) of its assets in cash. Then Barclays can lend the other HC 0.9 million to General Motors Company (GM). Barclays proceeds to mark a credit limit for GM, which draws this down by taking out cash. Barclays's balance sheet is now:

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Liabilities	Assets
HC 1 million, HMC deposit	HC 0.1 million, cash HC 0.9 million, GM loan

GM hands the cash over to Shell in exchange for oil. Shell deposits the cash with Barclays:

Liabilities	Assets
HC 1 million, HMC deposit HC 0.9 million, Shell deposit	HC 0.1 million, cash HC 0.9 million, GM loan

Barclays can now lend 90% of HC 0.9 million, that is, HC 0.81 million, to ICI. They will pay the money to Ford, who will deposit it with Barclays, and so on.

In fact, the system keeps expanding until the original HC 1 million in cash represents 10% of Barclays's total assets, which will total HC 10 million. At this point, Barclays won't lend any more money. If it did, the ratio of cash to assets would fall below 10%, and the government would object. In other words, the 10% ratio means that an extra HC 1 million of cash can support deposits of HC 10 million. The deposits created are 10 times the original cash. If the reserve ratio is R , the multiplier is $1/R$. In our example, R equals 0.1, so the multiplier equals $1/0.1$, or 10.

It follows that if the reserve ratio is lowered to 5%, the multiplier rises from 10 to 20. The smaller the reserve ratio, the bigger the multiplier. Equally, a draining of reserves from the system will force it to shrink by the same ratio. So, open market operations can be a very powerful force by which the central bank can influence the level of the banking system's activity.

All U.S. depository institutions—commercial banks, saving banks, savings and loan associations, and credit unions—must keep a percentage of certain types of deposits as reserves. The reserve requirements are set by the Federal Reserve under the Depository Institutions Deregulation and Monetary Control Act of 1980 (see Table 1.2).

Since the early 1990s, reserve requirements have been applied only to transaction deposits (basically, interest-bearing and non-interest-bearing checking accounts). Required reserves are a fraction of such deposits. Thus, total required reserves expand or contract with the level of transaction deposits

TABLE 1. 2 Required Reserves on Checking Deposits in 1996*

Dollar Amount of Deposits	Reserve Ratio [†]	Other Provisions
Up to \$4.3 million	0%	Depository institutions hold an average amount of reserves over a two-week maintenance period; they are allowed to carry forward for one maintenance period any excess or deficiency of up to 4% of their requirements; reserve deficiencies beyond the carry-forward amount are assessed a penalty equal to two percentage points above the discount rate.
\$4.3 million to \$52 million	3%	
Above \$52 million	10%	

*Time deposits and other bank liabilities are not subject to reserve requirements at present.

[†]Fraction of deposits held as required reserves.

and with the required reserve ratio set by the Board of Governors. In practice, however, the required reserve ratio has been adjusted only infrequently.

In recent years the role of reserve requirements in U.S. monetary policy has declined as reserve requirement levels have fallen. This is because of reductions in reserve ratios and also because of actions by banks to reduce their transaction deposits artificially. Policy has focused in recent years on achieving a relatively stable Fed funds rate. This depends in part on banks having a reasonably predictable demand for reserve balances at the Federal Reserve.

Recent reductions in reserve requirements have narrowed the range of reserve levels that a bank will want at the close of the day. The changes have meant reserve demands are less stable than before. Even for many large banks, meeting reserve requirements is no longer the prime motive for holding

reserve balances. Most of the large banks offset lower required reserve balances by holding required clearing balances that pay indirect interest. These balances restore some of the predictability and the flexibility to reserve-management strategies. But the cushion has still narrowed, and the day-to-day margin for error has fallen. As the banking system's ability to cope with moderate daily swings in reserves has diminished, the Fed has found that it had to pay more attention to daily levels of reserve balances.

A recent development that has affected the conduct of open market operations considerably was the Federal Open Markets Committee's (FOMC's) change in procedures, formalized in early 1995. This meant that monetary policy decisions were published immediately after they were made. Until then the Committee's policy decisions were announced with a five-to-eight-week lag through the release of its minutes, which contain the domestic policy directive. Under the new procedures, changes in the FOMC's stance on monetary policy, including any intermeeting changes, are announced on the day they are made. The FOMC continues to release its directive for each meeting with a delay, on the Friday after the next meeting. Hence, although the market will normally pay close attention to the activities of the Federal Reserve in its open market operations, the activities are no longer necessarily expected to signal changes in policy.

RESERVE REQUIREMENTS AND THE EURODOLLAR MARKET

There is one important point about reserve requirements: their effect on banking systems depends critically on how they are structured. The U.S. system has traditionally required that reserves be held on transaction and time deposits (though the latter was relaxed in 1990 to help the U.S. banking system recover from its difficulties) and that those reserves be placed in a non-interest-bearing account with the Fed. This factor led to the growth of the huge Eurodollar market, which is exempt from reserve requirements.

An example may show the effects. Consider a bank with the choice of taking a deposit in the United States or of booking the deposit through its London branch in the form of a Eurodollar deposit (see Chapter 2). Suppose that the domestic deposit attracts a 3% reserve requirement and that the reserves must be held in the form of non-interest-bearing deposits at the Federal Reserve.

Assume the deposit is for \$100. If the deposit is taken in the United States, only \$97 is available for on-lending; the other \$3 must be placed with the Federal Reserve, earning no interest. Suppose the bank pays 10% on the deposit. The \$97 must be lent out at 10/0.97, or 10.31%, to cover the extra costs of the sterilized reserve balance of \$3; that is, if rates are at 10%, the reserves cost 0.31%. A bank that does not have to hold reserves can afford to bid, say, 0.125% better and lend 0.125% cheaper, beating the U.S. bank by 0.25%, and still have a profit margin of 0.06%. (See Figure 1.2.) This fact has spawned a multitrillion dollar market, the Euromarket, discussed in Chapter 2.

Open market operations, then, depend on reserve requirements for their effectiveness. But the interaction of reserve ratios and other controls can sometimes have unpredictable results because of the complexity and the sophistication of today's financial markets. Accordingly, open market operations are not always as simple nor as powerful as the pure theoretical model would indicate.

Still, they do give a flexible and effective way of steering the markets. Each day, the Fed enters the market to undertake these daily smoothing operations. A further refinement is that the Fed can operate in the market on behalf of its customers or on behalf of the Federal Reserve System. The two are referred to as *customer repo* and *system repo*, respectively. The latter is thought to have policy significance (though, as mentioned earlier, less so now that the market is advised immediately of any policy change). On the other hand, the former, which is an operation by the Fed on behalf of other central banks who want to invest their reserves in dollars, is not thought to have policy significance.

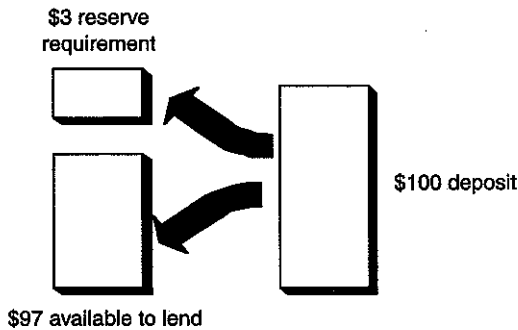


Figure 1.2 Impact of 3% Reserve Requirement

OTHER TOOLS OF MONETARY POLICY

If the Fed wants to make a more permanent adjustment to the level of bank reserves, it can do so in one of two ways: (1) It can offer to buy or to sell Treasury bonds on an outright basis, rather than on a repurchase or resale basis where the operation will unwind. (2) Much more rarely, it may move to alter the level of its reserve requirements. The former operation is more common: usually, the Fed will signal to the market that it is willing to buy certain amounts of government bonds. (This purchase is often referred to in the market as a *coupon pass*, meaning that the Fed is making a pass through the market to buy coupon-bearing government bonds. A similar operation on Treasury bills is referred to as a *bills pass*.)

Altering reserve requirements is a much more fundamental step, which the Fed takes only rarely. In 1980, for example, the Fed imposed marginal reserve requirements of 8%. Rises in bank borrowing were penalized by this method, which was an attempt to squeeze the domestic-credit growth rate. Since that time, changes in reserve requirements have rarely been used as an element of monetary policy because they have widespread and often distorting effects. In December 1990, however, the Fed removed its reserve requirements on time deposits to encourage banks to lend.

Another means by which the Federal Reserve supplies funds to the banking system is through its so-called *discount window*. This is the facility whereby the Fed, as lender of last resort, stands ready to supply funds to any member of the Federal Reserve System who needs them. A bank that is experiencing temporary financing difficulties, such as Continental Illinois in May 1984, may apply to the Federal Reserve for short-term assistance. Technically, the assistance is provided by a loan from the Fed against security of instruments that are eligible for rediscount at the Federal Reserve, such as eligible bankers' acceptances, Treasury bills, or other high-quality short-term monetary instruments. The discount window does not, however, form part of the normal routine monetary-policy tools—it is kept only for specific crisis requirements and, to a lesser extent, for specific seasonal needs of certain agricultural or other banks.

In general, the senior management of most U.S. banks display a universal reluctance to borrow from the Fed unless they absolutely must. They prefer to keep a good record with the Fed, so that in time of trouble there will be no question of their being able to get help if they need it. Also, in the late 1980s and early 1990s when the U.S. banking system was in considerable

difficulty, if a bank reported that it was using the discount window, there was some tendency for the market to see this as a sign of weakness. In consequence, senior management are very wary of using the facility unless there is a very good reason.

MONEY MARKETS IN OTHER COUNTRIES

Almost all major developed countries have money markets whose general operating structure is quite similar to that of the United States. Whereas in the 1970s and the 1980s there were many unique features—such as the insistence of the Bank of England that it deal only through the discount houses for its money market operations, and the very heavy reliance of the French authorities on regulatory ratios and “privileged circuits”—the general liberalization of the 1980s and the 1990s has meant that most major money markets operate in a broadly similar fashion. The repo market has become increasingly important in all of the major markets, including Japan where until recently the development of its repo market was held back by structural difficulties. Commercial paper has grown from a purely U.S. instrument to one that is commonly traded in most major domestic money markets. Certificates of deposit—which were forbidden in Germany, for example, until the mid-1980s—are broadly used as funding tools by banks in most markets. The one major development of recent years that warrants more detailed discussion is the arrival of the euro money market and the operations of the European System of Central Banks (ESCB) (discussed in more detail in Chapter 6).

With regard to the conduct of monetary policy, of course, there have been wider national variations, depending on the extent of the independence of the central bank concerned and also on the policy objectives of the authorities of the different countries. For example, during the period of 1996 to 1998, monetary policy in the 11 countries that joined together to become the European Monetary Union was dominated by the need to achieve “convergence” between the national economies involved. (This is discussed further in Chapter 6.) Again, however, with regard to the instruments of monetary policy, the similarities are generally greater than the differences, at least as regards the major economies of the Organization for Economic Cooperation and Development (OECD). Other central banks use tools similar to those of the Fed, but the balance of usage varies. The repurchase agreement is widely

used, but nowhere is it so widely used as in the United States. Most central banks use repos on a longer term basis than daily. For example, the ESCB (see Chapter 6) has set up a system of "main refinancing operations," rather similar to traditional German practice, whereby once a week (normally each Tuesday) it provides liquidity to the market for two weeks via repurchases or collateralized loans.

Again, similar to the traditional Bundesbank approach, the ESCB has opted to use both variable- and fixed-rate tenders for its repo operations. In fixed-rate tenders, the ESCB fixes the rate in advance; firms dealing with the ESCB bid the amount of money they want to transact at that rate. In the case of variable-rate tenders, both the amount and the rate are set by the ESCB's counterparts. The fixed-rate tender is generally considered to indicate the ESCB's target level of interest rates, whereas the variable-rate tender gives a less clear indication of the official view on rates.

The new Bank of Japan Law, which came into effect on April 1, 1998, led to some changes in the way in which Japanese monetary policy was conducted. Regular Policy Board meetings on monetary policy (Monetary Policy Meetings) were accompanied by the publication of minutes of the meetings, the aim being to improve the transparency of policy-decision-making process.

In view of the desperate condition of the Japanese banking system after its irresponsible "bubble" activities in the 1980s, the Bank of Japan in November 1998 announced further measures to provide liquidity to the economy. It was announced that the Bank of Japan, in its day-to-day money market operations, would expand the size of its repo operations, which already included commercial paper, by enlarging the scope of eligible commercial paper (from maximum 3-months maturity to maximum 12-months maturity). It also announced the establishment of a temporary lending facility for refinancing 50% of the increase in loans provided by each financial institution, at an interest rate of 0.5%. This was reinforced by plans to use corporate debt obligations as eligible collateral.

Since 1996, the Bank of England has used the repo as the primary tool of money market management, and the Swiss National Bank has also introduced repo operations. Other central banks, such as the Bank of Canada, typically also use the repo as a primary tool. On the other hand, foreign exchange swaps are also an important means of liquidity management in a number of countries, particularly those in which the foreign exchange market is large in relation to domestic money markets, such as Switzerland.

The recent introduction of a repo market in Switzerland may result in less use of this policy; but the technique is also used occasionally by the Bank of England, and the European Central Bank also includes the technique in its armory. The mechanics are laid out in Chapter 4.

Other important changes have included the rapid growth of markets previously considered "exotic" (so that many Asian countries now have money market structures whose flexibility and modernity begin to approach those of more established markets) and the continuing rise of the influence of the derivatives markets. An example of this trend has been the introduction of the overnight indexed swap market in a number of countries. The technique involves an interest-rate swap (see Chapter 16) where the floating rate is an overnight rate compounded up over the settlement period.

Compared with the situation at the end of the 1970s, for example, we can say that the world's money markets at the start of the twenty-first century present a broadly homogeneous structure. Hence, the rest of this book will concentrate broadly on a single global money market, without focusing in detail on those idiosyncrasies that make any given domestic market peculiar. This unification is itself the result of the influence of the growth and the development of the international Eurocurrency market, which is discussed in the next chapter.

2

Euromarkets and Foreign Exchange

In Chapter 1, we discussed domestic money markets. In this chapter, we begin by discussing the Euromarket, which is a transnational money market, and then move on to its twin sister, the foreign exchange market.

THE EURODOLLAR MARKET

What is a *Eurodollar*? Briefly, it is a dollar deposit that is traded outside the United States. If Citibank in London places a U.S. dollar deposit with Barclays Bank in London, that is a *Eurodollar deposit transaction*. The key feature of this operation is that it is not subject to Federal Reserve requirements. As we saw in Chapter 1, the Federal Reserve imposed a reserve requirement of 3% on deposits taken by U.S. banks until 1990. Therefore, a bank taking a U.S. dollar deposit in London could profitably undercut its domestic U.S. competitor.

This efficiency in reserve costs is the key reason for the spectacular growth of the Eurodollar deposit market, from its origins in the late 1950s to the multitrillion dollar market that it is today. However, legend has it that the origin of the markets was due not to this reserve efficiency, but to politics. During the 1950s, the Soviet Union was concerned that if it were to invest the dollars that it was earning from the sale of its oil abroad in the United States, it would face the possibility of a political decision to freeze its assets, since the Cold War was then at its height. (Jacques Attali, in his biography of Siegmund Warburg, stated that the origins of the market go back even

earlier, to the time of the Korean War when the Chinese placed some deposits with Banque Commerciale pour l'Europe du Nord in the name of the National Bank of Hungary.)

In 1958, pressure on sterling led the Bank of England to ask British merchant banks to switch their financing of third-country trade into U.S. dollars. British merchant bank demand met Russian supply, and the Eurodollar market was born. During the late 1960s, market growth was fueled by restrictions placed on it by President Johnson, as the Vietnam War placed a strain on the American balance of payment. A further kick to growth was given in the 1970s by the two successive oil crises, when Eurobanks were deeply involved in attempts to recycle the OPEC (Organization of Petroleum Exporting Countries) dollar earnings in the form of loans to less developed countries. Figure 2.1 shows the growth of the Eurodollar market over the years.

After a period of rapid growth (12% per annum from 1983 to 1990), international interbank credit shrank by 4.4% in 1991 and thereafter recovered only slowly. The major factor behind this was the retrenchment of Japanese banks, whose share in total interbank claims dropped from 36% at the end of 1990 to 29% by September 1994 and to 21% by March 1998. The slack was taken up by banks from the European Union, whose share grew from 35% to 54% over the same period.

Figure 2.2 shows the main centers for international deposits. It shows how the Japanese challenge to the United Kingdom of the late 1980s has fallen

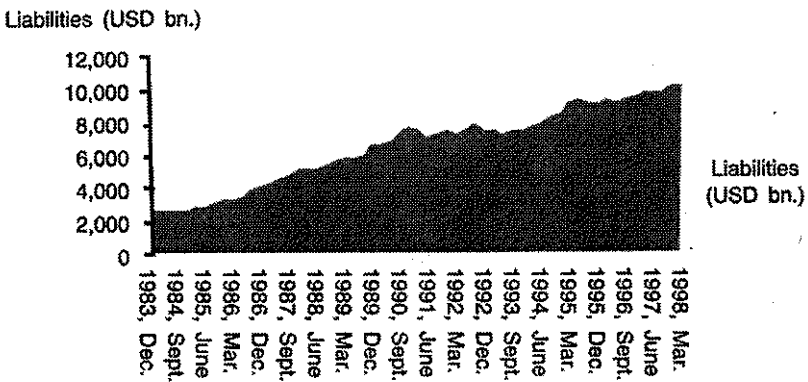


Figure 2.1 International Liabilities of Bank for International Settlements—Reporting Banks

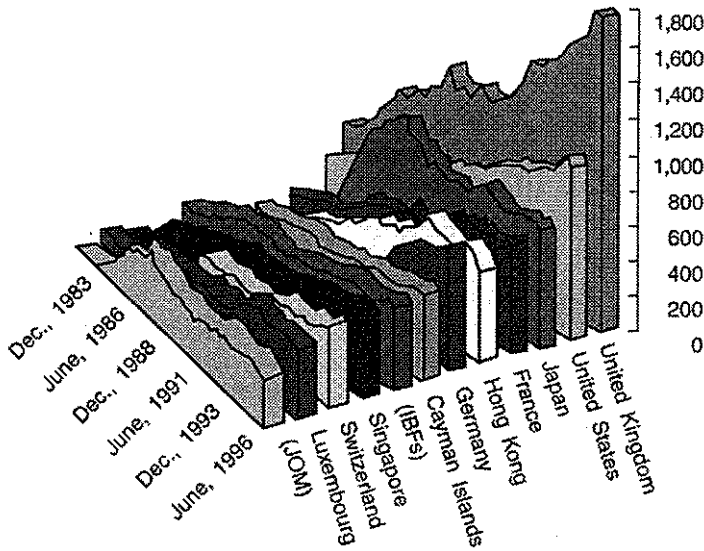


Figure 2.2 Banks' International Liabilities (USD bn.). Source: BIS.

away because the unsound Japanese banking practices of that time have made international depositors cautious of the solvency of Japanese banks. It also shows the role of the artificial "offshore-onshore" entities, International Banking Facilities (IBFs), and the Japan Offshore Market (JOM). (See Chapter 3. Note that the figures for the United States and Japan include IBFs and JOM figures, respectively, so that there is an element of double counting.) It is striking that the U.S. figures have grown steadily while the IBF figures have tended to stagnate: this reflects the removal of the Federal Reserve 3% reserve requirement on time deposits in the early 1990s. Although IBFs offer some tax benefits, they now offer no other particular advantage to a U.S. bank, which is therefore as likely to raise international funds directly as to route the deposit through an IBF.

A significant difference between Euromarket and many domestic deposit markets is that the Euromarket is almost exclusively concerned with *matched deposit dealing*—each deposit (liability) of an international bank will tend to be matched by an asset (usually a deposit in another bank) of the same currency and of similar maturity. Deliberate mismatches might be incurred with a view to making a profit, but the book of each bank as a whole will be matched within certain periods. Hence, loans are typically made for a

specified period and funded by a deposit of a similar period. This is very different from a domestic market, where large amounts of lending are typically done on the basis of a prime (or base) rate, with these loans being funded day-to-day in the domestic overnight or short-date money market or from retail deposits.

The key role of the Euromarket is twofold:

1. It provides the links between different forward foreign exchange markets. As we shall see later, forward foreign exchange rates are determined by relative interest differentials between Eurocurrency deposits in the currency in question.

2. It provides a mechanism for the taking and placing of deposits free of domestic central bank restrictions. This has spawned a freewheeling and innovative international banking system, where commercial banking and investment banking have blurred to produce a range of instruments from Eurocommercial paper through syndicated Eurocredits, to Eurobonds, and even to Euroequities.

The market is incidentally linked with a range of other markets, including those for interest-rate and currency swaps, interest-rate and currency options, financial futures, gold, and oil and other commodities. These will be discussed later.

WORKINGS OF THE EUROMARKET

By its nature a professional, wholesale market, the Euromarket has a wide range of participants. The objectives of the Euromarket dealing operation vary from bank to bank. There are at least four central objectives usually present: (1) to fund the bank's Eurocurrency loan book; (2) to provide a service to depositing customers; (3) to make profits from deliberate position taking; and (4) to ensure that the bank is seen in the marketplace as both a taker and a placer of funds, so that its name is kept in the market and is favorably received when it is necessary to raise funds.

The bulk of Euromarket activity is concentrated in the time deposit market—the taking and the placing of unsecured funds, without involving the purchase or the sale of paper—although repo activity in most major currencies has

grown rapidly during the 1990s. This recent trend has brought the international markets more in line with U.S. practice, in which, apart from the Federal funds market, banks typically lend to each other by means of repurchase agreements (involving, at least nominally, the repurchase and the sale of securities) or by means of certificates of deposit. The great bulk of the market is of rather short maturity. A proportion of these deposits is *on call*, meaning they can be withdrawn without prior notice. However, because payment is normally effected by means of transfers in the currency's home country, the minimum practical period for delivery is usually two days. This payment convention corresponds to that in foreign exchange—two working days are required for delivery.

Most Eurodollar deposits carry a fixed maturity. Normally, the deposit will be effective two business days after the contract is put into effect, and it will mature, for example, 90 days later. However, it is also possible to deal "value today" or "value tomorrow," depending on time-zone considerations.

Although the majority of Eurodollar deposits are time deposits, certificates of deposit (CDs) also play an important part. By far the largest market is for Eurodollar negotiable CDs. These are large-denomination, time-deposit liabilities evidenced by a written instrument, or certificate. The certificate specifies the amount of the deposit, the maturity date, the rate of interest, and the terms under which the interest is calculated. (See Chapter 8 for details.) Banks are free to offer their customers CDs in any size, but the minimum denomination acceptable for secondary market trading—the buying and the selling of previously issued securities—is usually \$1 million. The term to maturity of newly issued CDs is based on negotiation between the bank and its customer, the individual instrument usually being tailored to fit the liquidity requirements of the purchaser.

The operation of the market is best understood by following a deal. For instance, a major company such as Exxon has a placement of \$10 million in funds to make for three months. Exxon calls various banks and, on the basis of the rates quoted, decides to place the deposit with Barclays Bank. An interest rate of 10% is agreed on the three-month deal (which actually runs for 91 days). The interest due is calculated as USD 252,777.78— $(10/100) \times (91/360) \times \$10,000,000 = \$252,777.78$.

An acceptance ticket that contains the basic facts of the deal is prepared. This is then passed to the operations area of the bank, which sends out a separate confirmation. On the start date of the deposit—the spot date—a

CHIPS payment (i.e., a payment through Clearing House Interbank Payment System in New York) is made by Exxon from, for example, Citibank to Barclays for account of Barclays's Nassau branch. The funds never leave New York. They are simply credited to Barclays Nassau on a memorandum account at Barclays New York. At maturity, Exxon decides that it wishes to roll the deposit over for a further three months. On checking the rates, it finds that Bank of America now pays a better rate than Barclays. Accordingly it instructs Barclays to transfer the principal and the interest due by means of a CHIPS payment to Bank of America's London branch. Again the funds do not leave New York.

Euro-commercial paper (ECP) existed in its own right before the arrival of underwritten facilities. Attempts were made in the early 1970s to develop a Euro-commercial paper market, which reached a peak of \$2 billion in outstandings. But in 1974 the lifting of U.S. balance of payments controls cut back the market, because U.S. companies found it cheaper to fund domestically.

The growth of today's market began with underwritten facilities. Underwritten note facilities began in 1978 with an issue by the New Zealand Shipping Corporation. But the instrument attracted little attention. None were issued in 1979, and the 1978-to-1983 period saw only a total of 86 facilities representing USD 9 billion. The market began then to change its shape: rather than the emphasis on underwritten facilities that prevailed during the early development of the market, the emphasis started to shift toward issues that are not underwritten—true Euro-commercial paper.

The market has now clearly matured into an important short-term source of funds for global borrowers. The early rapid pace of growth dropped back in view of the higher-level, shorter-term rates in 1989 and 1990 and of growing liberalization of domestic commercial paper (CP) markets in countries such as Japan, but it has picked up again recently, as can be seen from Figure 2.3, which illustrates also the falling proportion of U.S. dollar ECP as a percentage of the total.

LEGAL NATURE OF A EURODOLLAR

Finally, it is worth touching on an issue that was raised very briefly earlier: What is a Eurodollar? We said then that it was a dollar deposit that was traded outside the United States. Similarly, a Euroyen is a yen deposit traded

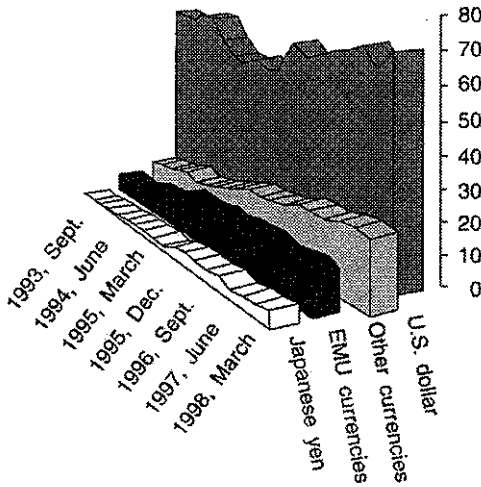


Figure 2.3 Euro-commercial Paper (USD bn.). Source: BIS.

outside Japan. We do need to make some refinements to this definition, however. For example, the IBF in New York and the JOM allow effectively for the on-shore trading of Eurocurrencies. A dollar deposit placed with an IBF in New York is in fact a Eurodollar because it is not subject to Federal Reserve requirements. By contrast, a dollar deposit placed in a country in which it is subject to domestic reserve requirements (as used to be the case in Germany, where reserve requirements did not operate by currency, but by the location of the deposit-taker) is not a Eurodollar. Thus, the key determining factor in whether a currency deposit is or is not a Eurocurrency deposit is whether it is exempt from domestic reserve requirements.

A related issue is the legal question of jurisdiction over the Euromarkets. Traditionally, the Bank of England had jurisdiction over the Eurodollar and over Eurocurrency activities of banks operating in London. It was the supervisory authority for these banks, and in London its word was (for practical purposes) law. (Its role has now been taken over by the Financial Services Authority.) But the taking and placing of U.S. dollar deposits (as was explained earlier) actually involves a transfer of U.S. dollar funds across the books of a bank in New York. Thus, Eurodollar activities are potentially subject to interference from the U.S. authorities.

This apparently arcane point has been a vital issue on several occasions, notably the freeze imposed on Iranian assets by President Carter, the dispute

between the United States and Libya that led to the freezing of Libyan assets, and the multinational freeze on Iraqi assets after the Iraqi invasion of Kuwait. The whole issue hinges on the sensitive question of the extraterritorial application of one country's law (in this case, the United States) in the domestic activity of another country (in this case, the United Kingdom). There have been a number of legal cases that have shed light on related issues: the seizure of assets in Palestine in 1947 (*Barclays Bank v. Arab Bank*), the case against Chase Manhattan regarding deposits in its branch in Saigon, the numerous cases arising out of the Iranian freeze, and, perhaps most interesting, *Libyan Arab Bank v. Bankers Trust*.

The salient facts of the last case are as follows: In 1973 Libyan Arab Foreign Bank (LAFB) opened a call deposit account at the London branch of Bankers Trust (BT). In 1980 a demand current account was opened in New York to give easy access to the New York clearing system (CHIPS). It was agreed between LAFB and BT that all day-to-day payments would be made out of LAFB's New York account, but that any balance of over USD 500,000 would be transferred at the end of each day to its London account in tranches of USD 100,000, or the other way if there was a shortfall in New York. It was further agreed that the New York account would be checked twice daily at 2:00 P.M. and 4:30 P.M. to check whether transfers should be made. President Reagan's freeze regulations came into effect at 4:10 P.M. Eastern Standard Time, and within minutes the U.S. Treasury had informed U.S. banks of its effect. As a consequence, LAFB found its accounts in both New York and London frozen.

In this case, BT contended that Eurodollar denominated accounts were not repayable on demand in cash anywhere outside the United States because they had to clear through the CHIPS system in New York. In September 1987, the High Court in London came to the view that the deposits were in London, subject to English law. The presidential freeze of Libyan assets could affect the usual transfers via New York clearing, but this was not the only possible way to repay the money to the Libyans. BT was obliged to use all methods open to it to discharge its obligation. It could pay cash (that is, bank notes) in dollars or in sterling, and it was obliged to pay not only the \$131 million on the London deposit account but also an additional \$161 million that should have been (but was not) transferred from the New York account to the London deposit account.

The issue of whether the home office of a Eurobank will be held liable for Eurocurrency deposits at its foreign branches was addressed in the United

States in *Wells Fargo Asia Ltd. v. Citibank*. Wells Fargo had deposits with Citibank in Manila. The authorities in the Philippines imposed a freeze on foreign payments in 1983. Wells Fargo sued in New York for repayment in New York. The court held that under the law of the Philippines, the branch was not a separate legal entity, and therefore Citibank was obliged to repay with assets from anywhere, as long as such assets were not from the Philippines branch. After a series of appeals, judgment was ultimately given in favor of Wells Fargo. This decision has been criticized and indeed seems illogical.¹

Clearly, each case will depend entirely on its circumstances. What the LAFB case does suggest, however, is that in general at least the British courts will tend to uphold the freedom of the Euromarkets from interference by other governments, unless the U.K. government also chooses to support this interference by making the actions of governments subject to legal enforcement in London. Naturally, the legal status of Eurocurrency deposits in other centers depends on the local legal arrangements.

THE FOREIGN EXCHANGE MARKET

What is the foreign exchange market, and what is its role? The *foreign exchange market* is the arena in which the currency of one country is exchanged for the currency of another, and in which settlement is made for international purchases and sales. Just as the domestic money market is the place where financial flows through a single economy are managed, so the foreign exchange market is the place where financial flows between countries are settled. Payments for imports and exports flow through the foreign exchange market; so do payments for international purchases and sales of assets. A Japanese investor buying IBM shares will go through the foreign exchange market to buy the U.S. dollars to pay the broker who has sold him the shares. Over the last decade, these international investment flows have played an increasingly important part in the foreign exchange market as securities markets have become more global. The foreign exchange market is also an arena for trading activities on a global scale by a range of participants. Their activities can drive currencies up and down depending on short-term views

¹See E. M. A. Kwaw, *Grey Areas in Eurocurrency Deposits and Placements*, Dartmouth Publications (Aldershot UK/Brookfield USA), 1994.

about the directions of such important factors as relevant interest rates and relevant inflation rates.

The foreign exchange market, therefore, is a turntable for the international flow of funds. Funds move *into* a country when its economic policies are seen as attractive or when firms within it are seen as being dynamic and well managed, thus making the stock market attractive. Funds flow *out* if there is political uncertainty, if interest rates are perceived as too low in relation to inflation, or if the country is perceived as running a chronic deficit on its balance of trade or payments with no action forthcoming to rectify the problem.

From time immemorial, governments and their central bankers have tried to influence the foreign exchange market. Typically, this has been done in two main ways: (1) exchange controls and (2) intervention. *Exchange control regulations* prevent the citizens of a country from doing certain things (such as sending money abroad) that are felt by the central bank to have a negative effect on the exchange rate. *Intervention* can take two forms: (1) changing the level of interest rates on the currency so as to make it more or less attractive to foreigners, or (2) buying or selling the currency so as to raise or lower its market value. Sometimes a central bank can get away with merely looking as though it will do something: dealers will cry, "The Bank of Japan is checking levels in the dollar," and that in itself may be enough to trigger a move in the dollar/yen rate. At other times, the central bank has to put its money where its mouth is, sometimes in ever larger and more desperate quantities. The Bank of England, for example, during the 1960s and 1970s often had to spend large amounts of money to support sterling. Those sums had to be borrowed from elsewhere—from either the Bank for International Settlements or the International Monetary Fund (see Chapter 5).

Although statistics have improved, nobody knows how big the world market for foreign exchange really is—just that it is huge. A recent estimate by the Bank for International Settlements (BIS) put the average daily turnover in the world market at \$1,490 billion in April 1998 (net of double counting), which compares with an average daily turnover on the New York Stock Exchange of \$36 billion for the first quarter of 1999. It also compares with the total foreign exchange reserves of all countries as reported by the International Monetary Fund (IMF) of SDR 1,200 billion (equivalent to \$1,600 billion). (The special drawing right [SDR] is defined in Chapter 14.) In other words, the entire reserves of all countries, if committed to foreign

exchange intervention, could be swallowed up in about one day's normal trading volume of the world market. Turnover in the spot market alone, at an estimated \$590 billion, is equivalent to 36% of world reserves. Of course, exchange rates are determined by the net demand for currencies rather than gross turnover, and central bank intervention can have psychological effects. But as the BIS has pointed out: "Exchange market intervention on its own is bound to be of only limited significance over a longer period."

Figure 2.4 shows the growth of world foreign exchange reserves since the early 1960s and also shows the percentage change on an annual basis. Although the absolute figures have grown very rapidly during the past 10 years, the speed of growth has never again attained the explosive 60% growth seen in 1971 when the pressure on the U.S. dollar was at its height and when all major governments were aggressively intervening to try to maintain the U.S. dollar's link with gold.

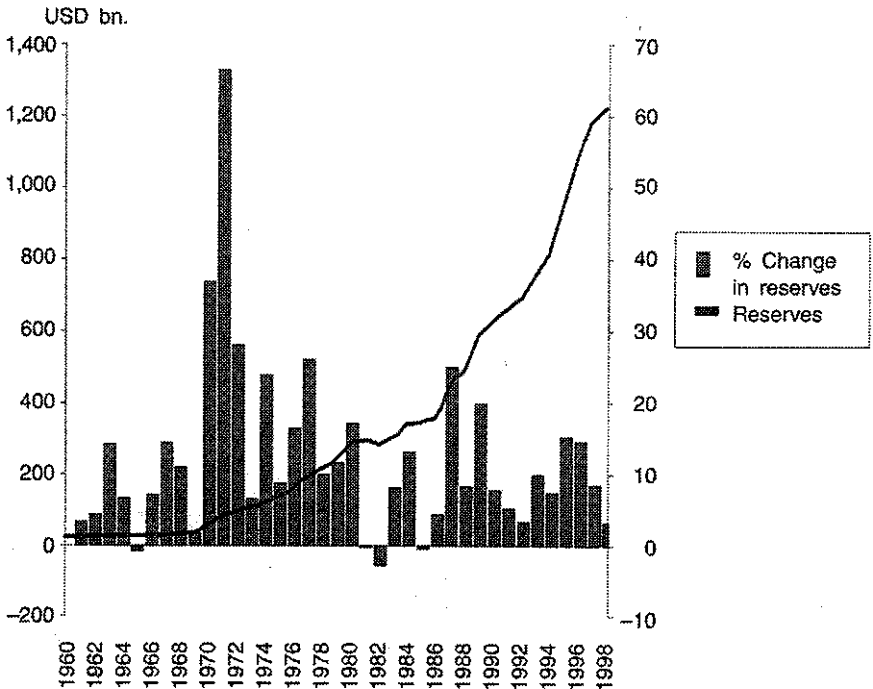


Figure 2.4 The Growth of World Foreign Exchange Reserves Since the Early 1960s

The BIS survey, whose coverage has been gradually expanding since the first survey in 1983, showed a total growth in turnover of 42% from 1989 to 1992; the growth rates for 1992 to 1995 and for 1995 to 1998 were 45% and 46%, respectively (after adjusting for the effect of exchange rate movements); so the market as a whole has sustained rapid growth over the decade. The 1998 survey showed interdealer turnover accounting for 63% of the total—a figure that is sharply down on earlier years; greater participation by investing institutions, in particular, appears to account for this. Another trend has been the tendency toward consolidation in the market: the U.K. share of world foreign exchange (FX) turnover in 1989 was 26%, while by 1998 this had risen to 32%. By the same token, the U.S. share over the period rose from 16% to 18%; both centers probably gained at the expense of Japan, whose share fell from 15% to 8% over this period.

Other key features of the most recent BIS survey of world foreign exchange markets are illustrated in Figures 2.5 to 2.7.

As Figure 2.5 shows, the four major markets are the United Kingdom, the United States, Japan, and Singapore, followed fairly closely by Germany, Switzerland, Hong Kong, and France, with Canada and Australia some way behind. Of course, there are numerous other centers, but those shown account for 85% of the world market.

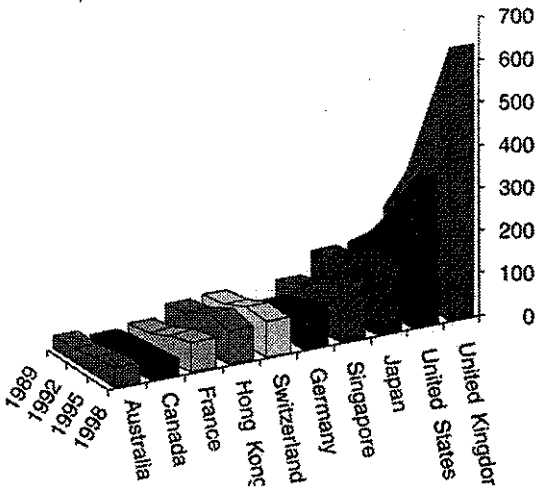


Figure 2.5 BIS FX Turnover Data

Figure 2.6 shows that if the study is confined to over-the-counter (OTC) derivatives turnover, the picture has some interesting differences: France overtakes Japan in importance, and Hong Kong and Australia drop out of the picture to be replaced by Belgium and the Netherlands.

Finally, Figure 2.7 puts the foreign exchange market in the context of the other markets surveyed by the BIS.

Collectively, the exchange-traded interest-rate instruments are the largest market, followed by forward foreign exchange. (This is a change from the earliest survey, when the spot market was larger, and is, of course, due to the development of cross-currency interest-rate trading via swaps and forward rate agreements [FRAs], which enhanced arbitrage with the forward market.) On the other hand, had the survey data split exchange-traded interest-rate derivatives between money market and bond instruments, which would make economic sense because they are quite distinct markets, the foreign exchange market would probably have shown up as the largest.

Participants in the market consist of five main groups: (1) commercial banks, (2) other financial institutions, (3) corporate customers, (4) central banks, and (5) brokers. By far the largest volume of trading is conducted by commercial banks, but the role of other financial institutions has grown considerably with the growth of global investment and also the growth of

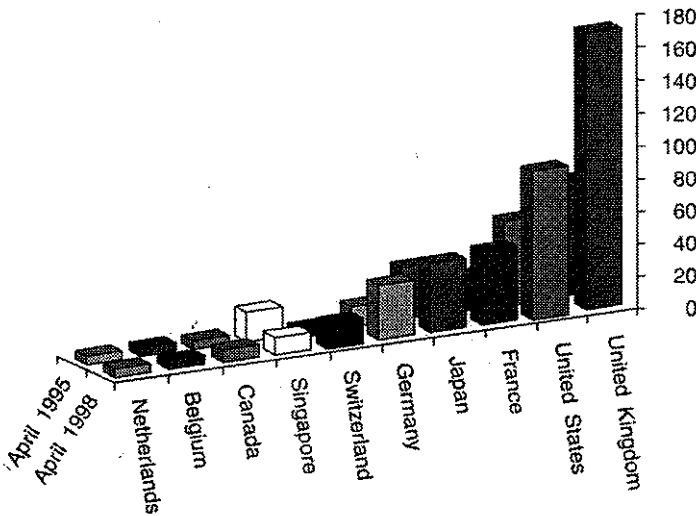


Figure 2.6 OTC Derivatives Turnover (USD bn.). Source: BIS.

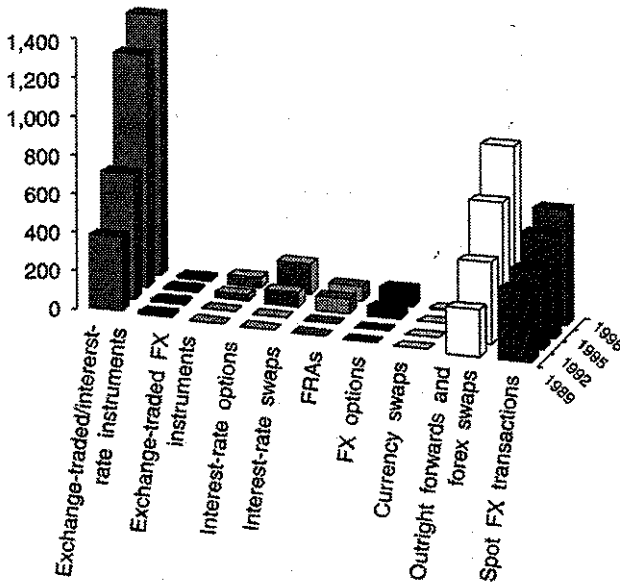


Figure 2.7 BIS Survey Data (USD bn.). Source: BIS.

the derivatives markets, in which the investment banks play an important role. Investment managers—in the shape of pension funds, mutual funds, and insurance companies—also play a key role, particularly because their trades are often seen as trend setting. In the corporate sector, the two largest trading groups have traditionally been the oil companies and the commodity companies. This is because commodity markets generally trade on an international basis in a single currency (usually the dollar, but also sterling for certain commodities) but have sales denominated in the local market currency. The role of the central banks is generally passive, responding to events. But occasionally their policies can take on tremendous significance for the market players. Their role is discussed more fully in the next paragraphs.

For some years now the pattern of market activity has been relatively common between the different centers. The major participants are the central banks, commercial banks, companies, and foreign exchange brokers. Banks typically trade directly with other banks on the international markets, although sometimes they will trade through a broker (human or, increasingly, electronic) if this is more convenient. In domestic markets, they will often

also trade directly with one another, but, perhaps more than in international markets, they also tend to use the services of a broker. Each of the two methods has its own advantages. In dealing directly, a bank can normally be sure of getting a price at which it can deal. The convention is that a bank that receives a call from another bank asking for a quotation will quote a "two-way" price at which it is prepared to buy or to sell the currency. But this price may not be the best available in the market at the time, or it may only be good for a limited amount. On the other hand, it is the broker's job to find a customer the best possible price in the market by using his or her large communications network with many other banks in the market. Accordingly, on some occasions a better price may be obtained through the broker: this, however, incurs a brokerage fee. At the same time, a bank contacted by a broker need not necessarily make a "two-way" price, so that the broker may not always be able to find the right side of the deal.

In recent years electronic brokerage has come to play a very important role, particularly in the spot foreign exchange market. The two main protagonists in this revolution have been Reuters and Electronic Broking Services (EBS). There has been some debate about how to define *electronic brokerage*. One might offer a generic definition of electronic broking of spot foreign exchange as follows: "A system by which a principal (bank) can broadcast an interest to buy or to sell a currency at a specified price in a specified amount against another specified currency; or for that principal to buy or to sell on the basis of another principal's interest expressed in the same terms."²

Electronic broking systems facilitate the first stage of this process anonymously and match buyer to seller. The impact of electronic broking has been considerable: by October 1998, for example, EBS was reporting a daily average trading volume of \$100 billion, or almost 7% of the market (using the BIS April 1998 figure for the total market).

One of the unexpected side effects of electronic broking was that smaller banks no longer had to rely on the services of larger banks—either directly or through brokers. Electronic broking allowed direct access to a wider range of counterparts. This cut out the traditional, expensive need to maintain a network of "correspondent" relationships with the bigger "supplier" banks.

Another structural influence on the foreign exchange market is the pres-

²I owe this definition to Trevor Cass of EBS.

ence or lack of exchange controls. Exchange controls are the earthworks that prevent the foreign exchange tide from flowing freely round the world. As a result of the Asian crisis of 1997–1998, some countries, notably Malaysia, have argued the view that “irresponsible foreign speculators” have damaged the country’s financial position and that this must be overcome by the imposition of exchange controls. The former criticism exactly reflects the cries in Britain and France, for example, in the 1960s and 1970s and reflects the same problem. This is the failure by the politicians involved to grasp that exchange rates are too liquid a market to be manipulated by a small conspiratorial group (be they hedge fund managers in 1997 or the “gnomes of Zurich” in 1967). The rest of the market will only follow such speculators if there are sufficient reasons for believing there is a potential problem. Undoubtedly there is often a herd mentality in the market—but for the herd to be stampeded, there has to be some evidence of a problem and, more important, evidence of a failure by the government concerned to act to correct the problem.

Other critics noted that countries such as Taiwan and India, which had never fully liberalized, had been less affected by the crisis. This was clearly true: a boat that is anchored rigidly to the shore is less likely to be buffeted in a storm than an oceangoing vessel is. By the same token, the price to be paid for such a strategy is an acceptance of rigidity and a limitation of freedom: the oceangoing vessel offers greater potential in the long run.

It remains the case, however, that the number of countries retreating behind the barriers of exchange controls is relatively small. The liberalization and globalization of the markets during the 1980s and 1990s now means that most important countries have relatively free markets. Now all major countries are effectively free from exchange controls, and the world’s communication networks are now so good that it is possible to talk of a single world market for foreign exchange. It starts in New Zealand around 9:00 A.M., just in time to catch the tail end of the previous night’s U.S. market. Two or three hours later, Tokyo opens, followed an hour later by Hong Kong and Manila and then half an hour later by Singapore. By now, with the Far East market in full swing, the focus moves to the Near and Middle East. Bombay opens two hours after Singapore, followed after an hour and a half by Abu Dhabi, with Jeddah an hour behind, and Athens and Beirut an hour behind still. By this stage, trading in the Far and Middle East is usually thin and perhaps nervous as dealers wait to see how Europe will trade. Paris and Frankfurt open an hour ahead of London, at which time Tokyo is starting

to close down, so the European market can judge how the Japanese market has been trading by the way they deal to close out positions. By lunch time in London, New York is starting to open up, and as Europe closes down, so positions can be passed westward. During the afternoon in New York, trading tends to be quiet, the problem being that there is nowhere left to which to pass the position. The San Francisco market, three hours behind, is effectively a satellite of the New York market. Positions can be passed on to New Zealand banks, but the market there is relatively limited. There has been an increasing tendency for banks to open two or three shifts so as to run 24-hour dealing rooms, but the vast majority of the market still tends to work in daylight hours.

Like its trading, the influences on the foreign exchange market are worldwide. Not only domestic and international money markets but also a range of other markets influence trading activity. Flows of funds into and out of the major stock markets, and the major bond markets, can have a significant impact. So, too, can sharp movements in either gold or oil or in some of the other major commodities. Activities in the futures markets can have an impact, as can flows arising out of the markets for interest-rate or currency swaps, currency options, or other financial options markets. We will look at all of these markets in more detail. But before we do that, it may be useful to look at the history of these markets. Although the details of past history may not seem relevant as we try to make sense of the maelstrom of information being pumped at us by the Reuters and Bloomberg screens and the newspapers, it is well to remember Santayana: "Those who cannot remember the past are condemned to repeat it." The forces that shaped the past may still be relevant to understanding the events of today.

3 The Euromarkets and Global Financial Integration

In this chapter, we consider the role that has been played by the Eurodollar and foreign exchange markets in helping the process of global financial integration. We begin by considering the historical development of the markets and move on to look at the process of financial integration that began to accelerate in the 1980s.

HISTORY OF THE FOREIGN EXCHANGE AND EURODOLLAR MARKETS

The history of foreign exchange markets goes back a very long way: they were old when the Bible reported money changers being chased out of the Temple by Jesus Christ. The global market itself began to develop during the nineteenth century, as the term *cable* for sterling will attest. It derives from the rate for the cable transfer between London and New York.

By the 1920s, the markets were developed enough for Maynard Keynes to form a syndicate to speculate on the deutschemark. But the economic chaos resulting from the depression of the 1930s led to the so-called “beggar thy neighbor” policies of competitive depreciation—one country, in order to try to boost the level of its exports, would depreciate its currency aggressively, only to be overtaken by another country intent on doing the same. This led to a reaction.

In 1944, the Allies met at Bretton Woods to lay down a postwar foundation for stable exchange rates. This took shape in the form of the International Monetary Fund (IMF; see Chapter 5). The object was to provide a system whereby exchange rates would be held stable and, if necessary, countries could be supplied with the finance to ensure that this took place.

The IMF's Articles of Agreement permitted adjustment of the currency's par value only if the country's balance of payments was in "fundamental disequilibrium." This was an imprecise concept, but it came to mean that exchange rates would be adjusted only as a last resort and only in conjunction with other policies to redress the disequilibrium.

The system worked well to begin with because, in the immediate postwar world, financial flows were very tightly regulated by exchange controls in a number of countries. In 1958, however, the international convertibility of most major currencies was restored, and the international financial system began to experience regular exchange-rate crises.

Early pressure on the U.S. dollar led, in 1963, to the introduction of the Interest Equalization Tax: a tax on bond issues made in the United States by foreigners. It led to the growth of the Eurobond market and thus helped the growth of the Eurodollar market, which was also helped by the existence of the U.S. Regulation Q. This was a Federal Reserve regulation restricting to 5.25% the rate of interest that could be paid by U.S. banks on deposits. As U.S. interest rates rose with inflation, so did much U.S. dollar deposit activity shift to the Euromarket.

Once the pressure on the dollar eased, the next flash point was the pound sterling, which was widely perceived as overvalued, given the United Kingdom's relatively high exchange rate, poor labor practices, and low productivity growth. The U.S. dollar, however, also began to come under increasing pressure for similar reasons, exacerbated after 1965 by the impact of the Vietnam War on the U.S. balance of payments.

Sterling was the first to crack, in 1967, partly as a result of the Seven-Day War between Israel and Egypt, which triggered concern about sterling balances. These were balances held in sterling by foreign central banks and by international investors as a result of the then key role played by sterling in the international financial system. The devaluation of sterling by 14.6% in November 1967 temporarily calmed the situation, but only briefly. With sterling removed from the firing line, the U.S. dollar now stood exposed to the full force of international speculation.

In 1969, the fall of General Charles de Gaulle resulted in strong upward

pressure on the deutschemark. The French franc was devalued by 11%, and the deutschemark revalued by 9.3%. During 1970, the situation calmed down somewhat, but in 1971 the downward pressure on the dollar and the upward pressure on the deutschemark were strongly renewed.

On May 28, 1971, U.S. Secretary of the Treasury John Connally announced, "We are not going to devalue. We are not going to change the price of gold." On August 15, President Nixon suspended convertibility of dollars into gold and announced a domestic wage price freeze. In December 1971, a meeting at the Smithsonian Institution in Washington, D.C., resulted in an agreement that a realignment of currencies included a devaluation of the dollar.

Figure 2.4 (page 28) puts in perspective the pressure on the international financial system during this period. As governments intervened to support the U.S. dollar in ever larger amounts, world foreign exchange reserves exploded, growing by over 60% in 1971. (To see how intervention increases reserves, see Chapter 4.)

The Smithsonian agreement marked the beginning of the end for the gold-dollar link. The U.S. Treasury had sold, net, more than US\$10 billion worth of gold between December 1958 and August 1971, cutting its gold stock in half. Sales to France and in the London gold market to stabilize the market price around the official price accounted for much of this total. In an effort to create an alternative international reserve asset, the United States pressed for the creation of a reserve asset whose supply could be systematically increased as the world economy expanded. This approach eventually resulted in an agreement to create *special drawing rights* (SDRs) of the International Monetary Fund in 1968; the first allocation of SDRs was made in January 1970. However, none of these efforts was sufficient to offset the underlying economic weakness of the dollar at a time when the economies of other countries were expanding after the devastation of World War II.

In March 1972, the European Economic Community (EEC) decided to fix narrow margins of 2.25% among member currencies in order to form a "snake" in the Smithsonian "tunnel." This became the seed that later grew into the European Monetary System (EMS). During May of 1972, the United Kingdom, Denmark, Ireland, and Norway joined the snake; in June, the United Kingdom and Ireland left the snake, together with Denmark (which rejoined in October). The pressure on the U.S. dollar continued, and the German government adopted exchange control measures designed to prevent

the inflows from abroad; at about the same time, the Swiss introduced negative interest rates, with the same objective.

In February 1973, the pressure on the U.S. dollar became intense, and the United States announced a 10% devaluation. This triggered the announcement by Japan and then by Italy and Switzerland that their exchange rates would float; in March, the EEC ministers announced the joint float of snake currencies against the U.S. dollar. The era of floating exchange rates had begun, although at the time, the situation seemed purely temporary.

The adoption of floating exchange rates turned out to be a very useful device in view of the imminent economic chaos caused by the Yom Kippur War in the autumn of 1973, which resulted in the imposition by the Organization of Petroleum Exporting Countries (OPEC) of an oil embargo. Initially, the U.S. dollar benefited as the oil producers redeposited their reserves in U.S. dollars and sterling. The banks involved then proceeded to recycle the OPEC deposits by on-lending them to developing countries to help them finance their balance-of-payments problems. Such recycling was actively encouraged by major governments. But when the developing countries were unable to repay their borrowings, official support for the banks involved was hard to find, and the less-developed-countries (LDC) debt crisis of the early 1980s began.

In both the United States and the United Kingdom, the failure of economic policy to produce the required reduction in balance-of-payments deficit led to severe pressure on the currency. Sterling experienced the crisis first, falling through \$2.00 in March 1976; in June, the United Kingdom was forced to borrow USD 5.3 billion under an international standby facility. In January 1977, the IMF approval of a loan to the United Kingdom, together with a further standby loan from the Bank for International Settlements (BIS) allowed sterling to begin to recover, which in turn exposed the position of the U.S. dollar to international attention.

The U.S. dollar came under intense pressure during the summer and autumn of 1977, with other countries having to make desperate efforts to prevent outflows from the United States into their currency. In November, Japan imposed a 50% marginal reserve requirement on "free yen" balances, and in December, the Bundesbank increased marginal reserve requirements on nonresident deposits to 100%. Negative interest rates in Switzerland reached -40% per annum.

In July 1979, Paul Volcker was appointed Chairman of the Federal Reserve, and in September and October, he raised the U.S. discount rate from 10%

to 12%, imposing an 8% marginal reserve requirement and announcing a "New Monetary Policy" that would focus henceforth on levels of bank reserves, rather than interest rates. Although this had the effect of temporarily stabilizing the situation, a further round of pressure began to develop in December 1979 when OPEC raised the oil price another 30% and the Soviet Union invaded Afghanistan. The price of gold moved from just under \$400 per ounce at the end of September to \$512 per ounce at the end of December and \$850 per ounce on January 25, 1980.

In December 1981, the United States introduced International Banking Facilities, which effectively allowed Euromarket activity in New York. International Banking Facilities (IBFs) are subject to restrictions that are aimed at stopping any leakage between IBFs and domestic banking. This was emulated in 1986 by the Japan Offshore Market (JOM).

Also in 1981, the new Reagan Administration decided to move away from what it judged to have been the heavy levels of foreign exchange intervention inherited from the previous administration. This reflected an ideological view that exchange rates were the product of economic policies and that the "supply side" policies of the new administration would be sufficient to produce satisfactory market conditions. In reality, what happened was that a combination of shortsighted tax cuts, aggressive increases in defense spending, and a lack of administrative control produced a very rapid rise in the U.S. budget deficit, which was offset by very tight Federal Reserve monetary policy. This pushed the U.S. dollar up sharply.

This in turn produced other repercussions, particularly for the LDCs, which had borrowed U.S. dollars in order to finance the balance-of-payments deficit caused by previous oil price rises. The strength of the dollar and high dollar interest rates made their position increasingly difficult, and in August 1982 Mexico triggered the beginnings of an international LDC debt crisis by announcing that it could not meet its obligations. Partly as a response to Mexico and partly because U.S. inflation was showing signs of coming under control as a result of the strength of the dollar and the relative slowdown of domestic demand, the Federal Reserve began to ease interest rates. This in turn triggered a strong bull market in U.S. dollar bonds and subsequently in U.S. equities.

By the summer of 1985, it was apparent that the ideologically based U.S. policy of "benign neglect" of the U.S. dollar appreciation (based in part on the simplistic view of President Reagan that "a strong dollar shows that the United States is strong") had led to massive distortions of international payments

in balances. The U.S. external deficit was beginning to explode as the United States was becoming increasingly uncompetitive: this in turn was leading to domestic U.S. demands for protection from foreign competition.

On September 22, at the Plaza Hotel in New York City, the finance ministers of the Group of Five (United States, Japan, Germany, United Kingdom, France) met to try to deal with the situation. Behind the scenes, delicate negotiations on intervention strategy took place. A statement of intervention policy, dubbed the "non-paper" because of its sensitivity, was prepared but never made public. The non-paper looked for a 10–12% fall in the dollar and for intervention shares assigned as follows: United States, 25%; Germany, 25%; Japan, 25%; United Kingdom, 12.5%; France, 12.5%. The Europeans, however, objected, feeling that the United States and Japan should share more of the burden. The United States offered a compromise: United States, 30%; Germany, 25%; Japan, 30%; United Kingdom, 5%; France, 10%.

The non-paper did not discuss interest rates and monetary policy, nor did the central bank governors attending the Plaza meeting discuss monetary policy or interest rates at the meeting. They considered the topic too sensitive to be discussed in the presence of politicians.

By January 1986, the United States was pressing other members of the Group of Five for a coordinated cut in interest rates, citing lower U.S. growth estimates for 1986 and also the collapse in oil prices as a justification. The Treasury secretary, James Baker, warned that unless other countries cooperated the dollar would fall farther. The central bankers, however, resisted this pressure. It was against this background that in February 1987 officials of the Group of Seven (the Group of Five plus Canada and Italy) met at the Louvre in Paris. They expressed concern that "further substantial exchange rate shifts could damage growth and adjustment prospects in their countries." Therefore, they agreed to "cooperate closely to foster stability of exchange rates around current levels."

In fact, the commitments of the Louvre Accord were much more precise—two specified midpoint rates were agreed: 1.8250 deutschemarks (DEM) to the dollar and 153.50 yen to the dollar. A variance in the exchange rate of plus-or-minus 2.5% was determined as a first line of defense for mutual intervention on a voluntary basis; at plus-or-minus 5%, consultation on policy adjustment was to be obligatory. Between these limits of 2.5% and 5%, intervention efforts were expected to intensify. Agreement was also reached on a total amount of USD 4 billion of "war chest" for intervention purposes,

with intervention totals assigned as roughly one-third to the United States, one-third to Japan, and one-third to European countries.

However, the failure to follow through in terms of fiscal coordination undermined the success of the Louvre Accord. Tensions grew between the United States and other partners, particularly Germany. Veiled threats by the United States to force a further dollar depreciation unless Germany expanded its economy more rapidly unsettled the markets, triggering the crash of October 1987 in the U.S. stock market. This, in turn, so terrified the U.S. authorities that U.S. interest rates were pushed artificially low for too long. By the end of the year, the dollar's value had fallen 21% against the yen and 14% against the deutschemark from its levels at the time of the Louvre Accord in February. In these circumstances, the Group of Seven officials held a telephone conference in late December and, in conjunction with the central banks, operated a "bear trap" against dollar speculators. The U.S. dollar was forced up sharply at the start of January 1988.

By early 1989, the dollar was again rising strongly, until in early April the Group of Seven announced strong opposition to a further dollar rise, coupled with official dollar sales by the Bank of Japan (the first such intervention since late 1985). During 1989, the U.S. dollar continued its ascent: it benefited from the withholding-tax fiasco in Germany, repeated government crises in Japan, and also the massacre in Tiananmen Square in China in June of 1989. In the last quarter of the year, the dollar eased back, partly in response to the Group of Seven meeting on September 23, 1989, when the finance ministers and central bank governors publicly criticized the rise in the dollar as being inappropriate. Over the course of the year as a whole, net sales of dollars by 19 countries participating in the "consultation" policy amounted to no less than \$75 billion, with the United States and Japan contributing \$40 billion and the Bundesbank \$4 billion.

Events in the international financial markets during 1990 could not help but be overshadowed by the dramatic developments on the geopolitical scene: the collapse of the Berlin Wall in November 1989 and the subsequent rapid move toward German reunification transformed the prospects of the deutschemark. A country with a strong external surplus, low inflation, and low interest rates was transformed into a much weaker economy with enormous capital requirements to refinance the crumbling infrastructure left by the failed communist regime. Long-term bond rates in Germany rose sharply over the course of 1990, underpinning a rise in Japanese interest rates, which over the course of the year triggered a collapse in the Japanese stock market.

Stock markets around the world were further severely damaged by the invasion of Kuwait by Iraq in August 1990. This triggered a sharp rise in the price of oil from \$18 a barrel to over \$40 at one point.

As the Kuwaiti crisis built toward war, the dollar began to weaken. In February 1991, just before the launching of the final attack on Iraqi forces, the authorities intervened to support the dollar and turned the tide. The subsequent rise of the dollar was particularly strong against the deutschemark, as the German difficulties with the absorption of the former East Germany became apparent. In July, intervention was required to stop the dollar rising too rapidly.

In November 1991, the Finnish exchange-rate crisis showed the scale of the pressures that can now be brought to bear on small currencies. The Bank of Finland later revealed that in 1991 as a whole, gross official sales of foreign currency had amounted to the equivalent of 17% of gross domestic product (GDP), or nearly 80% of annual exports.

During the latter part of 1991, negotiations within Europe proceeded over the European Monetary Union (EMU), and in December 1991, the terms of EMU were broadly agreed in the Maastricht treaty. However, in 1992, a serious crisis forced sterling and the Italian lira outside the EMS on September 16 ("Black Wednesday"), when the Spanish peseta also devalued but remained within the EMS. The Swedish and Norwegian currencies also came under very heavy pressure, with Sweden raising its marginal lending rate to 500%. The proximate cause of the crisis was the continuing German insistence on raising interest rates to curb the inflationary pressures generated by the absorption of the new East German Länder.

The Bank of England later published an estimate of the volume of official intervention that had taken place over the four months, June to September of 1992: the figure was over \$160 billion. The Bank of Italy estimated its intervention during September at over \$100 billion. Nevertheless, exchange market pressures persisted. In mid-November, the peseta and the Portuguese escudo were forced to devalue, and the Swedish krona was forced to float, while the BIS reported subsequently that Norwegian intervention in two days of this crisis amounted to 46% of Norway's nongold reserves. In January 1993, the Irish pound was devalued by 10%. In May, the peseta and the escudo were forced to devalue again.

The upward pressure on German rates caused a further EMS crisis in the summer of 1993. Intense speculation against the Danish kroner and the French and Belgian francs during July led to the decision at the start of August

to widen the EMS fluctuation margins to 15% from 2.25%—an admission of defeat by the European Union in the face of large international capital flows. (The EMS is discussed in detail in Chapter 6.)

In its review of developments, the BIS commented:

As one currency after another fell, so did the competitive position of others worsen, thus increasing the risk that one or other of them would become the object of the next speculative attack.

As to intervention itself, the question necessarily arises as to whether it was, in some sense, insufficient. Or was it simply ineffective in the new globalised financial world? Technology, innovation, free capital mobility and investors' desire for international portfolio diversification have by now all combined to increase vastly the potential for shifting large amounts of financial capital around the world, and across currencies, at great speed. . . . it is probably no exaggeration to say that the period from late 1991 to early 1993 witnessed the most serious and widespread foreign exchange market crisis since the breakdown of the Bretton Woods system twenty years ago.¹

The BIS also commented that the failure of policy responses to achieve the desired objective of pacifying the markets meant that policy became almost completely "boxed in": the only conceivable way out was a realignment. But the EMS had become for many politicians the cornerstone both of their drive toward European unity and of their counter-inflation policy: "The result of all this was that, when the crisis broke, it proved impossible to address, at the beginning, the issue of a general realignment . . . this piecemeal approach to crisis management opened the way for official positions to be misunderstood or misrepresented."²

The subsequent easing of EMS tensions allowed German and French rates to be lowered. This, together with falling U.S. rates, led to spectacular worldwide bull runs in bond and equity markets during 1993, which were brought to an abrupt end in February 1994 when the Federal Reserve began to tighten interest rates. Heavy losses were incurred by a number of financial institutions, notably the so-called "hedge funds"; but the six successive increases in U.S. rates failed to lift the U.S. dollar, which drifted down during

¹*Annual Report 1994*, pp. 196, 200.

²*Ibid.*, pp. 198–199.

most of 1994 and reached historic lows against the Japanese yen (JPY), breaking the psychologically important JPY 100 level, after which it plunged rapidly to JPY 84.

During the first half of 1995, the strength of the yen was coupled with severe pressure on Japanese financial institutions, as the extent to which the country's much-vaunted superiority had been based on a financial bubble became clear. Another problem that hit the international financial system was the backwash of the Mexican crisis (the so-called "Tequila effect"). Many Latin American countries, and indeed other emerging markets, suffered severe short-term capital outflows after the bungled devaluation of the Mexican peso in December 1994 led to a reappraisal by investors of the prospects for emerging markets during 1995, although the markets calmed somewhat in 1996.

July 1997 saw a very significant event: the devaluation of the Thai baht. Although at first it seemed as though this might be an isolated event, it was very rapidly followed by severe pressure on the Indonesian rupiah, the Malaysian ringgit, and several other Far Eastern currencies. Indeed, the rupiah collapsed spectacularly—from about 2,400 to 16,000 to the dollar—in early 1998 as the Indonesian dictator, Suharto, was forced to resign and rioting took place. The next phase began in July 1998 when Russia defaulted on its debts. This triggered a very troubling international financial contagion as a global "flight to quality" took place. Toward the end of September 1998, these developments led to the collapse of a hedge fund called Long-Term Capital Management, which required a bail-out from the Federal Reserve. This in turn triggered further nervousness. Liquidity began to dry up in major markets, culminating in the spectacular events of the week beginning October 5, 1998. The U.S. dollar opened on Monday at JPY 136, and, at one point on Thursday, touched JPY 112 before rebounding on the same day to JPY 121. Similar volatility occurred on Friday, and on both days there were intervals during normal London dealing hours when major banks were refusing to quote in amounts larger than \$1 million.

These events provide food for thought. The dollar/yen exchange rate is one of the two or three most liquid markets in the world under normal circumstances, with many hundreds of participants all around the globe. For such a market to "dry up" almost completely is an extraordinary event. Alan Greenspan, Chairman of the Board of Governors of the Federal Reserve, commented of this period that he had never seen its like in 50 years of

observing financial markets. It casts very serious doubt on the implicit assumption of many internal risk-management models, namely that foreign exchange positions can quickly be closed out. The cause for anxiety is that at no time was there a really major source of crisis. Whereas from time to time the market has become illiquid in the past, this has normally occurred because of extreme uncertainty about events beyond the market's control, such as the Arab-Israeli wars, the Russian invasion of Afghanistan, the Gulf War, or the 1991 coup against Gorbachev. But no such events were taking place in October 1998. What happened in this case was that investor risk aversion simply became extreme because of the cumulative series of events just discussed. It could be argued that the globalization of financial markets has simply produced a more extreme variant of the herd phenomenon.

A related point is the criticism of the foreign exchange market by outsiders: that it is inherently unstable and tends to overshoot the "true value" for a currency. These criticisms emerge on a regular basis following any rapid currency move. It is certainly clear that a move by the dollar during one week from JPY 136 to JPY 112 is not rational. On the other hand, there is still no evidence that politicians or civil servants are better judges of the "true" rate for a currency than the markets are. For example, in the October 1998 case quoted, the *Financial Times* (October 12, 1998, p. 22) pointed out that some Japanese officials felt that the yen should be trading weaker than JPY 140, whereas the Keidanren, Japan's business federation, had been arguing that a rate of JPY 110–120 would be appropriate. A calculation of the purchasing-power parity suggested a rate of JPY 130, but including assets in the equation (such as land) might make the "purchasing-power parity adjusted for assets" as weak as JPY 180. Conversely, some Japanese analysts argued that the yen should be stronger because of the favorable impact of a stronger yen on the balance-sheet ratios of the Japanese banking system, which at the time was struggling with enormous bad-debt problems. It was calculated that a JPY 5 depreciation of the currency produced a credit crunch worth 1% of GDP. The confusion in the marketplace, therefore, was in part a mirror of the confusion among analysts.

The next major development took place on January 1, 1999, with the introduction of the euro (discussed in more depth in Chapter 6). The primary impact on the structure of the foreign exchange market was, of course, the replacement of 11 European currencies by one single currency, with the

associated reduction in cross-currency turnover, offset in part by the fact that the euro promptly took its place alongside the dollar and the yen as a key currency for international investors.

As the preceding narrative shows, turbulence in the foreign exchange markets is almost routine and seems likely to continue until all the governments of the world conduct monetary and fiscal policy in harmony. This is a prospect we can safely say is not immediate. This turbulence is often channeled through, and financed by, the international money market, to which we now turn.

EUROMARKET STRUCTURE: THE ROLE OF OFFSHORE CENTERS

Particularly in its early days, the international money market was in large part conducted through offshore centers. For the U.S. dollar, London was the earliest offshore center; but later the Bahamas and to some extent the Cayman Islands became important. For the deutschemark, Luxembourg filled a parallel function.

The role of offshore centers in international finance is often not well understood. At the level of the private individual, these centers are most commonly associated with tax havens such as the Bahamas or the Cayman Islands. However, the importance of such centers in wholesale international finance is quite limited, apart from serving as the booking location for some transactions that need to be tax-transparent (e.g., the Cayman Islands are a common location for the “shell companies” set up for asset-swap transactions—see Chapter 16). The main offshore centers with which we shall be concerned are locations like London, Singapore, or Bahrain. These are locations that specialize in handling transactions in the currencies of other countries: Eurotransactions. Primarily, they provide a location that is exempt from domestic reserve requirements. This exemption does not mean that the market is unsupervised; London, as one of the first offshore centers in the form of the Eurodollar market, has always been supervised by the Bank of England, whose responsibilities were taken over in 1998 by the Financial Services Authority.

Following the successful development of London and other offshore centers,

both the United States and Japan moved to create what might paradoxically be called an "onshore offshore facility" for banks to operate Eurocurrency business from the home country, provided that these centers do not do business in the domestic market. The American version is called the International Banking Facility (IBF); the Japanese version is the Japan Offshore Market (JOM). In an IBF, a U.S. bank in New York can take Eurodollar deposits, provided that it refrains from lending them to an American resident. Similarly, a Japanese bank can take Euroyen deposits in Tokyo in the JOM, provided these are not then lent to a domestic Japanese resident. The purpose of these entities was to allow American and Japanese banks to operate in the Euromarkets without incurring the operating costs of setting up overseas. However, in order to prevent the domestic monetary policy framework from being undermined, it was necessary to "ring fence" these operations by preventing them from lending to domestic residents.

The net result is that offshore operations are quite often carried out onshore. The reason for the creation of the IBFs and the JOM is that the national authorities concerned recognized the competitive advantages of offshore centers and wished to ensure that the national banking system was able to enjoy these advantages and, yet, retain the traditional framework for domestic monetary policy operations.

THE MARKET'S ROLE IN RECYCLING PAYMENTS IMBALANCES

The Euromarkets in the early days tended to be seen as an arena for speculative operations. The coincidence of their growth with the growth in internationally footloose money was widely commented on, as was their role in financing the speculative attacks on the dollar that led to the abandonment of the fixed-exchange-rate regime. However, the quadrupling of oil prices between October 1973 and January 1974 precipitated an unprecedented transfer of wealth from consumers to oil producers and confronted the international monetary system with the twin problems of accommodating this transfer and financing the resulting payments deficits. Among the more notable countries resorting to the Eurodollar market for balance-of-payments financing purposes were France, Japan, the United Kingdom, and Italy. Subsequently, a number of LDCs came to the Eurodollar market for financing.

The very rapid expansion of financing activity through the Euromarkets began to put banks' capital ratios under strain. Because of the general financial gloom at the time (best encapsulated in a headline in the London *Evening Standard* at the time of the second oil price rise: "The End of Civilization As We Know It"), it was difficult for banks to raise new equity capital. In addition, banks were funding short term (usually with three- or six-month deposits) but were making three- or five-year loans to the borrowing countries. Thus the international banking system came under severe pressure. The collapse of the U.S. National Bank of San Diego and the losses sustained by the United California Bank in Basle, the Union Bank of Switzerland, and Westdeutsche Landesbank were followed by the collapse of Franklin National Bank and finally by that of Herstatt Bank. The mishandling of this last by the Bundesbank, which closed the bank during working hours, resulting in settlement losses (see Chapter 22) of which the most notable was \$10 million by Hill Samuel, triggered fears of a domino-style banking collapse. This led to a shrinkage in the market.

The feared collapse did not occur, and the market did play the central role in recycling the surplus dollar deposits from the oil producers to the countries requiring balance-of-payments finance. In the light of this experience, the commercial banks began to widen their horizons and to search out borrowers from around the world. Many of these were developing countries with high ambitions but low standards of public conduct: much of the money lent ended up in the pockets of corrupt politicians or bureaucrats. The announcement in August 1982 by Mexico that it was unable to repay its borrowings on time was the first in a series of defaults that included Argentina, Brazil, and a number of other countries. Bankers who had been encouraged by politicians to "support the emerging nations" during the oil crisis were now surprised to be told that it was their irresponsibility in lending these countries too much money that was the root of the problem.

GROWTH OF INTERNATIONAL SECURITIZATION

The problem that banks had experienced with capital ratios earlier was now compounded by the impact of these losses. The result was pressure to find alternative financing routes whereby borrowers could be financed through the securities market rather than through the banking system. At the same time, the authorities were seeking to find methods to stabilize the position

of the LDC borrowers. In 1989 the Brady plan was announced: in essence this provided borrowers with finance on the basis that the borrower issued bonds whose repayment at maturity was guaranteed by the purchase of zero-coupon U.S. Treasury bonds. Investors took the risk that the interest would be paid on the bonds.

Also during this period was seen the beginnings of a market for trading in loans to LDCs. Banks began to sell their loans at a discount—in hopeless cases such as North Korea, debt was sold sometimes at 15% of par. By 1993 the market had evolved to the point where the Emerging Markets Trading Association could estimate annual turnover at \$3,000 billion, and the bonds of Mexico, Brazil, and Argentina were rivaling those of major European countries in turnover terms. The market was severely affected by the “tequila effect”—the backwash of the Mexican devaluation in December 1994—but the volume of trading of countries’ distressed debt remained large and continued to expand further.

This trend was but one part of a wider international trend toward the securitization of bank assets. Pressures on bank balance sheets from the increased demand by regulators for higher capital, combined with heavy losses from lending to LDCs in the early 1980s and on property loans in the middle to late 1980s, meant that banks had to charge an increasingly large spread to recover their costs. As a result, the securities markets offered efficient alternatives to the banking system. The trend began first in the United States, where securitization of the mortgage market was very successful, with total outstandings exceeding USD 1 trillion by the late 1980s. Internationally, the trend was seen first at the short end of the market with the development of Euronotes, which began in underwritten form in 1985 and developed rapidly. The capital implications of underwriting meant that as the Basle ratios began to bite, the market began to switch to nonunderwritten issuance in the form of Euro-commercial paper (ECP). By the early 1990s, the ECP market was a significant source of funding for international firms and a key investment arena for short-term investors, thus contributing further to the process of global integration of short-term money markets.

Securitization has continued to develop as an important conduit for shifting bank assets into the securities markets; the recent development of credit derivatives³ has contributed to this process by allowing banks to issue credit-

³See J. K. Walmsley, *New Financial Instruments* (New York: John Wiley & Sons, Inc., 1996).

linked securities that pass the risk of the loan on to the investor; and the process seems likely to increase in importance.

The long-term implications of the pressure on banks' capital ratios have had an impact throughout the foreign exchange markets. Compared with the early 1980s, for example, the market for longer-dated forward foreign exchange trades has been greatly reduced because of the high capital requirements associated with them. In response, banks have tried to develop netting arrangements and other approaches, such as contracts for differences (see Chapter 22).

4 Links between Foreign Exchange and Money Markets

This chapter explores the links between foreign exchange and money markets. We start by seeing how the two link up at the level of a trader's position. Then we look at what this means for arbitrage and at how central banks intervene in the foreign exchange market and in the domestic money market. Finally, we discuss the effects that foreign exchange intervention can have in the domestic money market.

HANDLING AN EXPOSURE: FOREIGN EXCHANGE OR MONEY MARKET

We start from the point of view of a firm with foreign exchange exposure in a currency. As long as a currency has effective spot and forward exchange markets and money markets, and as long as exchange controls permit, an exposure can always be hedged in either market.

Suppose the treasurer of a British subsidiary of a U.S. company has a euro (EUR) payment coming due in 90 days. The treasurer needs the funds now to send to the United States. She can borrow euro against her receivable and convert them into U.S. dollars now, or she can sell the euro forward against the U.S. dollar and borrow U.S. dollars against the foreign exchange. The choice between the two will depend on the rates involved (see Table 4.1).

Table 4.1 Financing a EUR Receivable: Money Market Route versus Foreign Exchange

Day	Money Market Route		Foreign Exchange (FX) Route	
	Cash In	Cash Out	Cash In	Cash Out
EUR				
Day 1	EUR loan proceeds.	Convert to USD.		
Day 90	Receivable.	Repayment of EUR loan.	Receivable.	Pay to bank to settle forward FX deal.
USD				
Day 1	EUR loan proceeds.	Remit to HQ.	USD loan proceeds	Remit to HQ. against FX.
Day 90			Proceeds of forward.	Repay USD loan with proceeds of forward.

The following steps summarize the process in Table 4.1.

Money Market Route	Foreign Exchange Route
Step 1. Borrow EUR.	Step 1. Sell EUR forward against USD.
Step 2. Buy USD and pay parent.	Step 2. Borrow USD and pay United States.
Step 3. Receive EUR and repay loan.	Step 3. Receive EUR and settle forward deal.
	Step 4. Use proceeds of forward to repay loan.

A dealer in a bank has the option of handling his positions in the same way. If he received a euro deposit for 90 days and is lending dollars for 90 days, he will have the option of choosing the money market route or the foreign exchange route. He can on-lend the euro or do a foreign exchange

deal. He would buy dollars to on-lend and sell the dollars forward against euro to repay his euro deposit at maturity. Table 4.2 shows how his T-accounts would look.

The following steps summarize the process in Table 4.2.

Money Market Route	Foreign Exchange Route
Step 1. Take EUR deposit; on lend to market.	Step 1. Take EUR deposit; swap it for USD.
Step 2. Lend USD to customer, funding in market.	Step 2. Lend USD to customer.
Step 3. Receive EUR repayment from market. Repay customer deposit.	Step 3. Receive USD repayment from customer. Settle forward EUR purchase.
Step 4. Receive USD repayment from customer. Repay market.	

Table 4.2 Matching a Euro Liability and a Dollar Asset

Day	Money Market Route		Foreign Exchange (FX) Route	
	Cash In	Cash Out	Cash In	Cash Out
EUR				
Day 1	EUR deposit.	On-lent to market.	Receive deposit.	Sell EUR for USD.
Day 90	Repay EUR.	Market repays.	Receive EUR from forward.	Repay EUR deposit.
USD				
Day 1	Borrow from market.	Make USD loan to customer.	Proceeds of EUR spot sale.	Lend to customer.
Day 90	Repay market.	Customer repays.	Customer repays.	Pay for forward EUR purchase.

ARBITRAGE

It follows from Tables 4.1 and 4.2 that there is a very close connection between the interest rate and the forward exchange rate. For example, suppose the euro is at a premium forward against the dollar. In other words, the euro is more expensive in the future than it is now. The dealer who is selling euro spot and buying them forward at a more expensive price in order to lend dollars will need to make more on his dollar lending than he would on his euro lending. Otherwise, it would not be worthwhile switching the funds into dollars. From this, we can derive some general rules. (The exact calculations are set out in Chapter 11.)

1. *The currency with the lower interest rate will sell at a premium in the forward market against the currency with the higher interest rate.* Suppose that U.S. dollar three-month deposits yield 20% and that euro three-month deposits yield 10%. Then the euro must sell at a premium in the three-month forward market. Suppose it did not; suppose it sold at a discount. That means, conversely, that the dollar is at a premium against the euro. So a Eurozone investor could buy dollars spot and sell them forward at a profit. In addition, the investor picks up 10% interest differential. In a free market, this situation could never last. Investors would buy U.S. dollars spot and sell them forward until the weight of forward selling had driven the U.S. dollar to a discount; that is, the forward euro would show a premium.

2. *This premium (on an annualized basis) will tend to equal the interest difference.* Suppose, in our example again, that the premium did not equal the interest rate and that it were only 5% per annum. Then it would cost a Eurozone investor only 5% per annum to buy spot dollars and sell them forward. Yet the investor would receive a 10% interest improvement, so there is still a net profit of 5%. Again, in a free market, this situation would not last. Funds would move out of euro into dollars until there were no net profit in doing so, that is, until the forward margin (premium or discount) in annual terms equaled the interest differential.

3. *It follows from the equality of interest differentials and forward margins that if one changes for any reason, the other will move to offset it.* In practice,

the interest differential tends to be the dominant factor because the vast bulk of activity in the forward exchange market is conducted interbank on a swap basis. This relationship can be summed up as: *If the interest differential moves in a currency's favor, the forward margin moves against it to offset the favorable move* (see Figure 4.1).

To continue our example, suppose euro interest rates rise from 10% to 15% while the U.S. dollar rate remains at 20%. Interest rates have moved in the euro's favor. So the forward premium on euros will fall from 10% to 5% per annum so that it equals the new interest differential of 5%. Conversely, suppose now that U.S. dollar rates also fall to 15%. The interest differential has moved against the U.S. dollar, so the forward margins move in favor of the U.S. dollar: the premium on the euro (that is, discount on the U.S. dollar against the euro) disappears entirely because both interest rates are now at 15% and the differential is zero.

It should be stressed that the term *interest differential* is very crude. To be strictly accurate, one should use something like *net accessible interest differential*. In other words, the interest rate should apply to borrowing and lending that are, first, *accessible* to the international market, unaffected by exchange controls. To take a classic case, during the 1977-to-1979 period of heavy upward pressure on the Swiss franc, interest rates on the domestic Swiss money market were running at around 2% to 3% per annum. But those interest rates were not available to nonresident holders of the Swiss franc.

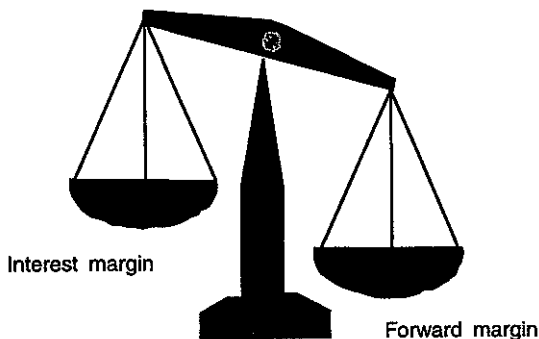


Figure 4.1 As the Interest Margin Moves, So the Forward Margin Moves in the Opposite Direction to Offset It

They were, on the contrary, charged a *negative* interest rate of—at its peak—10% per quarter, or rather more than minus 40% per annum. Domestic Swiss rates were not “accessible” to the market.

Second, the interest rate should be *net*. It should be adjusted for any reserve requirement factors, interest withholding taxes, or other adjustments applicable to nonresidents. For example, before the introduction of International Banking Facilities in New York, a U.S. bank was able to pay a better interest rate on a dollar deposit with its branch in London, compared with the rate it could pay for a deposit with its head office in New York, because the latter was subject to the full range of Federal Reserve System reserve requirements.

By the same token, if a nonresident were placing funds in a center where an interest withholding tax is levied on nonresidents, that person would need to allow for this tax before comparing an interest rate on a deposit in another currency that does not attract withholding tax. It is possible that the withholding tax could be reclaimed under a double tax treaty between the depositor’s country and the country in which the deposit is made. But against this must be set the extra cost and the inconvenience of processing the claim, and so forth. Also, many of the countries that are Euromarket centers have a rather limited network of double tax treaties.

Finally, it should be mentioned that the relationship between the net interest differential and the swap market permits a bank’s dealer to “create” a forward market if a deposit market is available. For example, if a dealer is asked to quote a forward price for a small amount of five-year Thai bahts, he has a problem. The forward Thai baht market does not stretch that far forward, and there is no real Eurobaht deposit market. But if he can obtain deposit quotes for five years in the domestic Thai market and feels safe in assuming that these are in line with what would prevail in the Eurobaht market if there were one, he can manufacture a swap price using the approach used in Chapter 11. Naturally, this is a very rough-and-ready procedure. It would only be safe to do it for a small-sized deal and then only if adequate margin were taken.

In fact what happens is that if the dealer has to sell forward Thai bahts, he buys spot Thai bahts now and places them on deposit, funding with borrowed dollars. The forward sale absorbs the dealer’s foreign currency liquidity at maturity. Likewise, a forward purchase creates forward liquidity in the foreign currency (see Figure 4.2).

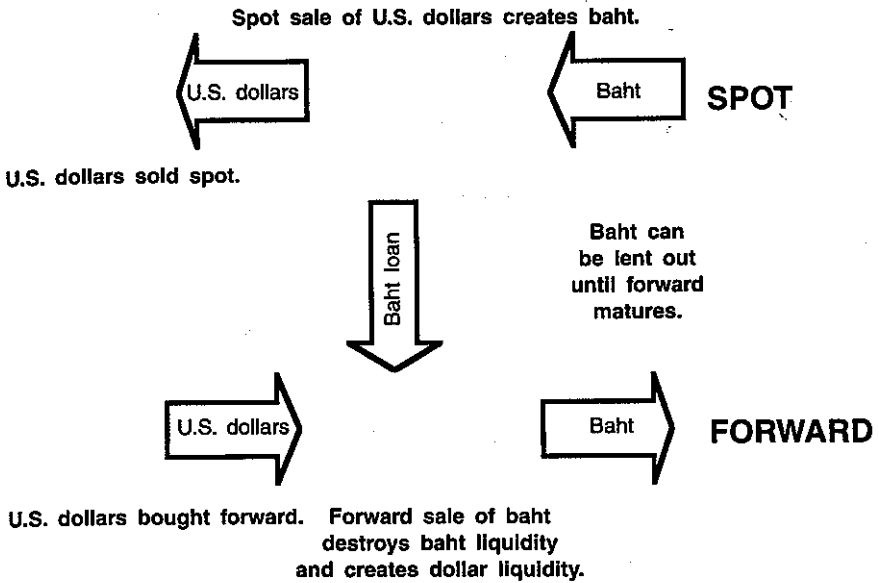


Figure 4.2 Forward Sale Absorbs Forward Liquidity

FOREIGN EXCHANGE INTERVENTION

Intervention by central banks in foreign exchange markets, in its pure form, consists of purchases/sales of foreign currency against domestic currency in the spot or the forward markets. Other forms of intervention are indirect, such as money market operations, charges in reserve requirements, and so on (see Chapter 1). In its pure form, then, intervention can be divided into spot, swap, and outright forward operations.

A study by the Bank for International Settlements (BIS)¹ found that official intervention took place mainly in the spot market. However, Switzerland, Germany, the Netherlands, and Austria used foreign exchange swap operations regularly to influence money market rates.

¹BIS, *Exchange Market Intervention and Monetary Policy* (Basle: BIS, 1988).

A spot purchase or sale of foreign currency against domestic currency tends to have an immediate effect on the spot exchange rate. If the euro is rising, and the European Central Bank (ECB) appears in the market to sell euros and to buy U.S. dollars, this will tend to depress the euro spot rate. It will also increase the ECB's foreign exchange reserves by the amount of U.S. dollars bought. It may affect the eurozone money supply, depending on who buys the euro and whether he or she invests the euro in bank deposits or in government bonds or is forced (as in Germany in 1970) to place the euro in a special deposit with the central bank. In the last two cases, the inflow is "sterilized" but in the first case it feeds through into the money supply. (See a discussion of this problem later in the chapter.)

An outright forward purchase or sale of foreign currency against domestic currency tends to have an immediate effect on the margin between the spot and the forward rates. The effect on reserves does not show up until maturity, when it is the same as outlined in the last paragraph. The Bank of England intervened in this way during the period 1964 to 1967. The aim was to support the forward sterling rate and so reduce the discount on forward sterling. This would cut the cost of forward cover on sterling assets and thus encourage investment in sterling assets. At the same time, operating on an outright basis rather than a swap basis meant the Bank did not have to supply spot sterling to the market. But the devaluation of 1967 meant that these forward operations cost the Bank £350 million, and they were then abandoned.

A swap operation also alters the margin between the spot and the forward rates. But it has an immediate impact on the spot market as well. The counterparty receives funds on his account now. If the Bank of England had intervened in the swap instead of the outright market, it would have been selling sterling spot and buying it back forward. The counterparties would have been long of spot sterling, which they would probably have sold off. That was why the Bank dealt outright forward. But swaps have been used by some central banks to affect the cost of forward cover: a notable example is the Bundesbank, which had amounts outstanding of up to \$2.7 billion from 1958 to 1969 and in 1971. However, experience tended to show that these swap interventions were misused by the combination of interest-rate arbitrage and Bundesbank swap transactions to carry on "round-trip trades" that made it possible to obtain interest-rate profits without using additional funds.

Figures 4.3 through 4.6 show how the Central Bank of an imaginary country called Home provides liquidity via a swap that runs over the domestic money market reporting date.

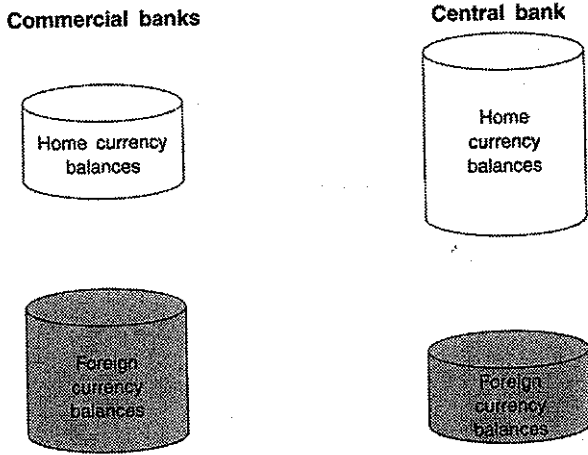
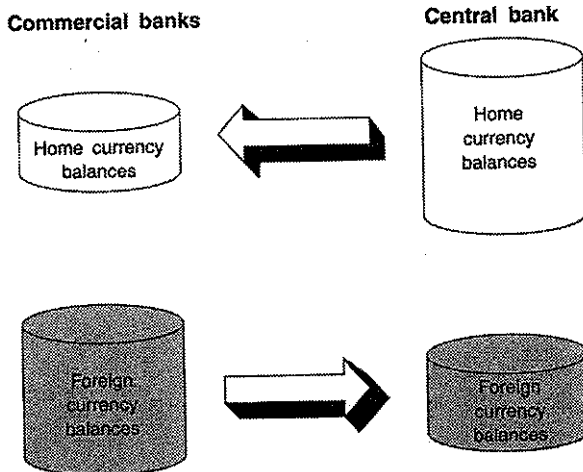


Figure 4.3 Stage 1: Domestic Liquidity Shortage



Central bank buys foreign exchange

Figure 4.4 Stage 2: First Leg of Swap—Central Bank Provides Home Balances in Exchange for Foreign Currency Balances

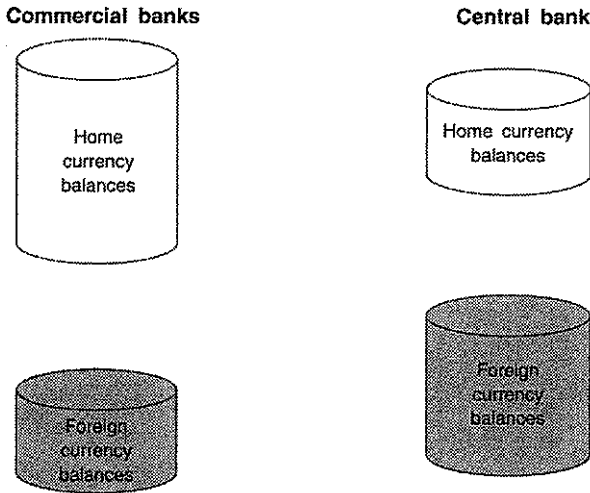


Figure 4.5 Stage 3: Reporting Date—Home Balances of Commercial Banks Increased by Swap

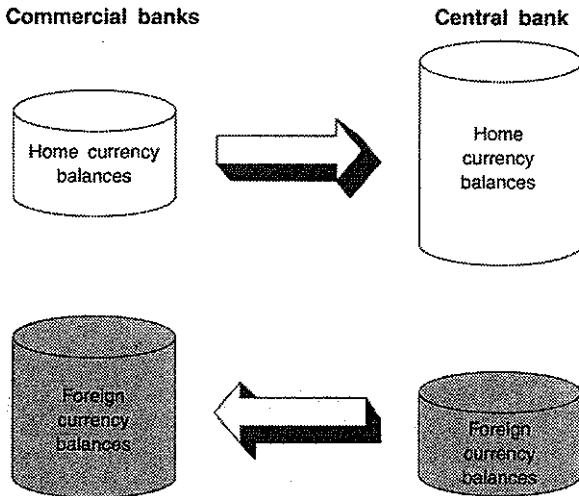


Figure 4.6 Stage 4: Swap Unwinds—Commercial Banks' Home Balances Fall Again

Another example of the link between the foreign exchange and the domestic money markets can be seen if we look at a drawing by the Federal Reserve (the Fed) Bank of New York on its swap network (see Chapter 5) to finance sales of foreign currencies and stabilize the dollar. The drawing normally leads to two opposite and offsetting effects on bank reserves (see Figure 4.7): (1) The sale of a foreign currency for dollars by the Fed in the exchange market causes a fall in U.S. bank reserves. The U.S. bank receives foreign currency, paying over dollars to the Fed. This cuts its dollar reserves. (2) The reserves work their way back into the system.

The way in which this happens will vary. It depends on the course of action taken by the securities trading desk at the Federal Reserve. Consider a swap with the Bank of Japan (see Figure 4.7). To start with, the swap drawing results in a credit of yen to the Federal Reserve's account at the Bank of Japan and in a credit of U.S. dollars to the account of the Bank of Japan at the Federal Reserve (Step 1). The latter account is then debited with these dollars that are invested in a special U.S. Treasury certificate of indebtedness. As a result, Treasury cash balances at the Reserve Bank increase

Step 1: The Drawing (USD 1 = JPY 100)	
Federal Reserve account: +JPY 10,000	Bank of Japan account: +USD 100
Step 2: The Transfers	
No change	Bank of Japan account: -USD 100 U.S. Treasury: +USD 100
Step 3: Fed Intervenes	
Federal Reserve account: -JPY 10,000 Citibank Tokyo account: +JPY 10,000	Citibank NY account: -USD 100
Step 4: The Recycling	
No change	U.S. Treasury account: -USD 100 Citibank NY account: +USD 100

Figure 4.7 Federal Reserve Swap Drawn on Bank of Japan

(Step 2). Under normal circumstances, the U.S. Treasury will then spend these dollars in the course of its operations (Step 4), putting reserves back into the system, so the original reserve draining is offset.

By comparison a direct intervention by the Federal Reserve in the foreign exchange markets to sell an existing balance of yen (that is, its own holding rather than the proceeds of a swap-drawing) will have an immediately draining effect on bank reserves, unless offset by other action (see Figure 4.8).

FOREIGN EXCHANGE INTERVENTION AND THE MONEY SUPPLY

At various points in this chapter, we have touched on the links between foreign exchange and money markets and how these are used by participants in the market, particularly by central banks when intervening. It is important to understand the wider effects of these links because they affect the way in which central banks and governments operate their policies. For instance, a central bank that is committed to intervening in defense of a fixed exchange rate cannot control its money supply. If it does want to control money supply, it cannot intervene in unlimited amounts. To see why, we need to look at some examples of what happens when intervention takes place. The exact effects can be complex. They depend on our definitions of the money supply and the assumptions we make about how flows involved are financed. Very roughly, things work like this. If the authorities refuse to intervene in the foreign exchange market, an inflow of foreign currency will not change the country's foreign exchange reserves. Hence, the inflow need not necessarily change the domestic money supply. But if the authorities intervene to buy the foreign currency, there will be an effect on the reserves. All other things being equal, this will affect the domestic money supply.

Yen	Dollars
Federal Reserve account	Citibank NY account
-JPY 100	-USD 100
Citibank Tokyo account	
+JPY 100	

Figure 4.8 Intervention Financed by Federal Reserve Balances (USD 1 = JPY 100)

A country that has had much experience of foreign currency inflows is Switzerland. In December 1978, for example, because of Swiss support for a weakening dollar, Switzerland's reserves rose to 150% of average exports. That figure compares with 50% for the previous month. The change for the United States and for the United Kingdom during this period was negligible. As a result, the Swiss money supply, which had grown by less than 1% on average during 1977, grew by 19.8% during 1978.

It became clear to the Swiss authorities that this process could not be continued indefinitely. During 1979, the degree of dollar support was sharply reduced. That allowed a much more restrictive monetary policy. The money supply was actually reduced during 1979 by 1.2%. This was achieved at the price of a firm exchange rate. From an average of USD 1 = CHF 2.4035 during 1977, the Swiss franc (CHF) strengthened to average 1.7880 during 1978 and 1.6627 during 1979. But a price was paid for this policy. The effects of the very rapid growth of money supply during 1978 and the subsequent weakening of the exchange rate during 1980 and 1981 were seen later in the consumer price index. This had risen by 0.8% on average during 1978, but it rose 3.7% during 1979, 4.0% during 1980, and, by March 1981, had risen by 6.4% compared with the same month of the previous year.

The detailed interrelationships are perhaps best understood by looking again at our country called Home. We start by making certain assumptions: First, all payments to Home residents from abroad are made in Home currency (HC). Second, Home residents and banks do not themselves hold foreign currency, nor do they lend Home currency abroad. Third, the public sector has no foreign currency transactions. Finally, nonresidents' Home currency deposits are excluded from the definition of the money supply.

We start with the way in which foreign exchange is taken into or paid out of the official reserves. The reserves are held by the Exchange Stabilization Fund (ESF). The ESF's working balances in Home currency are held in Treasury bills. When the ESF buys foreign currency, it sells these Treasury bills back to the government. In exchange, it receives Home currency with which it can then pay the seller of foreign currency. In order to finance the payment to the ESF, the government is forced to borrow elsewhere. In effect, government securities are switched from the ESF to other holders.

Consider the case of a Home exporter who is owed HC 100 for an export delivery. Assume the overseas customer does not already hold Home currency. Then the customer will have to sell foreign currency for Home currency and pay the proceeds to the Home currency account of the exporter. Under our

assumptions, the bank receiving the foreign currency will sell the currency immediately to the ESF. In order to buy the foreign currency from the bank, the ESF sells its Treasury bills to the government. This forces the latter to borrow elsewhere. In the absence of any other buyer, the government borrows from the banks. In effect, Home currency claims on the government are switched from the ESF to the banks. As there is a rise in the Home exporter's Home currency deposits, the money supply increases. The transactions associated with this change, as they affect the balance sheets of the banks and the ESF and the balance of payments, are shown in Table 4.3.

An inflow may also take the form of a rise in Home currency bank deposits held by overseas residents. This will not affect the money supply. In this case, the overseas resident sells foreign currency to a Home bank and places the proceeds in a Home currency account. The bank again immediately sells the foreign currency to the ESF. The ESF sells Treasury bills back to the government, which borrows Home currency from the bank. So the bank has effectively taken a Home currency deposit from a nonresident in order to on-lend it immediately to the government. However, this time there is no increase in the money supply because nonresidents' Home currency deposits are not included in the definition. The transactions are set out in Table 4.4.

All of this has worked on the assumption that the ESF buys all foreign currency that is offered to it. Assume the ESF never intervenes, and assume still that neither Home banks nor the Home private sector holds foreign currency. Then it is clear that any foreign currency sold to Home residents

Table 4.3 Effects of a Home Current Account Surplus

Sector	Liabilities	Assets
<i>Home Banks</i>		
Private sector HC deposits	+100	
HC claims on Treasury		+100
<i>ESF</i>		
Official reserves		+100
HC claims on Treasury		-100
<i>Balance of Payments</i>		
Current account: exports		+100
Capital account		
Change in reserves (increase, -)		-100

Table 4.4 Effects of a Home Capital Account Surplus

Sector	Liabilities	Assets
<i>Home Banks</i>		
Nonresidents' HC deposits	+100	
HC claims on Treasury		+100
<i>ESF</i>		
Official reserves		+100
HC claims on Treasury		-100
<i>Balance of Payments</i>		
Current account: exports		+100
Capital account		
Change in reserves (increase, -)		-100

is immediately sold back to nonresidents because we have assumed that Home people never hold foreign currency. The exchange rate must move until nonresidents are willing to buy back the Home currency. It is the exchange rate that now takes the strain. The reserves do not change.

Let us now allow for residents' foreign currency holdings. These holdings only affect the Home money supply when Home residents switch foreign currency into Home currency. To prove this, assume a Home current account surplus of HC 150 (see Table 4.5). Suppose that HC 50 of this is actually paid to the Home private sector in foreign currency. Suppose this foreign currency is deposited with the banks (which on-lend it to nonresidents). A further HC 60 worth is paid to Home residents in foreign currency and immediately sold for Home currency. The ESF finances its purchases of foreign currency by selling Treasury bills that are bought by the bank. The rest is financed by a fall in foreigners' Home currency bank deposits of HC 30 and a fall of HC 10 in overseas holdings of public sector Home currency debt. We assume this is sold to the banks. So bank lending to the government rises by the HC 10 of public sector debt and the HC 60 that the banks lend to the government to finance the increase in reserves. That makes a total of HC 70. This feeds straight through into the Home money supply. So does the HC 30 fall in foreigners' Home currency bank deposits that are paid to U.K. residents. So there is a net rise in Home's money supply of HC 100. This is equal to the private sector current and capital account surplus on the balance of payments less the increase in Home private sector foreign currency holdings. In other words, the HC 50 paid to Home residents in

Table 4.5 Effects of Home Current Account Surplus When Intervention Takes Place

Sector	Liabilities	Assets
HC deposits of private sector	+100	
HC deposits of nonresidents	-30	
HC claims on public sector		+70
Foreign currency deposits of private sector	+50	
Foreign currency loans to nonresidents		+50
<i>Balance of payments</i>		
Private sector current account surplus		+150
that is used to finance:		
Foreign currency lending by Home banks (increase, -)		-50
Overseas HC deposits with Home banks (increase, +)		-30
Overseas lending to Home public sector (increase, +)		-10
Change in reserves (increase, -)		-60

foreign currency, which was not switched into Home currency, had no effect on Home's money supply.

Now, let's boil this down to what matters. Foreign currency inflows and outflows can affect a country's money supply. That can happen only if the Exchange Stabilization Fund, in our example, is intervening in the foreign exchange market on a net basis; that is, the ESF must not just buy and sell in the market to smooth exchange rate movements, but it must be supplying foreign currency to the market or absorbing currency from the market. If intervention is taking place, the effect on the money supply need not be the same as the amount of intervention. As we saw, if the inflow produces a rise in nonresidents' deposits, the money supply need not be affected. In the same way, the effect on the money supply depends on how the ESF finances its interventions. In our example, if the ESF's Treasury bill holdings could be refinanced from overseas, the effect on money supply would be offset. In other words, foreign currency flows will tend in general to affect the money supply—but not always; it depends on what else is happening. But, as a rule of thumb, if Home central bank supports Home currency, it drains funds from Home money; if it supports another currency, it adds funds to the Home market.

A useful, detailed discussion of these issues can be found in the study by D. M. Dominguez and J. S. Frankel: *Does Foreign Exchange Intervention Work?*² They studied daily intervention data for the United States, Germany, and Switzerland. Their conclusion was that intervention, by influencing market expectations, can be effective irrespective of whether the intervention is sterilized. In general, this was not the view taken in the Jurgenson Report,³ which suggested that sterilized intervention had, at best, transitory effects.

²Institute for International Economics, 1993.

³*Report of the Working Group on Exchange Market Intervention* (Washington, D.C.: U.S. Treasury, 1983).

5 The International Financial System

Now that we have looked at some of the major markets, it is time to see how they fit together. In this chapter, we see how individual domestic markets and the market for foreign exchange and international deposit markets mesh to form part of the international monetary system. We look at some of the problems and ideas that have influenced the development of the system, and we describe its components.

If one had to pick out three strands that weave the story together, they would probably be international liquidity, adjustment, and choice of reserve asset. We will look at each briefly.

The word *liquidity* means having enough cash to meet day-to-day needs. For an individual, that means having enough cash in the bank or having readily saleable assets, such as government bonds, to meet regular monthly expenses. For a country, it means having enough foreign currency to pay monthly bills: the balance of imports, exports, and other cash flows into and out of the country. A country has to have *foreign* currency because (with certain exceptions, such as U.S. dollars) other countries prefer to be paid in their own currency.

Liquidity and *adjustment* are in a sense opposites. If people do not have enough liquidity to meet monthly bills, they have to cut their spending (or borrow). In other words, they have to adjust their behavior. It is the same for a country that is continually spending more abroad than it earns from abroad. In the end, it usually has to adjust its policies. The more liquidity it has, the less hurry there is about adjusting. The less liquidity it has, the more rapidly it must act. So liquidity and adjustment are a kind of trade-

off. Very often, countries have tried to put off adjusting their economies by using up liquidity or by trying to get liquidity by borrowing. In most cases, they end up having to make adjustments—either to devalue their currency (to make their exports more competitive internationally and to help the country earn more abroad) or to cut back on spending on imports, often by painful domestic-tax increases or interest-rate rises.

Over and over again, the United Kingdom, Italy, Brazil, Mexico, and other countries have had to make the forced choice between adjustment and international liquidity. Much of the Western world faced the same choice during the oil shocks of the 1973-to-1975 and 1979-to-1980 periods. More recently, in 1997 and 1998, a number of the “Asian tigers” went through a similar experience, complicated in their case by the effect of currencies previously pegged to the dollar and by inadequately supervised banking systems.

In 1998, Russia and Malaysia found different solutions to the liquidity/adjustment tradeoff: in the former case, by outright default; and in the latter case, by imposing exchange controls that trapped foreigners’ investments in the country for a one-year period. The Russian “solution” produced devastating results for that country’s financial situation, whereas the Malaysian “solution” had less obvious immediate effect, at the probable price of making it very hard for the country to gain back the trust of international financial markets. Dozens of countries before Malaysia have learned that taking the apparently easy immediate solution leads to long-term difficulties that are far greater.

The third strand in this analysis is choice of reserve asset. Official international liquidity consists of reserves of foreign currency; gold, which is generally saleable for currencies; and certain other items. After World War II, in 1945, international liquidity was held almost entirely in gold, U.S. dollars, and sterling. As confidence in dollars and sterling weakened, liquidity was switched into other currencies or gold. And the shock waves from these shifts of liquidity were seen in repeated currency crises (as we saw in Chapter 3), which ended in sterling’s 1967 devaluation and the 1971-to-1973 devaluation of the U.S. dollar. Still today, as confidence in a currency fades or grows, international liquidity ebbs away from or flows into that currency. Official liquidity may play a smaller relative role, given the extent of financial liberalization in recent years, but private investors’ choice of where to hold their assets now plays a similar role—witness the “financial contagion” of the later summer of 1998 when the Russian default

triggered a wholesale flight by international investors out of emerging-markets currencies.

INTERNATIONAL MONETARY FUND

The origins of today's international monetary system go back to 1944 when the Bretton Woods conference was held. At this conference, the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (IBRD, more commonly known as the World Bank) were established. The latter is mainly involved with development finance—a topic not covered here. The IMF aims to see that its members run their exchange-rate and balance-of-payments policies in an orderly way. If need be, it helps them do so by lending them money. The funds to do this come from members' subscriptions (quotas), the IMF's borrowings, and other sources.

Under the original Articles of Agreement of the IMF, members agreed to make their currencies *convertible*, that is, not to restrict exchange of their currencies for others. They also agreed to fix par values for their currencies in terms of gold. This meant fixed exchange rates among currencies. It also meant (in theory) convertibility from currencies into gold. To help members meet these aims, the IMF would lend to them in proportion to their quotas.

The structure of the IMF is defined in its Articles of Agreement. It has a Board of Governors, which is its highest authority, and meets once a year. But an Executive Board and the managing director control its day-to-day running. There are 21 executive directors. Of these, six are appointed by the countries with the largest quotas: the United States, the United Kingdom, Germany, France, Japan, and Saudi Arabia. The remaining members of the IMF elect the others. The Executive Board selects the managing director, who is also chairman of the Executive Board.

The quota of a country depends on its national income, foreign currency reserves, and other factors. Quotas are normally reviewed at least every five years. The size of the quota decides two important things: (1) how much a country can borrow from the IMF, and (2) how much voting power it has. A country can borrow up to 100% of its quota, plus certain special facilities.

The borrowings are made in a series of slices, or *tranches*. The more a country borrows, the more closely the IMF supervises its policies. For the first borrowing (the first credit tranche), the IMF requires a borrowing country to "make reasonable efforts" to overcome its problems. For second and higher

tranches, the fund usually only lends on a standby basis. This means: (1) there are performance targets that the borrower must meet; (2) successive installments of the borrowing are only allowed if the targets are met.

The mechanics of the borrowing (drawing) are that a country uses its own currency to buy the currencies of other countries (or special drawing rights, or SDRs, which are explained later). So a drawing on the IMF by a country raises the IMF's holdings of the country's currency, but reduces its holdings of the other currencies. The makeup of the IMF's resources changes, but not the total. An example is shown in Table 5.1. The account of the IMF that holds these currencies is called the general account (as distinct from the SDR account).

As was stated, borrowings are made in tranches. The first of these is the reserve tranche: it is equivalent to drawing down a credit balance. For the

Table 5.1 Home Borrows U.S. Dollars from the IMF General Account (USD 1 = HC 3)

	Home Account with with IMF (in Home currency, HC)	U.S. Account with IMF (in USD)
<i>I. Before Drawing</i>		
SDR holdings	100	100
Reserve tranche	0	0
Borrowings under		
First credit tranche	0	0
Second credit tranche	0	0
Third credit tranche	0	0
Fourth credit tranche	0	0
General Account holdings	HC 300 (Home original quota)	USD 100 (U.S. original quota)
<i>II. Home Borrows USD 100 and Pays in HC 300</i>		
SDR holdings	100	100
Reserve tranche	0	100
Borrowings under		
First credit tranche	300	0
Second credit tranche	0	0
Third credit tranche	0	0
Fourth credit tranche	0	0
General Account holdings	HC 600	USD 0

reserve tranche, the country is lending its currency to the IMF. Suppose that Home needs to borrow U.S. dollars. Home buys USD 100 from the IMF and pays HC 300. The IMF's U.S. dollar holdings are now less than the amount the United States originally paid in: it is as if the United States had lent the IMF dollars to buy Home currency. The difference between the United States' original quota and the IMF's present U.S. dollar holdings is credited to the United States as its reserve tranche. A country has automatic access to the reserve tranche (because, after all, it lent the money to the IMF). After that, it can borrow four subsequent tranches, each equal to 25% of its quota, and, as we saw, subject to tighter and tighter control by the IMF.

In addition to its general balance-of-payments assistance, the IMF has a number of special facilities designed to address needs arising from specific factors. The first of these, established in 1963, was the compensatory financing facility, designed to help stabilize the earnings of countries exporting primary commodities. Countries experiencing balance-of-payments difficulties for reasons beyond their control, because of temporary shortfalls in export earnings, could borrow under this facility if they cooperated with the IMF to find solutions to their problems. In 1988, the facility was broadened to become the *compensatory and contingency financing facility* (CCFF). This facility superseded the compensatory financing facility but kept its essential features. It added a mechanism for contingency financing of member countries that have entered into adjustment programs supported by the IMF.

A second special facility, designed to smooth out fluctuations in the prices of primary commodities and so to reduce variations in the export earnings of participating countries, was the *buffer stock financing facility* (BSFF), which was established in June 1969. Through this facility, the IMF could finance members' contributions to international schemes aimed at stabilizing commodity prices by building up a buffer stock.

During the 1970s, the IMF provided an oil facility. From 1974 to 1976, the Fund lent SDR 6.9 billion to 55 countries to help them overcome the impact of the oil prices of 1973 and 1974. In 1986, the *structural adjustment facility* (SAF) was set up to provide low-cost financial assistance to low-income members facing serious balance-of-payment problems and needing to undertake programs of structural adjustment. In December 1987, the *Enhanced Structural Adjustment Facility* (ESAF) was set up to provide additional assistance to these countries. Countries eligible for SAF loans may borrow under the ESAF, but access under ESAF is considerably larger; it

is normally expected to average about 150% of quota over a three-year-program period, with provision for up to 350% in exceptional circumstances, compared with 70% under the SAF.

In April 1993, the IMF created the so-called Systemic Transformation Facility, a temporary facility created in response to the needs of Russia and the other economies in transition. Its aim was to provide financial assistance to eligible members experiencing balance-of-payments needs resulting from severe disruptions in traditional trade and payments arrangements.

In response to the Asian crisis of 1997 and 1998 and the apparent spread of unwarranted financial contagion from one country to another during this period, the IMF took a number of steps. The first step, in December 1997, was to establish a *supplemental reserve facility* (SRF) to assist members in the throes of a crisis caused by external contagion.

Financing under the SRF is provided under a Standby, or an Extended, Arrangement in addition to the other resources made available under those arrangements. Access under the SRF is not subject to the usual annual and cumulative access limits but is determined on the basis of the financing needs of the member, its capacity to repay, the strength of its program, and its record of past use of IMF resources and cooperation with the IMF.

To minimize moral hazard, a member using resources under the SRF is encouraged to seek to maintain the participation of creditors, both official and private, until the pressure on the balance of payments ceases. The decision establishing the facility also states that all options should be considered to ensure appropriate burden sharing.

Financing is committed for up to a year and generally available in two or more purchases. The obligation to repurchase is within two to two and one-half years from the date of each purchase, but the member is expected to repurchase one year before the due date unless the IMF decides, at the member's request, to extend each such repurchase expectation by up to one year.

The second step was that in 1999 the IMF created *contingent credit lines* (CCL) for member countries with strong economic policies as a precautionary line of defense. The idea was that approval of financing under the CCL will signal the IMF's confidence in the member's economic policies and in the member's determination to adjust the policies as needed should contagion hit. The CCL was established for a two-year period and will be reviewed after one year's experience. It was intended to be a new instrument of crisis prevention by creating further incentives for members to adopt strong policies

and to adhere to internationally accepted standards and by signaling the IMF's willingness to provide its financing to members struck by contagion.

The CCL will not be subject to general access limits, but commitments under the CCL would be expected to be in the range of 300 to 500 percent of the member's quota in the IMF, unless otherwise warranted by exceptional circumstances, and with due regard to the IMF's liquidity position.

All this lending has to be financed. The main source of funds is the member countries' quotas subscribed to the IMF. Extra facilities have had to be arranged when the quotas were not enough. The first of these arrangements was known as the *General Arrangements to Borrow* (GAB). The GAB were set up in January 1962 in case the IMF had to make a large loan to the United States or the United Kingdom, the main reserve currency countries at the time. They were a four-year arrangement with 10 industrialized countries (the Group of Ten, or G-10). Switzerland later took part as an associate (not directly, because Switzerland was not a member of IMF until 1990). The participants are listed in Table 5.2.

The GAB were last activated in July 1998 for an amount of SDR 6.3 billion (about \$8.4 billion) in connection with the financing of an extended arrangement for Russia. Of that amount, only SDR 1.4 billion (about \$1.9 billion) was used. As agreed with the GAB participants, the IMF repaid the outstanding amount in March 1999.

Table 5.2 GAB Participants and Credit Amounts (after December 26, 1983)

Participant	Amount (millions of SDRs)
United States	4,250.0
Deutsche Bundesbank	2,380.0
Japan	2,125.0
France	1,700.0
United Kingdom	1,700.0
Italy	1,105.0
Canada	892.5
Netherlands	850.0
Belgium	595.0
Sveriges Riksbank	382.5
Swiss National Bank	1,020.0
Total	17,000.0

Credit arrangement with Saudi Arabia in association with the GAB 1,500.0.

The GAB have been renewed every four or five years, most recently in November 1997 when they were renewed for a further five-year period from December 26, 1998.

A supplementary arrangement to the GAB is the *New Arrangements to Borrow* (NAB), which became effective on November 17, 1998. The NAB are a set of credit arrangements between the IMF and 25 members and institutions (see Table 5.3) to provide supplementary resources to the IMF to forestall or to cope with an impairment of the international monetary system or to deal with an exceptional situation that poses a threat to the

Table 5.3 NAB Participants and Credit Amounts

Participant	Amount (millions of SDRs)
Australia	810
Austria	412
Belgium	967
Canada	1,396
Denmark	371
Deutsche Bundesbank	3,557
Finland	340
France	2,577
Hong Kong	340
Italy	1,772
Japan	3,557
Korea	340
Kuwait	345
Luxembourg	340
Malaysia	340
Netherlands	1,316
Norway	383
Saudi Arabia	1,780
Singapore	340
Spain	672
Sveriges Riksbank	859
Swiss National Bank	1,557
Thailand	340
United Kingdom	2,577
United States	6,712
Total	34,000

stability of that system. The NAB do not replace the existing GAB, which remain in force. The total amount of resources available to the IMF under the NAB is SDR 34 billion (about USD 46 billion), double the amount available under the GAB alone (see Table 5.2). The NAB were activated in December 1998 in connection with the financing of an extended arrangement for Brazil. As agreed with the NAB participants, in March 1999, the IMF repaid the outstanding amount.

As well as from the GAB, the IMF has borrowed directly from certain countries in other ways. For example, in March 1981, the IMF borrowed two annual tranches of SDR 4 billion from the Saudi Arabian monetary authority. Other facilities have been arranged from time to time with other countries and through the Bank of International Settlements (BIS).

All of the IMF's lending and borrowing activities that we have discussed so far are channeled through its *general resources account*. There is another account called the special drawing rights (SDR) account. The SDR was created in July 1969 under the First Amendment to the IMF Articles Agreement.

During the late 1960s, there were discussions of a possible shortage of international liquidity. It was feared that this might slow the growth of world trade. One way of increasing liquidity would have been an increase in the official price of gold. Legally this was tantamount to a devaluation of the dollar. The United States firmly opposed it. An alternative was to create a new form of international reserve asset through the IMF. The *special drawing right* was called by this name to emphasize that it was a kind of borrowing, rather than a new currency. This was done to pacify France, who had argued for a revaluation of gold.

Members of the IMF can use SDRs to make international payments between themselves just as they could use U.S. dollars. When it was originally created, the possible uses of the SDR were very restricted. Over the years, they have been widened so that central banks can buy or sell SDRs among themselves, use SDRs to make loans or as security for loans, and deal in SDR swaps or forward SDRs.

In January 1981, the valuation of the SDR was very much simplified. (See the section on currency units in Chapter 14.) It is now a basket of major currencies, whose weights are revised every five years. (From the start of 1999, with the arrival of the euro, the role of the deutschemark and French franc in the SDR disappeared; they were replaced by the euro. See Chapter 14.) In practical terms, SDRs are now equivalent to any other currency, with

one major difference: SDRs cannot be owned by private individuals, only by member countries of the IMF and by 16 "prescribed holders," including the BIS, the Swiss National Bank, and various regional central banks (such as the Eastern Caribbean Central Bank) and development banks.

Recent developments—Russia's financing requirements, the 1997/1998 Asian economic crisis—have put severe strain on the IMF's available resources. The most recent attempt to increase IMF quotas was stymied for a long time by the failure of the U.S. Congress to approve the U.S. contribution to the increase. This was as regrettable as it was unsurprising. For years the U.S. Congress has made an international exhibition of itself by imbecile posturing for its domestic electorate, coupled with a failure to grasp the workings of the international financial system.

Having said that, there are reasonable concerns regarding the role of the IMF, notably the issue of *moral hazard*: the extent to which it is right that international investors in Russia, for example, should be bailed out by the IMF. Investors in high-risk emerging markets like Russia earned very substantial returns for lending to Russia, and for them to be bailed out with taxpayers' money (from many countries, not just the United States) does raise legitimate policy issues. Indeed, in the summer of 1998, for example, the head of the Bundesbank criticized the IMF approach to rescuing the Asian economies hit by economic crisis: "The basic problem of any form of interventionist economic policy [is that] the other players come to expect interventions . . . it has become clear that an interventionist strategy for managing financial crises can easily lead to a dead end."¹

Clearly, the precise role for a body like the IMF needs to be kept under continuous review. On the other hand, defenders of the IMF approach would argue that foreign investors lost heavily during the Asian crisis and that the near meltdown in Indonesia might have led to serious regional instability. Likewise, on geopolitical grounds, few were prepared to contemplate abandoning Russia ("Indonesia with nuclear missiles," as one participant put it at the time).

Some IMF critics would argue further that "everything should be left to the markets"—whereas the IMF was important and necessary in the era before fully global capital markets, it is now increasingly irrelevant. I personally believe that this argument makes little sense, unless its proponents were

¹*Financial Times*, Friday, July 3, 1998.

prepared to go further and argue that there was no need for any domestic entities such as the Federal Reserve to operate as “lender of last resort.” If it is right for such entities to exist at the national level, why not at the international level? Implicit in the existence of bodies such as the Federal Reserve, the Securities and Exchange Commission (SEC), or the U.K.’s Financial Services Authority is the view that, occasionally, financial stability requires official intervention, be it in the form of regulation or in the provision of liquidity.

There is no doubt, however, that the role of the IMF is likely to continue to evolve; its relationship with the World Bank has changed in recent years, as has its relationship with the Bank for International Settlements (discussed next).

BANK FOR INTERNATIONAL SETTLEMENTS

The BIS is the central bankers’ central bank. It is very discreet and very influential. It was founded in 1930 to act as a trustee for the loans associated with the Young Plan for German reparations. The first members of the bank were the central banks of Belgium, France, Germany, Italy, Japan, and the United Kingdom, together with three private U.S. banks. The Federal Reserve Bank (the Fed) subsequently became a member, along with all the major European central banks (although, curiously, the Fed never took up its directorship of the BIS until September 1994, for various reasons concerned with the presence on the Board of certain Communist countries and the importance of gold in the BIS’s activities).

The composition of the BIS has been the subject of international discussion in recent years, with some arguing that it is too “European.” The admission to membership in 1996/97 of an additional nine central banks in Asia, Latin America, the Middle East and Europe ended the previous heavy concentration of BIS shareholding central banks in the industrialized world and eastern Europe. As of 31st March 1998, 45 central banks had rights of representation and voting at General Meetings of the BIS. These included all the G-10 central banks—Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom, and the United States—and the central banks of Australia, Austria, Brazil, Bulgaria, China, the Czech Republic, Denmark, Estonia, Finland, Greece, Hong Kong, Hungary, Iceland, India, Ireland, Korea, Latvia, Lithuania, Mexico, Norway, Poland, Portugal, Ro-

mania, Russia, Saudi Arabia, Singapore, Slovakia, South Africa, Spain, and Turkey, together with the Central Bank of Bosnia and Herzegovina, the Croatian National Bank, the National Bank of the Republic of Macedonia, and the Bank of Slovenia, which had been issued shares of the BIS pending a settlement of all outstanding questions in connection with the breakup of Yugoslavia.

More recently, another issue has raised its head: the question of the representation of the European Central Bank (ECB): The arrival of the ECB would, in principle, mean getting rid of 10 of the BIS's shareholders from a number of important central banks, and the issue thus poses delicate questions that will take some time to sort out.

The BIS board of directors is composed of governors of several of the major central banks, together with coopted directors from among the governors of those member central banks that do not have an *ex officio* representative on the board. There are also five representatives of finance, industry, or commerce appointed by the governors of the permanent-member central banks.

The BIS has three main roles: (1) It acts as a bank, primarily as a central bankers' bank; (2) It acts as a gathering place for central bankers and as a vehicle for international monetary cooperation; (3) It acts as trustee for various international loans. The BIS's first role as an intermediary provides a number of advantages to other central banks. The first is *anonymity*: sometimes it is not convenient for a central bank to be seen withdrawing its funds from the market. The second is *risk spreading*: a deposit with the BIS is very safe because the bank is highly liquid. (Typically, three-quarters of the BIS's assets have maturities of under three months.) The third is *liquidity*: deposits placed with the BIS can usually be withdrawn at very short notice. The BIS uses the funds received from central banks primarily for lending to other central banks. Its lendings may be swaps against gold, covered credits secured by a pledge of gold or marketable short-term securities, unsecured credits, standby credits, and the like. It places the balance of its funds in short-term deposits with international banks.

The banking activities of the BIS are probably less vital than its role as a vehicle for international monetary cooperation is. The most important part of this role is the least obtrusive: the monthly meetings of the BIS's board in Basle. Before the foundation of the BIS, meetings of governors of central banks were usually attended with a blaze of publicity and speculation concerning a crisis. Routine meetings on a monthly basis have contributed

much toward closer international monetary understanding. As a result, the BIS has been closely involved in almost every major international financial crisis since World War II. The gold pool from 1961 to 1968 operated on the basis of directives issued in Basle by the governors of the central banks of the Group of Ten. Successive packages launched in defense of sterling were usually arranged at Basle. The network of swap arrangements maintained by the Federal Reserve Bank of New York developed originally from the swap arrangements undertaken at the first Basle agreement.

Until 1994, the BIS also played a central role in the technical operations of the European Monetary System (EMS). Because of its original responsibility as a coordinator for international settlements in Europe, it has been closely involved in European payment arrangements since the war. During its lifetime, the BIS has managed the Agreement on Multilateral Monetary Compensation set up in 1947 to handle postwar European clearing arrangements; the 1948 Intra-European Payments Agreement; the European Payments Union of 1950 and its successor, the European Monetary Agreement of 1958; and most recently the European Monetary Cooperation Fund (EMCF), established in 1973, and the private interbank European Currency Unit (ECU) clearing system.

The BIS also acted as agent for the European Monetary Fund, the successor to the EMCF, set up in 1979: it handled the settlement of balances on behalf of the countries in the European Monetary System. It also ran the European Economic Community's (EEC) system of short-term monetary support and managed the financial aspects of EEC borrowings from overseas and the private interbank ECU clearing system. These activities were handed over to the European Monetary Institute (predecessor body to the European Central Bank) in January 1994.

Finally, the BIS has an important research-and-coordination role in the Euromarkets and a key role in facilitating international regulatory cooperation. Its *Annual Report* and *Quarterly Statistics* are widely regarded as the most authoritative sources of information on developments on the Euromarkets. And the BIS also provides the secretariat for the Committee on Banking Regulations and Supervisory Practices set up in December 1974 by the central bank governors to coordinate bank supervision after the Herstatt crisis (when Bankhaus ID Herstatt failed after unwise foreign exchange speculation).

More recently, in February 1999, the governors of the central banks of

the G-10 countries decided to upgrade the role of the BIS's Euro-currency Standing Committee (ECSC), which was renamed the Committee on the Global Financial System. Its role now is to act as a central bank forum for monitoring broad issues relating to financial markets and to make appropriate policy recommendations. Its tasks fall into three categories: (1) systematic short-term monitoring of global financial system conditions, so as to identify potential sources of stress; (2) in-depth longer-term analysis of the functioning of financial markets; and (3) policy recommendations aimed at improving market functioning and promoting stability.

ARAB MONETARY FUND

There is a regional Arab equivalent to the IMF, the Arab Monetary Fund (AMF), although it is neither large nor active. The AMF was set up by the Articles of Agreement of the Arab Monetary Fund concluded in April 1976 at Rabat in Morocco. The AMF was modeled closely on the IMF and includes 21 Arab countries: Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, the United Arab Emirates (UAE), and the Republic of Yemen.

The AMF's headquarters are in Abu Dhabi, and its primary work is to help member states with their balance-of-payments problems through short-term and medium-term loans (not exceeding seven years). It also gives guarantees designed to ease member borrowings from other sources. The AMF tries, too, to coordinate the monetary policies of member states and to extend technical assistance to their banking and monetary institutions.

Before the creation of the AMF, there were several Arab institutions that provided project finance, but none of them offered balance-of-payments support. This assistance was usually arranged on an ad hoc, bilateral basis through high-level political discussions with the leadership of the states concerned. The AMF represents an attempt to rationalize and to institutionalize this function. On the other hand, with paid-in capital of only approximately US\$ 400 million, it was a rather modest beginning. Furthermore, its early development was held back by alleged embezzlement of large sums by a senior official.

CENTRAL BANK SWAP NETWORK

A foreign exchange swap is a spot purchase of a currency coupled with a forward sale. The calculations involved are discussed in Chapter 11. The effects on the timing of a bank's exposure and how swaps are used by central banks to intervene in foreign exchange and money markets are discussed in Chapter 4.

This section discusses a rather special use of the swap by central banks: to borrow/lend foreign currency in exchange for domestic currency as a secured credit. The purpose is to lend the borrower foreign currency with which to intervene in the market.

The technique was first developed systematically by the U.S. Federal Reserve in the early 1960s. The first agreement was made by the Fed with the Banque de France in 1962. Between 1962 and 1967, the Fed negotiated agreements with other central banks and the BIS. Table 5.4 shows how the Federal Reserve swap network looked as of June 1998. Other countries have also put together swap arrangements, notably the United Kingdom, in defense of sterling, and the Bank of Japan, which has a swap arrangement with the Swiss National Bank for 200 billion yen.

We will look at the Federal Reserve network in detail because it is the most important. It consists of a set of standby credit agreements between the United States and other countries. Each arrangement provides for an exchange of currencies between the two countries with a commitment to reverse it in three months. At first, these swaps gave a full exchange-risk guarantee to both central banks. After July 1973, the exchange risk on drawings by the Federal Reserve was shared evenly with the foreign central bank from which it was borrowing. Other central banks borrowing from the Federal Reserve had to take the full risk. Then in 1981, it was agreed that the earlier system would be restored.

To see how the swap network actually works, let's suppose the Federal Reserve wants to sell euros to support the U.S. dollar. Suppose it needs EUR 90 million (equivalent, say, to USD 100 million) from the European Central Bank (though formally the deal might be done with the Bundesbank, until a swap line is negotiated separately with the ECB). What actually happens is that it sells the ECB USD 100 million in exchange for EUR 90 million, with an agreed reversal in three months' time at a fixed rate. The ECB's reserves of foreign exchange rise by USD 100 million, and those of the Federal Reserve rise by EUR 90 million. In other words, the swap has

Table 5.4 Federal Reserve Swap Agreements as of June 1998 (in millions of USD)

Institution	Amount
Austrian National Bank	250
Banque Nationale de Belgique	1,000
Bank of Canada	2,000
National Bank of Denmark	250
Bank of England	3,000
Banque de France	2,000
Deutsche Bundesbank	6,000
Banca d'Italia	3,000
Bank of Japan	5,000
Banco de Mexico	3,000
Netherlands Bank	500
Bank of Norway	250
Bank of Sweden	300
Swiss National Bank	4,000
Bank for International Settlements	
Dollars against Swiss francs	600
Dollars against other authorized	
European currencies	1,250
Total	32,400

Source: Federal Reserve Bulletin, June 1998.

increased both central banks' reserves. This apparent magic is caused by the fact that central banks report their reserves as the total of the assets in foreign exchange, without deducting the contingent liability on any forward exchange deals.

Central bank swaps, like any other swaps, can have an effect on the domestic money market. We saw how this works in Chapter 4. But in general the main reason central banks use them is to lay hands on foreign currency with which to defend their own currency. The Federal Reserve for many years did not hold foreign exchange reserves, hence, its interest in developing the swap technique in the early 1960s. Once the network was in place, the Bank of England became an active user in the 1960s to defend sterling; the Banque de France around the time of "the events of May" in 1968—and on other occasions—also used the system, as have many other central banks. During the period of "benign neglect" of the dollar, the swap network was used only

to give support to the Banco de Mexico; since the reversal of that policy, the authorities would certainly use the swap network if they needed to, but in practice they have not felt the requirement.

THE FEDERAL RESERVE

In addition to the multinational institutions that we have described, there is a second set of key players in the international monetary system; the central banks of individual countries, together with the ECB, which manages the euro zone of (at the time of writing) 11 European countries (see Chapter 6). Of these, the most important are the Federal Reserve, the European Central Bank, the Bank of Japan, and the Bank of England.

The U.S. Federal Reserve is a system rather than a bank. It was set up by Act of Congress in 1913—much later than most national central banks. The Federal Reserve Act divided the United States into 12 districts and provided for the creation within each district of a District Federal Reserve Bank. The system as a whole is controlled by the Federal Reserve's Board of Governors in Washington, D.C. The Board has seven members appointed by the president and confirmed by the Senate. Members of the Board are appointed for 14-year terms, which limits the political control exercised by the president over the Board. The Chairman of the Board, who is named by the president, serves in that capacity for only four years, although he or she can be reappointed. But the chairman's term does not start when the president's does, so an incoming president may have to wait until well into his or her term before appointing a new chairman. Also, the Federal Reserve's independence is bolstered by the fact that it is a legally independent institution. The president and the executive arm of the U.S. government can exercise no direct control over it.

The Federal Reserve is subject to U.S. law and so, in the end, comes under the authority of Congress. The relevant law is the Full Employment Balanced Growth (Humphrey-Hawkins) Act of 1978. The act requires that by February 20 and July 20 of each year, the Federal Reserve present a report on monetary policy to Congress. In the first of these, the Federal Reserve is required to set annual monetary policy targets. These have to be reviewed in the second report, which also provisionally sets the next year's targets.

The way in which the Fed handles monetary policy is as follows: Although it is in principle a group of 12 banks, in practice the Fed works through

two major bodies: (1) the New York Federal Reserve Bank, which handles the system's intervention in money and foreign exchange markets; and (2) the Federal Open Market Committee (FOMC), which mainly controls policy decisions on intervention. Members of the FOMC include all seven governors of the system, together with the president of the New York Reserve Bank and the presidents of 4 of the other 11 district banks. Every member of the FOMC has one vote, but the chairman of the Board of Governors has a decisive part in setting policy and acts as chief spokesperson for the system.

The FOMC normally meets about once a month. It reviews economic conditions, its goals, and current policy guidelines. At the end of the meeting, the FOMC issues a directive to the manager of the Open Market Account in New York. (The Open Market Account is the system's portfolio of U.S. Treasury and Federal Agency securities and of banker's acceptances, acquired in open-market operations.) The directive sets a short-term target that the FOMC thinks is needed to meet its annual target. And it usually sets a limit on the movement in the Federal Funds interest rate. For example, the key parts of the February 1998 directive were:

The Federal Open Market committee . . . established ranges for growth of M2 and M3 of 1–5% and 2–6%, respectively, measured from the fourth quarter of 1997 to the fourth quarter of 1998 . . . the Committee . . . seeks conditions in the reserve markets consistent with maintaining the federal funds rate at an average of around 5¹/₂%.

The control of America's gold and foreign exchange reserves ultimately rests not with the Fed but with the U.S. Treasury. The Secretary of the Treasury is legally responsible for stabilizing the exchange value of the dollar through the Exchange Stabilization Fund, which is owned by the Treasury and which controls U.S. gold and foreign exchange reserves. The swap network was a way for the Fed to get hold of foreign exchange to use for intervention. But that is only temporary: it has to be repaid. The Exchange Stabilization Fund owns the U.S. gold reserves and foreign exchange acquired from SDR sales and IMF drawings.

Policy on foreign exchange is controlled by the Treasury, whether the Fed likes it or not. Unfortunately, the Treasury is by its nature controlled by a politician. Thus, policy has swung back and forth over the years in line with changes in the political complexion of the president's cabinet. During the 1960s, the Federal Reserve, with Treasury support, became very involved

in international efforts to prop up fixed exchange rates. It developed a currency swap network; the Treasury issued Roosa bonds (U.S. Treasury bonds in foreign currency). By 1971, the U.S. Treasury under Secretary John Connally had come to an “America first” view, which led to the dollar devaluation and the breaking of the gold-dollar link.

For a few years, there was little intervention; “benign neglect” of the dollar was the policy. By 1977, this had led to unsustainable pressure on the dollar, and the swap network was reactivated. In 1981, under President Reagan, the pendulum swung back to another kind of benign neglect, based on the idea that intervention was wrong in principle. By 1985, this had led to unsupported upward pressure on the dollar and was abandoned at the Plaza Agreement. In recent years intervention has been undertaken from time to time, but usually only when markets were perceived to be “disorderly.”

EUROPEAN CENTRAL BANK

The newest body among the institutions we consider here, the European Central Bank, was created in June 1998. It did not spring into existence from nothing, however, because it subsumed an interim creation, the European Monetary Institute, which was created under the Maastricht Treaty of 1992 to prepare the ground for the creation of the ECB.

The ECB’s legal structure is modeled in part on the Fed in that it is a system of central banks, the European System of Central Banks, which consists of the ECB plus the 15 national central banks (NCBs) of the European Union (EU) countries. The NCBs are the sole shareholders in the ECB. So, in a sense, they control it; but they must obey the decisions of the ECB’s Executive Board and Governing Council. The shareholding structure of the ECB is as follows:

Deutsche Bundesbank:	24.4%
Banque de France:	16.9
Banca d’Italia:	15.0
Bank of England:	14.7
Banco de España:	8.8
De Nederlandsche Bank:	4.3
Banque Nationale de Belgique:	2.9
Other EU members:	13.0

The Executive Board, which is appointed by the EU member governments, consists of the ECB's president, vice-president, and four other members. The first set of appointments was marred by a squalid row between France and other EU members when the French president tried to impose M. Trichet, the Governor of the Banque de France, as the first head of the ECB. The appointment was defeated in favor of Wim Duisenberg, Trichet's Dutch counterpart, but at the price of an agreement that Duisenberg would stand down at some point during his term.

The other key ECB body is its Governing Council, which consists of the Executive Board plus the NCB Governors. Whereas the Executive Board is mainly concerned with running the ECB, the Governing Council "shall formulate the monetary policy of the EMU"; it is the supreme policy-making body in this area.

In addition, so long as there are states within the EU that are not members of the EMU, a General Council will handle relations with those EU members. The General Council consists of the Governing Council plus the governors of the central banks of the "out" countries (at the time of writing, Denmark, Greece, Sweden, and the United Kingdom).

The statutes of the ESCB are contained as a protocol to the Maastricht Treaty, and the primary lines of its conduct are laid down in that treaty. The relevant clauses are as follows:

Article 105

1. The primary objective of the ESCB shall be to maintain price stability.
Without prejudice to the objective of price stability, the ESCB shall support the general economic policies in the Community. . . .
2. The basic tasks to be carried out through the ESCB shall be:
 - to define and implement the monetary policy of the Community;
 - to conduct foreign exchange operations consistent with the provisions of Article 109;
 - to hold and manage the official foreign reserves of the Member States; . . .

Article 107

When exercising the powers and carrying out the tasks and duties conferred upon them by this Treaty and the Statute of the ESCB, neither the ECB, nor a national central bank, nor any member of their decision-making bodies shall seek or take instructions from Community institutions or bodies, from any government of a Member State, or from any other body. . . .

Article 109

2. The Council . . . may formulate general orientations for exchange-rate policy in relation to these currencies. These general orientations shall be without prejudice to the primary objective of the ESCB to maintain price stability.
3. Where agreements concerning monetary or foreign-exchange regime matters need to be negotiated by the Community with one or more States or international organisations, the Council, acting by a qualified majority on a recommendation from the Commission and after consulting the ECB, shall decide the arrangements for the negotiation and for the conclusion of such agreements.

As can be seen from these clauses, the ECB's role in life is to defeat inflation. Any other activity is subsidiary to that. It is also given the role of managing the European Monetary Union's (EMU) foreign exchange reserves, but there is some confusion in the matter of exchange-rate policy. The treaty is fairly tentative here, giving the finance ministers, acting through the Council of the European Union, the ability to "formulate orientations" and to negotiate with other countries or international bodies. However, because Article 107 forbids the ECB to accept instructions from the finance ministers, any exchange-rate policy to be executed by the ECB can only be set in place with the agreement of the ECB. This area of policy represents fertile ground for possible future conflicts and confusion.

It is worth noting that in legal terms the ECB is by far the most independent central bank that has ever been. Whereas the Bundesbank and the Federal Reserve were ultimately subject to their national constitutions and legislatures, the ECB was created by an international treaty—the Maastricht Treaty. For this to be amended would require the unanimous agreement of 15 member countries, which in normal circumstances would probably be very difficult to achieve. On the other hand, the ECB faces the challenge of winning the level of popular respect achieved by the Bundesbank, for example, in its fight against inflation.

BANK OF ENGLAND

The Bank of England is the second oldest central bank (after the Sveriges Riksbank) in the world and was founded in 1694. Until 1946, when it was nationalized, its shareholders remained private. So its evolution into the role

of a central bank has been very gradual in comparison with that of the Federal Reserve, which was born as a full-fledged central bank. Under the 1946 Act, the Treasury controlled the Bank as far as monetary policy was concerned.

During 1993, the British government took steps toward granting greater independence to the Bank of England by arranging for publication of the minutes of meetings between the Chancellor of the Exchequer and the Governor of the Bank about six weeks after the event and by requiring the Bank to publish an Inflation Report giving its assessment of how monetary policy was succeeding in controlling inflation. The most recent stage in this evolution was the Bank of England Act of 1998. This removed the government's ability to give instructions to the Bank of England with respect to monetary policy, thus granting effective independence to the Bank (although pedants would note that the Act reserved to the Treasury the power to define "price stability," for example, and retained various other background powers for the Treasury). It created a Monetary Policy Committee, for practical purposes the equivalent of the Fed's Federal Open Market Committee (FOMC).

Under the Act, the Bank is controlled by its Court of Directors, which consists of the governor, two deputy governors, and 16 directors, all appointed by the Crown. The term of office of the governor and the deputy governor is five years, that of the directors is three years.

Historically, the Bank of England was solely responsible for controlling what U.K. banks do. This centralization of control, together with the Bank's close working contacts with the banking system, has generally meant that its attitude toward regulation of city activities has been pragmatic and informal, in contrast to the bias toward regulation that we saw in the U.S. markets. This flexibility and informality helped the rapid development of the City of London's international financial activities during the 1960s and 1970s, despite the weakness of sterling.

However, the United Kingdom's entry into the European Economic Community (EEC) forced the Bank to harmonize its attitudes with the more legalistic approach of its counterparts in Europe. For example, in the Banking Act of 1979, the Bank had to introduce for the first time legal definitions of a *bank* and of *banking activity*. For the first time, also, this Act introduced a requirement that a bank should be recognized as such by the Bank of England in order to operate.

A more legalistic approach was also forced on the Bank as a result of the Financial Services Act of 1986 and of the wider involvement of banks in the securities industry through the so-called "Big Bang" of around that

time, under which the stock market was reformed and banks became heavily involved in the securities industry. Although the Bank of England had always been closely involved in the U.K. securities industry by virtue of its deep involvement in the City of London, the effects of the "Big Bang" were to tie it even more closely into the securities markets.

The latest development has been that the Bank of England Act moved this supervisory role to a new Financial Services Authority (FSA), which resulted in the transfer of the Bank's supervisory personnel to the FSA. The FSA has taken regulatory responsibility for almost all financial activities in the United Kingdom. (The equivalent in the United States would occur if the Office of the Controller of the Currency, the Securities and Exchange Commission (SEC), and the various state insurance and banking regulators were all merged into one entity.) The benefits of the change will be the provision of an integrated regulatory framework well adapted to the financial ("bancassurance") conglomerates being developed in London and the blurring together of many financial markets as a result of derivatives. But the possible downside may be a loss of closeness to the banking community.

As in the United States, the United Kingdom's gold and foreign exchange reserves are controlled by the Treasury, but their day-to-day management is entrusted to the Bank of England, which was responsible for the country's reserves long before the Treasury was. Indeed, the low gold content of U.K. reserves can be traced back to the Bank's private sector origins. During the nineteenth century, the Bank's attitude was "maximum banking profits consistent with convertibility of sterling"; this meant low holdings of non-interest-bearing gold. More recent gold outflows were caused by the defense of sterling during the 1960s and 1970s.

BANK OF JAPAN

Of the central banks we are considering, the Bank of Japan (BOJ) and the Swiss National Bank are the only ones still with private shareholders. Legally, under the Bank of Japan Law of 1942 (although it traces its origin to 1882), the Bank of Japan is a special corporation which is held 45% by the public and 55% by the government. In practice, the private shareholders have no say in running it.

In April 1998, a new Bank of Japan Law took effect. The thrust of the revised law is fourfold. The new law (1) explicitly defines the objective of

monetary policy as "price stability"; (2) gives enhanced powers to the Bank of Japan's Policy Board as its supreme decision-making body; (3) calls for the accountability of the central bank (the law requires the BOJ to ensure the transparency of monetary policy and to offer the markets and the general public accurate accounts of monetary-policy decision making, dictating such actions as publishing summaries of Policy Board discussions and regularly submitting monetary policy reports to the Diet); and (4) strengthens the BOJ's independence by abolishing the broad authority previously held by the Minister of Finance over central bank operations.

The Policy Board has nine members, consisting of the BOJ governor, two deputy governors, and six members chosen from among those with academic expertise or experience, including experts on the economy or finance. Matters of fundamental monetary policy, including changes in the official discount rate and the adjustment of money market interest rates, are decided by majority vote. Deliberations at board meetings are made public in the form of summary minutes about a month after the meetings.

Japan, like the United States and the United Kingdom, has a separate foreign exchange fund. In fact it has a Foreign Exchange Funds Special Account and a Precious Metals Special Account for the gold reserves. The Foreign Exchange Funds Special Account raises its finance by borrowing from the Bank of Japan, by issuing short-term bills (Foreign Exchange Fund bills), and by selling surplus foreign currency balances to the Bank of Japan.

SWISS NATIONAL BANK

The Swiss National Bank (SNB), founded in 1905, has two headquarters. The legal and administrative headquarters are at Berne, but the bank's directorate is at Zurich. It is a private corporation, but most of its shares have been held since the beginning by the Cantons and Cantonal banks. The SNB is controlled by a Bank Council consisting of 40 members. Detailed control of the bank is handled by a bank committee that is chosen by the council. But for practical purposes, the body that matters is the Directorate, which fixes the discount rate and decides on monetary policy. It consists of the governor and two deputy governors appointed by the federal government for six years. It also has deputy members, likewise appointed by the government for six years, and section directors, elected by the Bank Committee.

Switzerland has a strict policy of international neutrality, which meant

that for many years it refused to join the IMF and the World Bank. It joined formally only in 1992. But the SNB has always worked in parallel with other central banks, for instance, in lending money to the IMF under the General Arrangements to Borrow and other IMF financings. The SNB is a shareholder in the BIS—not surprising because the latter's headquarters is in Basle.

Like the Bundesbank, the SNB owns the country's reserves, which form part of the SNB's balance sheet. So any currency inflow immediately inflates the SNB's balance sheet. The bulk of the reserves are held in gold. The high level of gold holdings is partly due to the traditional legal requirement that 40% of the Swiss note circulation be backed by gold. Recent constitutional changes in Switzerland have sought to weaken the link between the Swiss currency and gold, allowing the SNB to sell some of its gold reserves.

6 The Euro and the European Monetary Union

The question of European monetary union (EMU) merits a separate chapter for several reasons. Firstly, in its own right, of course, the European Union (EU) represents a significant international economic force. An economy with a gross domestic product (GDP) of \$6 trillion and a population of 228 million people (Euro-11 countries) is a force to be reckoned with. Any major policy decisions taken by that entity will have major international repercussions.

In the context of this book, however, another reason for devoting a separate chapter to the subject is the fact that EMU raises a number of interesting technical questions for the foreign exchange and money markets. The process of unifying currencies raises several interesting issues.

POLITICAL BACKGROUND

Historically—to telescope complex events into a few sentences—the origins of the European Union go back to the vision of Jean Monnet. He perceived that by creating an apparently minor technical entity, the European Coal and Steel Community, it would be possible to create unobtrusively a framework that could then begin to be used for other forms of European cooperation, which could then (again unobtrusively) be used to develop into a European framework for economic cooperation, which became formalized in the Treaty of Rome. The technique of the founding fathers, if one may so refer to them, was to create Europe by stealth. This is not meant as a criticism; it was

probably the only practical way to do it, and the results have in many respects been thoroughly desirable.

The primary driving force behind the original concept of the European Economic Community (EEC) was to so bind France together with Germany that another European war would become impossible. It is probably fair to say that one of the main political aims of the Maastricht Treaty of 1992 (even if not expressed in public with such clarity) was to seize the moment after the fall of the Berlin Wall to lock Germany even more closely into Europe, before a reunited Germany became too dominant. This step provoked heated debate between those seeking a greater political unity in Europe and those seeking to defend the concept of national sovereignty.

Even the most ardent defender of the concept of a nation state would probably concede that another European war would be undesirable; and most would probably concede that the prospect of a major war between France, Germany, and other major European nations is now almost unthinkable. With the example of Yugoslavia nearby, they would probably concede that, to that extent, the achievements of the European Union have been unambiguously good. The debate has generally centered on questions of how far national sovereignty should be ceded to the center, particularly when many felt that "Brussels" was home to an unelected bureaucracy. This was probably the main reason why the United Kingdom, Denmark, and Sweden chose to stand aloof from the initial wave of monetary union. In addition, critics and defenders argued whether monetary union without fiscal union was a workable prospect. Also, the criteria that were laid down for entry into union were quite strict and in themselves provoked controversy (see the section "Maastricht and Convergence").

THE EUROPEAN MONETARY SYSTEM: PRECURSOR TO EUROPEAN MONETARY UNION

European monetary union evolved from the European Monetary System (EMS), which itself had its origins in 1972 with the creation of the "snake in the tunnel." This was a system by which certain European currencies were fixed against each other but fluctuated within a "tunnel" against the U.S. dollar. The move in 1973 to floating exchange rates derailed this, and the system was relaunched in 1979 as the European Monetary System.

The EMS consisted of three components: the Exchange Rate Mechanism

(ERM), the European Monetary Cooperation Fund (EMCF), and the European Currency Unit (ECU). The ECU is explained in detail in Chapter 14. Briefly, it consisted of an artificial currency unit made up from small amounts of the currencies of EMS members. The dollar equivalent of those currencies was added together to provide the value of the ECU. The Exchange Rate Mechanism was a system under which those EMS members that took part were committed to keeping their currencies fixed against each other within certain bands. This was done by declaring a parity, or central rate, for each currency against the ECU. This implied a parity grid of central cross-rates between each member currency and each other member currency.

Fluctuation bands around these central rates were permitted. In 1993, the intervention bands within the EMS were set at 15%. The original bands were 2.25%; the wider bands were set as a result of the 1993 EMS crisis.

When a currency reached the permitted limit, it was said to be at the intervention point. When any two currencies reached their compulsory intervention rates against each other, the two central banks concerned were obliged to meet all bids/offers made to them at the relevant rate. In some cases, this might mean a central bank selling a currency not held in its foreign exchange reserves or in an amount that exceeds its current holdings. Operationally this did not cause a problem because the intervening central bank had the right to draw on the EMCF's very short term financing facility (VSTF), which is explained in the following paragraphs.

There was an early warning system called the *divergence indicator* that measured the percentage of permitted fluctuation that a currency had reached. When the divergence indicator was at 75% of the permitted maximum fluctuation, there was a presumption that the relevant central bank would intervene.

The EMCF was set up by the Council of Ministers of the EEC in April 1973. The EMCF's main job was to run the VSTF, which finances intervention in EMS currencies. The VSTF allowed unlimited credit among central banks involved in the EMS. The central bank that borrowed from the EMCF (say the Banca d'Italia) could extend the term of its borrowing by using the short-term monetary support facility (STMS). Otherwise it must repay within 45 days of the end of the month when it borrowed the money (thus, the maximum it could borrow under VSTF was 75 days).

As with all lendings, the EMCF's credits had to be financed. The resources were provided by member central banks. They each deposited 20% of their gold and dollar reserves with the EMCF. Technically what happened was

that they swapped the gold and the dollars for ECUs issued by the EMCF. The swap was for three months. As each swap matured, it was rolled over; but the amount involved was adjusted in line with the market value of gold and of the dollar.

THE MAASTRICHT TREATY

The next stage in the process of creating European monetary union was the Treaty on European Union (usually referred to as the Maastricht Treaty), which was signed in February 1992. After a difficult ratification process, it came into effect on November 1, 1993. As a result, on January 1, 1994, the regulations on the second stage of European economic and monetary union came into effect.

Stage One, which began after the recommendations of the Delors Committee were accepted at the Madrid summit in June of 1989, comprised closer economic and monetary cooperation between member states within the existing institutional framework, aiming at greater convergence of economic performance. It also involved the completion of the Single Market and the strengthening of Community competition policy.

The key feature of Stage Two was the creation of the European Monetary Institute (EMI). The EMI took over the running of the then-existing EMS, had the job of facilitating the use of the private ECU, and oversaw the development of the ECU clearing system. It had the right to be consulted by the national authorities on monetary policy (although during Stage Two, monetary policy in individual countries remained firmly in the province of the national central bank). The first president of the EMI was Alexandre Lamfalussy, previously General Manager of the Bank for International Settlements (BIS).

MAASTRICHT AND CONVERGENCE

The other key feature of Stage Two was that it was designed to achieve a process of economic convergence to facilitate the creation of a single monetary zone. The protocol on convergence criteria annexed to the treaty laid down four key criteria to determine whether or not a particular economy had converged sufficiently closely to the norm to be eligible to join Stage Three.

The criteria were:

1. The achievement of a high degree of price stability—a rate of inflation close to that of, at most, the three best performing member states.
2. A government deficit at or less than 3% of gross domestic product at market prices, and a ratio of government debt to gross domestic product of 60% or less.
3. The observance of the normal fluctuation margins provided for by the exchange rate mechanism of the EMS for at least two years.
4. Durability of convergence being reflected in long-term interest rate levels. In particular, over a period of one year beforehand, the member must have had an average nominal long-term interest rate not exceeding by more than two percentage points that of, at most, the three best performing member states in terms of price stability.

A little-noticed provision of the treaty that became operative with the beginning of Stage Two is the exclusion of liability by the Community and the other member states for the debts of individual countries within the Union. This rule was intended to underscore the responsibility borne by each country for its own public finances and to make sure that everything is done to avoid excessive deficits.

Finally, with the entry into force of the Maastricht Treaty, the composition of the ECU currency basket was permanently fixed. (Previously, there had been a provision requiring a review every five years of the makeup of the ECU basket.) As a result of the Treaty, *one ECU* was defined as the sum of the following currency amounts: DEM 0.6242, FFR 1.332, GBP 0.08784, ITL 151.8, NLG 0.2198, BEF 3.301, LUF 0.130, ESP 6.885, DKK 0.1976, IEP 0.008552, GRD 1.440, and PTE 1.393.

EUROPEAN MONETARY UNION

The decisions of the Cardiff summit of May 1998 and the legal formation of the European System of Central Banks (ESCB) and the European Central Bank (ECB) in June 1998 may be said to have marked the true beginning

of the European Monetary Union and of the euro. Its legal existence began on January 1, 1999, but its economic existence may be said to have started with these two events. The May summit determined which currencies would enter the euro, and the formation of the ECB gave birth to the body responsible for controlling the currency. The nature and the role of the ECB and the ESCB are discussed in Chapter 5. The operating methods of the ESCB/ECB are discussed in the following sections.

The actual launch of the euro was a massive operation culminating in a long weekend from December 31, 1998, to January 3, 1999. During this period, many thousands of government and other bonds had to be redenominated into euros, with all the consequential changes to portfolio and position reports. Also, going into effect as of January 3, the new cross-border TARGET settlement system and the Euro1 system (see Chapter 22) began clearing euros, with all the necessary changes to settlement instructions, payment routings, and so forth. The entire operation was probably the largest single financial operation of the century involving, as it did, market participants across the globe. A second wave of changeover, the substitution of euro notes and coin for national units, was left for 2001.

MECHANICS OF THE CONVERSION TO THE EURO

The framework within which the conversion to the euro was carried out is based on three primary legal components:

1. The first is based on Article 235 of the Maastricht Treaty, which lays down the principle of "Neither compulsion nor prohibition." Under this, nobody in the European Union can be compelled to accept euro rather than national currency during the transition period, nor can they be prohibited from doing so. The article also provides that as of January 1, 1999, every reference in a legal instrument to the ECU is replaced by a reference to the euro at a rate of one euro to one ECU (Article 2). During the transition period, under the legal requirement of "no compulsion, no prohibition," customers of banks were entitled to make and receive payments either in "legacy currency" (deutschemarks, French francs, etc.) or in euro; and they were entitled to have the conversion between legacy currencies and euro carried out free of charge.

Article 235 also provides that the introduction of the euro shall not change

any term of a contract. This remains subject to anything to which parties may have agreed.

2. The second legal pillar is an EU regulation—Regulation 1103/97. This came into force on June 17, 1997. It lays down the means by which exchange-rate conversions must be carried out in EU member states. It defines the concept of *conversion rates*. It should be noted that, in this context, this is a very specific term. It defines one euro expressed in the national currencies of the *participating* member states. Thus, at the time of the launch of the EMU, there was no conversion rate between the euro and sterling because the United Kingdom was not a participating member state. The conversion rates are defined to *six significant figures* (thus DEM 1.95583 but ESP 166.386). They must not be rounded or truncated when making conversions.¹ Furthermore, because of potential inaccuracy, inverse rates derived from the conversion rates must not be used. The actual conversion rates are as follows:

1 euro =	BEF 40.3399
	= DEM 1.95583
	= ESP 166.386
	= FRF 6.55957
	= IEP 0.787564
	= ITL 1936.27
	= LUF 40.3399
	= NLG 2.20371
	= ATS 13.7603
	= PTE 200.482
	= FIM 5.94573

Finally, mention should be made of *triangulation*. Regulation 1103/97 provides that amounts to be converted from one national currency unit into another must first be converted into a euro amount (one currency unit to euro to other currency unit). This amount may be rounded to no fewer than three decimal places and then converted into the other unit. For example, to convert ITL 100,000 into Austrian schillings (ATS), the Italian lire are

¹Of course, anyone is entitled to disobey these rules if commercially convenient; however a citizen of the EU, if they did so, might be subject to legal challenge. The regulations do not, of course, in themselves bind residents of other countries.

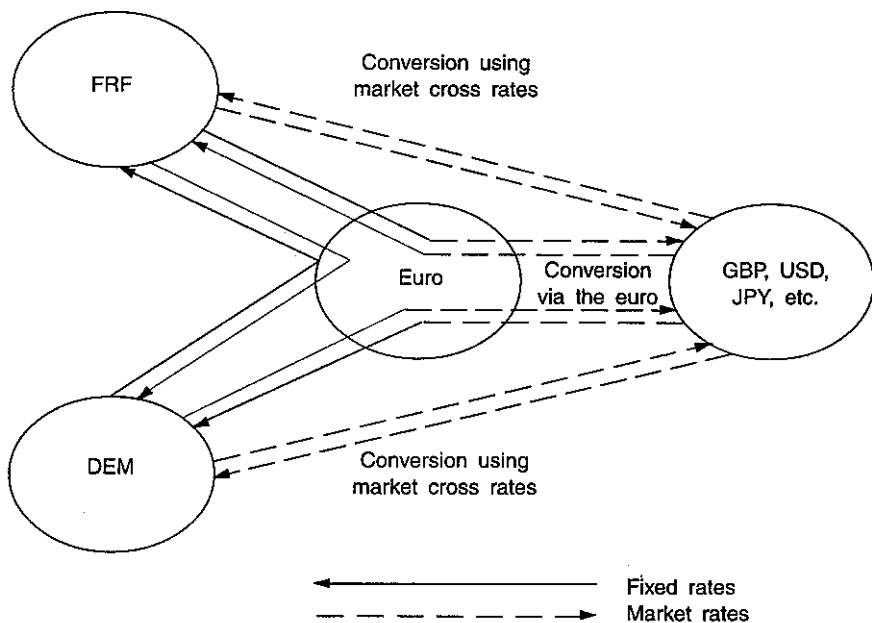


Figure 6.1 Triangulation. *Source:* Bank of England, Practical Issues Arising Out of the Euro, June 1998.

converted into euro using the conversion rate to produce EUR 51.64569, which is then rounded to EUR 51.646. That amount is converted, using the ATS conversion rate, to ATS 710.6645, which is rounded to ATS 710.66. The regulation states that no alternative method of calculation may be used unless it produces the same results.²

The conversion and rounding rules are only valid for conversions between the euro and participating national currency units and do not apply to conversions and rounding with respect to other nonparticipating currencies (e.g., sterling). Figure 6.1, produced by the Bank of England, illustrates the position.

²It has been demonstrated by the Commission that other methods, even when worked to 16 decimal places, can occasionally produce different results, so that it would be necessary to follow the triangulation method for full legal certainty, although once again considerations of commercial practicality—or software design—might lead firms to reject this option.

3. The third legal pillar is a regulation based on the Maastricht Treaty's Article 109L(4). This regulation, adopted by the new EMU members during the May 1998 summit, provides that euro will be substituted for participating currencies at the fixed conversion rates. Where in a legal instrument reference is made to a national currency unit, this reference shall be as valid as if reference were made to the euro. It also provides that as of January 1, 1999, payments can be made in the euro or in national currency (subject to anything that the parties might have agreed).

At the time of the introduction of the euro, much attention was paid to the question of continuity of existing contracts made, for example, in deutschemarks but now to be performed in euro. Although the preceding three regulations are, it seems, considered sufficient by lawyers to guarantee continuity of contracts within the euro area, some doubt was expressed regarding other jurisdictions. As a result, legislation was passed by New York State and by California and Illinois; and the International Swaps and Derivatives Association (ISDA) created a multilateral EMU Protocol. Signature by ISDA members of the Protocol ensured that all their contracts with other signatories would continue to be valid regardless of the arrival of the euro. The aim was to cover situations in which national reference rates such as PIBOR—the Paris interbank offered rate—were replaced by EURIBOR—euro interbank offered rate.

The arrival of the euro triggered a number of accounting issues, such as the appropriate treatment of capital gains and losses from foreign exchange. Firms that had, perhaps, borrowed French francs to buy Spanish assets found that the disappearance of exchange risk meant that all foreign exchange gains and losses crystallized for accounting purposes if they had not previously been recognized. This was of particular importance in Germany where some firms had substantial, unrealized, long-term exchange gains that had not been recognized for tax purposes; legislation was introduced to permit the smoothing of these gains for tax purposes by means of special reserves.

EURO CONVENTIONS

One of the problems in creating the euro was that the underlying national markets had several different interest-calculation conventions. As a result,

the major professional groups got together and issued a joint statement on market conventions that made the recommendations shown in Table 6.1.

Note that the ISDA swap day-count on the fixed side differs from the recommended bond day-count. Also, it should be noted that with respect to bond market interest accruals, there are at least three different interpretations of *actual/actual*: (1) the International Securities Market Association (ISMA) understanding of the actual/actual convention (which is also the U.S. Treasury convention); (2) the Association Francaise des Banques (AFB) method, which produces results different from those of the ISMA method; (3) the ISDA method, included in the 1991 ISDA Definitions. For example, consider a £10,000 nominal amount, with a 10% coupon, with the next coupon period being 182 days. Of these days, 61 are in the current year and 121 are in the next year, which is a leap year. The calculations would produce:

1. ISDA: $£10,000 \times 10/100 \times (61/365 + 121/366) = £497.72$
2. ISMA: $£10,000 \times 10/100 \times [182/(182 \times 2)] = £500$
3. AFB: $£10,000 \times 10/100 \times (182/366) = £497.27$

The ISDA position on actual/actual is now this: The existing ISDA method has been retained under the name "Actual/actual (Historical)." The AFB method has been introduced under the name "Actual/actual (Euro)," and the ISMA method has been introduced under the name "Actual/actual (Bond)." Counterparties are strongly advised to confirm what they mean by *actual/actual*.

ERM II

The start of Stage Three of monetary union and the launch of the euro were also the occasion of the launch of the so-called ERM II. This was a new form of the Exchange Rate Mechanism discussed earlier in the chapter. The background is that at the Amsterdam summit in June 1997, the European Council agreed to set up the so-called ERM II to come into effect after the arrival of EMU. Participation in the exchange rate mechanism is voluntary for the member states outside the euro area. It is based on central rates against the euro. There is one standard fluctuation band of $\pm 15\%$ around the central rate. Intervention at the margins will in principle be automatic and unlimited,

Table 6.1 Market Conventions for Euro

	Money Market	Bond Market	Euro Swaps
Interest calculation basis	Actual/360	Actual/actual	Floating day- count basis Actual/360 Fixed-rate day- count basis 30/360
Business days	TARGET working days	TARGET working days	TARGET working days
Value date	Spot (i.e., both euro LIBOR and EURIBOR are for spot value)		
Price convention		Decimals, not fractions	
Fixing period			Two-day rate-fixing convention
Coupon frequency		Annual (semiannual for Italian government bonds)	Annual

with very short term financing available. However, the ECB and the central banks of the other participants could suspend intervention if this were to conflict with their primary objective of price stability.

Decisions on central rates and on the standard fluctuation band are to be made by mutual agreement of the ministers of the euro-area member states, the ECB, and the ministers and the central bank governors of the non-euro-area member states participating in the new mechanism, following a common procedure involving the European Commission and after consultation of the Economic and Financial Committee. The ministers and the governors of the central banks of the member states not participating in the exchange rate mechanism will take part but will not have the right to vote in the procedure. All parties to the mutual agreement, including the ECB, will have the right to initiate a confidential procedure aimed at reconsidering central rates.

On a case-by-case basis, formally agreed fluctuation bands narrower than the standard one and backed up in principle by automatic intervention and financing may be set at the request of the non-euro-area member state concerned. Such a decision to narrow the band would be made by the ministers of the euro-area member states, the ECB, and the minister and the governor of the central bank of the non-euro-area member state concerned, following a common procedure involving the European Commission and after consultation of the Economic and Financial Committee. The ministers and the central bank governors of the other member states will take part in the procedure but will not have the right to vote.

On January 1, 1999, it was announced that the European Central Bank, Danmarks Nationalbank, and the Bank of Greece had established the compulsory intervention rates for the Danish krone (DKK) and the Greek drachma (GRD) in ERM II. The euro central rates as well as the compulsory intervention points for the Danish krone and the Greek drachma are:

1 euro = Upper rate—DKK 7.62824
 Central rate—DKK 7.46038
 Lower rate—DKK 7.29252

1 euro = Upper rate—GRD 406.075
 Central rate—GRD 353.109
 Lower rate—GRD 300.143

It will be noted from the rates shown that the Danes have opted for a 2.25% fluctuation band and the Greeks have opted for a 15% band.

EURO-AREA FOREIGN EXCHANGE RESERVES

As in a number of other areas, the management of foreign exchange reserves of the euro area represents an uneasy compromise between centralizers and decentralizers. The present balance seems unstable and is likely to be resolved in favor of the centralizers, but how long this will take is unclear. National central banks (NCBs) will transfer up to the equivalent of E 50 billion in foreign exchange assets to the ECB. Reserves in excess of this amount will continue to be held at the NCBs. But any transactions carried out with those assets will be monitored by the ECB "with a view to ensuring consistency with the single monetary policy and the foreign exchange policy of the euro area. . . . A framework has been elaborated on this issue, encompassing not only central governments but also all public authorities within the euro area. Hence in accordance with Article 31 of the ESCB/ECB Statute, foreign exchange operations carried out by the NCBs with their remaining foreign reserve assets . . . will be subject to prior approval by the ECB."³

MONETARY POLICY IN THE EUROZONE

With the arrival of European monetary union in January 1999, embracing 11 countries (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain), the euro immediately became the second largest currency in the world, in terms of the size of underlying financial markets.

As discussed earlier, it had a predecessor, the ECU, and there was a limited money market for trading in ECU. An ECU clearing system was operated by the Bank for International Settlements in conjunction with the ECU Banking Association (now called the Euro Banking Association; see Chapter 22). However, the ECU was purely an artificial currency unit (see Chapter 14 for discussion of such units) rather than a bona fide, legal-tender currency.

³*EMI Annual Report 1997*, p. 46.

With the arrival of the euro, 11 national currencies legally ceased to exist, to be replaced by one transnational currency—the first such currency in modern times. (One could argue that sterling, which was used as the currency of a number of countries in the British Empire, was also a transnational currency, but the underlying circumstances were of course very different.) Eleven independent monetary policies were merged into one. Now monetary policy in the Economic and Monetary Union is managed by the European System of Central Banks (see Chapter 5). The ESCB conducts its monetary policy through three main policy instruments. These are (1) minimum reserves, (2) standing facilities, and (3) open market operations.

Minimum Reserves. In October 1998, the ESCB decided to apply a reserve ratio of 2% on:

- Overnight deposits.
- Deposits with agreed maturity up to two years.
- Deposits redeemable at notice up to two years.
- Debt securities issued with agreed maturity up to two years.
- Money market paper.

However—and this is a key point—these required reserves will earn interest at the ECB's repo rate. Thus, it is unlikely that the ESCB reserve requirements will cause the type of distortion that arose from the Federal Reserve's 3% reserve requirements (Chapter 1 discusses how this led to the growth of the Eurodollar market). Generally speaking, assuming that the ESCB behaves like other central banks, it seems likely that these reserve requirements will be changed relatively rarely.

Compliance with the reserve requirement is determined on the basis of the institutions' average daily reserve holdings over a one-month maintenance period.

Standing Facilities. The ESCB stands ready at any time to borrow from or lend to the market. The marginal lending facility provides overnight liquidity (through the national central banks) against eligible assets. Under normal circumstances, provided there are sufficient underlying assets, there is no limit to the amount made available. Likewise, the ESCB, operating through the national central banks, stands ready to accept deposits from the market overnight.

The ESCB deposit facility and the marginal lending facility, under normal circumstances, will set the floor and the ceiling, respectively, for market rates. This system is quite like that used by the Bundesbank, where the floor was set by the discount rate and the ceiling by the Lombard rate.

Open Market Operations. The ESCB has five main types of instrument for the conduct of open market operations, the first being the most important:

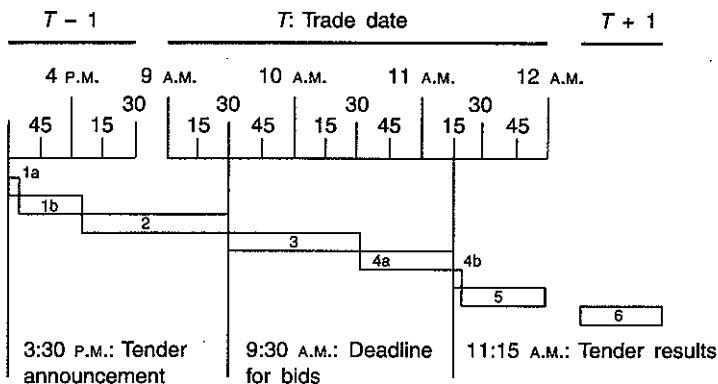
1. Reverse transactions (i.e., repos or collateralized loans).
2. Outright transactions (the purchase or sale of securities aimed at a permanent injection or draining of liquidity).
3. Foreign exchange swaps.
4. The collection of fixed-term deposits.
5. The issuance of ESCB debt certificates.

In a way rather similar to traditional German practice, the ESCB has set up a system of "main refinancing operations" whereby once a week, in accordance with a preannounced tender calendar (normally each Tuesday), it provides liquidity to the market for two weeks via repurchases or collateralized loans. These operations, strictly speaking, are not carried out by the ESCB but by the national central banks on the ESCB's behalf. In addition, the ESCB has the facility to execute "quick tenders" in its own name, should it feel that it urgently needs to "fine-tune" the market.

It is important to note in this context the distinction between Tier One assets and Tier Two assets. *Tier One assets* consist of marketable debt instruments fulfilling uniform criteria laid down by the ECB and applied across the Eurozone. In essence, Tier One assets are marketable debt denominated in euro held within the Eurozone and issued by an issuer from the Eurozone. *Tier Two assets* consist of assets (marketable and nonmarketable) that are of particular importance in one or more member states and that are acceptable to the national central bank in that country. For example, in France, certain kinds of bank loans qualify as Tier Two assets; in the Netherlands, the authorities are willing to accept equities.

Both Tier One assets and Tier Two assets are eligible for the main refinancing operations. However Tier Two assets are not normally used for outright operations. (Clearly, this could result in the ESCB owning assets that have a risk profile rather higher than it might wish.)

Longer-term refinancing operations are carried out by the ECB on the



- Step 1: Tender announcement.**
 - 1a. Announcement by ECB through wire services.
 - 1b. Announcement by NCBs through wire services (and direct if needed).
- Step 2: Counterparties prepare and submit bids.**
- Step 3: ESCB compiles bids.**
- Step 4: Tender allotment and announcement.**
 - 4a. ECB allotment decision.
 - 4b. Announcement of allotment result.
- Step 5: Certification of individual allotment results.**
- Step 6: Settlement.**

Figure 6.2 Normal Time Frame for ECB Standard Tenders

first Wednesday of each reserve maintenance period. These are three-month operations in which the ECB is not intending to send a rate signal to the market and so it acts as a “rate taker,” using variable rate tenders.

The distinction between fixed-rate tenders and variable-rate tenders is that in the former the ECB fixes the interest rate in advance and its counterparts bid the amount of money they want to transact at that rate. In the latter case, both the amount of money and the interest rate are set by the ECB’s counterparts.

One difference between repo operations in the Euro area and, say, repo in the United States or Japan is that it may involve a cross-border trade. A bank in Germany may do repo operations with the Bundesbank using French government bonds. In this example, the Banque de France would have to confirm to the Bundesbank that it had the bonds under its control before the Bundesbank would pay the German bank. The Banque de France acts as the Bundesbank’s correspondent; this is the so-called correspondent central bank model.

Figure 6.2 illustrates the ESCB’s operating time line in the case of its standard tenders.

7 Money Market Calculations

In this chapter, we discuss basic money market calculations as they relate to time deposits, including the calculation of forward-forward deposit rates. Because the calculations are very closely related, this chapter also covers Forward Rate Agreements (FRAs). We also look at net present value calculations and the zero-coupon curve, together with medium-term forward-forward deposit rates. In Chapter 8, we discuss the relevant calculations as they apply to money market paper, such as certificates of deposit, Treasury bills, and commercial paper, and to some basic bond calculations.

For the sake of simplicity, we concentrate on Euromarket calculations. This allows us to focus on the transnational aspects of the market and avoids questions of reserve requirements or other features specific to particular markets (which are treated separately at the end of the chapter). Therefore, throughout this chapter, all comments (unless otherwise stated) relate to the Euromarket—deposits traded outside the country of origin. Deposits traded in the country of origin are referred to as *domestic*.

CONVENTIONS

The Euromarkets use two bases for calculating interest: the 360-day year and the 365-day year. The 365-day year is used for sterling and for the Kuwaiti dinar. Almost all other currencies are dealt on a 360-day basis. Sometimes the Canadian dollar is dealt on a 365-day basis with customers,

but interbank Euro-Canadian is usually 360. Given mutual agreement, any basis can be used.

The method of calculation for a 360-day basis is as follows: Suppose the deal is for 91 days, the interest rate is 10%, and the principal amount is USD 1 million. Then the interest is calculated as $\$25,277.78 - (10/100) \times (91/360) \times \$1,000,000 = \$25,277.78$. Because this method uses actual days elapsed and a 360-day year, it is sometimes called a 365/360 basis or an actual/360 basis.

The calculation method for 365-day basis is similar, with 91/360 replaced by 91/365: $(10/100) \times (91/365) \times \$1,000,000 = \$24,931.51$.

Note that for the same nominal interest rate of 10%, the 365-day basis produces a lower interest amount. Thus a 10% Eurodollar rate (360-day basis) is equivalent to a 10.13889% rate on a 365-day basis. Equally, a 9.863% Eurodollar rate on a 360-day basis is equivalent to 10% on a 365-day basis. The 365-day method is sometimes called the 365/365 method, or the actual/365.

Another method of calculating interest rates was traditionally used in certain European countries for domestic deposits (and in certain bond markets) until the arrival of the euro (see Chapter 6). It is also used in many interest-rate swaps. This Continental method can be described as the 30/360 method, compared with the Euromarket (365/360) method or the sterling (365/365) method. The two latter methods compute interest on the actual days elapsed, whereas the Continental method treats the year as consisting of twelve 30-day months. Thus, a deal running from December 5, 2000, to December 5, 2001, would be treated as a 360-day deal. A deal running from December 5, 2000, to May 12, 2001, would be treated as having 157 days $[(5 \times 30) + 7]$ instead of the actual 158 days. Note that the result of this method is to produce a lower effective rate, for a given nominal rate, than the 365/365 sterling method would, which in turn is lower than the effective rate resulting from the 365/360 Euromarket, or U.S., method.

Euromarket practice is to pay interest at the maturity of the deal, except where periods of over one year are involved. In that case, interest is paid annually on the "anniversary" of the deal. Let's look at a two-year deal done on December 5, 2000. Interest would be paid on December 5, 2001. Interest would be paid again, and the principal repaid, on December 5, 2002. A two-and-a-half-year deal done on the same date would pay interest on the same dates, with a final interest payment (and repayment of principal) on June 5, 2003. If the anniversary is not a business day, the procedure adopted is

the same as in the forward market (see Chapter 10); it will be rolled forward to the next business day, providing this does not take us into the next month.

The deposit market quotes two rates for a given period: (1) The *offered rate* is the rate at which the dealer is prepared to lend money. (2) The *bid rate* is the rate at which the dealer is prepared to borrow. Normal U.S. practice is to quote the bid rate first. Normal London market practice is to quote the offered rate first. Hence “ $7\frac{1}{4}-\frac{1}{2}$ ” in the United States and “ $7\frac{1}{2}-\frac{1}{4}$ ” in London both mean “I lend at $7\frac{1}{2}$ per cent, I borrow at $7\frac{1}{4}$ per cent.”

A large amount of Eurocurrency lending involves the *London interbank offered rate* (LIBOR). It can be defined in two ways: (1) the rate at which funds are offered to a first-class bank in London for the maturity period in question; (2) the rate at which a first-class bank in London offers funds to another first-class bank in London. In either case, LIBOR attempts to measure the cost to a bank of raising new funds from the market in order to on-lend. It is the basis of almost all variable-rate lending in the Euromarkets. In view of its importance, it should be stressed that the LIBOR concept is purely judgmental. For example, three-month LIBOR for USD 1,000 million will very likely differ from three-month LIBOR for USD 5 million. We are considering the dealer's judgment of what it would cost him to raise that amount for on-lending. It may well be that he judges that it would cost him more to raise the larger amount, because it will move the market against him. Hence, normal practice for any given loan is to calculate LIBOR as the average of the rates quoted by several “reference banks” selected for the purpose. The rates published in the financial press reflect a consensus of often diverse views. LIBOR is usually fixed at a time specified in the original loan agreements (normally 11:00 A.M. London time) and is quoted for deposits starting from the spot date (see below) for various periods, of which the most common are three months and six months.

The LIBOR convention has spawned many variations, including SIBOR (Saudi or Singapore interbank offered rate), NIBOR or NYBOR (New York), KIBOR (Kuwait), PIBOR (Paris), FIBOR (Frankfurt), ADIBOR (Abu Dhabi), HKIBOR (Hong Kong), MIBOR (Madrid), and so on. In all cases, the concept attempts to measure a bank's funding costs for a loan, though the details vary from center to center. If no other details are given, it is normal to infer that the rate is for U.S. dollar deposits traded in that center. It is quite possible to apply the concept to other Eurodeposits or to domestic deposits (for example, many domestic U.K. loans are linked to sterling LIBOR).

The most recent variant is EURIBOR, defined as the interbank offered rate for banks operating in the Eurozone (i.e., excluding London, at the time of writing). The European Banking Federation in Brussels and the Association Cambiste International (ACI) are the sponsors of EURIBOR. Like LIBOR, EURIBOR uses the actual/360 day-count convention and is for spot value (i.e., published on D for value $D + 2$). The difference between LIBOR and EURIBOR is the makeup of the panels of banks whose rates are used. The British Bankers Association (BBA) LIBOR panel consists of 16 banks from the London market. The EURIBOR panel consists of 53 banks actually operating in the Eurozone.

Another important set of rates is the overnight rate in different markets. As discussed in Chapter 1, the domestic U.S. money market rate for overnight funds is usually called the Fed funds rate, and the Federal Reserve (the Fed) publishes the so-called effective Fed funds rate (a weighted average of transactions in the Fed funds market). A similar concept has evolved in the Eurodollar market and in other overnight markets, largely because of the growth of a market in interest-rate swaps (see Chapter 16) indexed to these overnight rates. Thus, for example, there is a sterling overnight index average rate (SONIA), which is calculated as the weighted average of overnight deposit trades reported by members of the Wholesale Market Brokers' Association. The European System of Central Banks (ESCB) provides an official "euro overnight index average" (EONIA) equivalent to the Federal Reserve effective overnight rate, and the Wholesale Market Brokers' Association calculates EURONIA (Euro overnight index average) for the London market.

The spot convention for deposits is the same as that for foreign exchange (see Chapter 9), that is, two working days. However, a difference may arise in the case of a holiday. Consider a situation in which New York and Frankfurt were open on a given day, but London was closed. Then the foreign exchange market would normally deal USD/EUR for that day, but London would not normally deal Eurodeposits maturing on a day on which it was closed. It would be possible in theory to do so but would generally be inconvenient.

TYPES OF DEPOSIT

A *call deposit* is defined as a deposit that is repayable "at call." In practice, due to time-zone considerations and to the need to transmit confirmations

between countries, such deposits may be repayable at up to two days' notice, unless special arrangements have been made. The situation varies according to the currency, and the ability to take call funds from a customer depends on the currency. In some currencies, there is not a well-developed call money market, which makes it difficult to lay off funds.

An *overnight deposit* is defined as a deposit that is made on one day and is repaid (or replaced) on the next business day. Overnight deposit trading is also complicated by time-zone considerations. A Hong Kong bank can deal U.S. dollar deposits overnight without difficulty, because New York will normally be 13 hours behind, giving plenty of time for instructions to be processed in Hong Kong and acted on in New York. However, London cannot normally deal overnight yen deposits.

The time-zone problem is less pressing for deposits starting tomorrow and maturing in the next business day, usually referred to as "tomorrow/next," or "tom/next." (It will be noticed that tom/next deals mature on the spot date.) It is possible to deal tom/next in most currencies that have a well-developed Eurocurrency market, but because of the time zone problem, the market tends to dry up very early.

As in the foreign exchange market, the deposit market quotes spot/next (from spot to the next business day), spot/week, and so on. A *period deposit* is defined as a deal starting on the spot date and maturing on some fixed and predetermined date. The phrase "the periods" usually refers to some or all of the "standard" periods of one, two, three, six, nine, or twelve months (see Chapter 10). Value-date conventions for period deposits are the same as for foreign exchange, with the exception that it would be possible (though in practice unusual) to deal for a value date in which the dealing center was closed but the settlement center was open. For example, suppose that New York and Frankfurt were open on a given day, but London was closed. The foreign exchange market—and London—would deal USD/EUR for settlement on that day, but London would not normally deal Eurodollars or Euro-euro deposits for maturity on that day.

YIELD CURVE

A *yield curve* is a graph that plots interest rates against time. To make it meaningful, the different interest rates should be for comparable instruments. In this chapter, that means interest rates for a deposit with a bank. In other

contexts, the interest rate might be for Treasury bonds maturing, say, in one, three, five, and ten years, and the graph would be referred to as a Treasury bond yield curve. Because of possible capital gains on a security (or on a CD) and the differing taxation treatment of interest earnings and capital gains, constructing a true yield curve for securities can be quite complex. But for “clean” deposits, the question of capital gain does not arise, so the yield curve concepts are quite simple.

Suppose we have the following set of interest rates: one week, 10%; one month, 10½%; two months, 10½%; three months, 10¾%; six months, 11%; nine months, 11½%; and twelve months, 12%. Then we can draw a simple yield curve as shown by *ABC* in Figure 7.1. We can see that, overall, it slopes upward to the right. This is called a *normal upward-sloping*, or positive, *yield curve*. It is normal because under normal circumstances a lender requires a slightly higher rate to compensate for locking away the funds for a longer period. Equally, a borrower will be prepared to pay slightly more for the benefit of being insulated against interest-rate movements for a longer time.

If the market thinks that rates are about to rise, the curve will rise more steeply; lenders will require extra compensation before they will lock in at today’s rates. They believe that rates will soon be higher, and so they would be better off to wait until the rates rise before they lend. In this situation, it might be that the three-month rate is 12%, and the twelve-month rate is 13%. We could draw a yield curve like *ABDE* in Figure 7.1.

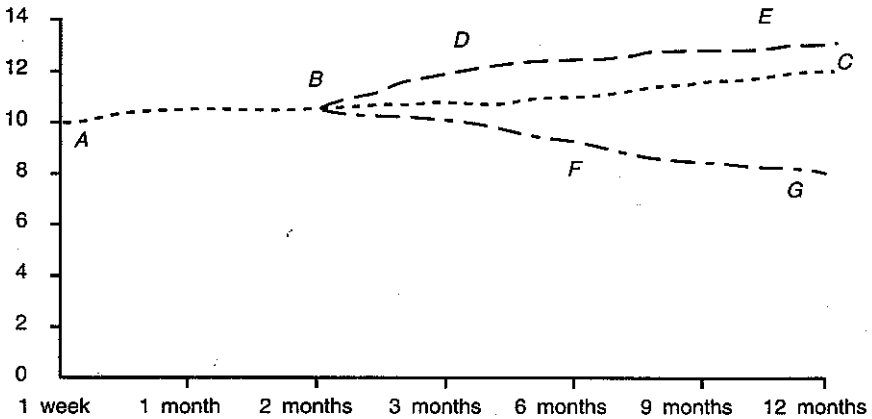


Figure 7.1 Yield Curve

Or it might be that the market expects rates to fall. In this case, lenders will be happy to lend for longer periods at rates below today's rates. They fear that if they wait before they lend, the rates they will receive will be lower still. In this case, the twelve-month rate might be only 8%, with the six-month rate at 9%, and the two-month rate at 10¹/₂%. We could draw a yield curve like *ABFG* in Figure 7.1.

Looking at a yield curve tells us a great deal about where the market thinks rates are going. If we look at Figure 7.1, we can see that if today's yield curve is *ABDE*, the market expects rates to rise, but not for a couple of months, because *AB* is sloping up gently in line with the normal pattern. If the yield curve were *ABFG*, the market is expecting rates to fall over a couple of months. Also, the slope of the curve suggests that between two and six months hence—*BF* on the curve—the market expects quite a sharp fall, which will steady off later; *FG* is flatter than *BF*. The yield curve is telling us visually about the implied forward-forward rates (which are discussed later). We will come back to how the yield curve, the forward-forward rates, and the implied zero-coupon rates are interlinked later in the chapter.

A technique used by many investors is called "riding the yield curve." Suppose that in the shorter maturities the slope of the yield curve is positive (and is expected to remain so). This means that, say, a six-month certificate of deposit (CD) yields more than a three-month CD. If rates do not change drastically, an investor can pick up extra yield by buying the six-month CD and selling it in three months to reinvest the proceeds in the six-month CD. In effect, the investor is collecting the premium for staying long in a market where a premium is paid for staying long. Of course, if rates have risen sharply in the meantime—as has often happened in recent years—the investor has earned less than he or she could have by staying short.

MISMATCH (GAP)

This brings us to the question of *mismatch* (usually referred to as *gap* in the United States). Mismatch happens when a trader borrows or lends money for a longer or a shorter period than would be needed to match his or her commitment. If a bank lends money for six months and funds the lending initially with a three-month deposit, it is mismatched. There are two kinds of mismatch: (1) interest mismatch and (2) funding mismatch (see Chapter 20). In our example, there is interest mismatch of three months. If after six

months the loan is due for repayment, then the funding mismatch is also three months. If the six-month loan is a roll-over loan whose final agreed maturity is, say, five years, then the funding mismatch is four years and nine months—the remaining period during which money must be raised to fund the loan.

Mismatching is the justification for a bank's existence. The origin of banking, after all, was in taking deposits, repayable at demand, and lending them out for a slightly longer period. Banking also carries risks; the control of these risks is discussed in Chapter 20. In proportion to the risk, banking carries the chance of profits.

Suppose we have the following bid offer rates: one month (30 days) at 10 to $10\frac{1}{8}\%$; three months at $10\frac{5}{8}$ to $10\frac{3}{4}\%$; and six months (180 days) at $10\frac{5}{8}$ to $10\frac{3}{4}\%$ (or 10.75%). The market expects a rise in rates in the next three months, followed by a leveling out. Suppose a customer borrows \$10 million for six months from the bank, and the bank thinks the market has got it wrong, and rates will fall. Then the bank will fund itself, say, for one month at $10\frac{1}{8}\%$ (or 10.125%). It earns $\$10,000,000 \times (10.75/100) \times (180/360) = \$537,500$ for the six-month loan, paying $\$10,000,000 \times (10.125/100) \times (30/360) = \$84,375$ for the one-month funds. Suppose in a month's time the rate for five-month money (150 days) has fallen to 10%, paying $\$10,000,000 \times (10/100) \times (150/360) = \$416,666.67$ (ignoring interest on interest). Its total costs are \$501,041.67, and its total earnings are \$537,500, leaving a profit of \$36,458.33.

This compares with the $\frac{1}{8}\%$ that the bank would have earned if it had immediately been able to fund itself for six months at $10\frac{5}{8}\%$, which would have shown a profit of only \$6,250 if it had not run a deliberate mismatch. Of course, the \$30,000-odd extra profit from this mismatch could just as easily have been a loss if the bank had misjudged rate movements. A number of the world's largest banks have lost tens of millions of dollars on mismatch positions, hence the need for tight controls.

BROKEN DATES

Suppose we need a period deposit rate for a date that is not a "standard" one; for instance, suppose we have the following Eurorand rates: one month at $12\frac{1}{8}$ to $12\frac{1}{4}\%$ for 30 days and two months at $12\frac{3}{4}$ to $12\frac{7}{8}\%$ for 62 days. We need a bid rate for one month plus one week, that is, 37 days.

The rough calculation is to take the bid rate for 30 days at $12\frac{1}{8}\%$ (or 12.125%) and then assume that the one week beyond the 30 days should be reckoned at the two-month bid rate, namely $12\frac{3}{4}\%$ (or 12.75%). All we have to do is average the two rates, weighting them by the number of days involved:

$$[(30 \times 12.125) + (7 \times 12.75)]/37 = [363.75 + 89.25]/37 = 453/37 = 12.243\%$$

This method is the one used by many people in the market for a quick approximation of a broken-date rate. Then they will make a quick mental adjustment to cover any special factors.

We need to think more carefully about the assumption that the one week (7 days) of the second month are "worth" $12\frac{3}{4}\%$; this in fact is not so. To see why, let us look at an extreme example. Suppose we have U.S. dollar deposits of one month (30 days) at 10% and two months (60 days) at 20%. We need a 37-day rate again. Using our crude method, we get:

$$[(30 \times 10) + (7 \times 20)]/37 = 440/37 = 11.8919\%$$

Now we calculate a 50-day rate:

$$[(30 \times 10) + (20 \times 20)]/50 = 700/50 = 14.0\%$$

Now a 59-day rate:

$$[(30 \times 10) + (29 \times 20)]/59 = 880/59 = 14.9\%$$

But we know that our 60-day rate should be 20%; it seems improbable that the 59-day rate will only be 14.9% and the 60-day rate will be 20%, unless there are some very special factors (which, by assumption, there are not in our example).

What is happening is that the days in the second month are "worth" more than 20%. If you have earned an average return of 10% during the first 30 days, then in order to earn an average return of 20% over the whole 60 days, the second 30 days must be yielding more than 20%. Otherwise they cannot pull the average over the whole period up to the 20% required. In market jargon, the "forward-forward rate for 60 days against 30 days" must be higher than 20%. In fact, it is 29.75196. If we now recalculate our 59-day rate, we find:

$$[(30 \times 10) + (29 \times 29.75196)]/59 = 1,162.80684/59 = 19.70859\%$$

which is clearly much more closely in line with what we should expect.

Notice that we have made a simplifying assumption about the second 30 days: that they can be treated all the same. We said that the forward-forward rate for the whole of the second 30 days was about 29³/₄%. This might not be the case if there were special dates within the period. Suppose that in the middle of our second month (day 45), there was a special reporting date and that, as a result of balance-sheet “window dressing,” the market was prepared to bid 100% for money running from day 44 to day 46. (This happens regularly over year-end, for example, in some countries.) Then we would have to refine our forward-forward rate calculations. In practice, most dealers will simply make a mental adjustment for this factor rather than make elaborate calculations. It is important to be aware of how it might affect the rate calculation, though.

FORWARD-FORWARD RATES

We turn now to the mechanics of calculating a forward-forward rate. Although this might seem a rather specialized exercise, the forward-forward rate is vital in at least two important areas: (1) forward rate agreements (see the section on FRAs) and (2) arbitrage between the deposit market and the financial futures market (see Chapter 15). For example, the rate on the three-month Eurodollar futures contract is nothing but an implied forward-forward rate. (Conversely, the deposit forward-forward rates are often driven by the rates in the futures market.)

The simplest approach is to consider a specific case: A bank is lending for 60 days at 20% against a deposit for which it has paid 10% for 30 days. What is the break-even rate on the second period—how much can it afford to pay for a deposit starting on day 31 and maturing on day 60? We assume that the deposit and the loan are for \$1 million and that interest is paid on a 360-day basis. (The basic formula for finding interest is Interest = Principal \times Rate \times Time.) Then, the bank pays interest in the first period of \$1,000,000 \times (10/100) \times (30/360), or \$8,333.33. The bank earns interest over the lifetime of the loan of \$1,000,000 \times (20/100) \times (60/360), or \$33,333.33.

However, in accordance with Euromarket convention, interest earned on

the two-month loan is not paid to the bank until the end of the two months, whereas the bank must pay away interest on the one-month deposit at maturity. So for the second period, it has to fund not only its \$1 million principal amount but also the \$8,333.33 that it has paid away in interest. So the amount to be funded in the second period is \$1,008,333.33.

Now we know that the bank has earnings of \$33,333.33 over the months and costs (so far) of \$8,333.33. So there is a net \$25,000 that is available to pay the interest on the new principal of \$1,008,333.33. To calculate the forward-forward interest rate, we work the \$25,000 as a percentage of the principal and annualize up from the 30-day period to a 360-day period:

$$\begin{aligned} \text{Forward rate} &= [100 \times (360/30)] \times [25,000/\$1,008,333.33] \\ &= 1200 \times 0.0247933 = 29.75196\% \end{aligned}$$

In order to reduce this to a formula—one set up in terms of middle market rates for simplicity—we define some variables:

- R1* = Rate for shorter, first period
- R2* = Rate for second period
- N1* = Number of days in first period
- N2* = Number of days in total second period (that is, including first period)
- B* = Interest basis (usually 360)
- P* = Principal amount
- I1* = Interest due in first period
- I2* = Interest due in second period
- I3* = Interest residual

Interest paid in the first period is:

$$I1 = (R1/100) \times (N1/B) \times P, \text{ or } [(R1 \times N1)/(100 \times B)] \times P$$

Interest earned in total second period is:

$$I2 = (R2/100) \times (N2/B) \times P, \text{ or } [(R2 \times N2)/(100 \times B)] \times P$$

Hence interest available for the second period, *I3*, is:

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$$\begin{aligned}
 I3 = I2 - I1 &= [(R2 / 100) \times (N2/B) \times P] - [(R1/100) \times (N1/B) \times P] \\
 &= P \times [(R2 \times N2) - (R1 \times N1)] / (100 \times B) \\
 &= P \times [(R2 \times N2) / (100 \times B) - (R1 \times N1) / (100 \times B)]
 \end{aligned}$$

Our forward-forward interest is calculated by working $I3$ back into an annual percentage of the principal (notice that the principal is now $P+I1$, and recall that $I1 = (R1 \times N1) / (100 \times B)$):

$$\text{Forward forward rate} = \frac{100 \times B \times I3}{(N2 - N1)(P + I1)} = \frac{P[(R2 \times N2) - (R1 \times N1)]}{(N2 - N1)(P + I1)}$$

If we set the principal amount, P , equal to \$1, or unity, the formula simplifies to:

$$\text{Forward forward rate} = \frac{(R2 \times N2) - (R1 \times N1)}{\left[1 + \frac{R1 \times N1}{100 \times B} \right] (N2 - N1)}$$

Putting that in words:

$$\begin{array}{l}
 \text{Forward} \\
 \text{forward rate} = \frac{\text{Long period rate} \times \text{Days in long period} - \text{Short period rate} \times \text{Days in short period}}{\text{Days left in long period} \times \frac{\text{Short period rate} \times \text{Days in short period}}{1 + 100 \times \text{interest basis (i.e., 360 or 365)}}}
 \end{array}$$

Although we have worked throughout in terms of mid-market rates, the formula can be applied using actual bid rates and offer rates chosen appropriately. If we want the rate for forward-forward lending, $R2$ will be the offered rate for the long period, and $R1$ will be the bid rate for the short period. The converse is true for the forward-forward borrowing rate.

It is perhaps worth noting that this formula is widely used in the market but expressed in different ways, some of which are superficially very different. For example, I have seen the following method:

- Step 1. Convert the rates into a yearly basis; that is, multiply the rate by the exact number of days and divide by 360.

- Step 2. Deduct the nearer factor from the farther factor.
- Step 3. Divide the difference by the nearer factor plus 100.
- Step 4. Then multiply by 360, and divide by the number of days in the intervening period.
- Step 5. Multiply the result by 100.

This method is equivalent to the previous method, as we can see by following each step.

Step 1 calculates: $(R2 \times N2)/360$ and $(R1 \times N1)/360$.

Steps 2 and 3 calculate: $[(R2 \times N2) - (R1 \times N1)/360]/[100 + (R1 \times N1/360)]$.

Steps 4 and 5 produce: $[\frac{((R2 \times N2) - (R1 \times N1)/360)}{(100 + (R1 \times N1)/360)} \times (100 \times 360)]/(N2 - N1)$.

Canceling out the 360s in the numerator and dividing both terms by 100 produces: $1 + R3 \times N1/360 \times 100$ We can see that the two formulas are identical.

$$\frac{(R2 \times N2) - (R1 \times N1)}{1 + \frac{R1 \times N1}{100 \times 360}} \times \frac{1 \times 1}{N2 - N1}$$

or

$$\frac{(R2 \times N2) - (R1 \times N1)}{\left[1 + \frac{R1 \times N1}{100 \times 360}\right] (N2 - N1)}$$

To show the application of the forward-forward formula, consider the case of a corporate borrower who knows that in three-months' time he will need to borrow \$10 million for three months. Because the Treasurer of the company is conservative, she wishes to lock in the rate at which the borrowing is done now and also to arrange the actual commitment of the loan. (In practice, the deal would probably be done through the FRA market, but dealing in the forward-forward market does actually lock up the funding.) The Treasurer approaches her bank and asks for a quotation on this basis.

Suppose that the three-month period has 90 days and the bid rate is 11% and that the six-month period is 182 days and the offered rate is 9%. In that case, the bank can raise funds for the longer period at 9%, laying them off temporarily at 11%. So the forward-forward rate is:

$$\frac{(9 \times 182) - (11 \times 90)}{92 \left(1 + \frac{11 \times 90}{36,000}\right)} = \frac{1,638 - 990}{92 \times 1.0275} = \frac{648}{94.53} = 6.855\%$$

and 6.855% is the rate at which the bank would be prepared to commit to lend to the corporation. (In practice, this would tie up both sides of the bank's balance sheet unnecessarily, and the deal would be fixed through the FRA market.)

COMPOUNDING AND INTEREST PAYMENT FREQUENCIES

The powerful effect of compounding of interest is well known. It is especially relevant in certain money market situations. We start by setting out the standard compounding formula in comparison with simple interest. On a simple interest basis, an investment of \$1,000 at 10% on a 360-day basis for 365 days will yield \$101.39 of interest. Suppose instead that we place the funds in an investment account also paying 10% but with interest compounded four times a year. Then the effective annual rate of interest, I^* , given the simple rate I and the number of compounding periods N , is given by:

$$I^* = [1 + I/N]^N - 1$$

where the interest rates are in decimal form. So in our case, with $N = 4$ and $I = 0.10$, $I^* = [1 + (0.10/4)]^4 - 1 = [1 + 0.025]^4 - 1 = 1.1038 - 1 = 0.1038$, or 10.38% on an annual basis.

One of the most common compounding conversions is from semiannual to annual, for which there is a useful shortcut. In this particular case, the formula produces $I + I^2/4$, and a simple rule of thumb is:

Converting semiannual to annual: Additional basis points are found by squaring the interest rate and dividing by four.

For example, 12% squared and divided by 4 produces a 36-basis-point adjustment to 12.36%.

The formula we have just laid out for finding the effective annual rate

works fine for annual calculations. But, going back to our investment account, suppose now that we know we will need the funds in 270 days' time. Then the number of compounding periods is not four, but three. And to compare the investment account with other 270-day investments (for example, a CD), we should allow for the fact that there will be less benefit from compounding. To do this, we should only compound as many periods as we will actually invest, and then we should gross up to put the result back on an annual basis.

The formula we use for this is:

$$r = [(1 + i/n)^{n'} - 1] \times 360/t$$

where r = the true period effective rate; n' = the number of compounding periods until our investment horizon, and t = number of days in the investment horizon.

On this basis, the 10% investment account offers 10.25% over the period to the investment horizon. If the funds were left in the account for a year, we would get 10.38% per annum. The loss of a compounding date reduces the available yield. If we were offered a 270-day CD paying 10.3% over the period, this would be a better bet than the investment account, even though the latter's effective annual rate is 10.38% because that effective rate relies on a compounding date from which we will never benefit.

Subject to this exception, the more compounding periods, the higher the effective annual yield. If an investment at 10% is compounded daily over 365 days, the effective annual rate is 10.52%. In fact, the effect tends to fall off with the number of compounding periods, as we can see from Table 7.1.

Table 7.1 Effective Rate Changes

Number of Compounding Periods per Annum	Effective Rate
1	10.00
2	10.25
3	10.33
4	10.38
6	10.43
12	10.47
52	10.51
365	10.52

These compounding formulas only work if the interest rate remains constant. In our example, the investor was certain to get 10% on the investment account over the year. But usually we are not certain what we will earn when we come to invest the interest we receive. The only instrument on which the reinvestment rate on the interest is certain is one on which no interest is earned—a discount instrument that pays interest only at maturity. In the money market, this will typically be a Treasury bill, commercial paper, or a bankers' acceptance. In the bond market, it is the zero-coupon bond.

One final point: The formula used N to denote the number of times that interest was actually paid, which was appropriate because we were looking at an investment horizon that coincided with the date for payment of interest. It often happens that, in pricing a bond or an interest-rate swap, we need a similar type of calculation for present value purposes (*present value* is explained in the next section). In those calculations, one is concerned also with valuing interest flows that may be accruing but not yet actually paid. In that case, we need to rewrite n as nt/b , where b is the interest basis, to get the more general version of the formula. In the preceding investment account example, n was 4, t was 270, and b was 360: so n was $4 \times (270/360)$, or 3. But suppose we were looking at a period of 295 days for our calculation: then we would have $n = 4 \times (295/360)$, or 3.28; and on that basis the interest applicable for the period would be 10.29%.

It may help to set the formula up from first principles. First we take the nominal periodic rate of interest, that is, 2.5% per quarter, and “decompound” this to a daily basis. Then we “recompound” back up over the appropriate fractional period. Our first step is to take the rate of interest down to a daily rate, which we do by writing:

$$d = (1+i/n)^{(n/360)}$$

where d = daily rate (bearing in mind that the market works on a 360-day year). So in this case, we have $d = 1.025^{4/360} = 1.0002744$. Our next step is to recompound this up over the 295 days. So we must work out

$$d^* = d^t$$

where t = number of days to our investment horizon. We have $d^* = 1.0002744^{295} = 1.084302$.

Finally, to put the number back into an annual interest rate, we gross up by the annual number of days:

$$r = \frac{(d^* - 1) \times 360}{295} \times 100 = 10.28776, \text{ or } 10.29$$

The net result is that a 10% rate paid quarterly compounded over a 295-day period is equivalent to 10.29% annually. For those who prefer the entire process in one formula, it is as follows:

$$\text{Decompounded rate} = \left[\left(1 + \frac{i}{n} \right)^{(nt/360)} - 1 \right] \times \frac{360}{t} \times 100$$

It is very important to be aware of the impact of compounding. First, it is often a critical issue in swap market calculations (see Chapter 16) where one might be swapping against, say, a semiannual rate, or a quarterly rate: it is important to know the true annual rate implied. Second, in countries with high interest rates, the effects of interest on interest are significant. Countries such as Indonesia have often had interest rates running at 200% to 300% per annum. With rates at these levels, the effect of compounding is significant. Consider the situation in which you are offered the choice between a one-year deposit at 300% and the alternative of running an overnight funding position for the next 365 days at 200% per annum (assuming you believe that rates will not move). Which is the better bet? One might well be tempted to save 100% and run the overnight position, but if you apply the formula for the decompounded rate, you will see that 200% compounded daily comes to a true annual rate of 634.88%. If you really believe rates will stay steady, it would be far cheaper to raise one-year money at 300%. At higher rates, the impact is even more spectacular—300% compounded daily comes to 1884% per annum.

THE CONCEPT OF PRESENT VALUE

In the next chapter, we will use the concept of *present value* a lot. In this chapter, we need it to understand the relationship of forward-forward rates to the zero-coupon curve and the pricing of forward rate agreements (see

section on FRAs below), and so we will start with an explanation of present value.

The present value of a sum of money X due at some future date D is that sum of money that, if it were invested at the interest rate prevailing for deposits from today to D , would accumulate to X .

Let us take an example. You offer to buy my car, but you do not have enough money to pay me today. You offer to pay me \$10,000 in one week's time. Because I need a car to go to work, I will have to replace the car today. If you do not pay me today, I will have to put up my own money to pay for the replacement car today. I have implicit faith in your ability to pay and in your trustworthiness, so the only question in my mind is whether the present value of what you will pay me is more or less than what I will have to pay today for the replacement car.

Suppose I know that I can invest my money for one week at 8%. Then I know that if I invest \$9,984.47 at 8% for 7 days on a 360-day basis, I will have $9,984.47 \times [1 + (8/100) \times (7/360)] = \$10,000$. Putting that another way, I know that the present value of \$10,000 in 7 days' time is \$9,984.47 using a discount rate of 8%: $\$9,984.47 = \$10,000/[1+(8/100) \times (7/360)]$.

Present Value over Several Periods

The formula we just defined is fine for what we were doing, namely discounting a single sum of money for a period of less than a year. To get the more general formula, it helps to start at the other end: a sum of money invested today. A sum with a present value of 100 invested today at an annual interest rate of $r\%$ will yield us $100(1 + r)$ at the end of year 1. (Note that r is a decimal; e.g., $10\% = 0.10$.) At the end of year 2, we will have $100(1 + r)^2$ and at the end of year n , we will have $100(1 + r)^n$. So we can say,

$$\text{Future value in year } n = \text{Present value} \times (1 + r)^n$$

Therefore, turning the formula around:

$$\text{Present value} = \frac{\text{Future value in year } n}{(1 + r)^n}$$

Another way of saying this is that the present value is the future value discounted back to today at a rate of r . It is very important to realize that

once we have discounted a sum of money back to today, it is valued in today's money. A sum of money, say \$150, due in one year's time, discounted back to today, to produce, say, \$135, is valued in today's money. Another sum, say \$2,000, due in five years' time, discounted back to today, to produce, say, \$1750, is also valued in today's money. Because the two sums are valued in the same money, we can add them together.

Therefore, provided we discount each cash flow properly, we can discount every single cash flow in a stream of multiple cash flows back into a single sum of money. This is what happens when a bond dealer works out the price of a bond (see the next section). Each coupon payment on the bond is discounted back to today. The present value of each coupon and the present value of the bond's repayment amount are added together. The total is the present value of all the cash flows of the bond. That total is what that stream of cash flows is worth today. Therefore, it will be the price that the dealer will be willing to bid for the bond.

Consider a stream of cash due at the end of each of the next five years: Year 1: \$110; Year 2: \$121; Year 3: \$133.10; Year 4: \$146.41; Year 5: \$161.05. Suppose we want to find the present value of this stream of cash flows. We can invest money for the five years at 10% ($r = 0.10$), so that is the rate of discount we consider appropriate. What is the present value of the stream of flows?

We take our formula Present value = Future value in year $n / (1 + r)^n$, and we apply it. The sum due at the end of Year 1 is to be discounted by $(1 + r)^1$, that is, 1.10; so \$110 in a year's time is worth \$100 today. Similarly, the sum due at the end of Year 2 is to be discounted by $(1 + r)^2$; we work out $\$121 / (1.10)^2$, which also turns out to be \$100. Likewise, $\$133.10 / (1.10)^3$ is worth \$100. If you check the others, you will see they also are worth \$100 today. So although the cash total of that stream of cash is \$671.56, the total net present value of the stream of cash is \$500. We can write:

$$\text{Present value of a stream of cash flows} = \frac{\text{Future value in year 1}}{(1 + r)^1} + \frac{\text{Future value in year 2}}{(1 + r)^2} + \dots + \frac{\text{Future value in year } n}{(1 + r)^n}$$

Net Present Value of a Steady Cash Flow

If the stream of cash flows that we are considering is a fixed amount—it is always the same, for example, the coupon payment on a bond—there is

a useful shortcut we can use in our calculations. Suppose we have a regular stream of payments coming of \$100 per annum. We can work out that the present value today of a stream of \$100 per annum payable over the next five years, discounted at 10%, is (\$90.91 + \$82.64 + 75.13 + 68.30 + 62.09) or \$379.07. That is to say,

$$\text{Net present value} = \$397.07 = \frac{\$100}{(1.10)} + \frac{\$100}{(1.10)^2} + \frac{\$100}{(1.10)^3} + \frac{\$100}{(1.10)^4} + \frac{\$100}{(1.10)^5}$$

We can let the payment of \$100 be represented by c and the 10% discount rate by r . For convenience' sake, also, we can write $v = 1/(1 + r)$. Then instead of having $\$100/(1.10)$, we have c times v , and we can write the net present value (NPV) of a regular cash flow c like this:

$$\text{NPV} = c(v + v^2 + v^3 + \dots + v^n)$$

In our example, c was \$100 and v was $1/1.10$, or 0.9090909; v^2 would be 0.82645, and so on. (In other words, v is the “discount factor” applicable to each period.)

We can simplify this some more. The expression in the brackets is often known as “an annuity certain.” Mathematicians and actuaries tell us it can be simplified to $(1 - v^n)/r$, and so we have

$$\text{NPV} = \frac{c(1 - v^n)}{r}$$

which is a convenient formula because it can be calculated in one cell of a spreadsheet, no matter how many cash flows are involved!

YIELD CURVES, FORWARD RATES, ZERO-COUPON CURVES, AND MEDIUM-TERM FORWARD-FORWARD RATES

Now that we have sorted out how to do present value calculations, we can come back to the basic yield-curve concept that we talked about earlier and dig a little deeper. The yield curve contains a lot of information embedded in it. First, the slope of the yield curve indicates the implied forward-forward

rates. If the slope between any two points is upward, the forward-forward rate for the period between these points is above the current rates; if the slope is downward, the forward-forward rate is below. So, embedded in the yield curve is a second curve of the forward-forward rates. And there is also a third set of rates: the "zero-coupon" curve.

The *zero-coupon rate* for any given maturity is what the market would be prepared to pay on a deposit or a bond that pays no interim interest payments but only a lump sum at maturity. (Some people refer to the zero-coupon curve as the *spot rate curve*.) Although the zero coupon curve may seem obscure, it can be important to interest-rate swap dealers (see Chapter 16) because they can, if they choose, treat their interest-rate positions as individual cash flows, which should be valued at the zero-coupon rate for that maturity.

Often, we cannot observe the implied zero-coupon curve directly, and it has to be worked out step by step. A convenient way to do this is as follows. Let us look at the one-to-five-year yield curve for Eurodollar deposits. Because interest payments, in line with Euromarket practice, are on an annual basis, the one-year-deposit rate is in fact a zero-coupon rate: there are no interim interest payments. The two-year-deposit rate is not a zero-coupon rate because there would normally be a payment of interest at the end of Year 1.

Suppose we are contemplating investing \$1,000 dollars, and suppose we have the following interest rates: one year at 8%; two years at 9%; three years at 10%; four years at 11%; five years at 12%.

Suppose we are interested in finding out what the two-year zero-coupon rate implied by these rates is. Suppose we deposit \$1,000 for two years at 9%. We know we will get two cash flows: a payment of \$90 at the end of Year 1, and \$1090 at the end of year 2. We will also receive a year's interest on the \$90 coupon payment, but we do not know what that will be worth.

One way around this uncertainty is to take the following approach: I know the one-year zero-coupon rate is 8%. So I know that the present value today of that \$90 is \$83.33 (ignoring day-count questions and discounting on an annual basis). I would be indifferent between receiving \$90 in a year's time and receiving \$83.33 today by, say, assigning my right to the coupon to someone else. Suppose I do that. Then I now have a two-year zero-coupon deposit—I place \$1,000 – \$83.33, or \$916.67, today, and in two years I will receive \$1,090.

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Now it is quite simple to work out the two-year zero-coupon rate: it is 9.045%. We can apply this technique step by step. The three-year deposit gives me cash flows of \$100, \$100, and \$1,100. I sell off the first two cash flows for \$92.59 and \$84.10, respectively. That makes my net investment today \$823.31, which returns \$1,100 in three years' time, for an implied zero-coupon rate of 10.14%.

At the end of this process, I have the following yield curves:

	Deposit Yield Curve	Zero-Coupon Yield Curve
1 year	8	8.00
2 years	9	9.05
3 years	10	10.14
4 years	11	11.30
5 years	12	12.56

Now it is simple to find the medium-term forward-forward rates. I know that I can earn 8% for one year on a zero-coupon basis; I can earn 9.05% for two years. The forward-forward rate is that rate that will make me indifferent between the two. We find it by applying the forward-forward formula, but we adjust it now for years instead of days. What we want is what we earn during year 2 expressed as a percentage of our principal at the end of year 1. To find what we earn during year 2, we take the difference between the final amount at the end of year 2, which will be (assuming a principal amount of \$1) $\$1.0905^2$. The final amount at the end of year 1 is \$1.08. So what we earn during year 2 is $\$1.0905^2 - \1.08 , and our percentage return is $(1.0905^2 - 1.08)/1.08 = (1.18919 - 1.08)/1.08 = 0.101102$, or 10.11%.

From this we can deduce the general formula for the forward rate from year $n - 1$ to year n :

$$[(1 + r_n)^n - (1 + r_{n-1})^{n-1}]/(1 + r_{n-1})^{n-1}$$

FORWARD RATE AGREEMENTS

Forward-forward rates are dealt through an active market in London and elsewhere for *Forward Rate Agreements* (FRA). These are contracts between

banks and their customers, or other banks, that allow for the forward hedging of interest-rate movements: they are the money market equivalent of forward foreign-exchange contracts. Another way of looking at them is to say they are single-period interest-rate swaps.

They provide a very useful way to hedge against future movements in interest rates. The prime advantage of FRAs is that they allow this to be done without tying up large parts of the balance sheet. Until the FRA market was developed in the early 1980s, banks would trade their view of interest rates through the forward-forward market (see section on forward-forward rates). But this meant taking and placing deposits for the periods in question, which meant inflating both the asset side and the liability side of the balance sheet. FRAs are a much more efficient method of handling the interest-rate-hedging required. (An alternative, where appropriate markets exist, would be financial futures—see Chapter 15.)

Let's define some terms. A *Forward Rate Agreement* is one in which a notional borrower agrees with a notional lender on the rate of interest that will be applied to a notional loan for some period in the future. Note the use of the word *notional*: there is no actual borrowing or lending involved. When the time comes to settle up, all that happens is an exchange of cash equal to the difference between the actual rate on the day and the rate agreed in the FRA.

The buyer of the FRA is the *notional borrower*—the party seeking protection against a rise in rates. The seller is the *notional lender*—the party seeking protection against a fall in rates. The *contract amount* (CA) is the notional sum on which the FRA is based. The *contract rate* (CR) is the rate of interest being hedged, usually LIBOR.

The *contract period* (CP) is the term from settlement date to maturity date, that is, the term of the notional deposit/loan. The *settlement date* is the date on which the settlement sum is payable. The *maturity date* is the date on which the notional loan/deposit matures. The *settlement rate* (SR) is the rate fixed on the fixing date as being that applicable to the settlement on the FRA. The *fixing date* is the date on which the settlement rate is fixed; for LIBOR, that would normally be two business days ahead.

The *settlement sum* is the sum paid in settlement of the FRA. If paid at maturity, it would be $(SR - CR) \times (CP/360) \times (CA/100)$, assuming the currency in question is dealt on a 360-day-year basis. However, in practice, the custom in the FRA market is to pay the settlement sum on the settlement date. (The practical benefit is that this immediately clears the deal off the

books and cuts down the credit exposure that would arise if one had to wait until the notional maturity date to be paid.)

Thus the settlement sum has to be discounted back from the one that would be payable at maturity to its present value today. For this, we use the present value formula developed in the earlier section The Concept of Present Value. Thus, for a sum paid on settlement date, the value would be

$$[(SR - CR) \times (CP/360) \times (CA/100)] / (1 + (SR \times CP)/36,000)$$

Note that the numerator is the same as before; the denominator is the discount factor to bring the value back to today. The formula can be simplified to

$$(SR - CR) \times (CP \times CA) / (36,000 + (SR \times CP))$$

Let's look at an example. I buy a 3 × 6 FRA (a six-month FRA starting in three months) for a contract amount (CA) of \$10 million. The rate (CR) is 10.5%. The contract period (CP) is 90 days. When the contract comes to settle, the settlement rate (SR) is 12.25%. Then the settlement value of the FRA is $[(12.25 - 10.5) \times (90/360) \times (10,000,000/100)] / (1 + [(12.25 \times 90)/36,000])$. This gives us \$43,750/1.030625, which equals \$42,449.97. Had we been prepared to wait for settlement until the end of the contract period, the sum payable would have been \$43,750; the discount factor we apply to this to find its present value on the settlement date is 1.030625.

The way in which FRAs are priced is simple: If there is a financial futures market for a comparable instrument, pricing is taken from the futures market. If not, pricing is taken from the cash-deposit-yield curve. Forward-forward rates for the period in question are worked out and applied to FRAs. Thus, if I wanted to find the correct price for the 3 × 6 sterling FRA, I could look either at the London International Financial Futures Exchange (LIFFE) three-month sterling deposit future contract or at the yield curve for three-month and six-month sterling deposits. From these I would work out the forward-forward rate for three months against six months, and this would give me the rate applicable for the FRA. Because the forward-forward, FRA, and futures markets are all closely integrated, arbitrage will keep the three markets in line.

One final point is to consider the way that FRAs will trade as interest rates move. It follows from our forward-forward formula, which drives the

FRA price, that if the long rate (R_2) moves, the FRA rate will move in the same direction by a factor of $N_2/(N_2 - N_1)$. For example, consider a 3 × 6 FRA: 90 days × 180. The impact of a rise in the six-month rate is $180/(180 - 90) \times 1\%$, or 2%.

Conversely, if the short rate, R_1 , moves, the FRA will move in the opposite direction by $N_1/(N_2 - N_1)$. For instance, in the same example, a 1% rise in the short rate will push down the FRA rate by $-90/(180 - 90) \times 1\%$, or -1%. The shorter the contract period ($N_2 - N_1$) and the further away the contract period is (i.e., the larger N_1 is), the bigger the effect. For example, in a 9 × 12 FRA, N_1 is 270 and N_2 is 360; the effect is $-270/(360 - 270)$, or -3%.

Therefore, the pricing of the FRA is affected if the yield curve changes shape, even if the general level of rates does not change. The size of the impact depends on the relative length of the period to settlement date compared with the contract period. Some general rules of thumb are:

- If all rates are going up, buy FRAs and buy the ones with the longest contract period to get maximum benefit. Conversely, if all rates are falling, sell the FRA with the longest contract period.
- If short rates are rising and long rates are unchanged, sell the FRA with the longest period to settlement date (for example, sell 9 × 12 rather than 3 × 12). Conversely, if short rates are falling with long rates unmoved, buy the FRA with the longest-deferred settlement date.

In the London market, it is normal practice to deal FRAs on FRABBA—the terms and conditions agreed for FRA dealing by the British Bankers' Association (BBA). The practice has the obvious advantage that all parties in the market can take certain standard terms (for example, the convention for subsequent declaration of nonbusiness days) for granted.

FRABBA has also laid down the British Bankers' Association Interest Settlement Rate (BBAISR) as the basis on which FRAs settle. The BBAISR is defined as the rate calculated by the information vendor from the rates quoted to it by eight BBA-designated banks. In their view, this is the offered rate at which deposits in the contract currency are being quoted to prime banks in the London interbank market at 11 A.M. on the relevant fixing date for settlement-date value. The calculation is done by eliminating the two highest (or in the event of equality, two of the highest) and the two lowest

(or two of the lowest, if equal). The average of the remaining four rates is then rounded up, if necessary, to five decimal places.

NEGATIVE INTEREST RATES

Many people raise their eyebrows at the idea of negative interest rates. But they do occur, and they can be highly profitable. It is very pleasant to be paid to borrow money. Negative rates generally happen in one of two ways: (1) there is intense upward pressure on a currency, or (2) there is intense downward pressure that is expected to be only temporary.

A third recent case of negative interest rates is pathological: the implosion of the Japanese financial system owing to years of dishonest banking practices resulted in a situation in which non-Japanese banks were unwilling to lend to Japanese banks. In an environment where Japanese government bonds were yielding less than 1% because of the extent of the Japanese depression, it was unattractive to raise yen finance even to invest in government bonds. International banks were thus bidding negative rates for such deposits. However, such a situation is normally extremely rare.

Negative interest rates can be thrown up in the forward-forward markets if a currency is under sufficiently intense pressure. During the spring of 1981, the French franc was extraordinarily weak, and the Banque de France was determined to support it by squeezing money market rates in the then thinly traded Euro-French franc deposit market. Overnight Euro-French francs at one point were lent out at over 5,000%, and one-week money was running at over 300%. Applying our forward-forward formula, we can see that the forward rate for the remaining six days was -424%. By lending out at 5,000% for a night, funded with one-week money, we could afford to lend for the remainder of the week at rates as low as -400% and still make money. Although this kind of situation can fairly be called an extreme case, fluctuations on this scale do occur in narrow money markets and can be very profitable.

A good example of the effects of the opposite situation, currency inflows, is the Swiss franc in 1977 and 1978. The inflow of hot money into Swiss francs was so great that the Swiss authorities imposed a commission on deposits with banks such that a foreign depositor in a Swiss bank account was paying 40% per annum for the privilege—a commission of 10% per quarter. Some people held on to their deposits, though, and watched the Swiss

franc appreciate by 50%. A negative interest rate can be worthwhile if the currency is rising faster than the negative rate eats away your capital. Another example of this occurred in the late 1980s during a period of upward pressure on the Hong Kong dollar.

DOMESTIC MONEY MARKET CONSIDERATIONS

As a rule, Euromarket trading rooms tend to concentrate on clean deposits and CDs. Exchange control, withholding tax, and other considerations tend to limit trading in other instruments. The discussion here will be very brief. (For more detail see the bibliography.)

The *U.S. Treasury bill market* is the largest and most liquid market in the world. This makes it an attractive short-term investment vehicle. Also, discount income on Treasury bills if under six-months' maturity is exempt from withholding tax. Interest payments on other Treasury securities (e.g., notes and bonds) and discount on longer bills are subject to withholding tax, although exemption can be obtained in certain cases. Treasury bills are issued in minimum denominations of \$10,000. They are in book-entry form; that is, they are held in a computer; it is not possible to take physical delivery. Treasury bills are auctioned monthly. Prices are calculated on the basis of actual number of days and 30-day months over a 360-day year, on a discount basis (Chapter 8). As well as the cash market, the Treasury bill futures market is very large indeed (see Chapter 15).

After Treasury bills, *commercial paper* is the next important short-term market. Commercial paper (CP) is a promissory note, usually unsecured and issued by a corporation for up to 270 days. (This limitation ensures exemption from registration procedures of the Securities and Exchange Commission (SEC), though a rating is still needed from an agency.) Typically the maturity is 15 to 35 days. CP is usually issued in multiples of \$100,000. Large issuers place their paper directly, using sales force if necessary. Others issue their paper through dealers. Either way, CP is normally the cheapest and most flexible method of short-term corporate financing. CP calculations, like Treasury bills, are on a discount basis. Euro-commercial paper (ECP) is an important outgrowth of the original U.S. commercial paper market. It is basically a very similar market except that the 270-day restriction does not apply because the paper is not subject to SEC restrictions. Settlement in the ECP market is normally, like other Euromarket dealing, for spot value. Delivery of the

paper is normally handled through the Eurobond clearing systems (Euroclear and Cedel). The relevant calculations are discussed in Chapter 8.

Banker's acceptances are a smaller market in the United States, but acceptances have the major advantage that they do not require the lengthy and expensive rating-agency assessment required of CP issuers (because the investor's credit risk in acceptances is the bank rather than the corporate borrower). A banker's acceptance (BA) is a bill of exchange: an order by the drawee (the accepting bank) to pay the payee a specific sum of money on a certain date. After the bank has accepted the BA, it may hold it or, more typically, sell it in the market. BAs are discounted instruments, traded on an actual days/360-day-year basis. They are generally in bearer form and normally in any given maturity up to 180 days—usually about 90 days. The market trades in minimum lots of \$1 million but more typically \$5 million. BAs may be eligible for rediscount at the Federal Reserve (the Fed), or ineligible. The distinction makes little practical difference except that the ineligible market may be a little less liquid and may cost a little more because a bank selling then incurs a reserve required cost. The term *Yankee BA* is often used, by analogy with the Yankee bond market, to refer to an acceptance issued in the United States by a foreign issuer.

Repurchase agreements are another large market. There are several types of repurchase, depending on the market. We will begin with U.S. practice. A repurchase, or repo deal, is a sale of securities with a commitment to repurchase them at a set date. The rate is an ordinary interest rate (that is, add-on rather than discount) calculated using an actual days/360-day year. So interest is calculated by the following formula (assuming a discount security and sale and repurchase prices that are equal—the repo is “priced flat”):

$$\text{Interest due} = \text{Principal amount} \times \text{Repo rate} \times \frac{\text{Days repo is outstanding}}{360}$$

The underlying securities are priced so as to give the lender (that is, the buyer of the security) a margin of protection (the “haircut”). In some cases the pricing is not flat; it is set in terms of a sales price and a repurchase price chosen to give an equivalent yield. In this case, of course, the RP (repo) rate is given by:

$$\text{RP rate} = \frac{(\text{Repurchase price} - \text{Sales price})}{\text{Sales price}} \times \frac{360}{\text{Days RP is outstanding}} \times 100$$

The interest due is then calculated as before. Alternatively, given the repo rate, the repurchase price is found (by simple manipulation of the previous equation) as:

$$\text{Repurchase price} = \text{Sales price} \left(1 + \frac{\text{RP rate} \times \text{Days outstanding}}{100 \times 360} \right)$$

If the security is not a discount one but an interest-bearing one, things are more complex. Assume first that during the repurchase period no interest payment is made. Then all that happens is that both sales price and repurchase price have to be defined to include accrued interest. If, however, interest is paid during the life of the deal, street practice is to pay interest on the security price including accrued interest until the next coupon date. Suppose we repo a bond at $102\frac{3}{8}$, which on day 11 pays a coupon, which belongs to the seller. Then on day 12, the security is repriced to 100. Suppose the repo is done at 10%; then the interest payable is given by (if the principal amount were \$100):

$$\frac{10 \times 102\frac{3}{8} \times 11}{100 \times 360} + \frac{10 \times 100 \times 19}{100 \times 360}$$

and then the repurchase price is:

$$102\frac{3}{8} + \frac{10 \times 102\frac{3}{8} \times 11}{100 \times 360} + \frac{10 \times 100 \times 19}{100 \times 360}$$

So the formula is:

$$\text{Repurchase price} = \text{Sales price} + \frac{\text{Repo rate} \times \text{Days till Sales price}}{100 \times 360} + \frac{\text{Repo rate} \times \text{Days remaining} \times 100}{100 \times 360}$$

Table 7.2 Domestic Money Market Interest Bases

Country	Calculation Basis
Australia	ACT/365
Canada	ACT/365
Eurozone*	ACT/360
Japan	ACT/360
New Zealand	ACT/365
Norway	30/360 (ACT/360 under 1 month; CDs ACT/365)
Saudi Arabia	ACT/360
Sweden	30E/360
Switzerland	ACT/360 or 30/360 (Federal Treasury bills)
United Kingdom	ACT/365
United States	ACT/360

*Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.

Repurchase agreements are attractive because they are secured on the paper being repurchased and also because of their flexibility of term; repos can be done, in theory, for any maturity. In practice, most repo deals are for overnight. Repos are also common in the international markets, both in domestic markets and in the Euromarket. As discussed in Chapter 1, they are among the main monetary policy tools for the European Central Bank, and there is a very large and liquid market for repos in euro. Likewise, the Japanese repo market is active and important; and the technique is widely used also for financing securities in a number of other countries including many "emerging markets."

A problem when dealing in domestic markets—quite apart from settlement and tax issues—is the wide range of variations of interest-calculation basis, compared with the common basis used in all Euromarket dealing (that is, actual days on a 360- or 365-day year). Table 7.2 attempts to give a summary of the interest-calculation basis used in various domestic markets. Parallel information for bonds is given in the next chapter.

8 Money Market Paper and Bond Calculations

In Chapter 7 we looked at time deposit calculations. Now we look at the calculations involved in trading money market securities, or “paper.” We also give a basic introduction to some bond calculations because they may be of help and also because they are relevant to the interest-rate swap market (see Chapter 16).

There are two main differences between time deposit calculations and money market securities trades: First, money market paper can be, and often is, sold before maturity—there is secondary market trading. This is not normally the case with a time deposit, which is typically held to maturity. In looking at money market paper, there is the possibility of a change in price of the instrument—the possibility of a capital gain or loss. Second, most deposits are dealt on an interest-bearing basis—I place \$100 with you and get back, say, \$105. But some money market paper is dealt on a discount basis: I invest \$92.75 with you and get back \$100; that is, the face amount of the deal is the amount at maturity, not the amount at the start of the deal, as it is with interest-bearing deposits or interest-bearing instruments.

We will start with the more straightforward money market calculations for certificates of deposit and for discount securities, in each case considering short-term instruments with only one payment of interest. Then we cover the basic calculations involved in pricing a bond. These calculations are important not only for bond traders but also for those involved in medium-term interest-rate swaps (see Chapter 16). Next we look at the very important concept of duration, which measures interest-rate risk. We also touch briefly

on convexity and immunization. We begin with the oldest interbank money market instrument, the certificate of deposit.

CERTIFICATES OF DEPOSIT

Some years after the birth of the Eurodollar market, the certificate of deposit (CD) was introduced. The CD has since become an important source of funds for banks. The CD was first issued in the U.S. domestic market in 1961 and in the Euromarket in 1966. Essentially, a CD is an instrument (normally negotiable) evidencing a time deposit made with a bank at a fixed rate of interest for a fixed period; CDs bear interest, and CD rates are, in general, quoted on an interest-bearing (rather than a discount) basis. Normally, interest on a U.S. dollar CD is calculated for actual days on a 360-day basis and paid at maturity. But for CDs issued with a maturity over one year, interest is normally paid semiannually.

Since its introduction, the concept of a CD has been introduced to most of the major money markets. The speed at which this has happened has varied in accordance with the attitude of the domestic authorities of the currency concerned. For example, until 1986, the Bundesbank did not permit the issuance of deutschemark CDs. This was because, having suffered the effects on its currency of massive inflows from abroad during the 1970s, the Bundesbank was not anxious to encourage the growth of a money market instrument that would allow foreigners to move into and out of the deutschemark market more easily.

Sterling CDs are dealt on a basis comparable to that of U.S. dollar CDs except that interest is calculated on a 365-day basis. Interest is paid annually on the anniversary of issue of CDs of maturity over one year. CDs are also available, of course, in most other major currencies.

Other Types of CDs

CDs are available in various types also. The first variation was the *floating rate CD* (FRCD), introduced in 1977. They usually have maturities of three to five years. Interest on FRCDs is normally payable semiannually and is usually linked to six-month LIBOR (London interbank offer rate). Other

FRCDs have been issued at different margins or at the “London interbank mean of bid and offer” (LIMEAN).

Another variant is the *discount CD*. This was introduced early in 1981 in the U.S. domestic market and subsequently in London. Here the CD does not pay a stated rate of interest. Instead, the certificate bears a wording along the following lines: “XYZ Bank certifies that a sum has been deposited with this bank that together with interest solely in respect of the period to the maturity date will on the maturity date equal USD *N*.” The advantage of a discount CD is that its price can immediately be compared with other discount instruments, such as Treasury bills. The disadvantage is that it cannot easily be compared with other CDs.

CD Calculations

Let’s start by assuming that the life of a particular CD is under one year, so that interest is due at maturity. Suppose we have a 15% CD for \$1 million issued with 90 days to maturity. (Because it is a U.S. dollar CD, it is dealt on a 360-day year basis.) What is the CD’s value at maturity?

Maturity value = Face value + Interest earned (calculated on a simple-interest basis)

$$\begin{aligned} \text{Maturity value} &= \$1,000,000 + \left(\$1,000,000 \times \frac{15}{100} \times \frac{90}{360} \right) = \$1,037,500 \\ &= \text{Principal} \times \left[1 + \left(\frac{\text{Coupon}}{100} \times \frac{\text{Days from issue to maturity}}{360} \right) \right] \end{aligned}$$

At any point before maturity, this CD will have earned a certain amount of interest already—the “accrued interest.” If we are buying a 15% CD for \$1,000,000 on a given day, we will want to know the accrued interest, which is given by the following (assuming we buy the CD on day 30):

$$\begin{aligned} \text{Accrued interest} &= \$1,000,000 \times \frac{15}{100} \times \frac{30}{360} = \$12,500 \\ &= \text{Principal} \times \frac{\text{Coupon}}{100} \times \frac{\text{Days from issue to purchase}}{360} \end{aligned}$$

We need to know what price we should be prepared to pay for this CD, assuming that the general level of interest rates is unchanged since it was issued; that is, a 60-day CD will currently also be issued at a coupon of 15%, so we have the choice between buying a new CD or the "secondary" CD, which has been outstanding for some time, both yielding a coupon of 15%. We know from the maturity value formula that the new CD will at maturity be worth $\$1,000,000 \times [1 + (15/100 \times 60/360)]$, or $\$1,025,000$. The amount we are prepared to pay for the old CD must be such as to produce an equal yield over the 60 days; that is, for the two yields to be equal, we must have $1,037,500/\text{Price for old CD} = 1,025,000/1,000,000$, which is the same as $\text{Price for old CD} = (1,000,000 \times 1,037,500/1,025,000)$, or $\$1,012,195.12$.

This price is a little below the face value plus accrued interest so far, which we know, from our first formula, to be $\$1,012,500$. The reason is that although interest has accrued, it is not yet payable. The buyer must wait to receive it and so will require a discount on the price he or she pays for accrued interest.

Suppose now that the general level of interest rates has changed so that a new 60-day CD pays 10%. Then we know, from the maturity value formula, that the CD's value per $\$1,000,000$ at maturity will be $\$1,016,666.67$. We want to know the price that we should pay for an old 90-day 15% CD with 60 days to run. As before, the value of the old CD at maturity is $\$1,037,500$, and as before we calculate the price by dividing the values at maturity into each other:

$$\begin{aligned} \text{Price} &= \frac{\text{Value of old CD at maturity}}{\text{Value of new CD at maturity}} \times \$1,000,000 \\ &= \frac{\$1,037,500}{\$1,016,666.67} \times \$1,000,000 = \$1,020,491.80 \end{aligned}$$

What we are doing is bidding up the price of the old CD to the point at which the yield when we buy the old CD is equal to the 10% coupon available on a new CD. Because the value of the CD at maturity is a function of the coupon and the days from issue to maturity, as we saw earlier, we can calculate the price of the old CD in terms of interest rates:

$$\text{Price} = \text{Principal} \times \left[\frac{1 + \frac{\text{Coupon on old CD}}{100} \times \frac{\text{Days from issue to maturity}}{360}}{1 + \frac{\text{Coupon on new CD}}{100} \times \frac{\text{Days from issue to maturity}}{360}} \right]$$

We can apply this to the case in which we want to value a CD that we intend to buy in the market. To do this, we have to change the bottom line of the formula: instead of writing "coupon on new CD," we can put "current yield on CD"; and instead of using the number of "days from issue to maturity," we write the number of "days from purchase to maturity." This gives us:

$$\text{Price} = \text{Principal} \times \left[\frac{1 + \frac{\text{Coupon on old CD}}{100} \times \frac{\text{Days from issue to maturity}}{360}}{1 + \frac{\text{Current yield on CD}}{100} \times \frac{\text{Days from purchase to maturity}}{360}} \right]$$

It follows from this formula that we can equally well calculate the yield on a CD if we know the price paid. By rewriting the formula, we can find that:

$$\text{Yield} = \text{Principal} \times \left[\frac{1 + \frac{\text{Coupon on old CD}}{100} \times \frac{\text{Days from issue to maturity}}{360}}{\text{Price}} \right] \times \left[\frac{360 \times 100}{\text{Days from purchase to maturity}} - 1 \right]$$

We can test this formula by seeing whether it works for the purchase of a CD on the issue date. In this case, the days from issue to maturity equal the days from purchase to maturity and the price equals the principal amount, so that the yield equals the coupon as one would expect.

Let's look now at the case of a trader who thinks that rates are going to come down and so buys a 90-day CD financing it with a 60-day deposit. The parallel case on the domestic U.S. market would be a CD financed by

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a term repo. The price at which we sell the CD after 60 days must be enough to pay our funding cost. So we know that we must have:

$$\text{Resale price} = \text{Principal} \times \left[1 + \left(\frac{\text{Funding cost}}{100} \times \frac{\text{Days held}}{360} \right) \right]$$

Suppose the CD is for \$1 million and is funded at 12% for the 60 days that we hold it; then we must have:

$$\text{Price} = \$1,000,000 \times \left[1 + \left(\frac{12}{100} \times \frac{60}{360} \right) \right] = \$1,020,000$$

But we know from our Yield formula that if we know the price that is paid on it, we can find the yield on the CD. And we have just found the price. So by using the price calculation in the Yield formula, we can find the break-even yield at resale:

$$\text{Break-even yield} = \left[\frac{1 + \frac{\text{Coupon}}{100} \times \frac{\text{Days from issue to maturity}}{360}}{1 + \frac{\text{Funding cost}}{100} \times \frac{\text{Days held}}{360}} - 1 \right] \times \left[\frac{360 \times 100}{\text{Days remaining from sale to maturity}} \right]$$

Let's apply this formula to our 15% 90-day CD, assuming that we buy it on the issue date and that we can finance it for 60 days at 12%. What yield can we afford to sell at and still break even? Our formula says:

$$\text{Break-even yield} = \left[\frac{1 + \left(\frac{15}{100} \times \frac{90}{360} \right)}{1 + \left(\frac{12}{100} \times \frac{60}{360} \right)} - 1 \right] \times \frac{(360 \times 100)}{30} = \left[\left(\frac{1.0375}{1.02} \right) - 1 \right] \times 1,200 = 20.588\%$$

In other words, because we were making 3% profit for 60 days, we can afford to see rates move up a good deal in the secondary market before we take a loss.

If we are buying a CD in the secondary market rather than in the issue date, we have to use the yield at which we buy the CD rather than the coupon. The remaining life of the CD is no longer the period from issue to maturity, but the period from purchase to maturity. With these modifications, the formula is now:

$$\text{Break-even yield} = \left[\frac{1 + \frac{\text{CD yield}}{100} \times \frac{\text{Days from purchase to maturity}}{360}}{1 + \frac{\text{Funding cost}}{100} \times \frac{\text{Days held}}{360}} - 1 \right] \times \left[\frac{360 \times 100}{\text{Days remaining from sale to maturity}} \right]$$

We have looked at finding out what yield we can afford to sell at in order to break even. The opposite question is: If I know the yield at which I bought the CD and the yield at which I sold, how much did I make during the holding period? The answer in general is that the holding-period yield is (Sale price - Purchase price)/Purchase price. It can be expressed as an annual interest rate by multiplying by (360/holding period). The most general case is going to be, that in which we buy a CD in the secondary market and then later resell it. The holding-period yield on a CD bought at an issue is a special case of this general case where the yield at purchase equals the coupon. We can solve this general problem by taking the formula we have just worked out and turning it around. We are looking for the break-even yield on resale because we already know at what price we have sold the CD. We are looking for the holding-period yield, which must, if we are to break even, equal our funding cost. So we rewrite our formula, and after some manipulation we get:

$$\text{Holding-period yield} = \left[\frac{1 + \frac{\text{Yield when bought}}{100} \times \frac{\text{Days from purchase to maturity}}{360}}{1 + \frac{\text{Yield when sold}}{100} \times \frac{\text{Days from sale to maturity}}{360}} - 1 \right] \times \left[\frac{360 \times 100}{\text{Holding period}} \right]$$

So far, all our calculations have been for CDs whose maturity was less than one year. Calculations for CDs over one year are more complex because there are multiple interest payments. A computer or financial calculator is desirable. A problem is the variable number of days involved, which can be affected by holidays. Also annual interest payments on CDs in the Euromarket are affected by leap years. Semiannual payments (for example, in the U.S. domestic market) are affected by the fact that the 365 days of the year are inherently impossible to divide equally into 182.5 days. The effect of holidays is also a complication.

However, the underlying principles are fairly straightforward. Let us assume that we are trading a CD with annual payments in a world with a 365-day year but no holidays and no leap years. Suppose it is a five-year half-million-dollar CD paying 10% interest annually on January 1. Interest is $\$500,000 \times (10/100) \times (365/360)$, or $\$50,694.44$. Suppose we hold the CD for 1 year and 37 days and wish to know the resale price if we sell at 9%. We proceed as follows: Today's price is the discounted value of future proceeds. We know that at the end of year 5, we will receive $\$500,000$ plus interest of $\$50,694.44$. We discount this sum back to the end of year 4 at 9%:

$$\frac{\$550,694.44}{1 + \frac{9 \times 365}{100 \times 360}} = \$504,645.53$$

If the CD were sold on day 1 of year 5, we would receive this price plus the interest payable on that date. So we must now discount back to the end of year 3:

$$\frac{\$504,645.53 + \$50,694.44}{1 + \frac{9 \times 365}{100 \times 360}} = \frac{\$555,339.97}{1.09125} = \$508,902.61$$

To this discounted rate at the end of year 3 must be added the interest payable at that date, and the total must be discounted back to the end of year 2:

$$\frac{\$508,902.61 + \$50,694.44}{1 + \frac{9 \times 365}{100 \times 360}} = \frac{\$559,597.05}{1.09125} = \$512,803.71$$

We then take this price and add it to the interest due at that date, making a total of \$563,498.14. We know that, as of day 37 in year 2 when we are selling the CD, this is the price we will receive if we hold the CD for another 328 days. So we discount this price over 328 days:

$$\frac{\$563,498.15}{1 + \frac{9 \times 328}{100 \times 360}} = \$520,793.12$$

And this is the price we need.

DISCOUNT SECURITIES

Treasury bills, commercial paper, banker's acceptances, and various other instruments are dealt on a discount basis; and from time to time this applies also to CDs. In cases where local exchange control forbids forwards exchange cover on interest payable, it may also be convenient to deal clean deposits on a discount basis. We will sell out the calculations as for a bill; they can of course be applied to the other instruments mentioned. We will look at the calculation for price, given discount rate; discount rate, given price or discount amount; conversion of interest rate to discount rate, and vice versa; holding-period yield; and the forward-forward bill rate (bill parity).

Price, Given Discount Rate

Suppose we have a bill for \$1 million that is being discounted at 10% for 90 days using a 360-day year. Then the discount amount is \$1,000,000 × (10/100) × (90/360), or \$25,000. The formula is:

$$\text{Discount amount} = \text{Face value} \times \frac{\text{Discount rate}}{100} \times \frac{\text{Discount period}}{360}$$

The price today (\$975,000) is the face value less the discount amount (\$1,000,000 - \$25,000), or:

$$\text{Price} = \text{Face value} \times \left[1 - \left(\frac{\text{Discount rate}}{100} \times \frac{\text{Discount rate}}{360} \right) \right]$$

Discount Rate, Given Discount Amount or Price

To find the discount rate given the price or the discount amount, we manipulate this formula. If the discount amount is given, we turn the Discount amount formula around to get:

$$\text{Discount rate} = \left[1 - \left(\frac{\text{Discount amount}}{\text{Face value}} \times \frac{360}{\text{Discount period}} \right) \right]$$

Conversely, if we are given the price, we turn the Price formula around to get:

$$\text{Discount rate} = \left[1 - \left(\frac{\text{Price}}{\text{Face value}} \times \frac{360}{\text{Discount period}} \right) \right]$$

Conversion of Interest Rate to Discount Rate and of Discount Rate to Interest Rate

We have been using a discount rate rather than an interest rate. The difference is that a discount rate is applied to the principal at the far end of the deal (the face value); an interest rate is applied to the principal at the near end. In our example, the face value is \$1,000,000, and the principal at the near end is \$975,000; so if we express the discount amount as a percentage of the near end, we see that it is not 10% but 10.2564%. The formula for converting a discount rate to an interest rate is:

$$\text{Interest rate} = \frac{360 \times \frac{\text{Discount rate}}{100}}{360 - \left(\frac{\text{Discount rate}}{100} \times \text{Discount period} \right)}$$

where the interest rate is on a 360-day basis. To make it a 365-day basis, we simply put 365 in the top line. To get the discount rate from the interest rate, we turn this formula around to get:

$$\text{Discount rate} = \frac{360 \times \frac{\text{Interest rate}}{100}}{360 + \left(\frac{\text{Discount rate}}{100} \times \text{Discount period} \right)}$$

Holding-Period Yield

Sometimes we need the holding-period yield on a bill—the return earned by buying a bill and later selling it. The profit on the deal equals Sale price – Purchase price, and in percentage terms is:

$$\frac{\text{Sales price} - \text{Purchase price}}{\text{Purchase price}} = \left(\frac{\text{Sales price}}{\text{Purchase price}} - 1 \right)$$

To gross this percentage up to a 365-day interest rate, we multiply by 365 divided by the holding period, so our final formula is:

$$\text{Holding - period yield} = \left(\frac{\text{Sales price}}{\text{Purchase price}} - 1 \right) \times \frac{365}{\text{Holding period}}$$

To put this formula in terms of the yield at the time of sale and the yield at the time of purchase, we would work out the sale price and the purchase price in terms of yield by using the formula for price. To put the holding-period yield on a 360-day basis, we would “gross up” by 360 rather than 365 in the top line.

Forward-Forward Bill Rate

We sometimes need to decide between buying a long bill and buying a short bill. In these circumstances, we need the forward-forward (bill parity) rate.

Say we can buy a six-month bill or two three-month ones. Given the rate on the six-month bill and on the first three-month bill, what must we earn on the second three-month bill to make the two deals equal? We start by assuming that the same principal amount, \$1 million, is invested in the six-month bill and in the three-month bill. At the maturity of the longer bill, we will receive a certain amount (in fact, the face value of the long bill). To break even, this must equal the face value of the later, second short bill. That face value must be equal to the proceeds of the investment in the first short bill (the face value of the first short bill) plus the discount earned on the second short bill. Hence:

Discount on second short bill = Face value of long bill – Face value of first short bill

To express this as a discount rate, we express it as a percentage of the amount at the far end, that is, the face value of the long bill. To express it as an annual rate, we gross it up by 360 (or 365) divided by the length of the second short bill, over which the discount is earned. So we have:

$$\text{Break-even rate} = \frac{\text{Face value of long bill} - \text{Face value of first short bill}}{\text{Face value of long bill}} \times \frac{360}{\text{Days in second short bill}}$$

This formula can be rewritten in terms of discount rates, but it then becomes a little complicated to lay out in words.

EURO-COMMERCIAL PAPER CALCULATIONS

Euro-commercial paper (ECP) is issued on both a yield-bearing basis and a discount basis, though the latter is more common. The basis of ECP calculations is simply the standard discounting (or if the ECP is interest-bearing, yield calculations) applicable to other short-term instruments.

Points to watch include:

1. Settlement basis: U.S. commercial paper is same-day value; ECP can be same-day, but it is more usually spot.

2. Days basis: 360 for U.S. dollars, 365 for sterling, and generally in line with Euroconventions for other currencies.

Otherwise the calculations are straightforward applications of the normal formulas. Thus, for *interest-bearing paper*,

$$\text{Settlement proceeds} = \text{Face amount} \times \left[\frac{1 + \frac{C \times D}{360 \times 100}}{1 + \frac{Y \times N}{360 \times 100}} \right]$$

where C = coupon, Y = yield, D = original maturity in days, and N = days from settlement to maturity.

For *discount paper*, correspondingly, we have

$$\text{Settlement proceeds} = \left[\frac{\text{Face amount}}{1 + \frac{Y \times N}{360 \times 100}} \right]$$

Often the question arises, what is the all-in yield (or cost to the borrower) of ECP issued in one currency and swapped into another? Provided there are no particular value-date complications (that is, ECP settlement is done for spot value), the calculation of the all-in yield/cost is exactly the same as any other swapped borrowing. For example, suppose we issue USD 5,000,000 of 30-day ECP for spot settlement. The paper is discount paper, and the rate is 5.75%. Then the proceeds on spot date are USD 4,976,041.67. Suppose spot Japanese yen are 126.75 per U.S. dollar, and the 30-day forward yen premium is 20 basis points. Then the 30-day forward rate is 126.55. So the yen proceeds on spot date are JPY 630,713,281.25, and at maturity the yen equivalent of the face amount is JPY 632,750,000. Then the implied interest rate is found from the following calculation:

$$(632,750,000.00 - 630,713,281.25) / 630,713,281.25 \times 360 / 30 \times 100 = 3.8751\%$$

which uses the formula $(F - P) / P \times 360 / D \times 100$, where F = face amount in foreign currency, P = proceeds at date of issue in foreign currency, and D = original maturity in days.

The issue becomes more complicated when the commercial paper value date occurs before the earliest possible foreign currency value date. Consider a Japanese company issuing a banker's acceptance (BA) in New York. Settlement in the New York BA or commercial paper market is done on a same-day value basis. It is impossible to give good value in yen because Tokyo has closed before New York opens. Hence the dollar proceeds have to be invested overnight (and the Japanese company must fund itself in yen overnight). If the paper is issued on a Friday, the delay is three days rather than overnight. In order to find the total cost, we need to go through the deal step by step: Suppose on Tuesday the Japanese company issues a BA for 30 days for \$5,000,000. The discount rate is 6.375%. So the dollar proceeds received today are \$4,973,437.50. These are invested overnight on the Fed funds market at 5.25%, so those proceeds plus interest the next day amount to \$4,974,162.79. Today (Tuesday) we swap these anticipated proceeds into yen, value tomorrow, with the swap maturing after 29 days from the start (that is, 30 days from today) to coincide with the maturity of the acceptance. Yen value tomorrow can be bought, say, at 110.55, and the 29-day swap over tomorrow is a dollar discount/yen premium of 30 points. So the outright cost is 110.25. So the yen value tomorrow of the BA proceeds plus interest from the Fed funds investment is $4,974,162.79 \times 110.55$, or JPY 549,893,696.76. These funds will only be received tomorrow. To fund itself in the domestic market, the borrower must raise overnight yen. It can borrow up to the amount that with the interest cost will equal the sum available tomorrow from the acceptance deal; that is, the amount it can borrow today is equal to the yen proceeds of the acceptance, discounted back one day at the overnight yen rate (which is, say, 3%). So the amount it borrows is equal to $549,893,696.76/[1 + (1/360 \times 3/100)]$.

We wrote $1/360 \times 3/100$ to make it clear that this is an overnight deal. If the paper were issued on a Friday, the factor would be $3/360 \times 3/100$. This sum is the initial yen borrowing. The yen repayment value is the amount of yen required to repay the acceptance—\$5,000,000.00 covered forward at 110.25, making JPY 551,250,000.00. So the all-in yen borrowing, grossed up on an annual basis is:

$$[(551,250,000.00 - 549,847,876.11)/549,847,876.11] \times 360/30 \times 100 = 3.0600\%$$

which can then be compared with the cost of raising yen directly.

BOND MARKET CALCULATIONS

The full range of bond market calculations is outside the scope of this book; but because bond markets are becoming increasingly interlinked through the foreign exchange and through currency and interest-rate swap markets, some knowledge of basic bond calculations is increasingly useful in any trading operation. This section lays out some of the basic calculations. (A full discussion can be had from *Yield Calculations*, by Paul Fage, Credit Suisse First Boston, October 1986; see also my book *Global Investing*, London: Macmillan, 1991.)

We start with simple bond calculations. It is a temptation to assume that one can just hit the buttons on the bond calculator, but it is important to at least understand the principles on which the calculations work.

The “classical” bond is an instrument bearing a fixed rate of interest, called its *coupon*. Valuing the classical bond is simple. Suppose we have a 10-year bond with a coupon of 5% per annum, which is paid once a year. Suppose the bond is issued in denominations with a face value of \$100. The price at which it is issued is *par*, that is, a price of \$100 per \$100 face value. So the cash flows are that we invest \$100 today and receive back \$100 in 10 years’ time, plus \$5 per annum in interest in the meantime:

After 1 year	\$5
After 2 years	\$5
After 3 years	\$5
.	
.	
.	
At the end of 10 years	\$105

The price of the bond is the value of these cash flows today. To find that present value, we use the NPV technique laid out in Chapter 7. So the price of the bond is the present value of all the cash flows given in our example; that is, we have:

$$P = \frac{5}{(1.05)} + \frac{5}{(1.05)^2} + \dots + \frac{5}{(1.05)^9} + \frac{5}{(1.05)^{10}}$$

If we use the notation we used in Chapter 7, we can see that the present value of the last redemption amount of \$100 can be written $100v^n$. To it,

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we can add the present value of the regular stream of coupon payments to get:

$$\text{Bond price} = P = \frac{c(1 - v^n)}{r} + 100v^n$$

Using the formula, we can see that our bond's price is:

$$\frac{5(1 - 0.952380^{10})}{0.05} + 100(0.952380^{10}) = 100(1 - 0.952380^{10}) + 100(0.952380^{10}) = 100$$

This is because we are discounting a 5% income stream at a discount rate of 5%. The coupon on the bond and its yield to maturity, or redemption yield, are the same: 5%.

What do we mean by the *yield to maturity*? It is that rate of discount that makes the present value of the bond's cash flows equal to its market price—given today's price, the yield to maturity tells us what the bond will yield over its life, allowing for both the income from the coupons and the change in price. If the bond's price in the market were 90, rather than the issue price of 100, there would be a capital gain of 10 points over the 10 years—a bit over 1% per annum—to be added to the coupon. So the yield would be a bit over 6% (actually 6.38%).

So, if the bond's yield to maturity (and, hence, the discount rate applied to its cash flows) were 7%, then the bond's price would be:

$$P = \frac{5(1 - 0.934579^{10})}{0.07} + 100(0.934579^{10}) = 85.95$$

The formula for yield to maturity given the price cannot be given in the same way as that for price given the yield. This is because the result must be found by assuming a given yield, finding the implied price, comparing it with the market price, adjusting the yield to a closer estimate, finding the new price, and so on—a process of iteration.

Accrued Interest

The previous bond-price calculation that we made works for bond prices that are worked out for an exact number of periods to maturity. We

were looking at a 10-year bond's cash flows, on the date the bond is issued.

What will the bond be worth, say, three months later? There are two parts to the answer. On the one hand, the bond will have a price that represents the future value of the cash flows at the new market yield to maturity (say 11%). On the other hand, the seller of the bond has owned it for three months, with no interest being paid: the interest has accrued at a rate of 5% per annum.

To work out the accrued interest, we need to consider the exact number of days from the issue date of the bond to the date it is being sold. Suppose the bond was issued on March 1, 2001, and is being sold for delivery on June 7, 2001. How many days are there in this interval?

Suppose that the bond traded is a U.S. corporate bond and that we want to calculate its accrued interest. The interest convention is a 30/360 day basis—we treat each year as having 12 months of 30 days each.

In our example the seller of the bond held it for March, April, and May—a total of 90 days—and for 6 days in June (excluding June 7, which is the value date of the sale—see the next section for value date rules.) So there are 96 days of accrued interest to consider. Suppose the seller is selling \$10 million worth of bonds. Then the accrued interest due is: $(5/100) \times (96/360) \times \$10,000,000$, or \$133,333.33.

Bond Price between Coupon Dates

In the previous section we worked out what the proper accrued interest should be on the \$10 million bond—in this case, \$133,333.33. Now we want to know what price the bond itself should be. The way we worked out its price before was (relatively) simple, because we were working out the price of the bond on the day of issue. There was no accrued interest to consider; and also, our discount factors were being applied to a round number of periods—10, in that case. Now, three months later, we have to consider a $9\frac{3}{4}$ -year bond. Hence we have to calculate the price differently.

The simplest way to proceed is to find what the bond would be worth on the next coupon date, that is, nine months from now, if today's rates were prevailing on that date. Then we discount that figure back to today's present value, using the appropriate discount rate.

Step one, then, is to work out what this bond is worth on March 1, 2002, at a yield of 11%. We again use the formula:

$$P = \frac{c(1 - v^n)}{r} + 100v^n$$

Here we have $v = 1/1.11$, or 0.9009009, and so

$$P = \frac{5(1 - 0.9009009^9)}{0.11} + 100(0.9009009^9) = 27.69 + 39.09 = 66.78$$

To 66.78 should be added the coupon payable on that date, 5, making a total value on that day of \$71.78. Our next job is to discount that back to today, June 7, 2001. To do this, we have to use an odd-period discount factor, using the procedure laid out in the previous chapter.

Here we have a discount rate of 11% per annum. Using the previous chapter's method, this converts to 10.846%. So now we must discount the price of \$66.78 that we worked out for value March 1, 2002, back to today, at the discount rate of 10.846%:

$$\left(\frac{71.78}{1 + \frac{0.10846 \times 264}{360}} \right) = \frac{71.78}{1.079537333} = \$66.49$$

We must bear in mind that this price of \$66.49 includes accrued interest, which we have worked out at \$133,333 per \$10 million, that is, \$1.33. So the "clean" price of the bond, excluding accrued interest, is \$65.16.

VALUE DATES AND INTEREST BASIS

Value dates in bond markets differ according to local custom. The U.S. bond market, for example, will normally settle in one of three different ways: (1) cash (delivery next day—normal for Treasury bonds); (2) skip-day (delivery the second business day after the trade), or (3) corporate (five business days after the trade—customary for corporate bonds). In the United Kingdom, gilt-edged bonds normally settle cash (next day), and corporate debentures settle after two days. Eurobonds settle after three business days ($T + 3$). Likewise, the different markets have different interest-calculation bases.

It is impossible to list all the possible settlement arrangements, so you

Table 8.1 Common Interest Bases

U.K. money markets	Annual actual/365
U.S. and Euro money markets	Annual actual/360
Treasury bonds (U.S. and U.K.)	Semiannual, actual/actual
Eurobonds	Annual, actual/actual (since 1/1/99)
Yankee bonds, federal agencies, U.S. corporate and municipal bonds	Semiannual 30/360
U.S. commercial paper, banker's acceptances	Discount basis, actual/360
U.K. bills of exchange, commercial paper	Discount basis, actual/365

should always check with the counterparty regarding the value date if the market is unfamiliar to you. Table 8.1 may be of some general help.

Table 8.1 is a crude summary because the "days basis" varies from market to market. There are three main bases:

1. *Actual*: Take the number of days between the two dates. This basis is used in U.S., U.K., and Japanese government bonds markets, and in U.K. and Japanese corporate and municipal bond markets (but not the U.S. corporate and municipal markets, which use *30-day month*. Note that Japan uses simple interest yields—see the end of this section).

2. *30-day month*: Take the number of days between the two dates— $M1/D1/Y1$ and $M2/D2/Y2$ —assuming 30-day months, using the following method:

- a. If $D1$ is 31, change to 30.
- b. If $D2$ is 31 and $D1$ is 30 or 31, change $D2$ to 30, otherwise leave at 31.
- c. Then the number of days between dates is given by: $(Y2 - Y1) \times 360 + (M2 - M1) \times 30 + (D2 - D1)$.

This method is used in Switzerland and in the U.S. federal agency, corporate, and Yankee bond markets.

3. *Continental 30-day month*: Take the number of days using the same formula as for 30-day month,

but:

- If D1 is 31, change to 30.
- If D2 is 31, also change to 30.

Until January 1, 1999, this method was used in the Eurobond market and in the domestic Austrian, Belgian, Dutch, German, and Swedish markets. It may still be applicable on some “legacy” nongovernment bonds that were not “reconventioned” following the arrival of the euro (e.g., private Austrian bonds continue using the old convention).

The next step is to determine the number of days in the year, because this also varies from market to market. Again there are three main methods:

1. Assume a 365-day year. This was used until January 1, 1999, in the French and until November 1998 in the U.K. government bond markets as well as in their corporate and municipal markets. It is still used in the Japanese markets.

2. Assume a year has the number of days given by “ $n \times$ days in current coupon period,” where n = coupon frequency. For example, if coupon is paid semiannually, the number of days in the period will range from 181 to 184, the number of days in the year will range from 362 to 368. This is used in U.S. Treasury bond market.

3. Assume a year has 360 days. This was used until January 1, 1999, in Austrian, Belgian, Dutch, German, Swedish, and the Eurobond markets; and it is possibly still applicable on nonreconventioned “legacy bonds” outstanding from before that date. It is still used in the Swiss and U.S. corporate and municipal markets.

In general, actual/365 and 30/360 produce the same annual interest total, but if the payment is semiannual, there will be slight differences in the half-year coupon. To see the differences between 30/360 and actual/365, take a year in which the semiannual coupon periods are divided into 181 and 184 days. Then on a \$10 million borrowing priced at 10% semiannual actual/365, the two coupon payments would be, respectively, \$495,890.41 and \$504,109.59, totaling \$1 million. On the 30/360 basis, they would be \$500,000

each. The annual total is the same, but there is a slight difference in the timing of the flows.

As mentioned, the U.S. Treasury bond market's day-count basis is not exactly actual/actual. Accrued interest (*AI*) on U.S. Treasury bonds follows the formula:

$$AI = \frac{N}{D} \times \frac{C}{F} \times FV$$

where *N* = number of days' accrual, *D* = number of days in coupon period, *C* = coupon/100, *F* = coupon payment frequency (normally 2), and *FV* = face value.

Take as an example, \$1 million of bonds traded for value July 2, 1999, coupon payable June 15 and December 15, with a coupon rate of 10%. Then *N* = 17 (June 15 to July 2), *D* = 183, *C* = 10/100, *F* = 2, and *FV* = \$1,000,000.

$$\begin{aligned} AI &= \frac{17}{183} \times \frac{10}{2} \times 1,000,000 \\ &= \frac{17}{183} \times \frac{10}{200} \times 1,000,000 \\ &= \$4644.81 \end{aligned}$$

The effects of the different bases are summarized in Table 8.2 (where *n* is coupon frequency).

Finally, interest calculations in Japan are radically different. Issues in the Japanese government bond market are quoted for dealing on a simple yield basis. Thus the price (*P*) of a bond is found as follows:

$$P = 100 \times \left[\frac{(C \times Y) + 100}{(S \times Y) + 100} \right]$$

where *C* = coupon, *P* = price (excluding accrued), *Y* = exact number of years to maturity including fractions, and *S* = simple yield.

Suppose a Japanese government bond has a coupon (*C*) of 5.1%, and it

Table 8.2 Interest Payments on Different Bases: Effective Annual Rate

Formula: Effective annual rate = $(1 + i/n)^n$

Basis		Basis	
Annual actual/365	10.00	Annual actual/360	10.14
Semiannual actual/365	10.25	Semiannual actual/360	10.40
Quarterly actual/365	10.38	Quarterly actual/360	10.53
Monthly actual/365	10.47	Monthly actual/360	10.62

matures on June 20, 2006. Purchasing on a simple yield (S) of 4.77 for settlement on August 1, 1997 (so that the life is 8 years and 323 days, or $Y = 8.884$ years) would give:

$$P = 100 \times \left[\frac{(5.1 \times 8.884) + 100}{(4.77 \times 8.884) + 100} \right] = 102.06$$

The relationship between simple yield and price is therefore:

$$S = \frac{100}{Y} \left[\frac{(C \times Y) + 100}{P} - 1 \right]$$

and in our example, the yield, given a price of 102.06, would be:

$$S = \frac{100}{8.884} \left[\frac{5.1 \times 8.884}{102.06} - 1 \right] = 4.770$$

9 Foreign Exchange Calculations

This chapter sets out the basics of a spot deal: where the settlement is made, when it is made, what the quotations mean, and how cross spot rates are worked out.

Settlement Country

A foreign exchange trade is an exchange of two currencies. When the deal has been agreed on, the parties to the deal arrange settlement. This takes place in the two countries whose currencies are being used. For example, a deal exchanging U.S. dollars for Japanese yen is settled by a payment of U.S. dollars in the United States against a payment of yen in Japan. In this book, the term *settlement country* will refer to the country where the actual transfer of funds is made.

Where the deal is made—the dealing center—need not be in one of the settlement countries. For example, it is possible to trade euro against yen in Singapore. A company making a euro/yen deal with a bank in Singapore may think that its yen and euro are being transferred in Singapore. This will seem especially plausible if the bank is running accounts for the company in Singapore denominated in the two currencies. But the bank's own currency holdings that correspond to these accounts actually will be held in the settlement countries. Therefore, the rules applying to such transactions—for instance, with respect to settlement dates—will be the same as for deals conducted in the normal way.

Spot Settlement

A *spot foreign exchange deal* is one made for settlement in two working days' time. Thus, under normal circumstances, a spot deal done Monday is settled on Wednesday. A *working day* is defined as one on which both banks are open for business in both settlement countries. An exception is made if the deal is done against the U.S. dollar—if the first of the two days is a holiday in the United States but not in the other settlement country, that day is also counted as a working day.

In the case of a dollar/yen deal done on Monday, we would normally have settlement Wednesday. This would not be affected by a U.S. holiday on the Tuesday. But it would be affected by a Japanese holiday on the Tuesday. In the latter case, the spot date would be postponed until Thursday, provided that both centers were open Thursday. If Tuesday were a normal day, but Wednesday were a holiday in either the United States or Japan, then the spot day would be Thursday (if both centers were open that day). In the case of a dollar/yen deal done, say, in London, the occurrence of U.K. bank holidays during the spot period is entirely irrelevant because all bank-account transfers are made in the settlement country rather than in the dealing center. On the deposit market, however, it would not be customary to deal for a date that was a holiday in the dealing center. In certain countries, such as the United States or Germany, bank holidays may affect only part of the country (depending on whether it is a local state holiday or, if religious, whether the area is mainly Catholic or Protestant, etc.). In this case, the date for settlement could vary according to the regional location of the bank accounts involved. The issue also arises in connection with the euro. Market practice in most centers seems to be to work on "TARGET days." However, depending on the center involved, local national holidays may be observed in some cases. Except for this mention, this complication will be ignored in this book.

Settlement of both sides of a foreign exchange deal should be made on the same working day. Because of time-zone differences, settlement on any given working day will take place earlier in the Far East, later in Europe, and later still in the United States. This implies a risk. To continue the dollar/yen example, a bank selling yen may deliver them in Tokyo before receiving the dollars in New York. If the recipient in Japan goes bankrupt before delivering the dollars (as happened in the case of Herstatt Bank), losses may arise.

The principle that the two sides of the deal should be completed on the

same day is referred to as the principle of *valeur compensée* or compensated value. Two exceptions to the principle of compensated value arise: (1) The first is for deals in Middle Eastern currencies for settlement on Friday. This is a holiday in most Middle Eastern countries. When this happens, the person buying the Middle Eastern currency (say Saudi riyals) makes payment (say in U.S. dollars) on Friday. Delivery of the riyals takes place on Saturday, which is a normal business day in the relevant countries (see Appendix B). (2) The second exception may arise in emerging markets (e.g., in Russia), where it is often customary for the stronger party (e.g., an international bank) to require the counterparty to pay over funds a day before it pays away the countervalue. This, of course, is a bilateral commercial negotiation between the two parties rather than a standard market convention.

QUOTED AND BASE CURRENCIES: DIRECT AND INDIRECT QUOTATION, CERTAIN AND UNCERTAIN QUOTATION

The term *quoted currency* means the currency that is variable in an exchange-rate quotation; the term *base currency* means the currency that is fixed. Thus, in $\text{GBP}1 = \text{USD } 1.7250$, sterling (GBP) is the base currency, and the U.S. dollar is the quoted currency. (For convenience, I shall write exchange rates as base/quoted, in this case GBP/USD.)

Direct quotation takes the form of variable amounts of domestic currency against a fixed amount of foreign currency. The foreign currency is the base currency. A Swiss bank quoting “85.5 Swiss francs per 100 euro” would be quoting direct—a variable amount of Swiss francs against a fixed euro amount. Many people say “normal” for direct currencies. Others, particularly in Continental Europe, would describe this as “uncertain for certain” (the 85.5, varying every minute or every hour, is uncertain, whereas the 100 euro is certain).

Indirect quotation, conversely, takes the form of fixed amounts of domestic currency against varying amounts of foreign currency. A British bank quoting “ $\text{GBP } 1 = \text{CHF } 2.3575$ ” is quoting indirect. Many people in the market say “reciprocal” for indirect quotations. Similarly, in the Swiss franc example just referred to, a French bank making such a quote would describe it as reciprocal or “certain for uncertain” because the euro is its base currency.

In the United States, both types of quotations are used: for domestic business, U.S. terms are often used, that is, normal direct quotation (CHF

1 = USD 0.5525). For international business and more and more for domestic business also, U.S. banks use European terms or reciprocal indirect quotation (USD 1 = CHF 1.35). The reason for this is the international market's habit of dealing against the U.S. dollar, using direct terms. U.S. banks have fallen into line with international market practice.

SELLING AND BUYING RATES

Where the currency's exchange-control regulations permit, a bank will normally quote a "two-way price" in the currency. So a bank might quote the exchange rate as USD 1 = CHF 1.2550/60. This conventional way of writing the rate shows that the bank will sell CHF 1.2550 in exchange for USD 1; it will buy Swiss francs at 1.2560. The lower rate is the selling rate for Swiss francs; the maxim is "Sell low, buy high."

The reason for this apparent perversity is that the bank's "income" from a sale is fixed at \$1; it tries to sell as few Swiss francs as possible in exchange for the \$1. To test the maxim, suppose the bank sells CHF 1.2550 million, receiving USD 1 million. It then uses the USD 1 million to buy CHF 1.2560 million, netting a final profit of CHF 1,000. The narrower the spread between the selling and the buying rates, the less the bank's profit.

The conventional quotation needs explaining when the "big figure" (of 1.25 in our example) is being straddled. Say we have a selling rate of 1.2495 and the buying rate is 1.2505. Normal market convention is to write this as 1.2495/05. The "big figure" on the left is 1.24; on the right side it is understood as being the next "big figure" up, 1.25.

CROSS-RATES

A *cross-rate* may be defined as an exchange rate that is calculated from two other rates. For example, the GBP/CAD rate can be derived as a cross-rate from the USD/CAD and the GBP/USD rate.

The practice in the world foreign exchange market at present is that currencies are mainly dealt against the U.S. dollar. If bank A asks bank B for its South African rand rate, that rate will be quoted against the U.S. dollar unless otherwise specified. Because the vast bulk of dealings are done against the U.S. dollar, it follows that the "market rate" for a currency at any moment is most accurately reflected in its exchange rate against the U.S. dollar. Thus

a bank asked to quote GBP/ZAR would normally calculate this rate from the GBP/USD and USD/ZAR rates, if an exact market rate is required.

I will use the rule that an exchange rate between two currencies, neither of which is the U.S. dollar, will be referred to as a *cross-rate*. The term *exchange rate* will normally refer to the rate for a currency against the U.S. dollar, unless otherwise specified.

CALCULATION OF CROSS-RATES

There are three cases to consider: (1) both exchange rates quoted direct, or normal; (2) both rates quoted indirect, or reciprocal; and (3) one rate is direct, and the other is indirect. Let's look first at the case where both are normal; for example, USD 1 = SGD 1.8650/60 and, USD 1 = CHF 1.3550/60. The U.S. dollar is the base currency in both cases. We want to find the selling and the buying rates for Swiss francs in terms of Singapore dollars (SGD) (the Singapore dollar will be our base currency).

If we are selling Swiss francs, we must be buying SGD. So we take the USD/CHF selling rate, 1.3550, and divide it by the buying rate for SGD, 1.8660. (We divide by the currency that is to be the base, in this case, the SGD.) The selling cross-rate, therefore, is CHF 72.61 per SGD 100 after rounding in the bank's favor. Similarly, the buying rate is found by taking the Swiss franc buying rate, 1.3560, and dividing it by the SGD selling rate, 1.8650, to give 72.71 per 100. Again we round in favor of the bank—this time upward.

A parallel procedure is followed when both currencies are reciprocal: the U.S. dollar is the quoted currency in both cases. For example, we have EUR 1 = USD 1.0630/40 and CAD 1 = USD 0.7985/89. We want the cross-rates, using euro as the base currency. The rate at which we sell U.S. dollars against euro (we buy euro) is 1.0630. We buy U.S. dollars against Canadian dollars, (we sell Canadian dollars) at 0.7989. Because we are dealing indirect currencies, we divide by the quoted currency. So we sell Canadian dollars against euro at 1.3305.

When one rate is normal and the other is reciprocal, the procedure is the same, but we multiply (the alternative is to convert the reciprocal currency to normal by taking reciprocals and then dividing by the base currency). Suppose we have EUR 1 = USD 1.0630/40 and USD 1 = SGD 1.8650/60. The rate at which we sell SGD against U.S. dollars is 1.8650; the rate at which we buy euro against U.S. dollars (sell U.S. dollars against euro) is

1.0630. Multiplying these gives a selling rate for SGD against euro of 1.9824 and a buying rate of 1.9855.

TRADING THE CROSSES

During the late 1970s and early 1980s, a very high proportion of interbank trading was done against the U.S. dollar. A few banks had someone who sometimes dealt deutschemark direct, but cross trading was generally neglected. But the arrival of the European Monetary System (see Chapter 13) and the growth in importance of the yen/euro relationship has meant that more and more banks have begun trading the crosses in their own right.

The trader who is dealing the crosses has a harder job because he or she has to watch three rates: the two rates against the U.S. dollar, and the cross. Let's take an example: Today we have USD/CAD 1.2510/15 and USD/JPY 145.10/20. That implies a cross-rate of CAD/JPY 115.94/116.07. The market sells yen and buys Canadian dollars at 115.94 (145.10/1.2515); it buys yen for Canadian dollars at 116.07 (145.20/1.2510). We shall refer to this as the implied cross-rate.

Let's start with USD 10,000,000 and do the round trip. We buy JPY 1,451,000,000. We sell the yen for Canadian dollars at 116.07, producing CAD 12,501,076.94. We take those Canadian dollars and we sell them for U.S. dollars at 1.2515, producing USD 9,988,874.90. We have lost USD 11,125.10, and the reason is obvious: all the rates are in line, and we paid three lots of bid/offer spread.

Now suppose that the cross-rate moves out of line. The implied cross is the same, but for some reason of its own, XYZ Bank is quoting the cross as 114.97/115.07. We take USD 10,000,000, buy JPY 1,451,000,000, and sell the yen for Canadian dollars at 115.07, producing CAD 12,609,715.83. We take those Canadian dollars and sell them for U.S. dollars at 1.2515, producing USD 10,075,681.84. We have made USD 75,681.84.

We have now made a profit, because the cross quoted in the market was below the implied cross. Canadian dollars could be bought cheaply on the cross. So if the quoted cross is below the implied, the Canadian dollar is cheap on the cross, and the yen is expensive. We should buy yen direct, sell them for Canadian dollars on the cross, and buy back U.S. dollars with Canadian dollars. Conversely, if the quoted cross is above the implied, the Canadian dollar is expensive on the cross. We should buy Canadian dollars direct, sell them for yen on the cross, and buy back U.S. dollars with yen.

10 Forward Contracts: Outrights

This chapter explains what a forward contract is, what premium and discount mean, and how to work out the cost of hedging, option forwards, cross and reciprocal forwards, and the value date for a forward contract.

WHAT IS A FORWARD?

A *forward* (short for *forward exchange contract*) is an agreement between a bank and another party to exchange one currency for another at some future date. The rate at which the exchange is to be made, the *delivery date*, and the amounts involved are fixed at the time of agreement.

Such a contract is to be distinguished from a foreign exchange futures contract. (These are discussed in more detail in Chapter 15.) However, for comparison, a *futures foreign exchange contract* is a contract between two parties for the exchange of a certain amount of foreign currency at a future date. The amount and the date are normally standard. For instance, in the case of the International Monetary Market of Chicago's sterling contract, the contract is for GBP 62,500. Delivery is normally the third Wednesday of the contract month (March, June, September, or December). A futures contract need not involve a bank as counterparty. Delivery of all or part of the sum involved normally completes a forward contract. This is unusual in the case of a futures contract, which is usually closed by trading in the reverse direction before the maturity of the original futures contract.

Two kinds of operation can be undertaken in the forward foreign exchange

market: (1) We can enter a contract to buy or to sell foreign exchange at some given future date. (This kind of trade is often called an “outright” forward contract.) Or (2) we can do a swap—we buy today, coupled with a forward sale, or we sell today, coupled with a forward purchase. These contracts are discussed in the next chapter.

PREMIUM AND DISCOUNT

Suppose a quoted currency is more expensive in the future than it is now in terms of the base currency. Then the quoted currency is said to stand at a premium in the forward market, relative to the base currency. Conversely, the base currency may be said to stand at a discount relative to the quoted currency.

Take the U.S. dollar as the base currency and the yen as the quoted currency. We may have a spot rate of USD 1 = JPY 120.50. The rate quoted by a bank today for delivery in one year’s time (today’s one-year forward rate) may be USD 1 = JPY 118.50. In this example, the dollar buys fewer yen in one year’s time than it does today. The dollar stands at a discount relative to the yen. Putting it in converse terms, the yen stands at a premium relative to the dollar.

The size of the dollar discount or yen premium is the difference between 120.50 and 118.50, that is, 2 yen. It would normally be quoted as 200 points. To arrive at the forward price, the yen premium or dollar discount must be subtracted from the spot. Conversely, a yen discount or dollar premium is added.

As in the spot market, banks in the forward market will normally quote a selling rate and a buying rate. The convention is that the selling rate for the quoted currency (the buying rate for the base currency) is quoted first. In our example, the spot rate might be quoted at 120.50/60, and the one-year forward discount for U.S. dollars (or yen premium) might be quoted at 200/190. In other words, if the dealer is buying U.S. dollars forward, he or she will charge a discount of 200 points, but if the dealer is selling, he or she will give away only 190 points discount. In the terms used in the London market, the dealer will sell yen at a premium of 200, but only buy at a premium of 190.

There is an apparent inconsistency in the quotation. The spot is quoted at 120.50/60, that is, low/high; and the yen premium/dollar discount is quoted

at 200/190, that is, high/low. In both cases, the same convention is followed; that is, the selling rate for the quoted currency is given first. The apparent inconsistency flows simply from the fact that the yen premium/dollar discount is to be subtracted from the spot rate. So the selling price for delivery in three months' time (often referred to as the outright three-month price) is 120.50 less 200 points, that is, 118.50. Now the buying price is 120.60 less 190 points, that is, 118.70. So we can quote the three-month outright as 118.50/70, which matches the way in which the spot is quoted.

A price of 200/190 indicates a premium for the quoted currency in the forward market and a discount for the base currency; conversely, a price of 190/200 would indicate a discount for the quoted currency and a premium for the base currency.

This can be summed up as: *High/Low = Subtract, Low/High = Add.*

In premium/discount terms in the United States: *High/Low = Discount for the dollar, Low/High = Premium for the dollar.*

In London, the tag is reversed as the market there looks at rates in currency terms: *High/Low = Premium, Low/High = Discount.*

Occasionally on a Reuters Monitor or on a table of rates, the forward price may be quoted as “-5/+5” or “5P5.” This indicates that the forward is “round par.” This term means that the middle rate for a currency in the spot market is identical to the middle price available in the forward market; the forward price is at par with the spot. Thus the dealer will buy dollars against the currency at a discount and sell at a premium; in European terms, the dealer will charge a premium to sell the currency and will only buy at a discount. It follows that a quotation of “-5/+5” or “5P5” applied to our spot rate example of 120.50/60 would produce a forward price of 120.45 selling rate and 120.65 buying rate.

A quote of 20/00 (or 20/P) indicates a forward dollar discount or currency selling premium of 20, but that the bank only buy at par (P). In our example, the forward price would then be 120.30/60. A quote of 00/15 (or P/15) indicates sales made at par, purchases at a dollar premium, or currency discount of 15. This would give 120.50/75 in our example.

HEDGING COSTS

We often need to work out a percentage cost per annum of a forward contract. This varies according to whether our calculations are based on the spot price

or on the outright forward price. Views differ on this; my own view is that the choice should vary according to the underlying deal. If one is hedging a forward commitment, then the outright rate should be used. Thus a firm needing to buy forward EUR 1 million against U.S. dollars for the purchase of machinery should use the outright rate. This is the important rate for its business; it determines the amount of dollars required. In other cases, it may be more appropriate to use the spot rate. If we were considering an investment, we would probably want to express the hedging cost or profit as a percentage of our original investment, so we would probably use the spot rate. It is like the money market difference between a discount rate and an ordinary interest rate.

Suppose again that we have a spot rate of 120.50/60 and a three-month forward rate of 200/190. Then, working on middle rates of 120.55 and 195, we can calculate that the approximate hedging cost for three months is 1.95 divided by 120.55, or 0.01618. (We might prefer to use the market's selling rates of 120.50 and 200.) Multiplying by 100 to express this in percentage terms, we find that this is 1.62% for three months. We multiply this by 4 to gross it up to annual terms of 6.48%. (This is slightly inaccurate. If we really needed to be exact to six places of decimals or so, we would gross it up by compounding.)

The formula, therefore, is:

$$\text{Hedging cost} = \frac{F}{O} \times \frac{12}{n}$$

or

$$\frac{S}{O} \times \frac{12}{n}$$

where n = number of months in forward contract, F = Forward premium, O = Outright, and S = Spot.

CROSS AND RECIPROCAL FORWARDS

A typical cross forward calculation arises when a customer needs a EUR/SGD forward. For this to be exact, it should be worked out from the pro-

fessional interbank prices, which are against the U.S. dollar. We have EUR/USD spot rates of 1.0850/60 and USD/SGD spot 1.8100/10. The three-month EUR/USD price is 150/140, while the three-month USD/SGD price is 200/190.

We first find the outright three-month EUR/USD price, 1.0700/20, and the outright three-month USD/SGD price, 1.7900/20. We then find the cross spot and three-month outright prices along the lines of Chapter 9 (i.e., multiplying in this case). This gives us a three-month outright price of 1.9153/1.9211 and a spot of 1.9639/1.9667. The forward premium for SGD against euro is then found by subtracting the three-month outright from the spot, giving us a premium of 486/456.

Let's take an example with a currency where the dollar is at a premium (the currency is at a discount). Suppose the Norwegian Krone spot against the dollar is 7.3310/40, and the three-month rate is 300/400; that is, dollar premium, Krone discount. Then, against euro, using the same euro/dollar rates, we get a spot of 7.9541/7.9647 and a forward margin of 779/597, that is, the Krone is at a premium against the euro, although at a discount against the dollar (because the euro is at an even greater discount against the dollar).

Reciprocal forwards are needed sometimes when a currency is quoted both direct and indirect. An example is the Canadian dollar against the U.S. dollar, which can be quoted as either as CAD/USD 91.22/26 or as USD/CAD 1.0958/63; a forward quote may need to be turned around also. We do this by calculating the reciprocals, and remembering, as in the spot cross-rate calculations, to switch the buying and the selling rates. The higher, or selling, price in U.S. dollar terms of 1.0963 will produce the lower, or buying, price in Canadian dollar terms of 91.22.

Suppose we have the rate quoted as USD/CAD 1.0958/63, with a three-month forward swap rate of 100/200. We want to turn the quote around. We know that the outright rate is 1.1058/1.1163. We now proceed to work out the quote in the opposite direction. The spot is CAD/USD 91.22/26, and we can calculate the inverted outright forwards as 89.59/90.44. From this we can find the forward margins as 163/82.

The use of margins in forward quotations is convenient because the margins tend to move much less quickly than the spots and because it is the margins that are relevant in the swap market. But certain currencies have limited or nonexistent swap markets, so that the banks will often quote the forwards in outright form. Equally, of course, when quoting to customers who wish

to transact on an outright basis, it would be normal to convert the quotation to an outright basis for the value date required.

CALCULATION OF FORWARD VALUE DATES

The first step in finding the standard forward value dates for periods of one month, two months, three months, and so on, is to fix the spot date (see Chapter 9). The standard forward date will normally be the same date in the relevant month. So, if spot is October 3, one month is November 3, two months is December 3, and so on.

If the date so found is a holiday, then the date is rolled on to the next day on which banks are open for business in both centers. Say we are dealing U.S. dollars against yen for one month, and November 3 falls on a weekend or a holiday in New York or Tokyo. We roll the date on to the 4th, if that day is a business day in both centers. If it is not, then we keep rolling the date on until such a day is reached.

Exceptions to this rule arise in the case of month-ends. A month-end date is the last day of a month on which banks are open for business in the two settlement countries. In a U.S. dollar/yen deal, if November 30 were a U.S. holiday, then month-end would be November 29, provided that day is a business day in both centers.

There are two exceptions to the standard rule, both of which are concerned with month-ends: (1) The first is the so-called "end-end" rule. This says that if the spot value date is a month-end, then all forward value dates are also month-ends. Suppose the October month-end is October 28; October 29 and 30 are the weekend; and October 31 is a public holiday. Then if spot is October 28 (that is, the month-end), the end-end rule makes the one-month date November 30 (if that is the November month-end), not November 28. The second exception is that forward value dates must not be rolled on beyond the month-end. Suppose that the one-month date would normally be March 31, but that date is a holiday. We do not roll the one-month date on to April 1, but instead roll it backward to March 30.

11 Forward Contracts: Swaps

In this chapter we look at swaps. After explaining how swaps are used to switch exposure between currencies and over time, we look at how they are used to “manufacture” interest rates. Then we look at how interest rates affect the swaps. Next we look at the use of medium-term swaps. Then we see how forward-forward swaps work. Finally, we look at the use of swaps in extending contracts and in working out broken dates.

WHAT IS A SWAP?

In general, a *swap* is an exchange of one currency for another on one day, matched by a reverse exchange on a later day. A typical swap trade might be the sale of GBP 1 million against USD 1.6 million for spot value, coupled with the purchase of GBP 1 million for delivery in three months against USD 1.61 million. We swapped GBP 1 million into dollars: we sold GBP 1 million and bought it back three months forward. The swap rate is the difference between the rates of exchange used in the two trades. In our example, where the spot trade is done at 1.6000 and the forward, at 1.6100, the swap rate is 0.01, or 100 points. Note that in this chapter we are not concerned with interest-rate swaps or with currency swaps, which are structured as multiple exchanges of currencies; these are dealt with in Chapter 16. Figure 11.1 illustrates the difference.

In most swap deals, the two exchanges are made at the same time with the same counterparty; but this need not be the case. One could buy spot from one counterparty and sell outright forward to another. Such a trade may

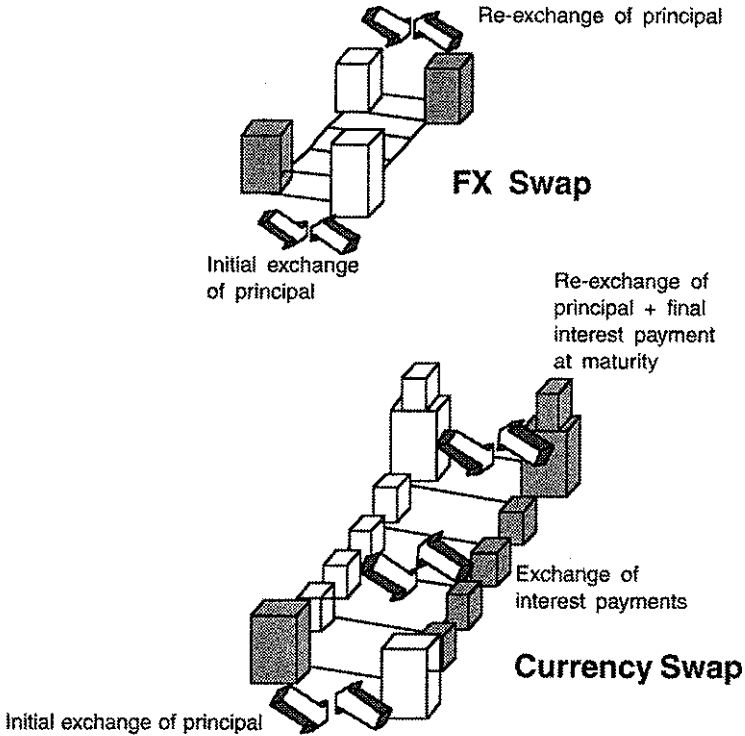


Figure 11.1 Foreign Exchange (FX) Swap vs. Currency Swap

be called an “engineered” swap to distinguish it from the more usual, or “pure,” swap.

In the pure swap, the spot rate used is not very important. What matters is the swap rate: the premium or discount received for the forward sale of dollars that are bought spot. The market tends to use a spot rate that is close to the current market rate, but chosen so as to make calculation easy.

USING SWAPS

Swaps have two basic uses: (1) to switch a deal from one currency to another, and back again, on a hedged basis; and (2) to move a given currency deal forward or backward in time.

An example of the first kind of swap could be if a bank had to lend a

currency for which, perhaps because of exchange controls and other problems, the “natural” market in the Euromarket is very thin. Let’s assume we are being asked to lend Home currency, but there is no Euro-Home market. So to provide Euro-Home funds, a bank will normally borrow U.S. dollars, buy Home in the spot market, and sell the Home currency back in the forward market. It “manufactures” Euro-Home from Eurodollars.

An example of the second type of deal is when a customer makes an outright forward sale of, say, EUR 5 million six months forward to a bank. The bank will hedge this by a spot sale and a forward swap, rather than an outright deal. Interbank outright deals are very rare because they are regarded as too risky. It may be difficult to find a counterparty willing to take such a risk. So the bank will sell the EUR 5 million in the spot market. It will then do a swap, buying EUR 5 million spot and selling them forward. (The steps are set out in Figure 11.2.) The swap carries no exchange risk, and it is much easier to find a counterparty. So the swap market helps to bring a forward exposure nearer so that it can be closed out more easily.

Equally, it can be used to push an exposure away in time. Suppose I am an exporter with a steady stream of euro coming in. Suppose the euro is very weak, so I am not inclined to sell my euro now because I expect the currency to recover. Then I could, if the exchange control system in my country permits it, swap my euro for three or six months, say, into Canadian

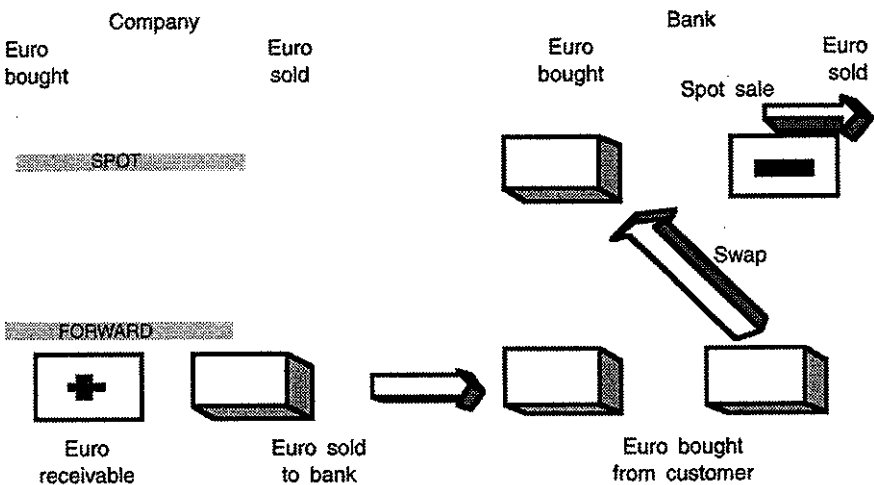


Figure 11.2 Using the Swap to Bring an Exposure Nearer in Time

dollars if I am based in Canada. I am still long of euro, but instead of switching out of euro I am effectively lending them and borrowing Canadian dollars against them. When the deal unwinds, I receive my euro back again and can—I hope—sell them at a better rate. (Figure 11.3 shows this in simple terms.) Equally, a bank might want to run a basic long position in euro without showing it in the spot book. To do this, it would swap the position out into the forward book. (We saw in Chapter 4 how a dealer would look at the foreign exchange and money market route to solve his problem. See also Chapter 12 on swapping out a position on the “short” dates.)

Another important use for swaps is as a straight trading operation. Swaps let us take a view on interest rates. Remember the rule of Chapter 4—if the interest differential moves in a currency’s favor, the forward margin moves against it. So let’s look at a situation where one-year U.S. dollars and euro are both 10%. The forward margin will be near zero (if you are not sure why, read over Chapter 4). So a U.S. investor pays no premium for forward euro. Suppose the investor thinks that in one month the 11-month rate for euro will be below the 11-month rate for U.S. dollars. That means that forward euro will be at a premium. So it makes sense to buy forward euro. And to do this without incurring an exchange risk, the investor can deal in the swap market, that is, sell euro spot and buy it 12 months forward, believing that

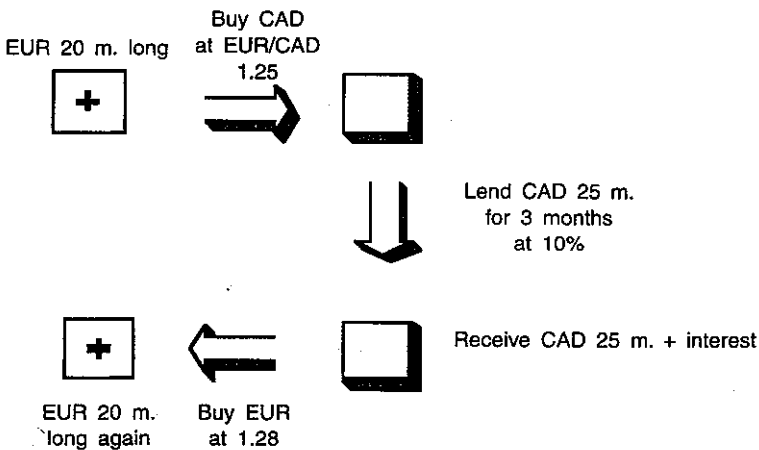


Figure 11.3 Using a Swap to Push Exposure Away

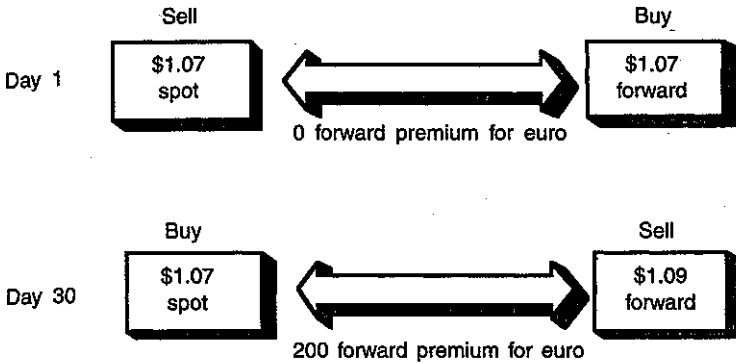


Figure 11.4 Taking a Forward Position

in one month the euro can be sold at a premium. (The steps are set out in Figure 11.4.)

SWAP RATES IN PERCENTAGE TERMS

We often need to express the swap rate in percentage terms, usually to compare it with an interest differential. The choice of base—either the spot price or the forward outright price—will depend on circumstances (see Chapter 10); in most professional deals, the relevant rate will be the outright forward rate. Suppose we have spot euro at EUR 1 = USD 1.10 and the three-month swap rate at 190/200, say 195 middle, yielding an outright of USD 1.1195. Then the hedging cost for three months (90 days) would be 0.0195/1.1195, or 1.74%; if the spot is used as a base, the cost is 1.77%. These rates are normally annualized by multiplying by 4—the number of days in a year, 360, divided by the number of days in a swap period, 90. The 360-day year is used to compare with Eurorates (see Chapter 7), but a 365-day basis could be used.

This process can be summed up in words as:

$$\text{Swap rate in \%} = \frac{\text{Swap rate in points}}{\text{Spot or outright in points}} \times \frac{360 \times 100}{\text{No. of days in swap}}$$

The formula is:

$$\text{Swap rate in \%} = \frac{F}{S \text{ or } O} \times \frac{360 \times 100}{N}$$

For a reciprocal currency like the euro, using the outright price gives higher swap costs if the hedged currency has a forward discount because then the outright is a smaller number than the spot. It works the other way around if it is at a premium. In our case, where the euro was being sold spot and bought forward at a premium, the hedging cost rises from 1.74%, using the forward rate for calculations, to 1.77%, if the spot rate is used.

FINDING INTEREST RATES FROM SWAP RATES— INTEREST UNHEDGED

We need the calculation of the swap yield if we must compare interest rates between currencies. Suppose we want to find the cheapest way to borrow Euro-Swiss francs (CHF). We can either borrow Euro-Swiss francs directly or borrow another currency (typically Eurodollars) and swap into Euro-Swiss francs. We have to find the cheapest rate at which a bank could lend Euro-Swiss francs.

The quickest, crudest measure of the cost of the deal is this: We take the Eurodollar interest rate and subtract the swap yield (be it positive or negative). Suppose that we have a middle USD/CHF spot of 1.5000 and that dollars are at a three-month discount (Euro-Swiss francs are at a premium) of 100 (mid-rate). Suppose it cost us 7% to borrow three-month Eurodollars. We need the swap yield. As we saw in the previous section, if F is the margin, S is the spot, and O is the outright, the swap yield is F/S or F/O , depending on circumstances. (When we work out the exact formula, we will see that the yield works out as F/S for normal or indirect currencies such as the deutschemark and as F/O for reciprocal or indirect currencies such as sterling.)

We take the swap yield here as $0.01/1.5 = 0.006667$. This is 0.026667 if we multiply by 4 to put it out on an annual basis. Putting it in percentage terms, we have 2.67%. This is the swap profit. Because the bank is buying its forward dollars at a discount (receiving a premium on the forward Swiss francs it is selling), the swap yield is positive. The profit on the swap can

be used to offset its Eurodollar costs. So the manufactured francs cost 7% minus 2.67%, or 4.33%. We then compare this with the cost of raising Euro-Swiss francs directly (Figures 11.5. and 11.6).

If the currency being produced is at a discount in the forward market— F will be negative—then $R2$ will be greater than $R1$. If the currency is at a premium— F is positive— $R2$ will be less than $R1$. Effectively, $R1$ is the direct interest cost, and F/S is the swap yield adjustment.

FINDING INTEREST RATES FROM SWAP RATES— INTEREST HEDGED

The formula in Figure 11.7 ignores the foreign exchange exposure on the interest payable on the deal. If there is a large swing in rates during the life of the deal, this could wipe out any profit. Suppose our rates are: spot CHF 1.5000 three months 100 CHF premium, USD deposits one year 7%. Then on the crude formula, we have a Euro-Swiss franc (CHF) yield of about 4.333%. But if at maturity the Swiss franc has weakened to 1.70, the realized

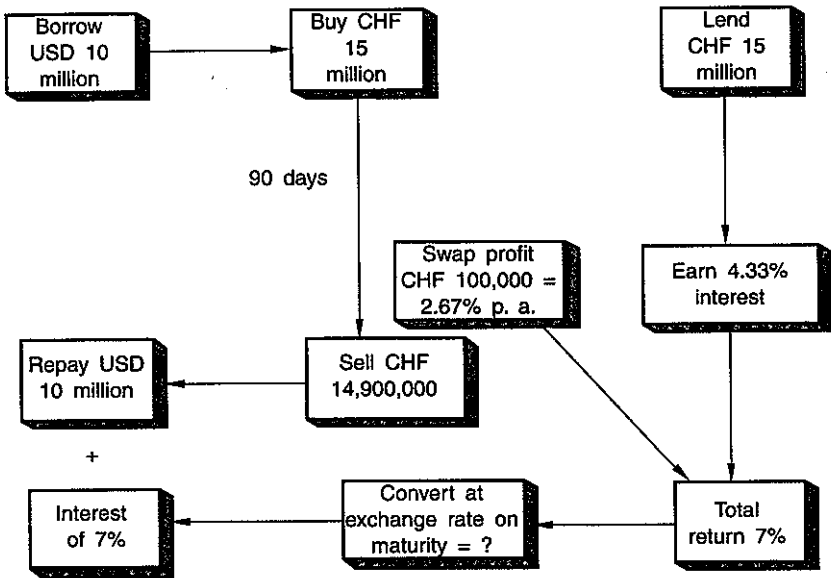


Figure 11.5 Arbitrage: Interest Unhedged

$$R2 = R1 - [(F/S) \times (360/N) \times 100]$$

where

- $R1$ = interest rate on currency borrowed
- $R2$ = interest rate on currency lent
- F = forward margin in points (treated as negative if the quoted currency is at a discount— $R2 > R1$)
- S = spot rate in points
- N = number of days

In words:

$$\text{Second currency interest rate} = \text{First currency interest rate} - [(\text{Swap/Spot}) \times (360/\text{Days}) \times 100]$$

For an investor looking at the differential between the two currencies, we would write:

$$\text{Interest differential} = (\text{Swap/Spot}) \times (360/\text{Days}) \times 100$$

If the actual differential is bigger than the amount implied by the swap calculation, the switch is worth making.

Figure 11.6 Crude Arbitrage Formula

yield is a good deal less. (The Euro-Swiss franc interest earned is now worth less in dollar terms.) So the bank needs to have a formula that works on a fully hedged basis, as is set out in Figure 11.7.

To find the formula, we work through a deal step by step (Figure 11.8). We will use the rates from our first example, that is, USD 1 = CHF 1.5000 three-month forward dollar discount, CHF premium 100, and three-month Eurodollars (90 days) cost 7%. The bank borrows US\$ 10,000,000 to swap into Euro-Swiss francs. It receives CHF 15,000,000 spot and pays away CHF 14,900,000 in three months. The profit on the swap is CHF 100,000. Now we know that in 90 days, the bank must pay interest of USD 175,000. It will cover this interest by selling its Swiss franc earnings forward at 1.49. We know it will need USD 175,000 × 1.49, or CHF 260,750, in 90 days. It has made CHF 100,000 on the swap, so to break even, its Swiss franc interest earnings must total CHF 160,750. These earnings are on a principal of CHF 15,000,000; therefore, over the three-month period, the interest rate is 160,750/15,000,000, or 1.0717%. Putting that on an annual basis, we multiply by four, getting 4.2867%.

The normal formula is used, for instance, when borrowing U.S. dollars (first currency) and lending yen (second currency):

Interest hedged formula: Normal exchange rate

$$R2 = [R1 \times (B2/B1) \times (S - F)/S] - [100 \times (B2/N) \times (F/S)]$$

In words:

$$\text{Second currency interest rate} = \left(\frac{\text{Second basis}}{\text{First basis}} \times \frac{\text{Outright}}{\text{Spot}} \right) - \left(100 \times \frac{\text{Second basis}}{\text{Days}} \times \frac{\text{Swap}}{\text{Spot}} \right)$$

This formula is exactly the same as the crude one except that the first currency's interest rate is multiplied by a factor to allow for the cost or the benefit of selling the interest forward.

The reciprocal formula is the same, except that the adjustment factors change; it is used, for example, when borrowing U.S. dollars (first currency) and lending euro (second currency):

Interest hedged formula: Reciprocal exchange rate

$$R2 = [R1 \times (B2/B1) \times S/(S - F)] - [100 \times (B2/N) \times F/(S - F)]$$

In words:

$$\text{Second currency interest rate} = \left(\text{First currency interest rate} \times \frac{\text{Second basis}}{\text{First basis}} \times \frac{\text{Spot}}{\text{Outright}} \right) - \left(100 \times \frac{\text{Second basis}}{\text{Days}} \times \frac{\text{Swap}}{\text{Outright}} \right)$$

The factor used to allow for the cost of hedging interest is inverted, and the swap yield is expressed as a percentage of the outright. Note also that if we are going "backward"—into dollars—the formulas are reversed. If a normal currency is being borrowed to produce dollars, we would use the reciprocal formula; if a reciprocal currency is borrowed, we use the normal formula.

Figure 11.7 Formula for Fully Hedged Arbitrage

This compares with the 4.33% we worked out earlier. The reason that this rate is slightly lower is that the bank bought forward its dollar interest payable against its Swiss franc interest earnings as well as swapping the Swiss franc principal. Because the dollar was at a discount (the Swiss franc was at a premium) forward, it made an extra profit. This meant it could lower the Swiss franc interest rate at which it lent and still break even. Conversely, if the dollar were at a premium and the currency were at a discount—for example, the Brazilian cruzeiro—its lending rate would have to be higher

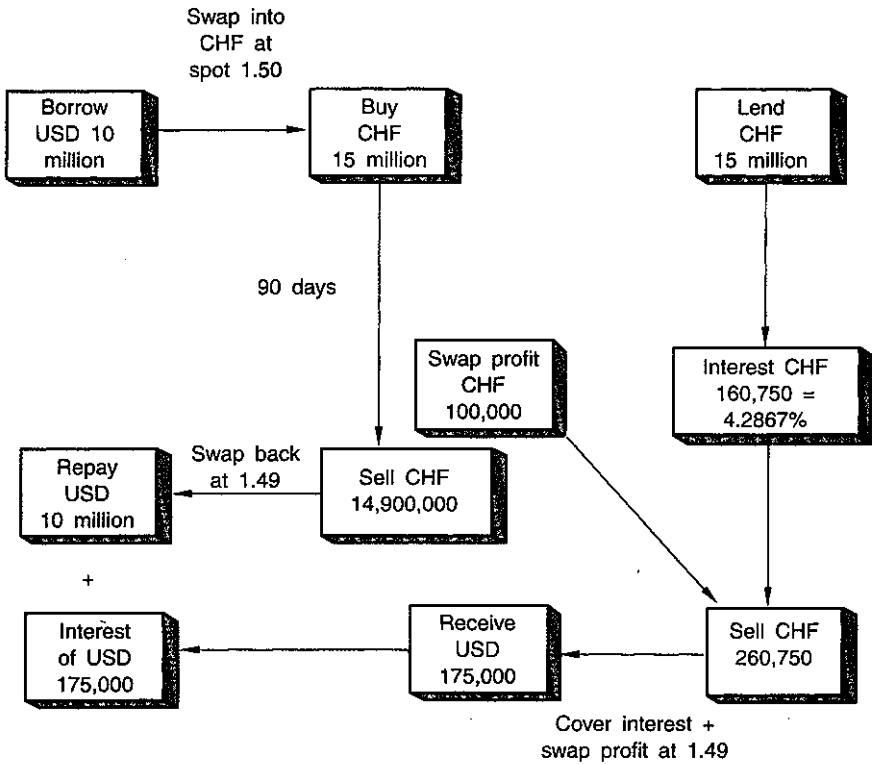


Figure 11.8 Fully Hedged Interest Arbitrage

to compensate it for the extra cost of covering its cruzeiro interest receivable. Indeed, it is in currencies that have a high rate of inflation (and greater risk of depreciation) that the use of this formula is particularly important.

To be absolutely accurate, our formula should take account of the spread in the spot rate because the principal amount is swapped but the interest is sold forward outright (that is, using the other side of the spot). But the effect is very small.

The formula we have set up (in Figure 11.7) can be used to value a deal that is not hedged. To value the deal, we must predict the rate at which the interest earnings are sold off when they are received. We plug this assumed rate into the formula by substituting it for $(S - F)$ —the rate at which we would sell off the interest if the deal were hedged—in the first term. So the normal formula is:

$$R2 = [R1 \times (B2/B1) \times (\text{Assumed rate}/S)] + [100 \times (B2/N) \times (F/S)]$$

and the reciprocal formula is:

$$R2 = [R1 \times (B2/B1) \times (S/\text{Assumed rate})] + [100 \times (B2/N) \times (F/S - F)]$$

To revert to our example at the start of this section, suppose we plug in an assumed rate of 1.7. We see that to break even the bank must earn 5.03% rather than the 4.33% shown by the crude formula; in other words, if it lends at 4.33%, it ends up by losing 0.7%. The calculation is:

$$[7 \times (360/360) \times (1.65/1.5)] - 100 \times (360/90) \times (0.01/1.5) = 7.70 - 2.6667 = 5.0333, \text{ or } 5.03$$

Several variations of the formula in Figure 11.7 exist, usually simplified to ignore the possibility of a 365-day basis and sometimes only applicable when going out of U.S. dollars into another currency. For example:

$$\text{Interest differential} = \frac{[(360/\text{Number of days}) + (\text{US\$ cost}/100)] \times [\text{Swap} \times 100]}{\text{Spot}}$$

FINDING SWAP RATES FROM INTEREST RATES

We have seen that the swap rate and the interest rate differential between two currencies are closely linked. In our examples so far, we have taken the swap rate as given and used it to derive interest rates. We now reverse the process and derive swap rates from interest rates.

The term *interest rate* contains a number of problems (see Chapter 4). In this chapter, *interest rate* is taken to mean interest rate available to participants in the international market, adjusted for special factors such as reserve asset costs and withholding taxes—in other words, to borrow a phrase, “net accessible interest rates.”

We begin with the simplest formula, ignoring spreads and the hedging of interest. We have: $S = 121.60$; $R1 = 5.75\%$; $R2 = 4.25\%$; $N = 91$; $B1 = 360$; $B2 = 360$. Here, S = middle spot rate for yen against U.S. dollar; $R1$ = interest rate on U.S. dollar; $R2$ = interest rate on yen; N = number of days in the deal; $B1$ = number of days in yen interest basis; and $B2$ = number of days in U.S. dollar interest basis.

184 Forward Contracts: Swaps

Suppose we have USD 1,000,000 to invest in either U.S. dollars or yen; we want to know the forward margin that would make the two deals equivalent. We start by noting the interest gap between the two currencies: if we invest in yen, there is an interest loss of 1.5000% for 91 days on JPY 121,600,000 that must be compensated for by a profit on the swap. The exact loss is:

$$\frac{121,600,000 \times 1.5 \times 91}{360 \times 100} = \text{JPY } 461,066.67$$

We must therefore make at least JPY 461,066.67 on our swap. So USD 1,000,000 sold spot for JPY 121,600,000 must cost only JPY 121,600,000 - 461,066.67, or 121,138,933.33. Hence our break-even outright forward rate is 121.138933, say, 121.14, making the break-even margin 46 points (121.60 - 121.14 = 0.46).

Notice that if our principal had been only US\$ 1, we would have had:

$$\frac{121.60 \times 1.5 \times 91}{360 \times 100} = 0.46107$$

from which we can deduce, in words:

$$\text{Forward margin} = \frac{\text{Interest difference} \times \text{Spot} \times \text{Days}}{\text{Interest basis} \times 100}$$

The formula is:

$$F = \frac{S \times (R2 - R1) \times N}{B \times 100}$$

where S = spot in points; F = forward margin in points; N = number of days; and B = common interest basis.

This crude formula is convenient for quick calculations. To find the exact formula, we work through an example. The steps are set out in Figure 11.9. We have USD/JPY 121.60, three-month (91-day) JPY interest rate is 4.25%, US\$ interest rate is 5.75%. Suppose we have a principal amount of USD 1,000,000. If we place the U.S. dollars, we have interest of \$1,000,000 ×

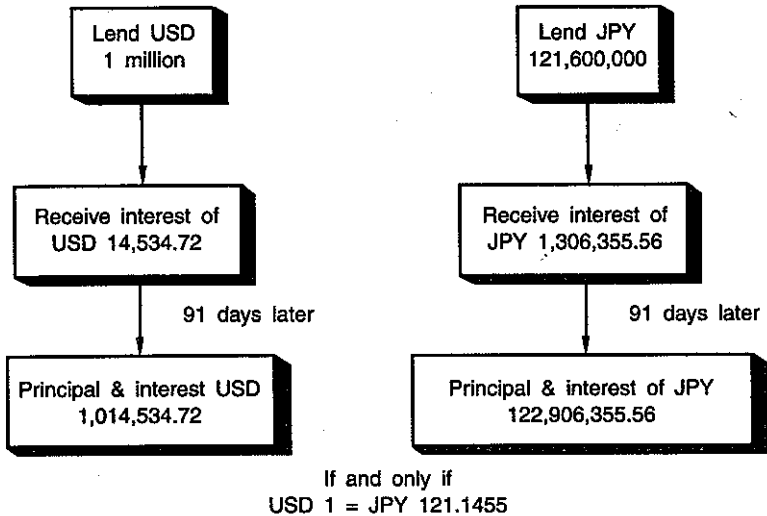


Figure 11.9 Finding a Swap Rate from Interest Rates

$(5.75/100) \times (91/360)$, or \$14,534.72. The yen principal is JPY 121,600,000, earning JPY 1,306,355.56. The outright rate that we need is the one that equalizes principal and interest on both sides—USD 1,014,535 and JPY 122,906,356; that is, $122,906,355/1,014,534 = 121.1455$. So the swap rate is 45.

In this example, because the interest rates are low and the period short, the difference is small. But suppose we consider a one-year deal, using the same spot, but setting the interest rates not at 4.25% and 5.75%, but at 5.75% and 60% (as might arise when looking at a deal against a high-inflation currency). Then the accurate margin would be 63 points, and the crude one would be 67 points.

To turn this into a formula, we write the interest rates as R_1, R_2 ; the spot as S ; the number of days as N ; the interest bases as B_1, B_2 ; the principal amounts as P_1, P_2 ; and the outright as O . We have $R_1 = 5.75; R_2 = 4.25; B_1 = 360; B_2 = 360; P_1 = 1,000,000; P_2 = 121,600,000 = P_1 \times S; S = 121.6$; and $N = 91$. Our dollar interest is $1,000,000 \times (5.75/100) \times (91/360)$, or $P_1 \times (R_1/100) \times (N/B_1)$. Our dollar total including principal is:

$$P_1[1 + (R_1 \times N)/(100 \times B_1)] = 1,000,000[1 + (5.75 \times 91)/(100 \times 360)]$$

Similarly, our yen total is:

$$P2[1 + (R2 \times N)/(100 \times B2)] = 121,600,000[1 + (4.25 \times 91)/(100 \times 360)]$$

Because our yen principal is 121,600,000, or $1,000,000 \times 121.6$, which is $(P2 = P1 \times S)$, we can write the second bracket as $(P1 \times S) [1 + R2 \times N/(100 \times B2)]$. To get the outright, we divide one into the other:

$$O = \frac{(P1 \times S)[1 + (R2 \times N)/(100 \times B2)]}{P1[1 + (R1 \times N)/(100 \times B1)]}$$

Canceling out $P1$, we have:

$$O = \frac{S[1 + (R2 \times N)/(100 \times B2)]}{[1 + (R1 \times N)/(100 \times B1)]}$$

To get the swap rate, we subtract the spot rate from both sides. To test the formula, we plug in our numbers:

$$\begin{aligned} O &= 121.6[1 + (4.25 \times 91)/(100 \times 360)]/[1 + (5.75 \times 91)/(100 \times 360)] \\ &= 121.6 \times 1.010743/1.0145347 \\ &= 121.1455 \end{aligned}$$

The formula just given is for normal (indirect) currencies. Once again, it has to be amended for reciprocal (direct) currencies. Suppose we have the same dollar rates as before, but we are looking at euro. We have $R2 = 2.75$; $B2 = 360$; $S = 1.0755$; and $P2 = P1/S = \text{EUR } 929,800.09$.

So our dollar interest is:

$$P1 \times (R1 \times N)/(100 \times B1) = 14,534.72$$

Our euro interest is:

$$P2 \times (R2 \times N)/(100 \times B2) = P1/S \times (R2 \times N)/(100 \times B2) = 6,463.40$$

Our euro total is: EUR 936,263.49

Because the exchange rate is quoted the other way up, we divide the dollar amount by the euro amount to get O :

$$O = \frac{P[1 + (R1 \times N)/(100 \times B1)]}{P1/S[1 + (R2 \times N)/(100 \times B2)]} = S \times \frac{[1 + (R1 \times N)/(100 \times B1)]}{[1 + (R2 \times N)/(100 \times B2)]}$$

$$= 1,014,534.72/936,263.49 = 1.0836$$

The calculations give a swap of 81 discount for dollars or 81 premium for EUR. The formula is identical, therefore, except that *R1* and *B1* change places with *R2* and *B2* (Figure 11.10).

This formula produces a swap rate that is consistent with the fully hedged arbitrage formula; that is, if we take a U.S. dollar borrowing rate of 5.75%, a euro spot of 1.0755, and swap of 81, we can produce euro on a fully hedged basis at 2.75% for 91 days. You may want to go through the formula by hand to convince yourself of this.

Normal Formula:

$$F = S\{[1 + (R2 \times N)/(100 \times B2)]/[1 + (R1 \times N)/(100 \times B1)] - 1\}$$

$$\text{Swap} = \text{Spot} \frac{\{[1 + (\text{Second currency rate} \times \text{Days})/(100 \times \text{Second interest basis})]\}}{\{[1 + (\text{First currency rate} \times \text{Days})/(100 \times \text{First interest basis})]\}} - 1$$

Reciprocal Formula:

$$F = S\{[1 + (R1 \times N)/(100 \times B1)]/[1 + (R2 \times N)/(100 \times B2)] - 1\}$$

$$\text{Swap} = \text{Spot} \frac{\{[1 + (\text{First currency rate} \times \text{Days})/(100 \times \text{First interest basis})]\}}{\{[1 + (\text{Second currency rate} \times \text{Days})/(100 \times \text{Second interest basis})]\}} - 1$$

where

- F* = swap rate
- S* = spot
- R1* = first currency interest rate
- R2* = second currency interest rate
- B1* = first currency interest basis
- B2* = second currency interest basis
- N* = number of days

Figure 11.10 Calculation of Swap from Interest Rates: Formula

MEDIUM-TERM CALCULATIONS

All our calculations so far have assumed that in each currency there is only one interest payment; that is, the forward foreign exchange transaction consisted of exchanging two zero-coupon cash flows. This is not the case if we are dealing for periods greater than one year. There are several ways to look at this problem. The cleanest is to convert both interest rates to zero-coupon rates and then apply the formulas we have already developed.

We saw in Chapter 7 how we work out the zero-coupon rate implied by a medium-term deposit. We took a one-to-five-year yield curve for Eurodollar deposits:

Year 1	8%
Year 2	9%
Year 3	10%
Year 4	11%
Year 5	12%

We started by finding the two-year zero-coupon rate implied by these rates. We started with a deposit of \$1,000 for two years at 9%. We took the present value today of the first interim interest payment of 9%, that is, \$90. That turned out to be \$83.33 when we discount it at the 8% rate applicable for the one-year period. We sold off our right to that interim coupon for \$83.33. That reduced our initial net cash investment from \$1,000 to \$916.67 today. In two years, we received \$1,090. The implied two-year zero-coupon rate was 9.045%.

We applied this technique step by step. The three-year deposit gave cash flows of \$100, \$100, and \$1,100. We sold off the first two cash flows for \$92.59 and \$84.10, respectively. That made a net investment of \$823.31, which returns \$1,100 in three years, for an implied zero-coupon rate of 10.14%.

At the end of this process, we had the following yield curves:

	Deposit Yield Curve	Zero-Coupon Yield Curve
Year 1	8	8.00
Year 2	9	9.05
Year 3	10	10.14
Year 4	11	11.30
Year 5	12	12.56

We can duplicate this process for our other currency, say yen. Suppose that here we have the following yield curve and the following associated zero-coupon curve:

	Deposit Yield Curve	Zero-Coupon Yield Curve
Year 1	9	9.00
Year 2	8	7.96
Year 3	7	6.91
Year 4	6	5.85
Year 5	5	4.80

Notice that for the first year the yen rate is above the U.S. dollar rate but that after the first year the pattern is reversed.

Our next step is to take the formula we worked out earlier for calculating the forward rate from interest rates (Figure 11.10) and apply it. However, we need to modify it for the multiyear calculation, as follows:

$$F = S \left[\frac{(1 + R_2)^n}{(1 + R_1)^n} - 1 \right]$$

Note that here we have removed the interest basis and the number of days from the earlier formula—the implicit assumption, therefore, is that the zero-coupon rates have been adjusted for any variation in the number of days in the year (i.e., leap years) and are both quoted on a consistent basis.

Suppose we run this formula now based on a spot of USD 1 = JPY 125. We will find, using the zero-coupon rates just calculated, the following forward rates:

Year	Swap (in yen)
1	1.16
2	-2.48
3	-10.69
4	-22.75
5	-37.52

So far, we have worked out a theoretically accurate way of working out what the rates should be. Often our problem is slightly different—we are confronted with a set of rates and want to know: Is it more attractive to deposit (or to borrow) five-year Swiss francs at 8% or five-year U.S. dollars at 13%? Is there any kind of arbitrage profit possible in the rates we are facing? The answers here are a little more complex than the theoretical calculations because of the fact that we may not actually be able to deal at the theoretical zero-coupon rates. We have to think about reinvestment risk.

We will begin by supposing that we have the choice of depositing for five years Swiss francs at 8% or U.S. dollars at 13%. Suppose that our principal amount is \$1 million and the spot rate is 1.8500. To begin with, we will make a simplifying assumption. We will assume that the Swiss franc interest receivable and the dollar interest receivable can both be reinvested on receipt at the going rate (that is, 8% or 13%). We also assume that we as investors are willing to leave these intermediate interest payments in their respective currencies; that is, we are not eager to cover the Swiss franc interest receipts back into dollars, or vice versa.

On this basis, we ask: What five-year swap rate equalizes these two deals? Our assumptions mean that we can treat this deal exactly like the one in the previous section; that is, we calculate cumulative interest plus principal in the two currencies and divide one into the other to get the break-even outright rate. (See Table 11.1.)

But all this only applies on our original assumptions. Let's relax our assumption about the reinvestment rate. We can no longer guarantee that the Swiss francs can be reinvested at 8% or the dollars at 13%. We see at once that we now have to make some assumptions about what reinvestment rates apply.

Table 11.1 Calculation of Medium-Term Swap from Deposit

	Interest	Cumulative principal + interest at year-end	Interest	Cumulative principal + interest at year-end
Year 1	131,805.56	1,131,805.56	150,055.56	2,000,055.56
Year 2	149,178.26	1,280,983.82	162,226.73	2,162,282.28
Year 3	168,840.78	1,449,824.60	175,385.12	2,337,667.40
Year 4	191,094.94	1,640,919.54	189,610.80	2,527,278.20
Year 5	216,282.31	1,857,201.85	204,990.34	2,732,268.55

Note: The implied outright forward rate is given by the ratio of principal and interest at the end of year 5; that is, $2,732,268.55/1,857,201.85 = \text{approx. } 1.4712$. Remembering that the spot rate was 1.8500, this gives us a five-year swap rate of 3788 (Swiss franc premium, dollar discount). In fact we could apply this method to each of the intervening years, too. This would give us an annual swap rate of 828, 1620, 2376, 3098, and 3788.

What difference does this make? For the sake of argument, suppose that all other rates are as in the previous example but that we expect dollar reinvestment rates will be higher. Say we expect 16%, 15.5%, 14.5%, 14%, and 13%, respectively. The Swiss franc rates are 8% flat all the way through. Then we find swap rates of 1291, 2421, 3345, 4153, and 4795, respectively. We no longer have the fairly smooth progression we had earlier. The early swaps are proportionately much larger than the later because the interest differential is higher.

This type of situation (or its converse) is much more common than our first assumption of unchanging rates. But if we relax that assumption, we find that the only way to solve our general problem is by trial and error (by iteration), unless we are given every single piece of information to begin with.

Let's look at a case where we are given all the information to begin with. We estimate that we can borrow five-year sterling at $14\frac{5}{8}\%$. We can lend year five dollars at $15\frac{3}{16}\%$. We have the following spot and forward rates:

	Spot Rate	Forward Rates
	\$1.7800/10	
Year 1		200/275
Year 2		300/400
Year 3		350/450
Year 4		400/500
Year 5		400/500

We start with a principal of GBP 10 million. With this we buy \$17.8 million. We know that our dollar interest receivable annually is \$2,740,921.88 and that our sterling interest payable is GBP 1,462,500. We know that our dollar interest, sold forward for sterling at the market's buying rate for dollars (that is, the righthand side of the swap), will yield:

Year 1 GBP	1,516,415.98
Year 2 GBP	1,506,001.03
Year 3 GBP	1,501,875.00
Year 4 GBP	1,497,771.52
Year 5 GBP	1,497,771.52

So our profit in sterling is:

Year 1 GBP	53,915.98
Year 2 GBP	43,501.03
Year 3 GBP	39,375.00
Year 4 GBP	35,271.52
Year 5 GBP	35,271.52

and our profit in dollar terms is:

Year 1	\$97,453.13
Year 2	\$79,171.87
Year 3	\$71,859.38
Year 4	\$64,546.88
Year 5	\$64,546.68

where the dollar equivalents are calculated at the relevant forward rates of 1.8075, 1.8200, 1.8250, 1.8300, and 1.8300. (We use the lefthand side of the spot because it is a swap deal rather than an outright.)

We assume (for simplicity) that these profits can also be lent out at the dollar lending rate of $15^{3/16}\%$, from the date that they accrue until the maturity of the deal. This produces cumulative earnings from each year as follows:

Year 1	\$171,560.45
Year 2	\$121,000.45
Year 3	\$95,344.17
Year 4	\$74,349.93
Year 5	\$64,546.87

The total over the five years is thus \$526,801.87. On the other hand, we know that to hedge our principal amount of GBP 10 million, we have to buy back GBP 10 million five years hence at a sterling premium (dollar discount) of 500 points, which will cost us \$500,000 at the far end. So the profit over the deal is $\$526,801.87 - 500,000 = \$26,801.87$. (Given the size of the principal amount and the fact that lines are being tied up for five years, it is not a particularly attractive deal.)

Now we can explore this deal's sensitivity to different assumptions. If we rework the figures on the assumption that accrued profits can be reinvested at only $14^{3/16}\%$ rather than at $15^{3/16}\%$, for example, the total profit falls from nearly \$27,000 to \$15,500. But a 1% change in the sterling interest rate is much more powerful. If the dollar rate (and reinvestment rate) are held unchanged at $15^{3/16}\%$, but the sterling rate is raised to $15^{5/8}\%$, the deal swings from a profit of nearly \$27,000 to a loss of over \$1.2 million. The reason is that this interest rate is acting on the whole principal, rather than on just the annual profits or losses as the reinvestment/refunding rate is. By the same token, a rise of 100 points in the first year's swap rate cuts the profit from nearly \$27,000 to about \$1,000, whereas the same change in year 4 cuts the profit much less, to \$10,000. This is because the dollar receivable is worth less in sterling terms in year 1, and that lower amount cumulates over time. The impact in year 4 is not cumulated over so long a time.

But the same rise of 100 points in year 5 makes a difference of \$100,000 because, again, it is applied to the whole principal, rather than just to the annual profits or losses, which are much smaller. Summing up, then, the reinvestment rate and the intervening year's swap rates are not particularly critical compared with the five-year interest rates and the five-year swap rate.

However, this does not mean they can be ignored. If the funding cost of the early losses in the deal were ignored, there would be an apparent profit of about \$122,000, which does not exist.

FORWARD-FORWARD SWAPS

A *forward-forward* is a swap deal between two forward dates. It might be done to take a view on the swap rates (further ahead than we did earlier) or to offset other flows. For instance, the treasurer of Zum Beispiel GmbH might have to pay EUR 5 million in six months, but she might also have a EUR 5 million receivable in one month. If she wants to lock in today’s swap rates, she would do a forward-forward deal.

Suppose we have: EUR/USD spot 1.1500 – 10, EUR one month 50/40, and EUR six months 280/260. The treasurer knows that she must sell dollars for euro in six months, for which she will benefit from a dollar premium (pay a euro discount) of 260 points. She knows also that she must sell euro for dollars in one month, for which she will pay a dollar premium (euro discount) of 50 points. The forward-forward rate is the difference between the two premiums, or 210 points. If the deals were done as outright, the one-month deal would be done at 1.1450, and the six-month deal would be done at 1.1250 for a net benefit (dollar premium, euro discount) of only 200 points. Doing the deals separately is more expensive because it adds the cost of dealing on both sides of the spot rate.

A common use of forward-forward rates is to take a view on interest-rate movements.

Suppose that we currently have the following EUR/USD rates in the market:

	Bid/Offer
Spot	1.0810/1.0820
Six months	40/30
Twelve months	30/20

This pattern happens when U.S. rates are slightly below euro rates for all periods, but rather less so at the far end. Suppose we think the market has got it wrong. We think that in the next six months, euro rates will fall but U.S. rates will not change very much. We think that in six months, the

six-month swap will be 100/200; that is, euro rates will be significantly below U.S. rates for the period. (Remember the rule of Chapter 4: When the interest differential goes against a currency, the swap goes in its favor.) So we decide to take a forward-forward position: “sixes against twelves.”

We think the euro will go from discount to premium in this period (dollars will go from premium to discount). So we want to be long of euro (short dollars) at the far end, vice versa at the near end. So we sell euro at the near end for a discount of 40 and buy it back at the far end at a discount of 20. The whole operation costs us 20 points.

Suppose we get it right. In six months, the swap has moved to 100/200. We have to buy euro at the near end and sell it at the far end. For this we get 100 points premium on our euro at the far end against the 20 points discount we paid, netting 120 points in total. Of course, 120 points is small compared with the probable movement in the spot, but as forward-forward dealers, we are much less exposed than if we took an outright position. The spot rate’s movements will only marginally affect our net exchange position, but there will be a cash flow difference—there will be a profit/loss to be invested/funded over the period until the position unwinds.

Let’s look at the arithmetic of the position. Suppose we do a trade for USD 5,000,000. We buy U.S.dollars/sell euro in the six-month maturity and sell U.S. dollars/buy euro in the twelve-month maturity, at the following rates for the following cash flows:

Sell forward EUR six months 4,642,525.53 against USD 5,000,000
 Buy forward EUR one year 4,633,920.30 against USD 5,000,000

Suppose that after six months we have the following rates:

Spot	1.0100/1.0110
Six months	100/200

We now close out the position for the following amounts: First we buy spot euro at 1.0110 in the amount of EUR 4,642,525.53 against USD 4,693,593.31; then we sell six months forward EUR 4,633,920.30 at 1.0210 (because we deal the swap off a spot of 1.0110) to receive USD 4,731,232.62. Bearing in mind that the original positions were dealt in an amount of USD 5,000,000 in each case, this leaves us with a net profit of USD 37,639.31.

Looking at that another way, we pay USD 4,693,593.31 today to close

out a position for which we received USD 5,000,000. Six months from now, at the far end of the deal, we will pay USD 5,000,000 and receive in exchange USD 4,731,232.62—in other words, our cash flow at the near end is positive and at the far end is negative.

What would have happened if instead the spot had moved in the opposite direction, so that we had:

Spot	1.2000/1.2010
Six months	100/200

In this case we would have the following transactions: First we buy spot euro at 1.2010 in the amount of EUR 4,642,525.53 against USD 5,575,673.17; then we sell six months forward EUR 4,633,920.30 at 1.2110 (because we deal the swap off a spot of 1.2010) to receive USD 5,611,677.48. Bearing in mind that the original positions were dealt in an amount of USD 5,000,000 in each case, this leaves us with a net profit of USD 36,004.31.

In terms of cash flow, we pay USD 5,575,673.17 today to close out a position for which we received USD 5,000,000. Six months from now, at the far end of the deal, we will pay USD 5,000,000 and receive in exchange USD 5,611,677.48. The profit is much the same—but this time, it accrues at the far end of the deal, rather than at the near end. The large move in the spot makes hardly any difference to the absolute profit of the deal. But it does make a difference when we take into account the interest cost of funding the loss that we now have at the near end of the deal when we close it out.

Forward-forward deals often crop up when a trader decides to cover a slightly different period from his natural interest. Let's look again at Zum Beispiel GmbH's treasurer, who has a South African rand receipt due in 13 months. She calls her bank late in the afternoon and is quoted: Spot 6.1410/20, 12 months 350/360, 13 months 450/460. The treasurer asks why the 13-month dollar premium/rand discount is proportionately so high and is told that the South African prime rates have just risen after the close of business in Johannesburg (which is an hour ahead of Frankfurt). Because the interest differentials have gone in the rand's favor, the forwards move to offset this by going further into discount. She is told that the forwards are expected to rise again tomorrow and that no one is eager to deal 13 months because it is an awkward period.

The treasurer decides to deal today but thinks it would not be worth paying

the 100 points extra for the 13th month. She thinks that if she waits a month the situation will have settled. So she deals for 12 months, which creates a forward-forward position: “twelves against thirteens.” She expects that if she waits a month, her position—which will then be “elevens against twelves”—can be closed out for about 20 points. If she is right, she has locked in her forward cover for the period at a total cost of 370 points instead of 450 because she avoided paying the extra cost of dealing into an awkward period.

SYNTHETIC AGREEMENTS FOR FORWARD EXCHANGE (SAFE)

A *synthetic agreement for forward exchange* (SAFE) is the foreign exchange equivalent of a Forward Rate Agreement (FRA—see Chapter 7): a contract for differences that acts as a substitute for a forward-forward foreign exchange deal. It originated in proprietary products developed by certain commercial banks and was developed into an instrument available to the London market as a whole under the aegis of the British Bankers’ Association.

SAFEs come in two types: (1) Exchange Rate Agreements (ERA) or (2) Forward Exchange Agreements (FXA). The difference is that whereas the FXA is an agreement regarding changes in both forward spreads and spot rates, the ERA covers the forward spread only. The general settlement formula for both types of SAFE is as follows:

$$[A2 \times \{(OER - SSR) + (CFS - SFS)\} / \{1 + (L \times D) / (100 \times B)\}] - \{[A1 \times (OER - SSR)]\}$$

- where
- A1 = first contract amount
 - A2 = second contract amount (for ERAs A1 = A2)
 - CFS = contract forward spread
 - SFS = BBA settlement forward spread
 - OER = outright exchange rate (set to zero for ERAs)
 - SSR = BBA settlement spot rate (set to zero for ERAs)
 - L = BBA interest settlement rate for the secondary currency (expressed as a number, not as a decimal)
 - D = number of calendar days in the swap period
 - B = 360 or 365

In this context, the *primary currency* is defined as that currency in which the contract amounts are expressed; the other currency is referred to as the *secondary currency*. The *first contract amount* is the amount of currency that would notionally be exchanged on the settlement date (which is actually the starting date for the SAFE, as with an FRA), and the *second contract amount* is the amount that would notionally have been exchanged on the maturity date. These two amounts can be different in the case of an FXA but not for an ERA.

In essence, the SAFE cuts down the settlement risk—and thus the credit exposure—on a forward-forward foreign exchange contract. Suppose today one-month against four-month forward-forward dollar/sterling swaps were trading at 55/51. Today is May 6, 2002, with spot May 10 and the one-month date June 10, the four-months date September 12.

Suppose I buy sterling forward-forward at 51 (that is, I contract to sell it on June 10 and buy it back on September 12). Suppose on June 10 when the deal then comes to settle, the forward margin for that period is 60. Then I can close out at a profit of 9 points. But that profit would in theory only be due in September. To cut down the settlement risk, we can settle the difference today, just like we did in the FRA in Chapter 7. As with the FRA, we will use the relevant BBA interest-settlement rate to discount the sums involved.

So far we have ignored any movements in the spot rate during the life of the deal. Suppose now we allow for this; say the spot rate in May is \$1.6600, and it has moved to \$1.7000 when the deal comes to settle. Suppose I deal a SAFE of GBP 10 million. Then, bearing in mind there will be 93 days from June 10 to September 12 and assuming a BBA interest-settlement rate of 7.5%, the settlement amount would be:

$$\left[(1.7000 - 1.6600 + \frac{(1.6600 - 0.0051) - (1.7000 - 0.0060)}{1 + \frac{93 \times 7.5}{36,000}}) \right] \times 10,000,000 = \$16,431.64$$

This SAFE exactly corresponds to a matched pair of swaps. Under the first, forward-forward swap done on May 6, I buy GBP 10 million at \$1.6600 value June 10 and sell GBP 10 million at \$1.6549 value September 12. This is closed off with a second swap on June 8 where I sell GBP 10 million

at \$1.7000 value June 10 and buy back GBP 10 million at \$1.6940 value September 12. The key difference is that under the SAFE, I am not contractually obliged to make or to take payments in the amount of GBP 10 million: I am only obliged to settle the difference amount, which as we see is a very small sum compared with the principal amounts. Thus, like a forward rate agreement and an interest-rate swap, and for the same reasons (it is driven by interest differentials), the SAFE incurs a credit exposure that is only a fraction of the amount of the notional underlying principal.

EXTENDING MATURING CONTRACTS

A further common use of a swap occurs when a forward sale of, for example, Japanese yen has been made to cover an export receivable; but as maturity approaches, it is found that the funds will not be received in time. A swap has to be done to adjust the maturity date.

At this point, we must allow for accumulated profit or loss. Suppose we use the original contract's spot rate as the "spot" rate on which the new swap is based. For example, suppose the corporation originally sold the bank yen two months forward against U.S. dollars; suppose the deal was done off a spot rate of 121.75 and a yen premium/dollar discount of 200, making an outright of 119.75. Assume that we now have to extend for a further two months owing to payment delays and that the two-month yen premium is now 220. If we use the original outright rate of 119.75 as the "spot" for our new extension, the new outright rate will be 117.55. But suppose in the meantime that the yen has strengthened to 115. The firm has made a loss—or less profit than it might have—by selling forward when it did.

Hence, if the bank lets the old deal mature and does a new deal based on today's rates, the customer will be delivering yen sold to the bank at 119.75 but will have to buy them from the bank in order to deliver them, and must pay 115 for them. Then the customer will sell them back to the bank at $115 - 2.20$, or 112.80. The steps are set out in Figure 11.11. Suppose the original sale had been JPY 500 million. At the original rate, this would have produced USD 4,175,365.34. But to buy in JPY 500 million for the extension at 115 will cost the customer USD 4,347,826.09—crystallizing a loss of USD 172,460.74. The yen are now sold forward at the current outright rate of 112.80, yielding USD 4,432,624.11 at the new maturity. If at this postponed maturity date it were necessary again to extend the deal and if

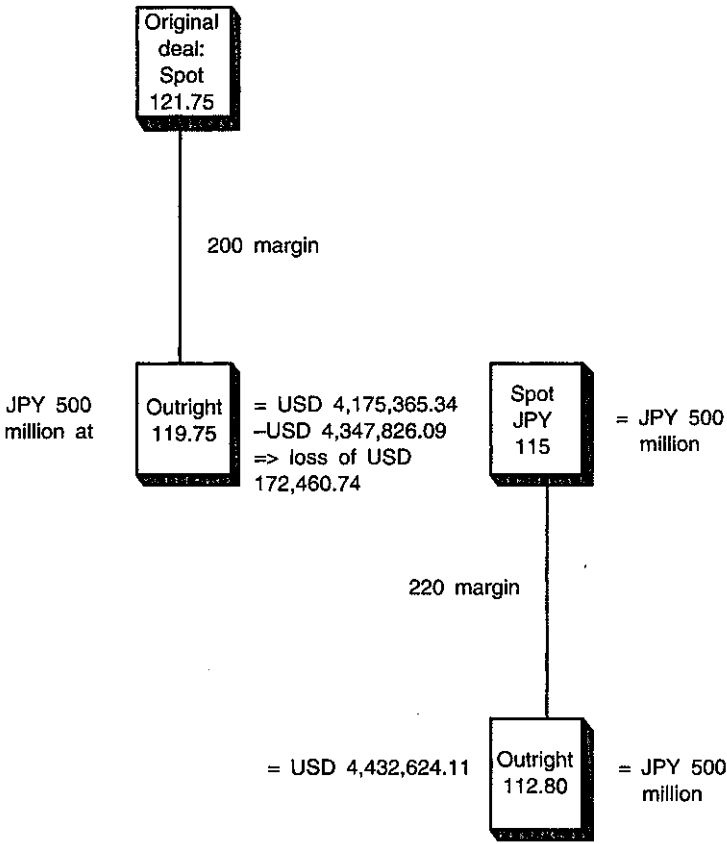


Figure 11.11 Extension of a Contract at Current Rate

the spot had moved back to 121, the extension would now crystallize a profit; and so on.

On the other hand, if the deal were extended at the original rate, the extension would not throw up any cash difference. (See Figure 11.12.) But there would be a hidden loss that could continue to accumulate indefinitely. This is an inherently undesirable possibility for both sides—the bank is providing an unsecured loan, and the corporation’s books are not reflecting its true position. Hence it is generally recommended that all extensions of forwards be made at current market rates. The drawback for a firm whose business requires many changes in delivery dates—such as a commodity

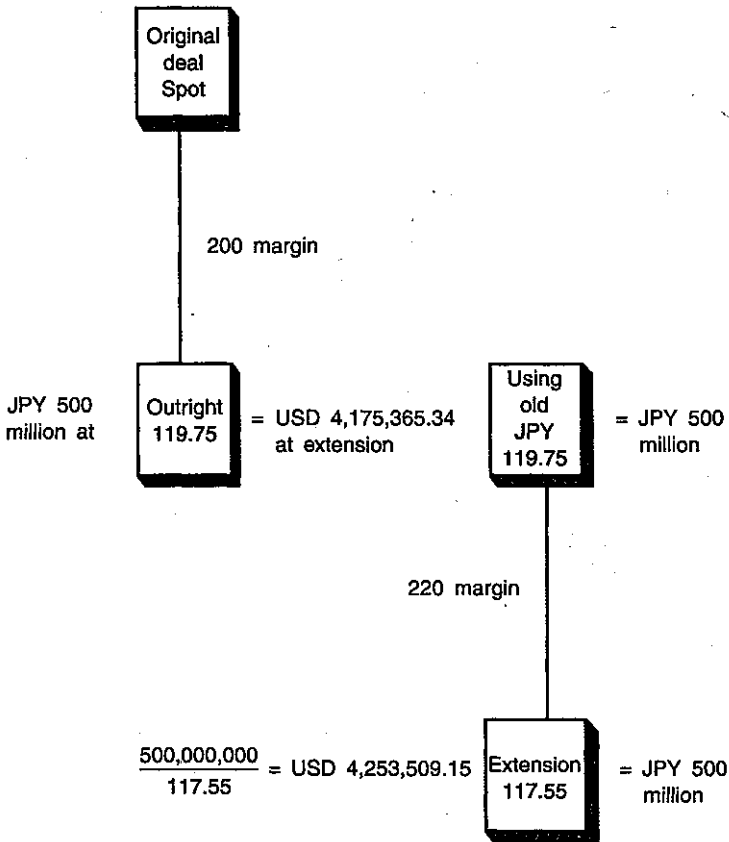


Figure 11.12 Extension of a Contract at the Original Price

trader—is that this method continually throws up a string of small profits or losses that have to be taken into or out of the normal cash flow of the business. So the choice of the correct rate on which to base the extensions depends on a balance of considerations. Proper credit control means they should be made at current market rates; cash flow simplicity requires that they be carried out at the original rates.

If a forward contract is extended at the historic rate, then the bank should adjust for the fact that it is lending the customer his loss (or taking his profit) as a deposit. This has to be worked back into the swap rate. We look at how this is done next.

EXTENSIONS AT HISTORIC RATES

Using current rates, the calculation of how to extend a maturing contract is straightforward; we saw it in the previous section—JPY 500 million sold forward at an outright rate of 119.75 was extended at the new forward rate of 112.80. The old forward was closed out by a spot purchase of JPY 500 million at 115. This threw up a loss of USD 172,460.74.

But suppose for some reason the contract is extended off the historic rate. (It should be stressed again that the authorities generally discourage the practice of extensions at historic rates. Speculative operators have in the past used the technique to conceal bad positions; there is a serious danger of loss of control. However, as discussed in the previous section, there can sometimes be valid operational reasons for permitting the practice, providing it is properly controlled.) In this case, the customer buys JPY 500 million to close out the old contract as before but does it at 119.75 so his or her cash loss does not show up. It only shows up in a smaller dollar inflow at the maturity of the new contract. The bank has lent the customer the loss until the new maturity. How do we adjust for this?

We start by realizing that this is a special case of the formula on page 187; that is, we have to get a swap adjustment from the interest the bank will charge its customer for lending him or her the loss (or taking the profit on deposit). It is a special case of the formula for swap rates from interest rates: one of the interest rates is zero. There is a loan of U.S. dollars to the customer but no yen deposit by the customer. So we take the formula

$$F = S \left[\frac{1 + \frac{(R2 \times N)}{(B2 \times 100)}}{1 + \frac{(R1 \times N)}{(B1 \times 100)}} - 1 \right]$$

We see that the denominator is 1 because $R1 = 0$. So now we have:

$$F = S \left(\frac{R2 \times N}{B \times 100} \right)$$

where F = adjustment needed; S = current spot rate; $R2$ = dollar interest rate; N = days in new contract; and $B = 360$.

Using the rates we had earlier, and assuming the dollar rate is 5%, we can write:

$$F = 115 \left(\frac{5 \times 60}{360 \times 100} \right) = 0.96 = 96 \text{ points}$$

This would be the adjustment if the bank lent the whole of the principal amount to the customer. But of course it is only lending the loss, so the adjustment has to be weighted accordingly. To find the dollar amount of the loss, we take the difference between the new rate (115) and the old (119.75) as a percentage of the new rate and apply this to the dollar amount of the old forward contract (being the dollar equivalent at maturity of the old forward). In our example:

$$\frac{115 - 119.75}{115} \times 4,175,365.34 = 172,460.74$$

To generalize this into a formula, we say that the dollar amount at the maturity of the original contract was \$1. Then the dollar loss is given by:

$$\frac{\$1 \times (115 - 119.75)}{115} = \frac{\text{New rate} - \text{Old rate}}{\text{New rate}}$$

If we designate the new spot rate as S_n and the old rate as S_o , we can write this as

$$\frac{S_n - S_o}{S_n}$$

and the whole formula is:

$$F = \frac{(S_n - S_o)}{S_n} - S_n \left(\frac{R \times N}{B \times 100} \right) = \frac{(S_n - S_o) \times (R \times N)}{B \times 100}$$

where F = adjustment to forward; S_o = old contract rate; S_n = new contract rate; R = interest rate on currency being received by customer at maturity (here, dollars); B = interest basis for interest rate; and N = number of days in new contract.

When we use the numbers from our example, we have:

$$F = \frac{(115 - 119.75) \times 5 \times 60}{360 \times 100} = -.03958 = 4 \text{ points against customer}$$

So instead of showing 220 points in the customer's favor in the new forward, the bank will show only 216. If the rates had moved in the customer's favor, F would be positive and the swap would be adjusted in the customer's favor.

BROKEN DATES

A forward (or a deposit) transaction that is not for certain standard dates—normally one, two, three, six, or twelve months, and in some cases one, two, three, four, five, six, seven, eight, nine, ten, eleven, or twelve months—is referred to as a “broken” or “odd” date. We calculate the outright forward price for such a date by using the swap rates. Suppose that we are buying yen against euro, the spot rate is JPY 115.50, and the two-month premium is 300, while the three-month premium is 450. Suppose that we are dealing on April 3 (spot 5th) for June 15 for a date that is 2 months and 10 days ahead. A convenient method of calculation is as follows:

The third month—between June 5 and July 5—has 30 days in it; so we take $^{10}/_{30}$, or $^{1}/_{3}$, of the third month's premium (which is 450 – 300, or 150 points), totaling 50 points. This is added to the two-month premium of 300, to produce a total of 350; so our outright rate for June 15 would be 115.50 – 3.50, or 112.00.

This “pro rata” method of calculation is acceptable for normal maturities where no special factors (for example, days of peak interest rates) are involved (see Chapter 13, Adjustments). The pro rata method is not always acceptable for shorter maturities, however. These are discussed in Chapter 12.

12 Short Dates

In this chapter, we look at the special features of deals done for value before spot. In particular we explain why the swap rate is reversed for outright deals before spot.

A *short date forward*, or deposit, rate is normally defined as one that is for a maturity shorter than one month. A stricter definition would be for one week; and an even stricter definition would include only rates before spot. However, the normal use is for rates up to one month.

We saw (Chapter 9) that under normal circumstances the spot date for exchange and deposit deals is two working days forward. This allows some dealing for value before spot, that is, value today or value tomorrow. These deals are normally tightly constrained by time factors. Deals done value today are only really possible for currencies whose time zone is substantially behind that in which the deal is being struck. For example, it is possible to deal dollar/sterling in London for value today, because the five- or six-hour delay between London and New York gives time to get the instructions processed in New York. But dollar/yen in New York cannot really be dealt value today because there will be no chance to get the deal processed in Tokyo, which has closed by the time New York opens for business.

Subject to these constraints, therefore, it is possible to deal for value before spot only for certain currencies in certain countries. Given that normally there are two days between today and spot, this gives us two margins: that from today until tomorrow (overnight, or O/N) and that from tomorrow until the next business day (tomorrow/next, tom/next, or T/N). These margins parallel the deposit rates for the same period.

The tom/next swap is the rate at which a currency can be bought or sold

against the next business day, which is also the spot date. If a deal were maturing value tomorrow and if it had to be rolled over to the next day, the tom/next adjustment would be used to calculate the new rate. The tom/next market is, as is the deposit market, a bit less affected by time-zone constraints than the overnight market. But it still tends to dry up during the course of the morning. Its importance lies in the fact that it is used to roll over a spot position (hence in the United States it is often referred to as the rollover) because it is the last business day before spot.

USING SHORT DATE SWAPS

Short date swaps work just like any other swaps. The only difference comes when we use them to calculate outright rates before spot. Suppose we have a dollar/yen (USD/JPY) spot rate of JPY 119.60/65. Suppose we have a swap rate from Wednesday to Thursday of 11/5. Suppose that spot is Wednesday and that we want Thursday's rate. This is a perfectly normal forward, so we have spot JPY 119.60/65 and forward 11/5, making Thursday's rate JPY 119.49/60 (remembering high/low = subtract). Notice that the spread has gone up from 5 points to 11 points. The spread on the outright equals the spread on the spot plus the spread on the forward.

But suppose now that our spot rate of JPY 119.60/65 is actually for Thursday. We want Wednesday's rate—a rate before spot. Our forward margins have to be worked backward in time to a date before spot. To go from Wednesday to Thursday, we subtracted 11/5. So to come back from Thursday to Wednesday, we think we should add 11/5. What happens? We get JPY 119.71/70. Our spread has gone negative; our selling rate is higher than our buying. Something is wrong.

Let's look at this another way. We know that the forward margin of 5 points from Wednesday to Thursday is the bank's—and the market's—rate for buying yen and selling U.S. dollars. Suppose on Wednesday we want to buy yen for value Wednesday and to sell them for value Thursday. We have to sell yen to the market at the market's *buying* rate for yen, that is, 5 points. Because the yen is at a premium and, the dollar at a discount, we will earn 5 points. If we deal the opposite way around—sell yen for value Wednesday and buy yen for value Thursday—it will cost us 11 points.

Now let's look again at our spot for Thursday, which is JPY 119.60/65. The market sells yen value Thursday at 119.60. At what rate will a bank

sell value Wednesday? It has to cover its Wednesday position by buying yen for value Wednesday (so that it can sell them to its customer). As always in a forward, it will deal value spot and then swap to its desired date—in this case Wednesday. It buys yen value Thursday at 119.60 from the market. Then in the swap market it buys yen for value Wednesday, selling them off again on Thursday to square up its spot position. But we saw just now that it earns 5 points by doing this. So it can sell yen value Wednesday at 5 points better than value Thursday; that is, 119.65. Conversely, we saw that if it dealt the opposite way around, that is, bought yen value Wednesday, it would cost the bank 11 points to do the swap. So it has to add this to Thursday's buying rate of 119.65, making 119.76 its buying rate for Wednesday.

In other words, when dealing outright before spot, the margin must be turned around. To go from Thursday's JPY 119.60/65 to Wednesday, we don't add 11/5—we add 5/11, to get Wednesday's JPY 119.65/76. If you stop to think about it, it does make sense because this is a “backward” margin, not a “forward.” We are going backward in time from the spot rate. The rule is: *Overnight and tom/next go backward, not forward, so you must turn them around to get the outright.* But once again, this applies only to outrights. It is only then that you work backward from spot. If you are swapping from tomorrow to the next day, you are going forward, so you don't turn the rates around. It's only when you want to use the tom/next to bring a rate back from spot to tomorrow that you turn it around—not when you are doing a swap from tomorrow to spot. The latter case is a perfectly ordinary forward.

Let's now look at a short date cross-rate. Suppose we need a EUR/JPY tom/next margin. We have the following rates:

	EUR/USD	USD/JPY
Spot		
Sell	1.0650	125.55
Buy	1.0655	125.60
Tom/next		
Sell	3	5
Buy	2	4

We begin by calculating the relevant spot cross-rates: Sell 133.71; Buy 133.83.

208 Short Dates

We reverse the two margins and apply them to the spot rates to get outright value tomorrow:

	EUR/USD	USD/JPY
Spot		
Sell	1.0650	125.55
Buy	1.0655	125.60
Tom/next		
Sell	3	5
Buy	2	4
	EUR/USD	USD/JPY
Sell	1.0652	125.59
Buy	1.0658	125.65

From this we can find the outright value tomorrow cross:

	EUR/USD	USD/JPY
Sell	133.77	
Buy	133.92	

This gives a margin from tomorrow to spot (that is, tom/next) of 6/9, which must be reversed again for quotation purposes to 9/6. Inspection confirms that this is correct because 9/6 shows that the JPY spot is at a premium over tomorrow. This is true because the selling rate value tomorrow at 133.77 is higher than the spot of 133.71, and similarly on the buying side. In fact, the mechanics of the calculation are exactly the same as those for any other cross-forward calculation. The only difference is the need to reverse the margins before starting the calculation and then to reverse them back again after completion.

OTHER SHORT DATES

Another short date rate that is commonly quoted is the *spot/next rate*, which is used for swapping from spot value to the next business day. It is often

needed in working out cross-rate adjustments (see Chapter 13). Like other short date rates for value after spot, there is no question of turning the spot/next margin around in calculations. It is an ordinary forward.

Other short dates often quoted include one-week, two-week, and, less frequently, three-week swap rates. (For all short dates after spot, there is no question of reversing the swap.) For rates between these dates, one tends to calculate a rate on a pro rata basis. We take the rates for the standard periods before and after the date in question and work out the daily average margin between these two dates. But short date rates are very heavily affected by special factors, most notably month-end dates, reserve-asset "makeup dates," tax-payment dates, or other days when reporting requirements or liquidity factors have a distorting impact. The rate has to be worked out exactly from interest rates (see Chapter 11). For example, because the end-of-year U.S. dollar deposit market is not uncommonly bid up to relatively high rates for a day or two, it would be wrong to work out a swap rate on a pro rata basis if it included the year-end (see Chapters 11 and 13).

SWAPPING OUT A POSITION IN THE SHORT DATES

The short date market is widely used for swapping out a position. Let's look at an example. We believe that the euro will be weaker in three months than it is today. We could sell outright forward euro in the three months' date. But we feel this is too risky. Accordingly, we do a swap; we buy spot euro (say EUR 1 million) and simultaneously sell the same amount forward in the three-month period. We are now overbought for value spot and oversold for value three months hence. Unless further action is taken, the EUR 1 million that are due to arrive on our account two days hence, on spot date, will remain there, earning no interest, until the forward sale matures, when the EUR 1 million will be paid away to our counterparty.

Hence we have two alternative courses of action: Either we can lend the money out from the spot date to the three-month date, or we can ensure that the money does not arrive on our account on the spot date by selling it off in the short date market. In other words, we buy and sell in the tom/next market (hence the tom/next is often called the rollover in the United States). The sequence of actions looks like this:

	Sell	Buy
Tomorrow	EUR 1 million	
Spot	EUR 1 million	EUR 1 million
Three months	EUR 1 million	

This operation amounts to lending the euro out day to day through the swap. We are undertaking a long-term forward liability and covering it on a day-to-day basis in the tom/next market. By contrast, an outright forward sale in the three-month period would be completely uncovered. We have now shifted our position nearer in time so that it is less risky. If we want to go oversold on an outright basis, we can now sell off our EUR 1 million that are due to arrive on the account tomorrow, knowing that funds will come into the account from our tom/next swap, which itself has squared off our three-month swap. The risk is much closer and more easily controllable. On the other hand, swapping a position out from day to day means writing a lot of tickets if we run the position for a while, so there is an extra cost. The compounding factor also has to be considered. In this case, it would work in our favor; but if we were selling a discount currency, it would work against us.

We can similarly use the spot/next to swap out a position. Figure 12.1 shows how if we are short EUR 5 million for value spot, we can use the spot/next swap to buy spot and to sell the next day. Our spot position is now square, and the position has been rolled forward to the next day—off the balance sheet.

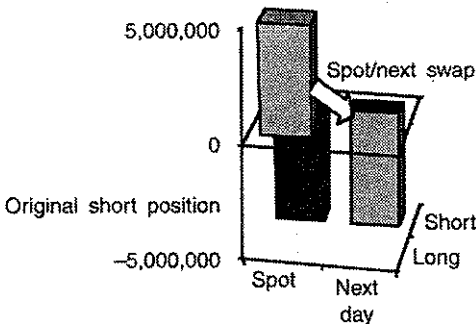


Figure 12.1 Swapping Out a Position Using Spot/Next Rollover

13 Adjustments

In this chapter, we explain how to adjust forward quotes for a nonstandard date. Then we show how to adjust cross prices for the effects of a holiday in one country. Next we show how to allow for payment today and how to adjust a deposit quote for withholding tax and reserve requirements. Finally, we show how to price the negotiation of a check.

NONSTANDARD RUNS

A helpful way of approaching this topic is to break the swap margin down into individual days. Suppose today is April 8, spot 10, and we are looking at a one-month U.S. dollar/yen (USD/JPY) swap from April 10 to May 10—a 30-day period. Suppose the swap is 105/90. Then we can say, crudely, that “the days are running at $3\frac{1}{2}/3$ ”—the daily average margin is the total margin in the period divided by the number of days. In order to get a swap from April 10 to May 9—a run of 29 days—we would reduce the swap by $3\frac{1}{2}/3$, making it $101\frac{1}{2}/87$.

Equally, we might want to adjust this run by bringing its start date forward a day as well, to April 9. Suppose that the tom/next (see Chapter 12) is also running at $3\frac{1}{2}/3$; then we would add this on to the margin to bring it back to 105/90. On the other hand, if the short date market were very tight, for instance, by reason of the U.S. Federal funds rate being very high, the tom/next rate might be 10/7, in which case we would adjust the run of April 10/May 9 at $101\frac{1}{2}/87$ by adding on 10/7 to make the run April 9/May 9 a total of $111\frac{1}{2}/94$.

This case shows that the forward margin need not be the total of a uniform daily average rate of $3\frac{1}{2}/3$ as we started by assuming. It might be that our original one-month swap of 105/90 concealed the fact that each week the Wednesday/Thursday swap premium was typically lower than other days. Suppose there were a weekly reporting procedure in Euroland that induced banks to bid for euro value Wednesday to sell back Thursday. (This doesn't happen, but parallel examples do occur. And the classic example of this used to be Thursday/Friday dollars because of the New York Clearing House funds system.) Then our weekly swap might look like this:

Monday/Tuesday	$3\frac{1}{2}/2$
Tuesday/Wednesday	$3\frac{1}{2}/2$
Wednesday/Thursday	5/6
Thursday/Friday	$3\frac{1}{2}/2$
Friday/Monday	$9\frac{1}{2}/7$

(that is, three "normal" days: Friday/Saturday, Saturday/Sunday, Sunday/Monday)

The way to adjust a standard forward run to a nonstandard one is to find the number of days' adjustment required at the start and the end of the standard run, then find the daily swap rate for those days (making allowance for special factors). Finally, add or subtract those individual margins from the standard rate.

NONSTANDARD FORWARD RUNS—EXAMPLES

The following example is essentially a forward-forward transaction (see Chapter 11), and applies in a sense to any calculation in which we seek forward margins over a date different from spot.

A customer has a forward contract maturing with a bank for value the day after spot and wants to extend it, say for a month. Suppose that last month, he sold the bank Norwegian krone (NOK) for July 18; today is July 15, spot the 17th. He wants to extend to August 17 (today's one-month date). We have the following rates:

USD/NOK	7.3220/30	(Value July 17)
Spot/next	5/3	(July 17/18)
One-month	85/75	(July 17/August 17)

Assuming that we are renewing the contract at current market rates (see Chapter 11), the bank sells the krone back to the customer at 7.3215 (7.3220 - 0.0005) for value July 18. The bank now needs to know the swap from July 18 to August 17. To do this, it deducts the spot/next (July 17/18) from the one-month (July 17/August 17) to give a margin of 80/72. So the bank pays the customer a further premium of 72 points for the swap from July 18 to August 17.

Let's look now at the case in which a customer has sold Swiss francs forward to her bank for value March 31 at 1.5120. Today is March 11, spot is March 13. Her accounts people say that the Swiss francs will not be paid to her until April 17. Because she prefers always to hedge her Swiss franc receivables immediately, she wants to change the maturity date of the existing contract at once. She therefore asks the bank to quote her a rate to adjust the maturity from March 31 to April 17.

Suppose the rates are as follows:

Spot	1.5230/40	(March 13)
One month	110/100	(April 13)
Two months	200/180	(May 13)

We find the swap from March 13 to March 31 on a pro rata basis (18 days out of 31) as 64/58; and we work out the swap from March 13 to April 17 as 122/110. We do this interpolating between the one- and two-month swap margins on a pro rata basis to get 12/10 as the swap from April 13 to April 17 (4/30 of 200 - 110 and 180 - 100) and adding the result to the one-month margin (see Chapter 11). So the swap margin from March 31 to April 17 is 58/52 (that is, 122/110 minus 64/58). As the bank has already bought these Swiss francs from the customer, it will make a new swap over March 31 (the choice of spot rate on which the contract is to be based being determined according to Chapter 11); it will sell back value March 31 and buy forward value April 17, paying a further premium of 52 points to the customer.

A very common case is one in which we want a set of standard periods over spot and over tomorrow. We have the following rates for the euro:

EUR/USD	1.0510/20 spot	(September 23)
	5/par tom/next	(September 22/23)
	130/120 one month	(September 23–October 23)

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5/2	(October 22/23)
270/250 two months	(September 23–November 23)
6/3	(November 22/23)

We need to find one and two months over tomorrow. Our quote for value tomorrow is 1.0510/25 (remembering that we reverse the tom/next). Our one-month quotation is 130/120 minus the adjustment at the far end of 5/2, plus the adjustment at the near end of 5/par, making 130/118. Our two-month quotation is 270/250 minus the far-end adjustment of 6/3, plus the near end 5/par, making 269/247. So we have:

EUR/USD value	September 22	1.0510/25
One month	Sep. 22–Oct. 22	130/118
Two months	Sep. 22–Nov. 22	269/247

HOLIDAYS

These principles have to be used when the effect of holidays has to be taken into account in cross-rates. Suppose we are looking at a Singapore dollar/yen (SGD/JPY) cross-rate calculation. Today is April 6, and the USD/SGD rate is being quoted spot April 8. But the US\$/JPY rate is being quoted spot the 9th because the 8th is a holiday in Japan. We see from the rules of Chapter 9, that the SGD/JPY spot date will be the 9th. So we must adjust the USD/SGD rate in order to make it appropriate for the 9th, before working out the cross-rate. We therefore have to find the rate for the USD/SGD swap for the 8th against the 9th—which is, of course, the spot/next swap rate—and apply it to the SGD spot. Suppose we have the following rates:

USD/JPY	Spot (8th)	131.25/131.30
	Spot/next (8th/9th)	15/10
USD/SGD	Spot (9th)	1.8770/1.8780

We calculate the outright for USD/JPY value the 9th as 131.10/131.20 [i.e., $(131.25 - 0.15)/(131.30 - 0.10)$]. We then find the cross-rate for value April 9 by dividing 131.10 by 1.8780 to get a selling rate for SGD/JPY of 69.81. Similarly, we have 131.20 divided by 1.8770 for a buying rate of 69.90 JPY per SGD, value April 9.

If in the preceding case it had been Singapore that had been on holiday on the 8th, the USD/SGD rate would have required adjustment. The rule, therefore, is: *Adjust the currency of the country that is not on holiday until you get to the first date when both countries are working.*

A parallel procedure has to be applied in the case of forward margins. Suppose we are again considering Singapore dollars and yen, and this time today is May 7, spot May 9 for both currencies. We are considering a one-month deal, which would normally be June 9, but for the fact that Japan is on holiday that day. We therefore have:

USD/JPY	131.25/131.30	(May 9)
	120/100	(May 9–June 10)
USD/SGD	1.8770/1.8780	(value May 9)
	300/290	(May 9–June 9)
	10/9	(June 9/June 10)

We adjust the Singapore dollars forward by adding on 10/9 to give us 310/299 for the period May 9 to June 10, giving us a cross of 69.89/69.95 and forward margins of 48/63.

The following situation would require some care. We are dealing euro/yen, and today is February 25:

EUR/USD	1.0750/1.0755	(February 28)
	30/40	(February 28–March 31)
USD/JPY	121.5/121.55	(February 27)
	100/90	(February 27–March 27)

The euro area is on holiday February 27, and Japan is on holiday March 31. Notice that the euro spot is dealing for the end of the month, and so the forward rate is also (see Chapter 10). However, the Japanese forward is not; and because Japan is on holiday on March 31, the cross forward should theoretically be rolled into April—but this would contradict the over-month-end rule of Chapter 10. So the cross forward must be dealt for value March 30, which means the euro/dollar forward must be brought back to March 30 by adjusting for the rate from March 30 and 31. And the yen must be rolled forward from March 27 by adjusting the rate for March 27 to March 30. Also, we must adjust the spot yen to February 28. Thus, we have:

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EUR/USD	1.0750/1.0755	(February 28)
	30/40	(February 28–March 31)
	2/3	(March 30–31)
USD/JPY	121.50/121.55	(February 27)
	10/5	(February 27–28)
	100/90	(February 27–March 27)
	5/4	(March 27–30)

We proceed first to sort out the spot calculation for February 28. This is a matter of adjusting the yen rate to 121.40/121.50 for value February 28. Next we find forward margins for the two currencies for the period February 28 to March 30. We start by adjusting the euro rate to end on March 30 by removing the rate for March 30 to March 31; thus the euro forward margin becomes 28/37 for the period February 28 to March 30. Turning now to the yen, we need a forward for the period February 28 to March 30. Notice that the original margin was February 27 to March 27. We start, therefore, by adjusting this to run over February 28 by removing the rate for February 27 and 28, that is, 10/5. This gives us a rate of 90/85 for February 28 to March 27. We must then add in the rate at the far end to extend the margin from March 27 to March 30; adding in the 5/4 quoted for that period gives us a forward rate of 95/89 for the period of February 28 to March 30. So we now have:

EUR/USD	1.0750/1.0755	(February 28)
	28/37	(February 28–March 30)
USD/JPY	121.40/121.50	(February 28)
	95/89	(February 28–March 30)

Bearing in mind that the euro is quoted indirect so that we multiply (see Chapter 9), we have:

EUR/JPY	130.50/130.68	(February 28)
	68/51	(February 28–March 30)

Fortunately, we don't often have to deal with such complex cases. The complexity, though, arises simply from the number of adjustments required—and, in the instance given, the need to be on the alert for the value-date rules—rather than any intrinsic difficulty in the calculation.

The formula required may be set out as follows:

$$M = [(S1 - A) \times (S2 - B)] - [((S1 - A) - (F1 - A + C)) \times ((S2 - B) - (F2 - B + D))]$$

- where *M* = cross margin required to be calculated
 - S1* = spot rate for first currency, unadjusted
 - S2* = spot rate for second currency, unadjusted
 - F1* = forward rate for first currency, unadjusted
 - F2* = forward rate for second currency, unadjusted
 - A* = spot adjustment for first currency
 - B* = spot adjustment for second currency
 - C* = forward adjustment for first currency
 - D* = forward adjustment for second currency
-] any or all of which may be zero

In words, we have:

$$\text{Margin} = [(\text{Adjusted spot for first} \times \text{Adjusted second spot}) - (\text{Adjusted first spot} - \text{Adjusted first margin})] \times (\text{Adjusted second spot} - \text{Adjusted second margin})$$

This formula is set out in full to match the steps just taken. (For two direct currencies, we would divide rather than multiply.) However, there is a shortcut possible on the right-hand side.

Where we are calculating the cross outright forward, the spot adjustments are made both to the spot rate and to the forward rate. So they cancel each other out. This is equivalent to saying that we could have proceeded as follows: Calculate adjusted spot cross euro/yen as before; adjust euro forward as before; take unadjusted spot yen, and apply to it the forward margin adjusted only for the period March 27 to 30; that is, instead of applying a margin of 95/89 to 211.40/55, we apply 105/94 to 211.50/60. The end result is the same, and this shortcut method is perfectly acceptable, providing we understand why it is correct: The spot adjustment “washes out” because it is applied both to the spot and, in the opposite direction, to the forward. Hence the shortcut formula is:

$$M = [(S1 - A) \times (S2 - B)] - [(S1 - F1 - C) \times (S2 - F2 - D)]$$

and in words:

$$\text{Margin} = [(\text{Adjusted first spot} \times \text{Adjusted second spot}) - (\text{Unadjusted first outright} - \text{First forward adjustment})] \times (\text{Unadjusted second outright} - \text{Second forward adjustment})$$

PAYMENT TODAY

Depending on time zone, it is sometimes possible to deal for value today, with good value being given on both sides of the deal today. For instance, if at 11:00 A.M. London time, a company sells to a bank in London U.S. dollars against payment of sterling, it is possible for both these payments to be made for value that day, because the London clearing does not close until 2:30 P.M. and there is a five-hour delay permitting the payment of U.S. dollars on the same day. However, if the same company sold yen to the bank, good value in yen could not be given for value that day because by that time the Japanese clearing system would be closed. The bank would be able to pay its customer sterling, but it would not receive the yen until the next day.

The practice in these circumstances would be for the bank to allow for the fact that it is "out of funds" overnight, until the yen arrive on its account in Tokyo. Because it is left short of sterling, the bank will charge its sterling lending rate; the lending rate will be worked back into its sterling/yen rate to reflect its costs. This is a special case of the formula we worked out in Chapter 11 for working out swaps from two deposit rates. In this case, the yen rate overnight is zero because the bank does not have the use of the money. So our original formula:

$$F = S \times \left[\frac{1 + \frac{R2 \times N}{B2 \times 100} - 1}{1 + \frac{R1 \times N}{B1 \times 100}} \right]$$

simplifies to:

$$F = S \times \left[\frac{R2 \times N}{B2 \times 100} \right]$$

because the bottom line simplifies to 1 because $R_1 = 0$. The rate to which the “forward” adjustment F is being applied is not the spot rate S , but the rate for tomorrow, call it T . So we can write:

$$\text{Adjustment} = T \times \frac{N}{365} \times \frac{R}{100}$$

where T = rate for value tomorrow; N = number of days that the bank is “out of funds,” normally one, but three at weekends, and so on; and R = lending rate for sterling overnight (or three days, etc.).

EFFECT OF WITHHOLDING TAX AND RESERVE REQUIREMENTS

The bulk of this book, which is concerned with rates, arbitrage calculations, and the like, assumes that the interest rates used are “net accessible interest rates.” The word *net* implies “net of all withholding tax and other tax adjustments, and net of all reserve requirement costs”; while the word *accessible* means “generally available to the international market,” that is, taking into account the effects, if any, of exchange control regulations. Sometimes we must adjust for these factors.

The impact of a withholding tax can be summarized in the following formula:

$$\text{Adjustment} = 100 \times \frac{a}{100} \times \frac{b}{100} \times \frac{c}{12} \times \frac{d}{100}$$

where a = Interest rate charged on the loan made by the bank to the borrower whose country imposes withholding tax; b = rate of withholding tax; c = number of months between deduction of withholding tax by the borrower’s country and the date tax is repaid to the bank; and d = bank’s domestic-currency interest rate for the period.

As an example, suppose a U.K. bank lends at 10% for one year in June 2001 to a Swiss borrower who is required to deduct withholding tax on the loan at 35%. Swiss withholding tax is repaid at the end of the calendar year for which it is deducted, so the bank is out of funds on the withheld portion

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for six months (from June 2002 when the interest is paid and tax deducted until January 2003 when the tax is repaid). Suppose that the interest rate (forward-forward) for June 2002 to December 2002 is today 13%. Then the adjustment needed is:

$$100 \times \frac{10}{100} \times \frac{35}{100} \times \frac{6}{12} \times \frac{13}{100} = 0.2275\%$$

Another adjustment is needed in domestic dealing to allow for the cost of reserve requirements. In the United States, for instance, loans tend to be made at prime, which allows for reserve costs; but on the bid side, when taking funds by the issue of certificates of deposit (CDs), it may be necessary to adjust the bid rate for reserve costs. In the United Kingdom, domestic sterling loans to a nonbank are often made at LIBOR (London Interbank Offer Rate) plus a margin plus reserve asset cost. The formula is complicated by the fact that there may be several kinds of reserve assets, some of which yield interest and some of which do not. The general formula is:

$$\text{Adjustment} = \frac{A1R1 + A2(R1 - R2) + A3(R1 - R3) + \dots + AN(R1 - RN)}{100 - (A1 + A2 + \dots + AN)}$$

where $A1$ = amount required to be held interest free (if not permitted to be netted against liabilities); $A2$ = amount required to be held at first rate of interest; $A3$ = amount required to be held at second rate of interest; AN = amount required to be held at N th rate of interest; $R1$ = interest rate the bank can earn on liquid assets (say, three-month deposit rate); $R2$ = rate received on $A2$; and RN = rate received on AN .

In the U.S. case, the formula simplifies to $(A1 \times R1)/(100 - A1)$ because there is only one class of reserve asset, namely balances at the Federal Reserve. Often dealers quote the all-in rate, which of course is:

$$R1 = \frac{A1 \times R1}{1 - A1} = \frac{R1 - (A1 \times R1) + (A1 \times R1)}{1 - A1} = \frac{R1}{1 - A1}$$

Hence if a bank issues a CD at 12% with a 3% reserve requirement, the adjustment is 0.371; the all-in cost is 12.371%. In the euro area, reserves

are remunerated at a single rate, the European System of Central Banks (ESCB) repo rate (see Chapter 6). In other countries, there may be several classes of reserve asset, some of which bear interest.

NEGOTIATION

A bank will often buy, or negotiate, a foreign currency check from one of its customers. The check will then be sent to the country in which it is payable for clearance. For example, a bookseller may sell books by mail order to a Japanese customer and receive in return a check drawn on a bank in Tokyo, expressed in Japanese yen. The bookseller will sell the check to his bank in exchange for his domestic currency, say dollars; the bank will then send the check to its Tokyo branch or correspondent, who will present it to the Japanese bank for payment.

The bank's foreign exchange rate for this transaction has to reflect—as in the similar case of payment today—the fact that it pays away funds to its domestic customer before being credited with the Japanese yen. The length of time involved in such a transaction depends both on the distance between the bank and the overseas center—Tokyo in this case—and on the efficiency of the domestic clearing system in the overseas center. Hence the foreign exchange rate applied to the transaction must reflect the cost to the bank of being out of funds for the relevant period of time; the adjustment will depend on prevailing interest rates and on the number of days involved. The formula to be applied is that used in the fourth section of this chapter: Payment Today.

14 Artificial Currency Units

In this chapter we explain what an artificial currency unit is. We look at the Special Drawing Right (SDR) and briefly at the history of the other most important artificial unit, the European Currency Unit (ECU), or Euro. Then we look at the green currencies of the European Economic Community (EEC) and at the concept of a trade-weighted exchange rate.

Artificial currency units can be split into three main types: (1) standardized units used in international monetary cooperation; (2) units of account used in multinational agreements; and (3) currency “cocktails” consisting of units created out of a number of national currencies.

Standardized units with the aim of helping international transfers have included the gold franc of the Latin Monetary Union, which nominally existed among Belgium, France, Greece, Italy, and Switzerland between 1865 and 1921, and the CFA franc of the Communauté Financière Africaine (CFA). However, they have been rare.

Units of account have been widely adopted for the purpose of international agreements. Examples include the accounts of the Bank for International Settlements (BIS), which have been kept in “Swiss gold francs” since 1930; the Telecommunication Convention of 1932, which adopted the gold franc of the Latin Union as its unit of account; the Convention for the Unification of Certain Rules Regarding Air Transport, 1929, which adopted the so-called Poincaré gold franc; and the EEC unit of account, which was defined as equal to the then gold equivalent of one U.S. dollar. The EEC unit was phased out in favor of the ECU (see section European Currency Unit) and now the euro. Typically, the chief aim of an artificial currency unit has been to help the bookkeeping of a multinational organization such as the BIS or the EEC

or (as in the case of the air transport convention) to lay down international standards of value for payments.

Currency "cocktails" have had a slightly different purpose, namely to protect borrowers or lenders from the effects of currency fluctuations. Hence, they are primarily a post-1945 phenomenon. The first such "cocktail" was the European Unit of Account (EUA), which was launched in 1961 with a bond issue for SACOR of Portugal. However, this original version of the EUA was essentially a currency option; the investor had the option of taking payment in one of the 17 currencies of members of the European Payments Union. Most cocktails have consisted of some kind of currency basket.

Currency *baskets* consist of an average of a number of currencies. The first basket was the Euro (see section Other Currency Units), but the concept was effectively launched by the International Monetary Fund (IMF) when in June 1974 it revalued its Special Drawing Rights by setting one SDR equal to the sum of specified amounts of selected currencies. As these currencies fluctuated, so the value of the SDR fluctuated. In 1975, the EEC followed suit by setting up a new European Unit of Account, which in 1979 was superseded by the European Currency Unit.

In general, currency cocktails and currency baskets were the creatures of the rapid inflation and turbulent currency markets of the 1970s and are now rarely used in international financial markets. They attempted to give protection to longer-term investors in bond markets against loss of value of any one currency, but the parallel growth of hedging instruments, such as currency swaps and the forward foreign exchange market, meant that investors had little need to accept the loss of liquidity that was entailed by having the bond denominated in a currency cocktail. The one significant exception to this, primarily for political reasons, is the use of the SDR by the IMF.

SPECIAL DRAWING RIGHTS

The nature of the SDR is twofold: It constitutes (1) an international reserve asset and (2) an international unit of account. The SDR was created by the First Amendment to the IMF's Articles of Association. This created a Special Drawing Account (SDA) at the IMF. Member states were issued with SDR, permitting them to obtain convertible currencies from the SDA under certain circumstances. Only member states, and certain designated official institu-

tions, may at present legally hold SDRs. During 1970, the first tranche of SDR allocations was made, in three annual installments, totaling approximately SDR 9,500 million; allocations were made according to member states' quotas at the IMF. The valuation of the SDR at this time was defined in terms of the gold value of one U.S. dollar.

However, in 1971 the U.S. dollar was devalued. The SDR did not devalue, and its value was set at SDR 1 = US\$ 1.08571. Following the second dollar devaluation of February 1973, its value was set at SDR 1 = US\$ 1.20835. The IMF recognized the arrival of a floating exchange rate system and, on July 1, 1974, introduced a new SDR, consisting of 16 units of currency, whose values were added together to produce the value of one SDR. This was the so-called *standard basket*. The amounts were chosen to reflect the relative importance in world trade of the currencies involved and were set so that the value on July 1, 1974, of the new and the old SDR was US\$ 1.20835. The method used was to determine the percentage share of the basket to be held by each currency. These percentages are converted into units of currency on the base date. These then constitute the basket.

The composition of the SDR basket was revised effective July 1, 1978. It was announced that this basket would be revised at five-year intervals. However, effective January 1, 1981, the IMF announced a new, simplified basket for the SDR consisting of five major currencies, which is now revised every five years. When the euro was launched, the most recent revision took place—the IMF replaced the currency amounts of deutschemark and French franc in the SDR valuation basket with equivalent amounts of euro, based on the fixed conversion rates between the euro and the deutschemark and French franc. The other currencies (Japanese yen, pound sterling, and U.S. dollar) remain in the basket. So, effective January 1, 1999, the value of the SDR is the sum of the values of the following amounts of each currency:

Euro (France)	0.1239
Euro (Germany)	0.2280
Japanese yen	27.200
Pound sterling	0.1050
U.S. dollar	0.5821

To find the exchange rate for the SDR, we calculate the total dollar value of the "bits" of national currency in the basket. The financial instruments

in the SDR interest-rate basket—the market yield of three-month Treasury bills for France, the United Kingdom, and the United States; the three-month interbank deposit rate for Germany; and the three-month rate on certificates of deposit in Japan—remained unchanged. The SDR interest rate is determined weekly as a weighted average of interest rates on these five instruments, with weights reflecting the values of the currency amounts shown in the preceding list.

The next revision of the SDR basket is due, at the time of writing, to take place not later than 2000, with any changes to take effect on January 1, 2001. The SDR interest-rate basket will be revised at the same time.

As we said earlier, private institutions may not legally hold SDRs, although they may deal in instruments linked to the value of the SDR. IMF member states, and certain designated official institutions (including the BIS, the Swiss National Bank, the World Bank, the International Development Association, the Andean Reserve Fund, the Arab Monetary Fund, the East Caribbean Currency Authority, the International Fund for Agricultural Development, and the Nordic Investment Bank) are allowed to hold SDRs.

In recent years private institutions have become more involved in the SDR market (although, in point of fact, this should be referred to as “the market for currency instruments index-linked to the SDR” because the banks cannot legally own SDRs). For example, since 1975, and particularly since the introduction of the simplified basket in 1981, a market in deposits linked to the SDR has existed. However, the SDR market has never grown very large. This is probably because the U.S. dollar is a significant component of the SDR: if you wish to diversify out of dollars, it makes little sense to switch into the SDR when you could switch into the ECU (and now the euro), which has no dollar component.

There has for some years been debate as to whether there should be a new allocation of SDRs. In particular there has been pressure for an “equitable” allocation of SDRs to allow for the fact that almost 40 countries—many of them from less-developed areas—had joined the IMF since 1978, when the last allocation of SDRs was made, and so had never received any SDR allocation.

To ensure that all members receive an equitable share of cumulative SDR allocations, the Board of Governors adopted a resolution on September 23, 1997, approving a proposal for a Fourth Amendment to the Articles. The amendment, which will become effective when approved by three-fifths of

the members having 85 percent of the total voting power, will provide the authority for a special one-time allocation of SDR 21.4 billion to raise all participants' ratios of cumulative SDR allocations to their quota. The ratio will be set at a common benchmark of 29.3 percent, which will double the amount of SDRs already allocated.

EUROPEAN CURRENCY UNIT

The European Currency Unit (ECU) had its origin in the EEC Unit of Account, which was created under the Treaty of Rome for the purpose of providing a unit of account for EEC institutions. The ECU was then defined as equal to 0.88867088 grams of 0.9 fine gold, the official par value of the U.S. dollar. Following successive devaluations of the U.S. dollar, the emergence of floating currencies, and the creation of the SDR basket concept, the EEC decided to introduce a basket unit of account for its own accounting. This was known as the European Unit of Account (EUA) (not to be confused with the earlier, private European Unit of Account, discussed in the next paragraph). It was defined as equal to the sum of the following amounts: FBC 3.66 + LuxFr 0.14 + HFL 0.286 + DKK 0.217 + DEM 0.828 + ITL 109 + FFR 1.15 + GBP 0.0885 + IEP 0.00759. The EUA was introduced first in 1975 in respect of the Lome Convention on development aid and the European Investment Bank's balance sheet. It was subsequently introduced in respect of the European Coal and Steel Community's operational budget (1976), the General Budget of the European Communities (1978), and customs matters (1979).

The ECU was created in 1979 with a value identical to that of the EUA and an identical composition (but with a revision clause permitting changes, unlike the EUA). The ECU took over all the existing functions of the EUA and was also introduced as the unit of account for the European Monetary System (EMS; see Chapter 6), where it took over from the European Monetary Unit of Account, a slightly different unit of account used previously for the bookkeeping of the European Monetary Cooperation Fund. Under the EMS, EEC members' currencies were linked to a central rate defined in terms of the ECU.

The ECU as an official currency was born on December 18, 1978, as part of the setting up of the EMS of linked exchange rates by members of the EEC. The EEC regulation that created the ECU defines it as a "basket

of members' currencies," that is, the sum of fixed amounts of each member's currency. The value of the ECU in U.S. dollars was found by taking the dollar value of 0.1828 deutschemarks, adding to it the value of 0.0885 pounds sterling, and so on.

The first definition of the amounts fixed the makeup of the ECU from its beginnings to the first revision, which took place on September 17, 1984, when the Greek drachma was included, Greece having joined the EEC in the interim. In September 1989, the basket was revised again to accommodate two new members, Spain and Portugal. There were no further amendments to the weights, and the Maastricht Treaty of 1991 stated that there would be no further modifications prior to the European Monetary Union (EMU). With the arrival of EMU, all ECU assets and liabilities¹ were converted into euro at a one-to-one rate, and thereafter the ECU ceased to exist for practical purposes.

OTHER CURRENCY UNITS

A wide range of other currency units have been devised on various occasions for various purposes. They include: Arab dinar, Arcru, Asian Monetary Unit, Barclays B-Unit, Eurco, European Currency Unit (private, non-EEC version also known as the European Monetary Unit), European Unit of Account, and Gold francs.

The *Arab Accounting Dinar* is used in the accounts of the Arab Monetary Fund. The *Arcru* is a privately developed currency unit (*Arcru* stands for "Arab Currency Related Unit") that is no longer widely used. The *Asian Monetary Unit* is used in the Asian Clearing Union that settles payments imbalances among Bangladesh, Burma, India, Iran, Nepal, Pakistan, and Sri Lanka. The *Barclays B-Unit* was developed by Barclays Bank International to facilitate international trade. It is no longer used.

The *Eurco*, or European Composite Unit, was introduced in 1973 in a loan to the European Investment Bank. It was defined as the sum of DEM 0.9, FFR 1.2, HFL 0.35, FBC 4.5, DKK 0.2, ITL 80, IEP 0.005, STG 0.075,

¹A minor exception is some private contracts or bonds where the ECU definition was independent of the official ECU, in which case they would continue as before.

and LuxFr 0.5. In this issue, interest was payable in the currency chosen by the borrower, whereas principal was repayable in the currency chosen by the lender. The ECU in its private form was introduced in 1970. It sets up fixed exchange rates among the currencies of the six member states of the EEC at that time (ECU 1 = DEM 3.2225). Thus, it set up a currency option arrangement rather than a true unit of account. Because the investor could ask for repayment of principal in the strongest of the six currencies, the concept was very attractive to lenders, but less so to borrowers. It was also used under the title European Monetary Unit.

The *European Monetary Unit of Account* was used in the bookkeeping of the European Monetary Cooperation Fund before the introduction of the European Currency Unit. One EMUA was defined as equal to DEM 3.21978, BEC 48.6572, DKK 7.57831, FRF 5.55419, and NLG 3.35507. It was designed to guarantee the exchange value of outstanding balances in the fund.

The *European Unit of Account*, in its private version, was introduced in 1963 for a bond issue by the Portuguese company SACOR. The initial formula (which was changed subsequently in various ways for various issues) was that the EUA was set equal to the then gold value of the U.S. dollar, 0.88867088 grams of fine gold. The bond contract defined 17 reference currencies (those of the members of the then European Payments Union), whose currencies in turn had gold par values. Thus the cross rates among the 17 reference currencies were determined by their gold par values. The EUA's gold value would only change if (1) all reference currencies had changed in the same direction; and (2) at least two-thirds had changed in the same direction. These complex rules ensured that no change in the EUA's gold value took place between 1961 and 1971 when the U.S. dollar devalued against gold. The EUA was then linked to the EMUA and then, following the launch of the European Currency Unit, to the latter unit. The EUA was set equal to ECU 1.1972258.

Gold francs have been used as units of account for many years, and a number of different varieties exist. Perhaps the first was that of the Latin Monetary Union, which linked certain European countries between 1865 and 1921. This gold franc was subsequently adopted as the basis for the Telecommunication Convention of 1932. Its value was defined as 10/31 of a gram of gold 0.900 fine. A second gold franc, known also as the Poincaré franc, was used in the Convention for the Unification of Certain Rules Regarding Air Transport of 1929 and related conventions; it was defined as equal to

65.5 milligrams of gold 0.900 fine. (This was replaced by the SDR under the Montreal Protocol of 1975.) The statutes of the BIS provide that the authorized capital of the bank shall be 500 million Swiss gold francs, equivalent to 145,161,280.32 grams fine gold; and the annual accounts of the BIS are maintained in these gold francs.

GREEN CURRENCIES

Reference is occasionally made to "green" currencies. These were the notional rates of exchange used by the EEC in the management of its Common Agricultural Policy (CAP). As such, one could not deal in them directly. However, they did impinge on the foreign exchange operations of corporations involved in EEC agriculture. From January 1, 1999, green currencies no longer apply for the 11 member states selected to participate in EMU, who will receive CAP payments in euros. Countries like the United Kingdom, which are not participating, will now use the market rate in order to convert CAP payments into their national currencies. Thus, for all intents and purposes, the green rate regime has been abolished, although the possibility still exists that it might be resurrected for countries outside the EMU.

By way of historical background, in 1962, the EEC issued its Regulation 129/62 setting up a unit of account (u.a.) for agricultural purposes. Its value was declared equal to 0.88867088 grams of fine gold—equivalent to US\$ 1 at the time. This gave rates of exchange (Green rates) of u.a.1 = DEM 4.0 = FFR 4.93706, for example. Hence, when the EEC set a price of u.a. 212.30 per ton for white sugar, this was equivalent to DEM 849.20 and FFR 1048.14.

However, in 1969, the French franc devalued, changing its parity against gold so that its value against the unit of account moved to FFR 5.55419. This would have resulted in a rise in the price of white sugar to 212.30×5.55419 , or 1179.15, a rise of 12.6%, which would have been paralleled in all other agricultural commodities. The inflationary effects of this were unacceptable to the French government, which arranged to postpone the devaluation of the green rate.

This meant, however, that white sugar still sold in France for FFR 1048.14; if exported to Germany, the French exporter would receive DEM 849.20, for which his bank would give him FFR 1179.15. It was necessary to prevent

cheap French exports from swamping the German market. The EEC decided to place a tax on French exports to the rest of the EEC and to subsidize French imports from the EEC. These taxes and subsidies were referred to as Monetary Compensatory Amounts (MCAs).

The move to floating exchange rates during 1971 through 1973 forced the EEC to move toward a corresponding system of floating MCAs to offset exchange-rate movements. This came in a series of regulations of which the most notable were 974/71, providing for variable MCAs, and 509/73, providing for a weekly variation in MCAs to cope with the floating of sterling. By this stage, telegrams from the EEC Commission to member states, setting out new MCAs, averaged 40 to 50 feet in length.

In order to simplify matters, a new system was devised in June 1973 (Regulation 1463/74). The unit of account on which the system depended was no longer linked to the U.S. dollar but to the central rates of the "joint float" currencies of the EEC. This meant that for member currencies, MCAs were fixed provided that central rates were unchanged, even if the joint float varied against the dollar. For nonmember currencies, such as sterling, variable MCAs continued in force.

Following the entry into force of the EMS (see Chapter 6) on March 12, 1979, the unit of account laid down for calculating agricultural prices was the ECU. The EEC wanted to maintain the common level of prices, so it was decided that the price levels in old units of account would be multiplied by an adjustment coefficient. This factor came to 1.208953.

Summing up simply, we can say: Green rate of exchange + MCA = Market rate of exchange.

As indicated earlier, the arrival of the euro means that it seems likely that the green currency regime will become a thing of the past.

CALCULATION OF TRADE-WEIGHTED EXCHANGE RATES (EFFECTIVE EXCHANGE RATES)

Although not strictly an artificial currency unit, the calculation of a trade-weighted index for a currency is related to the concept and so is included here. Before the advent of floating rates, a devaluation or a revaluation of a currency occurred against all other currencies simultaneously. A 5% revaluation of the deutschemark against the U.S. dollar implied a 5% revaluation against the French franc, and so on. With the advent of floating rates,

however, the impact of a 5% revaluation against the U.S. dollar coupled with a 2½% devaluation against the Swiss franc is not clear-cut. Hence attempts were made to take account of the average change of a currency against all others.

A 20% depreciation of the Argentine peso against the dollar is less important to the United States than a 10% depreciation of the euro is, because Europe is a much more important trading partner for the United States than Argentina is. So the various currencies' changes need to be weighted by taking account of the share of a country's trade held by a partner currency. Such a trade-weighted index may be called a "simple average" trade-weighted index.

Suppose we have four countries, A, B, C, and D. Suppose that we are constructing a trade-weighted index for A and that A's exports and imports are conducted with B, C, and D in the following proportions: B, 50%; C, 30%; D, 20%. Suppose in Period 1 we have the following exchange rates for one unit of A's currency against the others: $A1 = B2 = C2.5 = D3$. Suppose in Period 2, A revalues against B by 10%, devalues against C by 20%, and revalues against D by 15%. Then we can weight the percentage changes and add them: $+(10\% \times 0.5) - (20\% \times 0.3) + (15\% \times 0.2)$. The weighted change is 2%; so if we express the index for Period 1 as 100, the index for Period 2 is 102.

However, this simple index takes no account of the effects of the exchange rate on changes in third-country trade. Thus, because A has devalued against C by 20%, it is now able to encroach on C's trade with B, and so on. To take full account of these effects requires a matrix of cross-elasticities in international trade, and this is the approach adopted by the IMF in its Multilateral Exchange Rate Model and by the Bank of England in its index for sterling.²

The exact method of calculation is complex and varies from country to country. An example of such a multilateral-exchange-rate calculation is that used by the Federal Reserve, which has developed indexes for three currency groups.³ For each group, nominal and real (price-adjusted) indexes have been

²The most recent revision to the Bank's index is described in the February 1995 edition of the *Bank of England Quarterly Bulletin*. No conceptual changes were made; but the trade weights were updated to 1989–1991 values, and the index was rebased to 1990 = 100.

³For further detail, see "New Summary Measures of the Foreign Exchange Value of the [U.S.] Dollar," *Federal Reserve Bulletin*, October 1998.

created. The first, and primary, group is that of the currencies of important U.S. trading partners. This now has 26 currencies, down from 35 before the introduction of the euro. The other two groups are subsets of the broad index currencies.

One of these other two groups comprises the major international currencies—the euro and the currencies of Australia, Canada, Japan, Sweden, Switzerland, and the United Kingdom. These are used in the construction of what is termed the *major currency index*. Until the introduction of the euro, this included 16 currencies. It is now a seven-currency index.

The third group comprises the remaining currencies. In this group are the currencies of important U.S. trading partners, but these currencies are not heavily traded outside their home markets. This group is used to construct what the staff terms “the other important trading partner” (OITP) index. It includes the currencies of 19 major U.S. trading partners: Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela in Latin America; China, Hong Kong, India, Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan, and Thailand in Asia; Israel and Saudi Arabia in the Middle East; and Russia in Eastern Europe.

The weighting scheme in the construction of the indexes uses a measure of trade competitiveness. The importance of changes in the value of a foreign currency depends on the share of that country’s goods in markets that are important to the United States. If a country’s goods are important in those markets, its currency will be heavily weighted in the index.

We can think of competition between U.S. goods and the goods of a particular foreign country as taking place in the United States or in foreign markets. For competition in the United States, a weight equal to a country’s share of U.S. imports is used. This is a proxy for the degree of competition from that country. Competition in foreign markets can be split into competition in the foreign country’s home market and in third-country markets. We use two kinds of weights to reflect this: (1) We use a weight equal to a country’s share in U.S. exports to measure how much U.S. goods compete with foreign goods in that country’s home market. (2) We construct a second type of export weight to measure how much a particular foreign country’s exports go to third-country markets.

An example would be the case when U.S. goods compete with German goods in Japan. We measure this as the product of Germany’s share in Japan’s imports and the share of U.S. exports going to Japan. So a country will have

a high combined export weight if it is a key destination for U.S. exports or if it is a major exporter to other countries that take a large share of U.S. exports. The weight in the summary index is then computed as the simple average of the bilateral import share weights and the combined export weights.

Other widely used indexes include those calculated by JP Morgan, the Bank of England, and the IMF.

15 Financial Futures

In this chapter, we start to look at the derivatives markets. The term *derivatives* is usually applied to futures, options, and interest-rate and currency swaps. These are markets that were “derived” from other markets: the first financial futures contracts were derived from the foreign exchange market; interest-rate swaps were derived from the bond market; and so on. In general, the derivatives markets have shown very rapid growth during the 1980s. For example, in 1980 the annual trading volume of interest-rate futures contracts was 12 million. By 1998, the top-ten contracts worldwide traded 488 million contracts, with 98 million in U.S. Treasury bond futures alone. In 1980, the share of futures activity accounted for by the United States was 100%; by 1993, the figure had fallen below 50% because the market had begun to move to a global footing. Interest-rate and currency swaps also grew during the decade, from a volume of perhaps \$1 billion to \$2 billion of currency swaps outstanding in 1980 (when interest-rate swaps did not exist). By April 1998, according to the Bank for International Settlements (BIS), the markets traded a daily average of \$155 billion in interest-rate swaps and \$10 billion in currency swaps. Options, particularly options traded over the counter (that is, outside organized exchanges) also grew strongly, and by 1998 the BIS estimated that the average daily volume of foreign exchange options was \$87 billion.

THE MARKETS

Of the derivatives markets, the first to develop was that for financial futures, which now make up a very important segment of the worldwide financial

markets. *Futures contracts* are standardized agreements to buy or to sell a specific commodity at a specific time and place in the future, at a price established through open outcry in a central, regulated marketplace. The two key components of a futures contract are (1) that the agreement is standardized and (2) that price is the only variable. The origins of such contracts go back to Chicago in the nineteenth century, when futures contracts on grain were first developed. (Some would argue they go back to the Dutch tulip mania of 1634).

A *financial futures contract* is a contract to deliver, or to take delivery of, a financial instrument at a future date. For example, a Treasury bill futures contract is a contract to deliver, or to take delivery of, a Treasury bill on a specified date. In some cases, in which delivery is difficult, the contract may be settled by a cash payment, for example, Eurodollar futures contracts.

Let us take a simple example. I want to invest \$100,000 in a U.S. Treasury bond for delivery in June. I can wait until June—taking the risk that the price might move against me—or I can buy a futures contract. I go to the futures market and see that the price for June 15 delivery is 92—if I were to settle today, I would have to pay \$92,000. I buy one contract. I do not pay for the bonds today. Instead, I put up a margin deposit.

The amount of this margin is fixed by the Futures Exchange at \$4,500 per contract. So I put up \$4,500 on deposit with my futures broker. The deposit is evidence of my good faith that I will fulfill my obligation to take delivery of the bonds in June. As bond prices vary, the value of my futures contract varies. I have a profit or a loss on my purchase. If losses erode the value of my margin, my broker will call on me to put up extra margin. Conversely, if I earn profits, I will get back some margin. The aim is to keep the margin stable in line with the value of my obligation.

When the contract comes to settlement, suppose I decide to take delivery of the bonds. A settlement price for the bonds is fixed. Say that price is 105. Then I must pay \$105,000 for my bonds; but on that settlement day, my futures contract is also worth \$105,000. So I have a \$13,000 profit on the futures contract that offsets the rise in price of the bonds. The futures contract has served to fix my bond purchase price.

The main attraction of futures in risk management is their leverage, or “gearing” in U.K. terminology. Suppose a trader deliberately takes a position, either as a straightforward speculation or as an arbitrage. The simplest case is the trader who wants to back his judgment on the outlook for interest rates or currencies. The essential difference between doing this in the futures

market and doing it in the “cash market” is that in the futures market, one can trade on margin. This gives a high degree of leverage. This leverage lets the speculator make large profits compared with the amount of margin money committed.

Suppose on December 1, 2001, a trader thinks interest rates will rise in the next few months, causing bond prices to fall. She deposits the required margin (say, \$4,000 per contract) with her broker. She sells two Treasury bond futures contracts at 67-00. Two weeks later, interest rates have risen. Prices for Treasury bond futures contracts have dropped to 66-08. The trader closes her position by buying two bond futures contracts. She makes a profit of \$750 on each contract. The \$1,500 profit on the \$8,000 margin is a return of over 18% during the two weeks, before deducting commission and exchange fees. Leverage has increased her returns.

This leverage works both ways, making it possible to lose more money than originally invested. Because of this, prices are marked to market on a daily basis by the exchanges. Settlement is made daily through the clearing corporation. Thus, if prices move against an investor, his account is debited.

If the debits reduce the money in the margin account below the prescribed “maintenance” level, additional margin must be posted to bring it back up to the initial margin level. Hence the investor quickly feels the effect of any weakening in his or her position through margin calls. It is this margin call system that has generally protected the exchanges and their member firms from losses via investor default: although investors are highly leveraged, the margin maintenance system quickly brings to light any potential problems.

Another attractive feature for those who wish to trade in the major futures markets for its own sake is that they are very liquid. Average daily trading volume on the Chicago Board of Trade (CBOT) Treasury bond futures contracts in 1998 was just under half a million contracts for a face value of almost \$50 billion. One could shift a significant volume in this market without making a major impact. In other instruments, this is less true. Many futures contracts have not proved successful, and daily volume is negligible. In this case, if one wishes to trade in a particular instrument that is not readily available, one is reduced to trading in a proxy instrument and to making allowances by means of appropriate weighting factors, considered next.

Table 15.1 gives the date of introduction of major contracts; Table 15.2 shows the main activity in 1998. As will be seen, the development of financial futures is recent. The International Monetary Market (IMM) in Chicago opened futures trading in seven foreign currencies in May 1972.

Table 15.1 Date of Introduction of Some of the Major Futures Contracts

1972	IMM	Foreign exchange
1974	IMM, Comex	Gold
1975	CBOT	GNMA
1976	IMM	U.S. Treasury bill
1977	CBOT	U.S. Treasury bond
	CBOT	90-day commercial paper
1978	Sydney	Gold futures
1979	Sydney	Bank bill futures
	CBOT	U.S. Treasury 10-year notes
1980	IMM	CD
	Sydney	AUD futures
1981	IMM	Eurodollar
1982	LIFFE	GBP, DEM, CHF, JPY currency futures
	LIFFE	Euro dollar, Long gilt, 3-month sterling deposits
	CME	Standard & Poor's (S&P) 500
1983	Sydney	All Ordinaries Share Price Index
1984	LIFFE	FT-SE 100, UST-bonds
	Sydney	Australian Treasury bonds
1985	Tokyo SE	JGB futures
1986	MATIF	French government bonds
	SIMEX	Nikkei-DJ futures
1988	Tokyo SE	TOPIX futures
	Osaka SE	Nikkei-225 futures
	LIFFE	Bund future
	CBOT	5-year Treasury note futures
1989	TIFFE	Euroyen, yen/dollar
	LIFFE	Euro-DEM LIBOR future
1990	DTB	Bund future, DAX future
	CBOT	2-year Treasury note futures
1991	LIFFE	Italian government bond futures
	DTB	Bundesobligation (BOBL) future
1992	MEFF	Spanish government bond future
1993	MEFF-RV	Spanish IBEX-35 future
1994	Osaka	Nikkei 300 futures
1995	IDEM (Italy)	MIB30 equity futures index
1996	CBOT	U.S. Treasury Yield Curve Spread futures
	CME	Mexican peso futures
1997	CME	E-mini S&P 500 future
1999	LIFFE	EURIBOR future
	MATIF/MEFF/MIF	EURIBOR future
	CME	Euro FX future

Table 15.2 Top Futures Contracts Jan-Oct. 1998

	Million Contracts	
	Traded	Exchange
U.S. Treasury Bond	98.5	CBOT
Eurodollar	93.3	CME
Bund	78.4	Eurex Deutschland
Euromark	46.9	LIFFE
1-day interest rate	30.2	BM&F Brazil
Sterling deposit	29.4	LIFFE
BOBL	27.8	Eurex Deutschland
10-year Treasury note	27.5	CBOT
S&P 500	26.8	CME
CAC40	21.5	MONEP
Notionnel	21.4	MATIF
Euroyen	18.8	TIFFE
USD/Real	16.8	BM&F Brazil
5-year Treasury note	15.1	CBOT
KOSPI 200	13.7	Korea Stock Exchange

Source: Futures & OTC World, December 1998.

The first interest-rate futures contract was introduced in October 1975, but the first really successful interest-rates futures contract was the 91-day Treasury Bill Contract introduced by the Chicago Mercantile Exchange (CME) in January 1976. This was followed in August 1977 by the CBOT futures contracts on U.S. Treasury bonds.

In September 1982, the London International Financial Futures Exchange (LIFFE) opened for business. It started with two contracts, for Eurodollars and for pound sterling; but by early December the initial complement of seven contracts had all been introduced. The additional five contracts were: short sterling interest rates, long gilt-edged government securities, Swiss franc, Japanese yen, and Deutschemark futures. In 1988 LIFFE introduced a futures contract based on German government bonds (Bunds), following this up in April 1989 with a future based on DEM LIBOR (London Interbank Offered Rate) and an option on the Bund future. During 1997 and 1998, however, a successful challenge to LIFFE's dominance in this contract was made by the German futures exchange—the first example in the history of the futures markets when a contract established on one exchange was successfully taken away by another exchange. The key to this development

was the fact that the German exchange was screen-based, whereas LIFFE was using the traditional "open-outcry" method, which was inherently more expensive. Other contracts traded on LIFFE include the Financial Times Stock Exchange (FTSE) 100 contract for U.K. equities and, since January 1999, a very liquid EURIBOR (Eurozone Interbank Offered Rate) deposit future contract.

The Tokyo futures market was established in October 1985. But in an astonishing explosion of trading, volume in the Japanese government bond futures contract on the Tokyo futures exchange after only 10 months exceeded that in the U.S. Treasury bond contract. Daily trading in the Japanese contract reached an average of \$32.8 billion in August 1986, compared with \$19.7 billion in U.S. bond contracts.

In September 1988, the Tokyo Stock Exchange (TSE) introduced futures based on its TOPIX equity index, and its Osaka counterpart introduced a contract on the Nikkei 225 equity index. In June 1989, the Tokyo International Financial Futures Exchange (TIFFE) opened for business, trading Euroyen and Eurodollar deposit contracts as well as a yen/dollar contract. The former has been successful—trading 23.3 million contracts in 1993—but the yen/dollar future failed. Japanese futures markets, particularly the Nikkei-225, suffered from some official disapproval in the early 1990s. The collapse of the Japanese "bubble" was blamed in part on derivatives, and the authorities took steps to discourage stock market derivatives. They also encouraged the creation of the Nikkei-300 index future on the grounds that the Nikkei-300, as a capitalization-weighted index, was less open to manipulation than the Nikkei-225, which is a price-weighted index.

The next important financial futures exchange to open after Tokyo was in France, where in February 1986, the *Marché à terme international de France* (MATIF) was opened. A contract on French Treasury bills was introduced in 1986, which developed poorly, owing to the lack of liquidity in the secondary cash market, but in September 1988, the MATIF successfully introduced a contract on PIBOR (Paris Interbank Offered Rate).

In 1989, the MATIF, the CME, the CBOT, and Reuters signed a contract for a system called Globex. Reuters developed Globex as a worldwide automated dealing network for trading outside official exchange hours. Tensions between the CME and the CBOT prevented its early success, but the MATIF's participation in 1993 gave the system a substantial boost. Since February 1999, CME members have had simultaneous access to the products of French and U.S. markets through a single trading screen running Globex2, the U.S.

version of the Nouveau Système de Cotation (NSC) trading system developed by MATIF. Members of the Spanish and Italian exchanges, MEFF and MIF, also have access to Globex2.

The German futures exchange, DTB, which opened in 1990, was initially particularly successful in equity options—by 1993 the DAX option was the second most widely traded option contract in the world after the S&P 100. A key feature of the DTB is that it was the first fully electronic futures exchange (partly because regional jealousies in Germany militated against establishing a single floor in Frankfurt). This allowed for greater efficiency and for a lower-cost structure, which allowed Eurex (as the DTB exchange is now called, to reflect its alliance with the Swiss futures exchange) to wrest the Bund contract from LIFFE during 1998.

Other financial futures exchanges operate in Australia, Brazil, Canada, Denmark, Italy, Hong Kong, Israel, Korea, Malaysia, Singapore, and Spain, among others. The market is now effectively global.

A key issue is the battle between traditional “open-outcry” (whereby prices are set by an auction in a “pit” where traders shout bids and offers) and the new technology. The latter is represented by Globex2, by the Eurex screen system, and by LIFFE’s screen-based trading system. This is the Automated Pit Trading System (APT), which aims to emulate the features of open-outcry pit trading, and now the “connect” system.

ORGANIZATION OF THE MARKETS

Before discussing the financial futures contracts in more detail, let’s review the organization of the markets. Because the original futures markets were floor-traded, the discussion will tend to concentrate on the traditional style of futures market. Obviously, computer-based systems fulfill the same economic functions and are often designed to capture, as far as possible, the features of the floor-trading system.

The following description, in outline, applies to the CBOT, the CME, and other similar institutions. Essentially, the membership of the market can be divided into two categories: (1) *Brokers*, who trade for nonmember customers and for other members, and (2) *locals*, who trade for themselves.

The locals are essential for the liquidity of the market. They are usually involved in three types of trading:

1. *Position Traders.* They will take a position, sometimes very large, and keep it until something causes them to change their mind. Position traders are relatively long-term traders, particularly compared to scalpers.

2. *Scalpers.* These are floor traders who are constantly buying and selling. Often, scalpers keep positions for only a matter of minutes or seconds. Their contribution to the market is continuous moment-by-moment liquidity.

3. *Spreaders.* They concern themselves with the relative value of one contract month against another. They are arbitraging one period against another. Their contribution to the market is to give liquidity to the more distant periods.

The other main source of liquidity is the very large number of small, individual speculators who trade on the exchange through the brokers. Although each may trade only one or two contracts, there are many thousands trading on the exchange, who again contribute to liquidity.

Trading takes place in the pits during specific hours. There is a separate trading area for each contract, so there is a bond pit, a Eurodollar pit, and so on. Orders are received on the trading floor by telephone or telex and are passed to the broker in the pit. Traders shout out the quantity and the price at which they want to buy or sell. They also use standard hand signals, especially when trading is noisy.

At the close of each day's trading, every member submits a trade confirmation record for every deal done on behalf of the firm or its customers. Every one of these trades must be *cleared*, that is, verified and guaranteed, by the clearinghouse. The clearinghouse settles the account of each member firm at the end of the trading day. It matches each of the day's purchases and sales, and it collects all losses and pays all profits. Its contribution to the safety of the market is to be the buyer from every seller and the seller to every buyer. A sale of Treasury bill contracts by A to B becomes a sale (by A) to the clearinghouse and a purchase (by B) from the clearinghouse.

This is a key safeguard for users of the exchanges. There is no need to worry who has taken the other side of the trade. The exchange clearinghouse itself guarantees the performance of every trade because it is the exchange itself that takes the opposite side to every contract. However, the exchange will not deal directly with public customers, only with its clearing members.

In effect, the exchange does business only with its clearing members and the clearing members do business with all others. For example, the exchange sets margins for its clearing members, and its clearing members in turn set margins for their customers. Thus, customer margins flow directly to the clearing member who, in turn, must settle with the exchange at the close of business each day. Each day the exchange requires a cash settlement from the clearing member based on the day's market positions and activity. This is regardless of the status of the member's customer margin money. A clearing member might let a customer be short of margin for a period of time, but this would have to be funded at its own expense. The clearinghouse would not allow a clearing member to be undermargined overnight. Also, the exchange will supervise the financial status of its clearing members. So far, these arrangements appear to have been successful in preventing major problems; both the CBOT and the CME state that there has never been a financial loss to a customer due to default on a futures contract on their exchanges.

EURODOLLAR FUTURES

There is now a wide range of instruments traded in the financial futures markets, from the simplest (the Eurodollar or Treasury bill contract) to the more complex (Treasury bonds, stock index futures) to the exotic (DIFFS—contracts developed in Chicago for trading on interest-rate differentials between two currencies). An exhaustive survey would probably also exhaust the reader's patience because the differences between many of these, for example, a contract on three-month U.S. dollar deposits and a contract on three-month sterling deposits, are relatively minor and confined to clearing and settlement issues rather than to any major differences in concept. Therefore this chapter discusses only three kinds of contract: (1) a short-term interest-rate contract, (2) a short-term discount-rate contract (Treasury bills), and (3) a foreign exchange contract. With variations applicable to local clearing and settlement conditions, the principles explained should be applicable to futures markets on foreign exchange and money markets worldwide.

We will start with what is perhaps the simplest futures contract, the Eurodollar future. It is also probably the most important short-term interest-rate futures contract on a worldwide basis. To give an idea of the scale of the CME's liquidity in this contract, in normal times 500 lots and often 1,000

lots can change hands without changing the price; that is, up to \$1 billion can be done in a single trade.

The Eurodollar contract is traded in substantially similar form in Chicago, on the CME, and in Singapore on SIMEX. SIMEX and the IMM have a "mutual offset" arrangement whereby positions taken in Singapore can be closed in Chicago and vice versa.

The CME contract is for a \$1 million, face-value, Eurodollar, time deposit with three-months' maturity. Last trading day is the second London business day before the third Wednesday of the delivery month. Delivery months are March, June, September, December, and the spot (current) month. A specific feature of this contract is that it is cash-settled; that is, unlike the Treasury bill or Treasury bond contracts, physical delivery of the underlying instrument does not take place. The primary reason for this is that there would be an implied credit risk on the bank whose Eurodollar deposit was delivered. Because the Eurodollar futures market now stretches out almost to four years in maturity, predicting the credit quality risk would be difficult.

The cash settlement has been an important element in the success of the contract. By contrast, the domestic U.S. certificate-of-deposit (CD) contract (which settled by actual delivery of CDs) was introduced in 1981. The Mexican crisis of 1982 and the Continental Illinois' collapse in 1984 quickly meant that the traditional CD "run" (whereby the top-ten U.S. banks' paper was traded interchangeably) disintegrated. Traders delivered the weakest CDs into the futures contract; buyers of CD futures found themselves "wearing" weak paper. This process destroyed the contract. Cash settlement means there is no risk of this happening.

The size of the Eurodollar contract is \$1 million face amount. The price is quoted in terms of an index, that is, the difference between the deposit rate and 100. Thus, a Eurodollar deposit rate of 9% is quoted in index form as 91.00. Prices are quoted in multiples of 0.01 (thus, the minimum possible change in the value of the contract—the tick value—is US\$ 25: $(0.10/100) \times (90/360) \times (\$1,000,000)$).

The settlement mechanics are that on the last trading day the CME clearinghouse uses the British Bankers Association (BBA) quoted LIBOR rate, which is obtained by the following BBA Survey Procedure:

1. At 11:00 A.M. London time, 16 BBA-designated banks provide quotes that reflect their perception of the rate at which U.S. dollar deposits are generally available to the marketplace.

2. The four highest and the four lowest rates are eliminated.
3. The average of the remaining eight quotes is taken.
4. The average, rounded out to the fifth decimal place, is the fixing for the day.

The decision to use this BBA rate (rather than the previous practice until January 1997 of the CME's own settlement rate being calculated) was made to help convergence of CME interest-rate contracts with over-the-counter (OTC) interest-rate markets, which typically fix to BBA rates.

Settlement using the BBA fixing results in the final settlement price being rounded to the fourth decimal place (rather than the previous practice of rounding to the second decimal place). This means that at expiration the final settlement price will be rounded to the nearest \$0.25 per contract, rather than the current \$25. These rates are currently displayed daily on Telerate page 3750.

Suppose the settlement rate works out at 6.5%. Then the *settlement price*, which is used to work out the payments due to and due from holders of outstanding futures contracts, will be $100 - 6.5$, or 93.5. Thus, on the settlement date, the interest rate implied by the futures contract must be equal to the cash three-month-deposit rate prevailing at that time. So, in fact, looking at futures prices gives a quick forecast of where the market sees the three-month Eurodollar rate going.

Suppose today is June 13, 2001. The September Eurodollar futures contract is trading at 93.5. That means that the market is saying, "In September, Eurodollar rates will be at 6.5%." (Remember the contract prices as 100-Eurodollar rate). I believe that by the time we get to September 15, the rate will have risen sharply to 9%. That would imply that on its settlement date the Eurodollar future would trade at 91. The market expects rates to fall, I expect rates to rise. I sell 50 September Eurodollar contracts at 93.5. If I am right, then in September, the futures contract will settle at 91. I sold at 93.5; I close out the position by buying back at 91. I will make a profit of 2.5, or 250 ticks. The value of a tick is \$25, so my profit will be \$6,250 per contract, or \$312,500 in total.

Here I simply traded on my view of rates. But another way of looking at this is to argue that by dealing today at 93.5, I have effectively "locked in" a deposit rate of 6.5% in September. That ability to lock in future rates is what makes the Eurodollar futures market so attractive to banks. It allows them not only to trade speculative interest rate views but also to offer hedges

to their corporate customers who are borrowing and to arbitrage against other markets, notably the rate for forward rate agreements (see Chapter 7) and interest-rate swaps (see Chapter 16).

TREASURY BILL FUTURES

The IMM Treasury bill future was the first successful interest-rate futures contract; and although it has lost ground to the Eurodollar contract, it remains an important instrument in its own right as well as being used in "TED spread" trading (the spread between Eurodollars and treasury bills). The main reasons for its decline are (1) the Euro contract, introduced in 1982, was soon traded on other exchanges worldwide, whereas a position in the IMM Treasury bills contract can only be traded during Chicago hours; (2) trading in the secondary Treasury bill market can be affected by the amount of paper locked away. In the spring of 1989, for example, of \$7 billion of three-month bills auctioned, \$4.4 billion were bought by "noncompetitive" buyers intending to hold the bills as investments to maturity. Thus of that bill only \$2.6 billion was available; an aggressive investment bank, working perhaps with one or two other institutions, could easily establish a sizable enough position in the cash market to squeeze the futures market. A few squeezes of this type were enough to discourage some trading in the futures market, which in turn made the market easier to squeeze.

The standard contract is for 13-week U.S. Treasury bills having a face value at maturity of US\$ 1 million. The delivery unit on the IMM is Treasury bills maturing 90 days hence. At the seller's option, he or she can deliver 91- or 92-day maturity bills. (In point of fact, the vast majority of deliveries are made in 91-day bills.) The price is quoted in terms of the IMM index, that is, the difference between the actual yield and 100. (It should be borne in mind that Treasury bill rates are quoted on a discount basis and not a yield basis; see Chapter 9.) Prices are quoted in multiples of 0.01 (thus the tick value is US\$ 25, as for the Eurodollar contract).

Contracts for the 90-day Treasury bill are traded for March, June, September, and December. Trading in the contract normally ends on the second business day after the 13-week Treasury bill auction of the third week of the delivery month (that is, usually the Wednesday following the third Monday of the month). Delivery takes place the following day (the Thursday).

Unlike the Eurodollar contract, the Treasury bill contract settles by delivery

of a Treasury bill. So the pricing of the Treasury bill future is primarily driven by its relationship to the cash market for Treasury bills. The link between the two markets is called the *implied repo rate*. The basic idea behind the implied repo rate can be explained as follows: Suppose I buy a Treasury bill that is deliverable into the futures contract. At the same time, I sell a Treasury bill future with the intent of delivering the cash bill as settlement of my futures position. This position will have a revenue and a cost. The revenue will be the profit (if any) on the sale price of the future in excess of the cost of the cash bill. The cost will be the cost of financing my holding of the cash bill until I deliver it in the futures settlement. The implied repo rate is the rate that I can afford to pay as a cost of finance and still break even.

The implied repo rate measures the interest expense saved by a leveraged buyer who chooses a futures contract instead of a cash settlement purchase. It measures the time value of money for the time period between cash and futures settlement dates. If the implied repo rate is above the actual financing rate for the period, futures are expensive relative to the underlying instrument—we should buy cash and sell futures. Conversely, if the implied repo rate is below the actual rate, futures are cheap relative to the instrument—we should buy futures and sell cash.

In practice, of course, these rules cannot be automatically followed because of the fact that the trader is uncertain about the amount of variation margin that will have to be paid or received in the interval from now to maturity. Also, the trader is not always able to arrange finance for the period from now to maturity at a single fixed rate.

Calculating the Implied Repo Rate

Suppose today, August 3, 1998, I can sell September bill futures at 89.14 (that is, a rate of 10.86%). Because delivery will be due on Thursday, September 22, the December 22 bill is the deliverable bill to the September contract. Assume that today I can buy the cash Treasury bill maturing December 22 at a discount of 10.52%. Is it profitable to buy the cash bill and sell it into the September future?

The purchase price of the cash bill is found by the formula:

$$P = 100 - [R \times N/360]$$

where P = bill price; R = discount rate; and N = days to bill maturity. In this case, $R = 10.52\%$ and $N = 140$ (delivery is August 4). Therefore,

$$P = 100 - [(10.52 \times 140)/360] = 95.909$$

The selling price in September, via the futures contract, is found from the same formula, with $R = 10.86\%$ and $N = 91$. Therefore,

$$P = 100 - [(10.86 \times 91)/360] = 97.255$$

From these two prices, we can now find out the implied repo rate. It is the annualized rate of return that is earned by buying the bill at 95.909 and selling it 49 days later at 97.255. We will be able to afford to pay a financing cost that is no higher than that return. The calculation is the same as for any other annualized return:

$$\text{Implied repo rate} = [(97.255/95.909) - 1] \times (360/49) = 0.1031, \text{ or } 10.31\%$$

If we do this trade, we will earn a return of 10.31%. Provided we can finance our Treasury bill holding for less than that, we will make a profit. However, it is unlikely that we would lock up our finance for the whole period in advance because a more common use of this trade, if there is an arbitrage opportunity, is to put the trade on and hold it until the arbitrage disappears. At that point, we unwind our financing and sell the position. Thus, our financing would normally be the overnight repo rate (hence the origin of the term). So then the position would be subject to financing risk. If overnight repo rates jumped sharply, we would have to cut the position, probably at a loss.

Generalizing from the preceding, the general formula for the implied repo rate is as follows:

$$\text{Implied repo rate} = 100 \times (Pf/Pc) - 1 \times (360/N)$$

where Pf = futures price, Pc = cash price, and N = days in the trade.

For the Treasury bill calculation, if we want to express the formula in terms of interest rates, it is:

$$IRP = \left[\frac{100 - \left(\frac{R_f \times 91}{360} \right)}{100 - \left(\frac{R_c \times D_c}{360} \right)} - 1 \right] \times \frac{360}{D_c}$$

where R_f = futures bill discount rate; R_c = cash deliverable bill discount rate; and D_c = number of days to cash bill maturity.

OTHER SHORT-TERM CONTRACTS

Fed Funds Contract

In 1989 the Chicago Board of Trade introduced a 30-day interest-rate futures contract. Initially this was not widely used, but the interest-rate volatility of 1994 boosted volumes significantly; it is now commonly called the Fed funds futures contract. The contract calls for delivery of the interest paid on a principal amount of \$5 million overnight Fed funds held for 30 days. The contract is cash settled against the monthly average of daily Fed funds effective rates calculated and reported daily by the Federal Reserve Bank of New York.

Note that the deferred Fed funds contracts (for later months) listed track the one-month forward rate implied by an *uncompounded* average of expected overnight Fed funds rates. For this reason, the forward rates implied by 30-day futures prices tend to be lower than comparable term rates, which are typically based on compounded averages.

Brazilian DI Futures

This future, trading on the Brazilian Bolsa de Mercadorias & Futuros (BM&F) is based on the overnight interbank deposit (DI) rate published by the central clearing (CETIP). It is included here because of an unusual feature. Unlike the Eurodollar futures contract, the DI contract is traded monthly, and its

price reflects not the forward-forward interest rate but the implied discount factor to the settlement date of the contract. Each contract is traded with a face value of R\$ 100,000 for one month. The last trade date is the business day preceding the expiry day. Because the price reflects the discount factor, forward rates have to be calculated by compounding the present value of the first future—the reverse of the normal procedure. (See discussion on forward rate calculations in Chapter 3.)

EXTENSIONS ALONG THE CURVE

Bundles, Packs, and Stubs

In September 1994, the Chicago Mercantile Exchange introduced “bundles” of Eurodollar contracts. A Eurodollar bundle is the simultaneous sale or purchase of one each of a series of consecutive Eurodollar futures contracts. The first contract in any bundle is usually the first quarterly contract in the Eurodollar *strip*: a consecutive set of contracts, usually covering one year. The exception to this convention is the five-year “forward” bundle, which covers years 5 to 10 of the Eurodollar futures strip. For example, on May 20, 1996, the first contract in the five-year forward bundle would be June 2001 (the 21st contract in the strip) and March 2006 (the 40th contract) would be the last.

For any bundle, the price will be quoted in terms of net change from the previous trading day’s settlement price. Specifically, the bundle’s price quotation will reflect the simple average of the net price changes of each of the bundle’s constituent contracts. For example, suppose that all of the nearest 21 contracts (e.g., the June 1996 to the June 2001) have risen by three ticks since yesterday’s settlement. The prices of the next seven contracts (September 2001 to March 2003) have risen by four ticks. Under these conditions, the quotation for the seven-year bundle would be: $[(21 \times 3) + (7 \times 4)]/28$, or 3.25 ticks. This example highlights the fact that bundles are quoted in increments of a quarter of a basis point, unlike the underlying futures contract, which is quoted in increments of one basis point.

After a buyer and a seller have agreed on the price and the quantity of a bundle, they must assign mutually agreed prices to each of the constituents. In principle, any set of prices may be used, provided that at least one constituent contract lies within that contract’s trading range for the day. (This prevents

bundle prices moving too far out of line from the current market.) In practice, most traders use a computerized system provided by the CME. This calculates the average price of the bundle from the components and then adjusts for any discrepancy between the result and the agreed price at which the bundle was traded. This is done by adjusting the component contract prices, applying the adjustment to the most distant contract first.

A second innovation introduced by the CME is the Eurodollar "pack." A *pack* is the simultaneous purchase or sale of an equally weighted, consecutive series of four Eurodollar futures. There are generally nine different packs trading at any given time: Red, Green, Blue, Gold, Purple, Orange, Pink, Silver, and Copper, representing years 2–10.

The difference between a bundle and a pack is that a bundle consists of several packs. For example, a three-year bundle consists of 12 futures contracts. Another way of constructing a similar position would be to buy the four Eurodollar contracts comprising year 1, together with the packs for years 2 and 3. Packs are quoted in the same way as bundles, that is, as a net change from the previous settlement price. They are quoted in minimum increments of one-half tick, for example, +2.5 bid/+3 ask.

A *LIBOR stub* contract consists of three equally weighted, consecutive one-month LIBOR contracts. All three contracts are executed simultaneously, at an average net price change from yesterday's settlement price. This creates a synthetic Eurodollar futures contract, but the advantage is that it can be constructed for nonstandard dates (e.g., the Eurodollar future contract is March/June/September/December; we could construct a LIBOR stub from February to May). This is convenient for over-the-counter swap traders.

The Strip Yield Curve

A very important application of Eurodollar futures lies in their use to create synthetic Eurodollar deposits either for a hedge or for an arbitrage. To understand this, we begin with the idea of the strip.

For any financial instrument for which there is a futures market, we can create a synthetic longer-term instrument using the underlying cash instrument plus a series, or strip, of futures contracts. For example, suppose it is March 15, and I buy a three-month Treasury bill maturing June 15. I could also buy June, September, December, and March Treasury bill futures so

that I can fix the rate at which I roll over the cash three-month bill when it expires. In fact, I have created a synthetic fifteen-month Treasury bill.

We can take the same approach with Eurodollar futures. The combination of a three-month deposit with three subsequent Eurodollar futures contracts can create a synthetic one-year deposit. This can be arbitrated against the actual one-year deposit. But in terms of balance-sheet usage, it is more effective to arbitrage against the one-year interest-rate swap market (see Chapter 5). To do this trade, we need to know how to work out the one-year rate from the futures strip.

We want to find the long-period deposit rate from the short-period rate and the forward-forward rate. This is the reverse of the approach set out in the forward-forward rate formula of Chapter 3. So we have:

$$\text{Long period rate} = \frac{360}{\text{Long period days}} \times \left(\left[\left(\left[\left(\text{Futures rate} \times \frac{\text{Difference between long and short period days}}{360} + 1 \right) \times \left(1 + \frac{\text{Short rate} \times \text{Short days}}{360} \right) \right] - 1 \right) \right]$$

$$R_2 = \frac{360}{N_2} \times \left\{ \left[\left(\left[\left(R' \times \frac{N_2 - N_1}{360} \right) + 1 \right] \times \left(1 + \frac{R_1 \times N_1}{360} \right) \right] - 1 \right\}$$

where R_1 = Short period deposit rate; R' = Rate implied by futures contract; N_1 = Short period days; N_2 = Long period days; and R_2 = Long period rate.

To work out the strip, we start by working out the six-month rate from the three-month rate and the nearby futures contract. Then we find the nine-month rate from the resulting six-month rate and the next futures contract. Then we find the twelve-month rate from the resulting nine-month rate and the next futures contract.

Let's take an example. Today is March 15. We know what the 90-day Eurodollar rate is in the ordinary, or "cash," market. We know the 90-day Eurodollar prices on the CME for June, September, and December. What we want to know is what, in the ordinary Eurodollar market, the rates for

180-day, 270-day, and 360-day Eurodollars would have to be to match the prices implied by the futures market. Suppose we have: 90-day Eurodollar 14.40%; CME June Eurodollar 84.88 = 15.12%; September 84.96 = 15.04%; December 85.16 = 14.84%.

We take the cash Eurodollar rate and the June futures Eurodollar rates for 90 and 180 days, respectively. Putting them into the formula, we get:

$$\begin{aligned}
 R_2 &= \frac{360}{180} \times \left(\left[\left(0.1512 \times \frac{180 - 90}{360} \right) + 1 \right] \times \left(1 + \frac{0.1440 \times 90}{360} \right) \right) - 1 \\
 &= 2 \times \{ [(0.0378 + 1) \times (1 + 0.036)] - 1 \} \\
 &= 2 \times \{ 1.0751608 - 1 \} \\
 &= 0.1503216 \\
 &= 15.03\%
 \end{aligned}$$

A 180-day Eurodollar should fetch 15.03% to match the combined 90-day Eurodollar plus June futures contract. The next step is to work out a 270-day Eurodollar using the 180-day rate we have just calculated as the cash rate, *R*₁, in our formula. The result of combining the 15.03% “synthetic” 180-day Eurodollar with the 15.04% on the September futures contract comes out at 15.4%. We then take this “synthetic” 270-day rate and combine it with the December futures contract rate to produce a “synthetic” 360-day Eurodollar at 15.696%.

These successive steps have produced a strip yield curve that looks like this, compared with the actual (or cash market) yield curve:

	Strip Yield Curve	Cash Market Yield Curve
90-day “cash” Eurodollar	14.40%	14.40
Synthetic 180-day Eurodollar	15.03%	14.40
Synthetic 270-day Eurodollar	15.41%	14.30
Synthetic 360-day Eurodollar	15.696%	14.30

The strip yield curve calculated from these formulas sometimes differs from the implied forward rates in the cash markets because (1) the participants in the futures markets may not entirely share the view of participants in the cash markets, and (2) the two markets may be imperfectly linked. The

Eurodollar cash and futures markets are very tightly bound together, but there are times when they can move out of line, if only briefly; and in the cash markets, there are credit exposure considerations that do not affect futures trading.

FOREIGN EXCHANGE FUTURES

Foreign exchange futures are not so important in their own right as interest-rate futures contracts, because the liquid interbank forward foreign exchange market has always provided tough competition for the futures. But there is an important market for arbitraging between the futures and the forward markets, and so it is important to understand the mechanics.

We will take as an example the Chicago Mercantile Exchange contract for euro. This is for an amount of EUR 125,000, with contracts for March, June, September, and December. Delivery date is the third Wednesday of the contract month, and delivery is made by payment of euro against dollars paid by the buyer of the contract.

The operation of the market is very simple. Today is January 11, 2001. The March futures contract settles on the third Wednesday in March, which is March 17, 2001. The future is trading at \$1.0617. I know that in the interbank forward market the euro/dollar rate for that date is \$1.0612. I buy interbank forward EUR 1,250,000 and sell 10 futures contract to make a five-point profit.

Because this type of arbitrage is so easy, many banks specialize in “trading the futures dates.” Therefore, the futures market price is in practice fixed by the cash market price for that day, which is worked out in the usual manner (see Chapter 9).

There are two complications to this simplicity: The first is that traditionally U.S. foreign exchange quotations were reciprocal, that is, JPY 100 = US\$ 0.8264 rather than US\$ 1 = JPY 121. Thus in comparing with the normal interbank forward quotations, one has to invert the futures price.

The second complication applies when dealing crosses. It flows from the fact that the standard amounts of the contracts are expressed in the foreign currency. Thus the yen contract is for ¥12,500,000; the euro contract is for EUR 125,000. Unless the euro/yen cross is at 100, one of these two contracts will be “heavier” than the other. Suppose the actual euro/yen cross is EUR 1 = JPY 115. Then the yen contract is worth EUR 108,695.70, whereas the euro contract is worth EUR 125,000. Therefore in trading the crosses on

the futures market, one would need to weight the size of one's position. The weight is the current cross-rate as a proportion of the cross-rate implied by the contracts. In this case the number of yen contracts would be 115% of the number of euro contracts; for example, one might sell 230 yen contracts and buy 200 euro ones.

The specifications of the CME's new euro contracts are:

Ticker Symbol	E C
Trading Unit (Underlying)	Euro 125,000
Quotation	US\$ per euro
Minimum Price Fluctuation (Tick)	\$0.0001/euro = \$12.50/contract
Contract Months	March, June, September, December
Regular Trading Hours (RTH)	7:20 A.M.–2:00 P.M. (Chicago, or Central, time)
GLOBEX 2 Trading Hours	2:30 P.M.–7:05 A.M. (Chicago, or Central, time) (On Sundays, trading begins at 5:30 P.M.)
Last Trading Day	Second business day before the third Wednesday of the contract month

The CME has also introduced cross-currency contracts for the euro, whose specifications are as follows:

Euro FX Cross-Currency Contract Highlights

	Euro/British Pound	Euro/Japanese Yen	Euro/Swiss Franc
Ticker symbol	RP	RY	RF
Trading unit (underlying)	125,000 euro	125,000 euro	125,000 euro
Quotation	British pounds per euro	Japanese yen per euro	Swiss francs per euro
Minimum price Fluctuation (Tick)	0.00005	0.01	0.0001
Contract months	Six months in the	March-June-September-December	quarterly cycle

(continued)

Euro FX Cross-Currency Contract Highlights (continued)

	Euro/British Pound	Euro/Japanese Yen	Euro/Swiss Franc
GLOBEX 2 trading hours (Chicago time)	Sundays and holidays: 5:30 P.M.–2:00 P.M. of the next business day		
	Monday–Thursday: 2:30 P.M.–2:00 P.M. of the next business day		
Last trading day	Second business day before the third Wednesday of the contract month		

HEDGING

To *hedge* is to reduce risk. When an investor faces the risk of a change in interest or exchange rates that he or she does not want to bear, the investor may use financial futures to offset the risk: If the risk is of a fall in interest rates, the investor buys futures. If the risk is of a rise, he or she sells futures. To be precise, one may say that in such circumstances, a hedger transfers risk by temporarily offsetting a position in a cash market with a related position in a futures market.

Let's look first at a short hedge. Suppose that a company has agreed to borrow Eurodollars on a three-month rollover basis. It fears that interest rates are about to rise. It wants to lock in current interest-rate levels on its borrowings. It will then sell Eurodollar futures contracts to the amount required. This is a "short" hedge. The mechanics are as follows:

Suppose today is March 14, 2002. Three-month Eurodollar LIBOR is 8%. Three-month Eurodollar futures for delivery June 16 are 92 (8%), but the firm fears that by June, three-month LIBOR on its \$10 million borrowing could be 10%. That would mean that the spot contract in June would be 90. So the firm sells 10 June contracts at 92. If its fears are correct and the June contracts do go to 90, it buys back the contracts on June 14 (last trading day for the contract) at 90 and makes a profit of 2.00 per contract, that is, 200 basis points. Each basis point on a \$1 million contract is worth \$25, so its profit is $\$25 \times 200 \times 10$, or \$50,000.

The company now borrows for three months (say, 90 days) at 10%, costing: $10/100 \times 10 \text{ million} \times 90/360$, or \$250,000. From this can be deducted the profit on the futures (\$50,000), making a total cost of \$200,000, producing

an effective rate of 8%, which the borrower has locked in today for three months hence. In other words, it has locked in today's futures rate for its borrowing.

What would have happened if the interest rate had gone the other way, say, to 6%? Then the euro contracts would have traded at around 94. Closing them out would have cost 2.00 per contract, so the loss would be \$50,000. The cost of the cash borrowing would then be $6/100 \times 10 \text{ million} \times 90/360$, or \$150,000, and the all-in cost would again be \$200,000. In other words, the cost is insensitive to interest-rate movements.

What we have just said is broadly true. But the hedge will not actually be perfect for two reasons: First, there would be an impact from changes in the pattern of variation margin during the interval to the futures delivery date. In practice, we are hedging a future cash flow with an instrument where profits and losses hit our books today. A related point is whether one should hedge not the nominal amount of the borrowing, but today's present value of that amount. This is often referred to as "tailing the hedge" and is customary if the deal is large.

Second, there will be basis risk—the futures market may not move exactly in line with the cash market. Particularly if rates turn out to be fairly stable, there can be a bigger profit and loss impact from basis risk than from interest-rate movements.

FUTURES AND FRAs

Eurodollar futures are closely linked to the market for FRAs (see Chapter 7) and, because FRAs are a kind of single-period swap, to the interest-rate swap market. Suppose today is March 13, 2002, and the three- and six-month Eurodollar deposits, value March 15, are trading at 8.25% and 8.5%, respectively. Suppose the days in each period are 90 and 180, respectively. We know from our forward-forward formula (see Chapter 7) that the FRA rate should be $\{(8.5 \times 180) - (8.25 \times 90)\} / \{(180 - 90) \times [1 + \{8.25 \times 90/36,000\}]\}$ = $(1,530 - 742.50) / (90 \times 1.020625)$ = $787.5/91.85625$ = 8.57%.

That would imply a futures price for June (the price for a 90-day Eurodollar deposit running from June 15 to September 15) of 91.43. Suppose in fact that the future were trading at 91.25, implying a forward rate of 8.75. Then

it would be possible to buy the future (hedging against a fall in rates) and also to buy the FRA (hedging against a rise in rates). The future would lock in a lending rate of 8.75% and the FRA would lock in a borrowing rate of 8.57% for a spread of 18 basis points.

In other words, if the FRA rate is below the rate given by the future, buy the future and buy the FRA. Conversely, if the FRA rate is above the future, sell the FRA and sell the future.

The hedge will not be quite so perfect as it looks because of the time value of money on the variation margin. Consider a company with a \$10 million floating-rate loan linked to six-month LIBOR. It fears rates will rise, and so buys a 6 × 12 FRA from its bank. Suppose we have the conditions: value March 19, 2001, then we have:

LIBOR		Future	
3 months	8.50%	June	91.28
6 months	8.70%	September	91.17
9 months	8.88%	December	91.02
1 year	9.05%		

For convenience we take the year as having 360 days and six months as having 180. Thus the forward rate is $[(9.05 \times 360) - (8.7 \times 180)] / \{180 \times [1 + (8.7 \times 180/36000)]\}$, or 9.01%. Suppose the bank loads its quote to 9.10%. Having done the deal, it wants to hedge using the futures market. It sells 10 September contracts (at an implied rate of 8.83%) and 10 December contracts at an implied rate of 8.98%.

We work out the implied total cost over the six-month period that is locked in by the futures contracts. We do this by compounding the near contract (at 8.83%) up over the second period at the second rate of 8.98%: $[1 + (8.83 \times 90/36,000)] \times [1 + (8.98 \times 90/36,000)] = 1.022075 \times 1.02245 = 1.045020584$, or 4.502% per six months, which equates to just over 9% annually.

It looks as if the bank has locked a 10-basis-point profit over six months on \$10 million—say, \$5,000. But now suppose that the day after the deal is done, cash Eurodollar rates fall 1% and stay fixed at that level until the September futures date. We would have the following rates:

LIBOR		Future	
3 months	7.50%		
6 months	7.70%	September	92.07
9 months	7.88%	December	91.92
1 year	8.05%		

Suppose the September futures contract we sold has risen by 90 ticks, and the December has risen by 90 ticks. Bearing in mind that the tick on this contract is worth \$25 and that we did 10 contracts in each maturity, our loss totals $2 \times 10 \times 90 \times 25$, or \$45,000. Because we have assumed that rates now remain rigidly fixed to the September delivery date, there are no further changes in our position and no variation margin movements; we have to fund this loss till delivery date. Say we do this at the six-month rate of 7.7%; then our funding cost is \$1,732.50 (\$45,000 at 7.7% for half a year)—one-third of our apparent profit disappears.

The problem is that the value of a future settlement amount under the FRA is being hedged with an instrument that throws up changes in value today. One way around this would be to hedge not the settlement amount but the present value of the settlement amount (i.e., we would “tail the hedge”). With the passage of time, that present value rises, so that we would gradually increase the size of the hedge as we get closer to the settlement date, if we want to be perfectly hedged. (But by that time, we might be more confident about the trend in rates and happy to leave the balance of the position open.)

OPEN INTEREST AND VOLUME

Any trader in the futures markets needs to know the liquidity and the depth of the markets. The two most general measurements of liquidity and depth for any futures market are (1) *trading volume*, the number of contracts traded during a period of time; and (2) *open interest*, the number of open contract units at a point in time.

Futures trading volume is reported as one side only. In other words, a daily volume of 12,000 means 12,000 contracts bought and 12,000 contracts sold. Buys and sells are not added together. The number of contracts bought always equals the number sold because there must be a buyer for every seller.

A large volume of trading is a good indication of a liquid market. Liquidity can be gauged by the ability of market participants to execute commercial-size orders quickly at a price close to the price of the last transaction.

Open interest is the number of contracts recorded with the exchange at the close of business each day as transactions that have not been either offset by an opposite trade or settled by delivery. Open interest, like trading volume, counts one side only—an open interest of 5,000 is 5,000 bought positions and 5,000 sold positions. A relatively large open interest tends to indicate commercial hedging, because hedgers are more likely than speculators to hold positions as prices fluctuate.

Both volume and open interest are frequently watched as technical indicators of the state of the market. For example, a gradual increase in volume during a downtrend often indicates a continuation and an acceleration of the price decline. Gradually increasing volume during an uptrend suggests a further rise in prices. Equally, a rising price trend with a gradual increase in open interest means that new long hedgers or speculators are entering the market. They are paying higher prices to persuade new short hedgers or speculators to sell. If this process continues for several days, the new long speculators will be accumulating profits and additional buying power (because they have extra margin). The new speculative sellers will have losses and will be feeling financial pressure (because they have to put up extra margin). Such a market is technically strong, particularly if volume is increasing along with open interest.

16 The Swap Market

We need to be clear about what we mean by *swaps* in this chapter. This chapter covers interest-rate and currency swaps, but not traditional forward foreign exchange swaps. These were covered in Chapter 11.

In this context, we can use a general definition: *A swap is a contract to exchange a series of cash flows that are calculated by reference either to a rate fixed in advance or to some known price or index.*

Thus, I could swap a fixed rate of 6% on \$100 million against the right to receive six-month LIBOR (London Interbank Offered Rate) on the same amount; or 7% on EUR 200 million versus 4% on the equivalent amount of Japanese yen.

Swaps, as just defined, took off during the 1980s. From perhaps \$2 billion in notional value outstanding in 1980, the interest-rate and currency swap market has now grown to the point where an estimated \$20 trillion (i.e., \$20,000 billion) of contracts are now outstanding. This represents an 84% per annum compound-growth rate over 15 years, and it makes the swap market the fastest-growing of any financial markets in recent years. The first swaps to emerge were currency swaps, which began in the mid-1960s. But the market remained a fairly small one during the 1970s. The emergence of the interest-rate swap, in 1980 and 1981, together with the decision by the World Bank to start an ambitious currency swap program, transformed the situation.

The market now has a huge range of counterparties, using swaps for a range of different reasons. Banks use swaps for asset and liability management. Companies and government bodies use them for similar purposes and also to raise finance through the bond market, notably the Eurobond market,

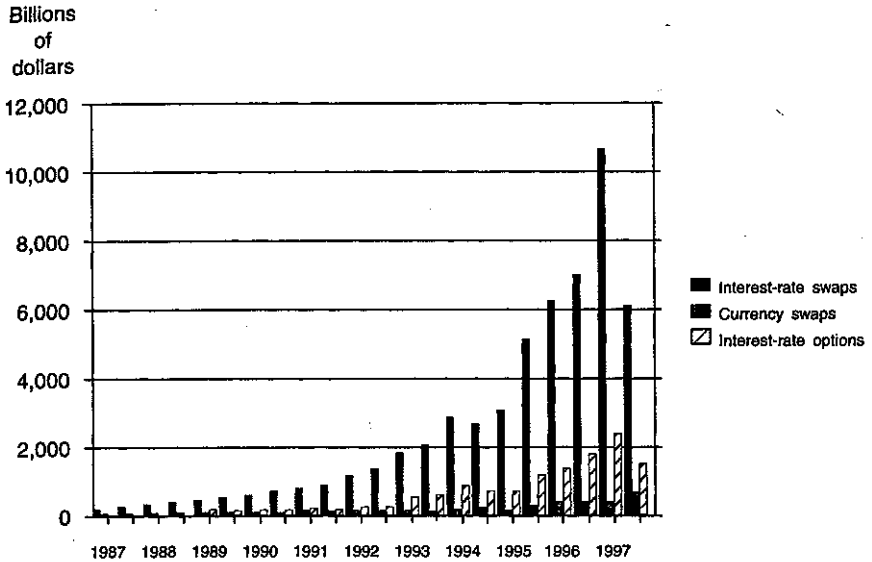


Figure 16.1 Swap Market Growth Rate 1987-1997. Source: ISDA.

at rates that are better than those their bankers can offer. This flexibility has underpinned the huge growth in the market.

Figure 16.1 illustrates the relative growth of interest-rate swaps, currency swaps, and interest-rate options (which are discussed in the next two chapters). It shows clearly that although the currency swap market started before that for interest-rate options, it has been overtaken by the latter.¹ The primary reason for this is the impact on banks' capital adequacy ratios of the currency swap structure: it involves (normally) a re-exchange of principal at maturity. This is discussed further in the section on currency swaps below.

Swaps have had a great impact on bond markets. Earlier issuers of new bonds were relatively tied down. If they issued, say, a deutschemark bond, the extent to which they could hedge the long-term exchange risk of the bond was rather limited. The growth of the currency swap market meant

¹The ISDA statistics do not, of course, signal the start of the interest-rate options market, but rather the point at which the ISDA Board felt that it was worth gathering the statistics. On the other hand, the general point remains true: interest-rate options markets are much larger and have grown faster than the currency swap market.

that for the first time, issuers could tap the currency market in which they could raise the cheapest funds. A company such as Toyota could issue a bond denominated in New Zealand dollars and then do a currency swap to transform its liability into yen. Equally, the growth of the interest-rate swap market meant a similar liberation in the choice between fixed and floating rate bonds.

Once the swap technique had been invented, of course, people found many other ways of using it. Interest-rate swaps have been used to switch from floating rate to fixed, from fixed to floating, from fixed-rate to zero-coupon, from zero-coupon to floating, from zero-coupon to semiannual fixed, and so on. Essentially, the combination of interest-rate and currency swaps now means that any stream of cash flows can be transformed into virtually any other stream: annual ISMA (International Securities Market Association) basis Japanese yen payments can be transformed into quarterly U.S. dollar, amortizing lease-type payments, if desired, at a price. Swaps have been applied to a range of other markets including equities, commodities, and even market volatility.

Despite early worries about the credit risk implied in swaps, an International Swaps Dealers Association (ISDA) survey in the early 1990s showed total write-offs of US\$ 33 million on portfolios aggregating over \$250 billion, a default rate of 0.01%—considerably better than traditional banking default rates. (However, a U.K. government veto on swap payments due from the London borough of Hammersmith and Fulham caused problems. Partly for political reasons, the municipality had used swaps and options to generate revenue from speculative transactions. The legal ability of the municipality to undertake such activity was later overturned by the House of Lords on the grounds that they were outside the legal framework governing municipalities. This then overturned swaps with a number of other municipalities.)

INTEREST-RATE SWAPS

The cash flows of an interest-rate swap are illustrated in Figure 16.2, showing an exchange of a fixed rate of interest (the unshaded blocks all of the same size) against a floating rate (the shaded squiggles). In this example the swap is a two-year swap with semiannual payments of interest. (Although, for purposes of exposition, the payments are shown in the diagram as being made

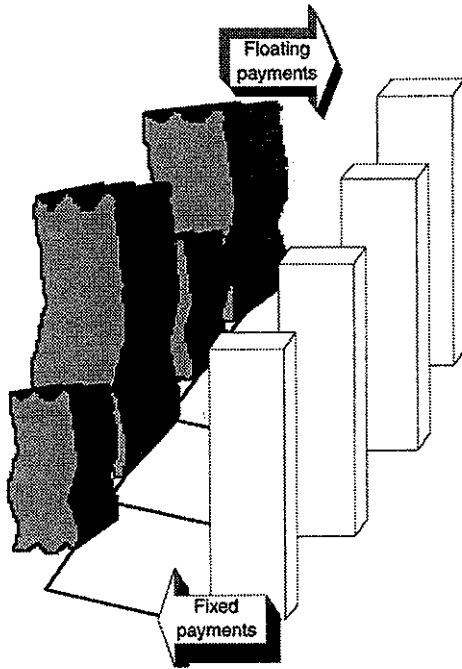


Figure 16.2 Two-year Swap with Semiannual Payments of Fixed Against Floating LIBOR

in full, market practice would normally be to net the two amounts into a single sum, positive or negative.)

As Figure 16.2 shows, in the swap there is no actual borrowing or lending. It is purely a contract to exchange interest flows. An example may help.

Suppose it is December 1, 2002, and you are the corporate treasurer of XYZ Ltd. You have borrowed floating-rate money from a syndicate of banks for five years at six-month US\$ LIBOR + $\frac{1}{2}\%$. The amount borrowed is \$10 million. Your company does not have the financial strength to access the public bond markets, so it is hard for you to raise five-year money at a fixed rate. However, you fear that interest rates will rise. You decide to enter into a swap with a bank to fix for five years the cost of your interest-rate liabilities, which would otherwise rise as LIBOR rises.

Suppose the bank quotes you a fixed rate of 9.5% against six-month LIBOR, payable semiannually on a 30/360 basis (i.e., assuming 12 months of 30 days—as is common in the U.S. corporate bond market and the Eurobond

market). Payment on both sides is in arrears. Then you are committed to the cash flows shown in Table 16.1.

On the other side will be the floating-rate income. The bank pays you six-month LIBOR. Consider two outcomes: (1) LIBOR rises by $\frac{1}{4}\%$ every six months over the period from a starting level of 8%, and (2) LIBOR falls by $\frac{1}{4}\%$. Let us assume for simplicity that the LIBOR is paid also on a 30/360 basis—normally it is actual/360 for U.S. dollar swaps. Table 16.2 shows the results.

The payments by the bank to you will exactly match your LIBOR payments to your banking syndicate, except for the latter's $\frac{1}{2}\%$ margin. So the LIBOR

Table 16.1 Interest Rate Swap Cash Flows

June 1, 2003	\$475,000
December 1, 2003	475,000
June 1, 2004	475,000
December 1, 2004	475,000
June 1, 2005	475,000
December 1, 2005	475,000
June 1, 2006	475,000
December 1, 2006	475,000
June 1, 2007	475,000
December 1, 2007	475,000

Table 16.2 Swap Cash Flows If Rates Rise/Fall

	Fixed Payment	Income	
		Case I LIBOR Rises	Case II LIBOR Falls
June 1, 2003	\$475,000	\$400,000	\$400,000
December 1, 2003	475,000	412,500	387,500
June 1, 2004	475,000	425,000	375,000
December 1, 2004	475,000	437,500	362,500
June 1, 2005	475,000	450,000	350,000
December 1, 2005	475,000	462,500	337,500
June 1, 2006	475,000	475,000	325,000
December 1, 2006	475,000	487,500	312,500
June 1, 2007	475,000	500,000	300,000
December 1, 2007	475,000	512,500	287,500

payments always net to zero, and your cost is fixed at the $9\frac{1}{2}\%$ swap rate plus the $\frac{1}{2}\%$ syndicate margin, for an all-in cost of 10% .

Origins of Interest-Rate Swaps

The origins of the interest-rate swap technique were in the Eurobond market where fixed-rate issuers wished to raise floating-rate money. A typical example in the early days would be a Japanese bank. Because most banks typically lend money on a floating-rate basis, Japanese banks were not in the habit of issuing fixed-rate Eurobonds. They did not need fixed-rate funds. Therefore, their paper was relatively scarce in the fixed-rate bond market and commanded attractive premiums. Thus, they were able to issue cheaply and then to swap into floating-rate funds.

An example would be as follows: A strong borrower, AAA, would pay LIBOR + $\frac{1}{8}\%$ for a seven-year revolving credit from its banks, if it chose to arrange one. For a seven-year bond issue, it would pay 11% . Conversely, a weaker borrower, BBB, must pay 12% for a seven-year bond issue, or LIBOR + $\frac{1}{2}\%$, for seven-year money from its bank.

The difference between the two borrowers in the bank credit market is only $\frac{3}{8}\%$. But in the bond market, it is 1% : a "credit differential" of $\frac{5}{8}\%$. The first swaps used this differential to arbitrage. AAA issued a bond and entered into a swap with BBB at, let us assume, 11.25% . Both borrowers were able to save money: here, the $\frac{5}{8}\%$ is split as $\frac{3}{8}\%$ for AAA and $\frac{1}{4}\%$ for BBB.

There has been a tendency in the academic literature to explain swaps in terms of relative comparative advantage. Although this explains why the technique was created, I think it is better to think of the interest-rate swap market as an arena where we trade LIBOR for forward delivery. Just as there is a market for the forward delivery of euro against U.S. dollars, so there is a market for the forward sale or purchase of LIBOR or EURIBOR (Euro Interbank Offered Rate). A firm doing a swap where it pays 5% per annum on \$100 million against six-month US\$ LIBOR for five years is contracting to buy forward deliveries of six-month US\$ LIBOR on \$100 million. We can say that 5% per annum is the price of forward deliveries of US\$ six-month LIBOR for five years.

Hence, the interest-rate swap market has become an arena for transferring interest-rate risk, which sits alongside the interest-rate futures market and

Table 16.3 Swap Quotes

Treasury (T)	Swap Spread	Swap Cost
2-year 7.64	T + 47/54	8.11/18
3-year 7.75	T + 65/70	8.40/45
4-year 7.78	T + 68/76	8.46/54
5-year 7.90	T + 70/78	8.60/68

the FRA market. In all these markets, those who anticipate rising rates trade with those who either expect a fall in rates or else have a requirement to switch their exposure to a floating-rate basis (e.g., banks which have borrowed fixed-rate funds which they now plan to lend on a floating-rate basis).

Quoting an Interest-Rate Swap

Suppose today is March 3, 2001. You are pricing a swap for your company that is interested in swapping out of six-month US\$ LIBOR and paying a fixed U.S. dollar rate. On consulting a Reuters swap screen, you see the following.

To use this data, one needs to know that swap rates are priced off the corresponding U.S. Treasury bond. Thus, if the company were to pay fixed for two years, the swap cost would be the two-year Treasury rate, 7.64%, plus the swap spread of 54 basis points. The all-in total would thus be 8.18%, plus the credit spread (if any) being charged by the intermediary bank for providing the swap. If the company wanted to deal in the opposite direction—receive a fixed rate—the spread would be 47 basis points for an all-in cost of 8.11%, which is what it would be paid by the market, less any credit spread charged by the bank.

It is important to be aware that the rate is quoted on a “Treasury bond basis,” that is, a semi-annual actual/365 rate. To convert this to a 360-day rate, we multiply by 360/365 to convert 8.18% to 8.07% (note the 11-basis-point difference). To convert this to an annual rate (to make it comparable to, say, a Eurodollar money market rate), we need to use the formula:

$$r = (1 + i/n)^n - 1$$

where r = annual rate as a decimal; i = semi-annual rate as a decimal; and n = number of periods per annum (2, in this case).

So this case we have

$$r = [1 + (0.0807/2)]^2 - 1, \text{ or } 8.23\%$$

In summary, to convert a Treasury bond rate to an annual money market rate: (1) Multiply by 360/365, reducing the nominal rate (by 11 points in this case) and (2) compound up to annual, raising the nominal rate (by 16 points in this case). If the company borrows on a Eurodollar money market basis but is charged interest semiannually rather than annually, then the current swap rate for comparison purposes would be 8.07%.

The Pricing of Interest-Rate Swaps (IRS)

There are a number of practical issues to be looked at in swap pricing, but it may help to start with a simple framework. Suppose we are pricing a three-year swap. For simplicity, suppose that it is priced against annual LIBOR and that we have the annual rates shown in Table 16.4.

We know that a rational way to price the three-year swap is to proceed as follows: The three-year-swap rate must equal the "present value" average of the forward rates; that is, the rate will be set so that the present value of the fixed cash flows on the swap equals the present value of the cash flows of the forward rates. If this were not so, it would be possible to set up a series of long-dated forward-rate agreements whose value would be greater than or less than the swap's value. So we could create an arbitrage, at least in theory. In practice, this would depend on the availability of such agreements in the market.

Table 16.4 Cash, Zero-Coupon, and Forward Rates

Year	Cash Market Rate	Zero-Coupon Rate	Forward Rate
1	5.0	5.0	5.0
2	6.0	6.0302987	7.0707071
3	7.0	7.0969352	9.2625064

We can put this another way. The present value average is that rate that would make the present value of sums placed at the forward rate (discounted at the zero-coupon rate for the given final maturity) equal to the present value of sums produced by the swap.

We have a situation in which the present value of sums placed at the forward amount is (assuming principal amount of \$100):

$$\frac{5\%}{(1.05)^1} + \frac{7.0707\%}{(1.060303)^2} + \frac{9.2625\%}{(1.07069)^3}$$

And we want to find the swap rate such that the preceding sum is equal to:

$$\frac{\text{Swap rate}}{(1.050)^1} + \frac{\text{Swap rate}}{(1.060303)^2} + \frac{\text{Swap rate}}{(1.07069)^3}$$

It turns out that in this case the applicable rate is 7%, the same as the cash rate for year 3. This seems a trivial result for all that hard work; but this is because in our example we used (1) equal principal amounts in each period and (2) a spot (i.e., nondeferred) start for the swap. But this simple method can be applied where one or both of these conditions does not apply, which makes it much more interesting and useful; and we now turn to these.

IRS Variants

Amortizing Swaps

Suppose we want to price a three-year *amortizing swap*, where the principal amount outstanding on the swap in year 1 is \$100 million; in year 2, \$75 million; and in year 3, \$50 million. We proceed exactly as in the previous discussion, except that each term is weighted according to the amount involved. The present value of the forward flows is:

$$\frac{100 \times 5\%}{(1.05)^1} + \frac{75 \times 7.0707\%}{(1.060303)^2} + \frac{50 \times 9.2625\%}{(1.07069)^3}$$

And we want to find the swap rate such that the preceding sum is equal to:

$$\frac{100 \times \text{Swap rate}}{(1.050)^1} + \frac{75 \times \text{Swap rate}}{(1.060303)^2} + \frac{50 \times \text{Swap rate}}{(1.07069)^3}$$

The answer comes out to be 6.5378%. It is lower than the previous result because the higher amounts of principal in the early years when rates are lower have pulled down the result.

Deferred-Start (Forward) Swap

Applying the same technique to a *deferred-start swap* is equally simple: we just set the outstanding principal amount to zero for each year until the swap starts. Suppose we have the same conditions as before, but now we want to quote a two-year swap for \$100 million starting one year from now. We simply plug in principal amounts of 0, 100, and 100, as we did with 100, 75, and 50 before. Once again we have the value of the forward flows as:

$$\frac{0 \times 5\%}{(1.05)^1} + \frac{100 \times 7.0707\%}{(1.060303)^2} + \frac{100 \times 9.2625\%}{(1.07069)^3}$$

And we want to find the swap rate such that the sum is equal to:

$$\frac{0 \times \text{Swap rate}}{(1.050)^1} + \frac{100 \times \text{Swap rate}}{(1.060303)^2} + \frac{100 \times \text{Swap rate}}{(1.07069)^3}$$

In this case the answer turns out to be 8.1181%—by delaying the swap until the higher rates start to apply, we have pulled up the average.

Obviously, this technique could also be applied to an amortizing swap with a forward start date—one simply sets to zero the principal amounts until the start date of the amortizing swap. Similarly, it can be applied to an accreting swap—one whose principal value grows over the time (i.e., the reverse of an amortizing swap). It can also be applied to a so-called “roller-coaster” swap (one whose principal value rises and falls).

Forward swaps have had a wide range of uses. They allow hedging of exposures that have not yet begun. Sometimes they can be used to achieve arbitrage: for example, there was a period when U.S. municipalities could achieve attractive funding by entering forward-start swaps to lock up attractive rate levels because the municipal bond curve was very cheap to the Treasury curve, whereas the swap curve was unaffected.

Overnight Rate Swaps

Overnight index swaps began to develop in 1995. Such swaps are normally against a published index of a daily benchmark funding rate, paid on a compounded basis. The attraction is the ability to switch a longer-term rate to an overnight rate, thereby allowing a match against, for example, repo positions. By early 1996, the daily average turnover in the French market, the first to develop, was around FRF100 billion. With the arrival of the euro, the European Central Bank undertook to provide a calculation of the euro overnight interbank average rate, EONIA.

The sterling market began in March 1997. The market uses as its overnight rate reference the sterling overnight interbank average, SONIA. SONIA is the daily weighted average of all overnight interbank deposits of more than £5 million made before 3 P.M. through the Wholesale Market Brokers Association—about 70% of the market.

Swaps against overnight rates have developed in a number of other markets. In Brazil, for example, there is a market in floating DI (the overnight rate published daily by the central clearing house, CETIP). This swap, floating DI versus fixed euro dollars, would typically work as follows: party A would pay party B a previously negotiated fixed rate (e.g., 66% per annum) while party B would pay party A a floating amount that is linked to the DI rate at the maturity date. The term is normally short—30, 60, or 90 days—and there is only a single payment at maturity. Unusually, market convention is that the fixed side of the swap is calculated with daily compounding.² During the first half of 1995, approximately \$80 billion worth of such swaps were traded through the Brazilian Bolsa de Mercadorios & Futuros (BM&F). These swaps are cleared through CETIP. Even larger quantities of swaps are registered direct with CETIP: a recent report stated that \$4 billion of swaps were being registered each day direct, compared with \$1.2 billion at the futures exchange.

Basis Swaps

In contrast to simple fixed-rate to floating-rate swaps, *basis swaps* involve two floating rates, for instance, U.S. dollar LIBOR and the U.S. Treasury bill rate. A borrower such as the World Bank wishing to raise money against a borrowing target measured against U.S. Treasury bills might do a Eurobond

²Discussed in detail by H. Shefi, in *Risk*, Latin American Supplement (December 1996).

issue that is swapped by the bank leading the issue into LIBOR. That bank might have quoted a swap rate into Treasury bills that the World Bank felt was uncompetitive. The World Bank might prefer to take the swap into LIBOR and arrange a separate swap into the Treasury bill rate. The structure would then look as shown in Figure 16.3.

LIBOR in Arrears

At certain times, depending on the shape of the short-term yield curve, a swap may be done in which LIBOR is fixed in arrears, that is, a swap in which the floating rate is set at the end of the interest-rate accrual period rather than at the beginning, as would normally be the case. End users who believe that short-term rates will not rise as much as forward rates predict might seek to receive a fixed rate while paying LIBOR in arrears. (It is equally likely and perhaps more common that one might do a basis swap of conventional LIBOR versus LIBOR-in-arrears.)

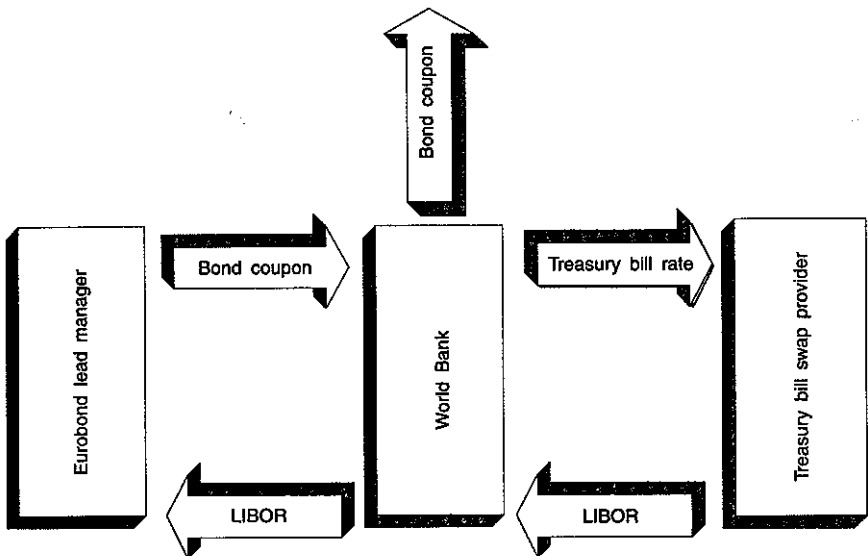


Figure 16.3 Treasury Bill/LIBOR Basis Swap

Table 16.5 Arrears Reset Data

Year	Cash Market Rate	Zero-Coupon Rate	Implied Forward Rate
0.5	3.5	3.5	
1.0	3.875	3.9162	4.3342
1.5	4.375	4.4364	5.4845
2.0	4.75	4.8306	6.0222
2.5	5.25	5.3672	7.5412
3.0	5.5	5.6349	6.9836

Suppose we have the situation in Table 16.5.

In this situation the payer of the three-year fixed rate stands potentially to benefit from an arrears reset swap. Instead of receiving the initial LIBOR of 3.5%, the payer expects to receive 4.3342%. This is the current market expectation for six-month LIBOR six months from now, as implied by the forward rate. The payer expects to receive in the final period 6.9836%. A crude estimate of the benefit from the arrears reset structure is, therefore, $6.9836 - 3.5$, or 3.4836%. This would be spread out over the life of the swap and built into the price. (In practice we would work out the two sets of cash flows implied by the swaps and discount the difference using the appropriate zero-coupon rates. Also we would need to allow for the fact that if the swap were long-term, the arrears structure has more convexity than the conventional structure; it has been shown³ that on a 10-year swap the adjustment might be of the order of 2 to 3 basis points.)

CURRENCY SWAPS

The *currency swap* market is thought to have begun in the United Kingdom during the 1960s. The reason was the existence at that time of U.K. exchange controls that prevented U.K. firms wishing to invest abroad from simply selling sterling to buy foreign currency. The Bank of England wanted to prevent outflows of sterling and so required British firms to borrow overseas

³A. Li and V.R. Raghavan, "LIBOR-in-Arrears Swaps," *Journal of Derivatives* (Spring 1996).

to finance overseas investments. This had a drawback: their overseas subsidiaries were often quite weak credits compared with the U.K. parent. Yet the U.K. parent often could not guarantee the overseas subsidiary because of exchange controls. So bankers came up with the idea of a swap between the U.K. parent and an overseas counterparty. The use of the swap meant that the Bank of England could be sure that an outflow of sterling today would be offset by an inflow at a later date when the swap unwound.

It may be helpful to start with a brief outline of how a currency swap works. Suppose that ICI needs U.S. dollars for its operations in the United States and DuPont needs sterling for its U.K. operations. A solution to their need is for ICI to sell its sterling to DuPont for dollars. To cut out the risk of exchange-rate movements, they contract to reverse the deal in, say, five years. Say ICI sells £10 million to DuPont in exchange for \$18 million.

Effectively, ICI is lending sterling to DuPont, who is lending dollars to ICI. (Though the legal structure does not involve any assets on the balance sheet and the deal is not documented as a loan, it is an exchange of currencies.) So during the life of the deal, ICI pays the rate for five-year dollar loans, say 7%, and DuPont pays the rate for five-year sterling loans, say 9%. At the end of the deal, ICI and DuPont re-exchange. (In some countries, such as the United Kingdom, it is desirable to interpose a bank between the two parties because tax law would otherwise require the interest payments to be made net of tax. Interposing a bank also has the advantage of insulating the two parties from the credit risk of the other.)

The cash flows are set out in Table 16.6 from ICI's point of view, assuming that ICI borrowed the £10 million to lend to DuPont, also at 9%. At the start of the deal, there is an inflow of £10 million from the original funding. This is paid across to DuPont at the start of the swap. In exchange, there

Table 16.6 Currency Swap Cash-Flows (in millions of dollars and pounds)

	Swap	Cash Flows		Net
	\$	£	Original	
Year 0	\$18	(£10)	£10	\$18
Year 1	(\$1.3)	£0.9	(£0.9)	(\$1.3)
Year 2	(\$1.3)	£0.9	(£0.9)	(\$1.3)
Year 3	(\$1.3)	£0.9	(£0.9)	(\$1.3)
Year 4	(\$1.3)	£0.9	(£0.9)	(\$1.3)
Year 5	(\$19.3)	£10.9	(£10.9)	(\$19.3)

is an inflow of \$18 million from DuPont. The net effect is an inflow of \$18 million.

For each of the next five years, ICI pays its lending bankers £0.9 million in interest on the original funding and receives a corresponding payment from DuPont of £0.9 million, while paying out \$1.3 million to DuPont. (Where practical, these payments are netted off.) The last payment includes redemption of the principal amounts. The net result is that a sterling stream of cash flows is transformed into a dollar stream.

Let us look at an issuer who wants to raise five-year money in U.S. dollars. Suppose the issuer's advisers tell it that the cheapest course would be to raise five-year yen (JPY), and swap them into U.S. dollars. How will this work?

Suppose that the rate (ignoring fees) for five-year JPY Eurobonds is 7% and that the bond is issued at par for JPY 2 billion. Suppose today's spot U.S. dollars/deutschemark rate is \$1 = JPY 100. Suppose that an American company wants five-year JPY financing at a rate of 8%, in exchange for being paid 10% on the U.S. dollar equivalent financing it will provide. We assume that the deal can be structured so that all interim flows, and the principal being re-exchanged at maturity, can be exchanged at a rate of \$1 = JPY 100.

Here the issuer's bond cost is 7%; but the issuer earns 8% on the swap, so there is a net additional 1% saving, making a total dollar cost of 9% per annum. What has happened is that the issuer, perhaps because it is a better-known credit in the Euromarket, is able to raise five-year money cheaper than its swap counterpart: in exchange for passing on the cheap JPY, it is able to borrow cheap dollars.

Notice that the final cash flow includes exchange of principal amounts, unlike the interest-rate swap deal; thus, the credit exposure on a currency swap will usually be much larger than under an interest-rate swap. (In fact, in a currency swap, it is theoretically possible to lose more than 100% of the principal amount.)

The IBM/World Bank Swap

A more detailed real-life example may be of interest: In 1981, IBM and the World Bank entered into a currency swap. The World Bank, which had issued comparatively little U.S. dollar paper, could raise funds at an attractive

rate in the U.S. market. It wanted Euro-Swiss francs (CHF) and deutschemarks, but it had issued a lot of bonds in Switzerland and Germany. IBM wanted to crystallize its foreign exchange gains on some existing Swiss francs and deutschemark bonds outstanding. The solution benefiting both was for the World Bank to issue a U.S. dollar bond and swap the proceeds with IBM. Details of the transaction have never been published in full; the following outline draws on D. R. Bock's description.⁴

The bond issue was launched on August 11, 1981, settling August 25, which became the settlement date for the swap. The first annual exchange under the swap, however, was to be on March 30, the next coupon date on IBM's bonds—215 days (rather than 360 days) from the start date.

The first step was to calculate the value of the Euro-Swiss franc and deutschemark flows that were, say, at 8% and 11% per annum, respectively. The initial 215-day period meant that the discount factors were $215/360 = 0.597222$, 1.597222 , 2.597222 , and so on. Applying the Swiss franc rate of 8%, then, the discount factors were $1/(1.08)^{0.597222} = 0.95507746$, $1/(1.08)^{1.597222} = 0.88433099$, and so forth.

Agreement to the final terms of the swap was made on August 11, two weeks before the settlement date. So, using two-week forward foreign exchange contracts, the World Bank bought the Swiss franc and deutschemark net present value (NPV) amounts worked out earlier. Supposing that these contracts were at CHF 2.18 and DEM 2.56 per US\$ 1, the dollar amounts needed by the World Bank were \$87,783,247 to buy the Swiss francs and \$117,701,753 for the deutschemarks, totalling \$205,485,000.

It was then necessary to work out the dollar amount of the bond to be issued. Supposing the issue to be at a coupon of 16% with fees of 2.15% (i.e., net proceeds of 97.85%), the dollar amount of the bond issue had to be $\$205,485,000/0.9785$, or \$210,000,000. The final results of the deal are shown in Table 16.7.

Cross-Currency Basis Swap Without Re-Exchange at Maturity

Suppose companies ABC and XYZ enter a cross-currency floating-rate (basis) swap, trading deutschemark LIBOR for dollar LIBOR for three

⁴B. Antl, ed., *Swap Finance* (London: Euromoney Publications, 1986), pp. 281–223.

Table 16.7 IBM/World Bank Swap Cash Flows

Exchange Date	CHF Flows	CHF	DEM Flows	DEM
		Discount Factor		Discount Factor
3/30/82	12,375,000	0.95507746	30,000,000	0.93957644
3/30/83	12,375,000	0.88433099	30,000,000	0.84646526
3/30/84	12,375,000	0.81882499	30,000,000	0.76258132
3/30/85	12,375,000	0.75818128	30,000,000	0.68701020
3/30/86	212,375,000	0.70201045	330,000,000	0.61892811
NPV	CHF 191,367,478		DEM 301,315,273	

years. The normal method is as follows: Suppose that the spot rate today is US\$ 1 = DEM 1.65 and that the three-year outright forward rate is US\$ 1 = DEM 1.50. Then ABC and XYZ would agree to exchange, say, US\$ 100 million against DEM 165 million today, reversing the exchange in three years; that is, the forward exchange is done at today's spot rate rather than at the outright forward market rate currently quoted. This is because the two interest rates are different. Hence one side will benefit from a higher rate of interest. The profit/loss generated by re-exchanging at today's spot will offset that.

To make this concrete, suppose that the U.S. dollar/Euro-Swiss franc spot rate is 1.65 and that we have the following set of interest and exchange rates today:

Year	CHF Rate (%)	Zero-Coupon %	Forward Rate	Forward US\$/CHF
1	8	8.0	8.0	1.7301
2	7	6.9653	5.9406	1.7448
3	6	5.9204	3.8611	1.6904

Year	US\$ Rate (%)	Zero-Coupon %	Forward Rate
1	3	3.0	3.0
2	4	4.0202	5.0505
3	5	5.0689	7.1981

Given these interest-rate levels, it is likely that CHF LIBOR will be above USD LIBOR. So whoever in this swap is paying the U.S. dollar rates is likely to benefit at the expense of the other party. But this is compensated for by re-exchanging at the spot rate. If I lend CHF 165 million and borrow USD 100 million (which is what the basis swap amounts to, although it is not in legal terms a loan/borrowing), then at maturity I would like to be able to pay back US\$ 100 million and receive CHF 169.04 million at the implied forward market rate. But that way I would benefit twice. By re-exchanging at 1.65, I give up the exchange-rate profit, in exchange for earning the higher Swiss franc interest rates.

But suppose that we want to structure this swap *without* a re-exchange at maturity and without the initial exchange. We just contract that I will earn CHF LIBOR from you and I will pay you USD LIBOR. Clearly, you will want some incentive to enter into this trade. I will have to pay you something for giving up the re-exchange at maturity. The way in which we work this out is as follows:

The value of the re-exchange measured in U.S. dollars is $[(1.6904 - 1.65)/1.6904]$, or 2.39%. The present value of that, discounting using the three-year U.S. dollar zero-coupon rate, is 2.0605%. It is clear that you will only be willing to enter into the transaction if I pay you that amount today. Or we can convert it back into a sum of basis points per annum, using the payment (PMT) function in a spreadsheet or a calculator. We find the annual payment that, over three years, will extinguish an amount of 2.0605; the answer turns out to be 0.7566. So you would be willing—subject to credit risk—to accept an equivalent structure under which I pay you US\$ LIBOR + 0.7566% in exchange for you paying me CHF LIBOR.

Differential (Quanto) Swap

The *differential (diff) swap*, sometimes called a quanto swap, allows users to take a view on the interest-rate differential between two markets. A differential swap is somewhat like the swap we just discussed. One party pays the floating rate of one currency and receives the floating rate of another, plus or minus a spread. The difference is that payments are denominated in one currency. A typical example might be a three-year diff swap whereby a Euro–Swiss franc borrower wishes to pay the lower USD LIBOR rates on a borrowing totaling CHF 175 million. Unlike the swap we just discussed,

here the USD LIBOR is paid on an amount of Swiss francs. The spot rate is CHF 1.75. The counterparty, Bank X, is willing to do this trade, provided it receives USD LIBOR + 136 basis points (bp). This margin compensates Bank X for the hedging costs in the transaction, discussed later in this section.

The borrower, Company A, contracts with Bank X that Company A will pay X USD LIBOR + 136 basis points on a principal amount of CHF 175 million, and A will receive from X CHF LIBOR on the same amount. All payments are in Swiss francs. The cash flows involved in the swap are shown in Table 16.8, from the point of view of A, on the assumption that the LIBOR movements are as set out in Table 16.8.

What is happening here is that A, in the first period, pays X six-month U.S. dollar LIBOR plus the margin of 136 basis points (i.e., 4.86%) and receives from X the CHF LIBOR of 6.25% for a net receipt of CHF 1,243,277.78. Thereafter, assuming the LIBOR fixings are as set out in the table, A receives a stream of future payments varying with the relationship between the two LIBORs; it is clear that had the LIBORs moved differently, A might have ended up making payments on the swap rather than always receiving from X.

The pricing of the swap will be driven by the way in which X manages its exposure. There are a number of ways used in the marketplace to hedge diff swaps. One possible route would be to fix the interest-payment cash flows by entering into three-year fixed-floating swaps in U.S. dollars and Swiss francs. This could be done either as a pair of straight swaps or by aligning the nominal coupon on the two swaps (i.e., one swap becomes an off-market swap with an up-front payment to balance this).

Suppose that the latter alternative is taken: we align the two swaps by setting the U.S. dollar swap rate equal to the Swiss franc swap rate. Suppose that the market rates for interest-rate swaps in the two currencies are 7.375% for Swiss francs and 4.875% for U.S. dollars. As will be seen from the earlier discussion of swaps at off-market rates, this will require an up-front adjustment. In this case, the present value of the incremental swap flows is USD 6,612,064.87. (The discounting here is done at the swap rate rather than at the zero-coupon rates for simplicity.) This would result in the cash flow structure shown in Figure 16.4.

If we strip out from this the matching cash flows, we see that we are left with the situation in Figure 16.5.

The critical problem that we have is that X is receiving from A USD six-month LIBOR on CHF 175 million, but paying away six-month US\$

Table 16.8 Diff Swap Cash Flows

Date	Days	Six-month		Margin	Total	Counterparty		Net
		USD LIBOR	Six-month CHF LIBOR			Payments	Receipts	
01/03/98						(CHF)	(CHF)	
01/09/98	184	3.5	6.25	136	4.86	4,347,000.00	5,590,277.78	1,243,277.78
01/03/99	181	3.75	6.5	136	5.11	4,496,090.28	5,719,097.22	1,223,006.94
01/09/99	184	4.0	6.75	136	5.36	4,794,222.22	6,037,500.00	1,243,277.78
01/03/00	182	4.25	7.0	136	5.61	4,963,291.67	6,193,055.56	1,229,763.89
01/09/00	184	4.5	7.25	136	5.86	5,241,444.44	6,484,722.22	1,243,277.78
01/03/01	181	4.75	7.5	136	6.11	5,375,951.39	6,598,958.33	1,223,006.94

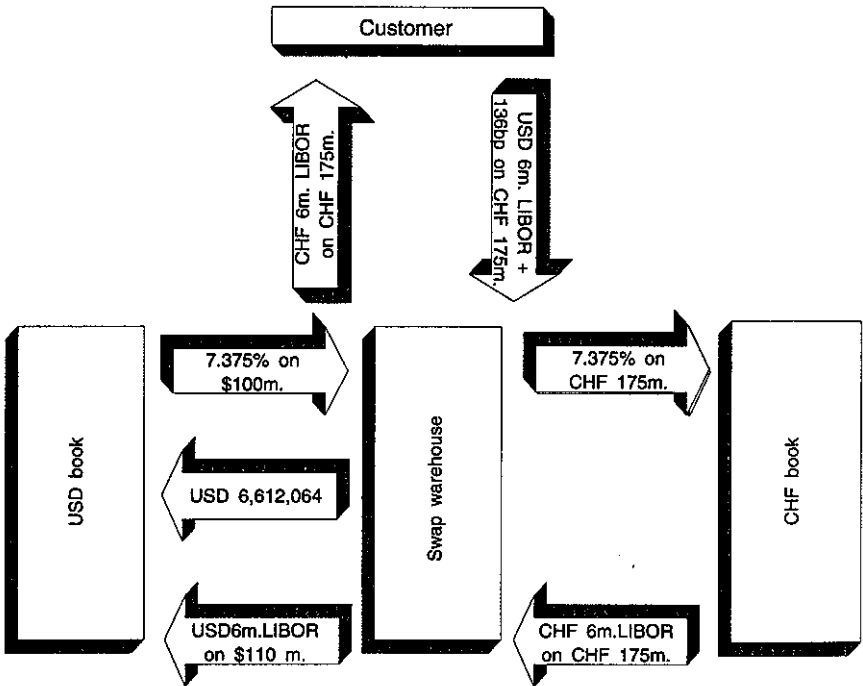


Figure 16.4 Diff Swap Cash Flows

LIBOR on USD 100 million. It is obvious that these two are only equivalent if the exchange rate remains at USD 1 = CHF 1.75. Depending on which way exchange rates have moved, we will have a net receipt or a net payment from this pair of cash flows.

An alternative way of looking at the problem is to focus on the U.S. dollar interest rate swap and argue that provided that USD LIBOR is below 7.375%, then we will have a positive U.S. dollar cash flow from the swap in the swap warehouse; if it is above 7.375%, our cash flow will be negative. Institutions manage their exposures under the diff swap in various ways: either using options, or some version of dynamic hedging, or in other cases seeking to offset the trade with matching components elsewhere in the book.

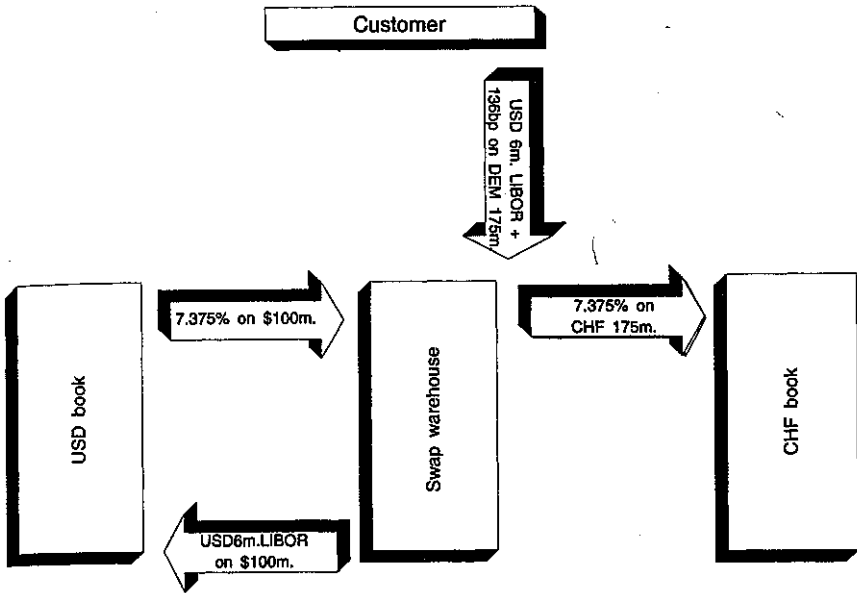


Figure 16.5 Net Diff Swap Flows

Hybrid Swaps

There are many possible variants of the basic swap technique. In some cases interest-rate swaps have been done that include links to commodity markets. This type of integrated hedging structure aims to link interest expense to profitability. Using such a composite hedge, an oil refiner, for example, is able to index its floating-interest-rate charges to the company's gross profit market. This "crack spread" tends to determine the cash flow of the refiner and thus its ability to service interest-rate payments. It is possible to develop a custom-made interest-rate swap in which the interest rate charged is linked to the crack spread. If the refiner's profits fall, squeezing cash flow, its interest costs decline at the same time. In essence, a crack spread option is embedded in the interest-rate swap. It may be, of course, that the customer may be able to handle the separate components, in which case it is clearly better off handling each transaction individually. However, for administrative purposes, many customers find it more convenient to have the transaction "bundled" together.

17 Options Basics

INTRODUCTION

An *option* is a contract that conveys the right, but not the obligation, to buy or to sell a financial instrument. Options are a very useful tool in money and foreign exchange markets. They allow us the luxury of a one-way bet. We can bet that a rate will go up and make a profit from that; but if the rate comes down, we don't lose. Options are particularly useful for hedging cash flows when we feel rather uncertain about the future. They have a second use: they can be used to take leveraged, or geared, positions. These attractions have led to very rapid growth in the options markets in recent years. There are options on "cash" markets for foreign exchange, deposits, bonds, bills, equities, and commodities. There are options on swaps and on equity indexes; and there are options on a range of futures contracts.

Options are also important because they bring an extra dimension to financial instruments. The development of options markets has meant it is possible to trade volatility; that is, one can take a view not on the direction of a price change, but on how volatile it will be. In many cases, such as the "straddle" strategy discussed later, the trader takes no view on the direction of the market but bets that it will be more volatile than today.

Because of their importance and because of the many varieties of "exotic" options that have developed, we will devote this and the next chapter to them. In this chapter we will deal with the basic structure of the instruments. We will also look briefly at some of the major valuation models currently in use. In the next chapter we will set out the main kinds of option presently available.

People think options are complex. This is true in part. Arriving at the exact theoretical value of many options is a difficult matter. But the basic fact about an option is that it is a one-way bet. You pay a price for the privilege of the one-way bet. Deciding on whether that price is worth it to you is very simple. It has very little to do with the market's calculation of fair value—where all the complexity lies. The golden rule of options is: *Use your common sense, and assess the value to you.*

Either the option meets your business or investment needs at a price that you think is worth it, or it doesn't. If you are buying an option, the value to you may be much more—or much less—than the market is charging. Conversely, if you are selling (or writing) an option, no matter what you think the fair value of the option is, its price will be what the market will pay for it. All those elaborate computer models mean nothing if no one wants to buy the option at the price that you have chosen to believe is fair. This distinction between *marking-to-model* and *marking-to-market* was brought home sharply to NatWest Markets, the capital markets subsidiary of National Westminster Bank in London, in March 1997. The bank announced a GBP 50 million loss arising from mispricing of interest-rate options (specifically, by pricing caps using average volatilities rather than a separate volatility for each caplet—see the next chapter).

Given all that, we still need to know how the market arrives at the price, if for no other reason than to make sure we are not somehow being robbed. Before discussing the major pricing models, we will start by setting out briefly the background.

THE OPTIONS MARKET

Though their growth is recent, options have been around a long time. Some point to the Dutch tulip mania as the first appearance of options; others have gone farther back, although these early contracts containing option elements can hardly be considered as options in themselves. "Traditional" options on equities (in effect, an over-the-counter option written by a market maker) developed on the London stock market in the nineteenth century. But until 1973, even though it was possible to buy an option, it was not really possible to trade it. *Exchange-traded options* were introduced in 1973 by the Chicago Board Options Exchange (CBOE). The single most important CBOE inno-

vation was to set up standard option prices and expiration dates. This allowed development of a secondary market, which brought liquidity into options trading.

The growth of exchange-traded options has been rapid. The CBOE was followed by the American Stock Exchange, the Philadelphia Stock Exchange, the Midwest Stock Exchange, and the Pacific Stock Exchange. Early entrants into the market elsewhere were the European Options Exchange in Amsterdam, the London Stock Exchange, and the London International Financial Futures Exchange (LIFFE, set up in 1982, merged with the Stock Exchange's London Traded Options Market in 1990). In Sweden, the Optionsmaklarna (OM) has become an international player, setting up its operations in London and also in other centers. In France, the Monep is active, and the Deutsche Terminborse (Eurex) is likewise an important market. Table 17.1 shows selected contracts worldwide.

The debate on over-the-counter (OTC) versus exchange-traded options has

Table 17.1 Some Options Contracts

Contract Name	Options on Futures	
	Exchange	Currency
Options on deutschemark futures	CME	USD
Options on Eurodollar futures	CME	USD
Options on Japanese yen futures	CME	USD
Options on Swiss franc futures	CME	USD
Options on long-term Bund futures	DTB	DEM
Options on the BOBL futures	DTB	DEM
Option on 3-month Eurodollar interest-rate futures	LIFFE	USD
Option on 3-month EURIBOR interest-rate futures	LIFFE	EUR
Option on 3-month sterling interest-rate futures	LIFFE	GBP
Option on EURIBOR 3-month futures	MATIF	EUR
Options on 90-day bank-accepted bill futures	SFE	AUD
Options on Eurodollar futures	SIMEX	USD
Options on futures on Swiss government bonds	SOFFEX	CHF
Options on 3-month yen futures	TIFFE	JPY
	Options on Cash Markets	
Currency options	PHLX	US\$
Euroyen	SIMEX	JPY

lasted a long time. The merits of exchange trading are transparency—the last price at which the contract traded is always known—and (usually) liquidity—a traded option that we have bought can be sold again. This is not so easy for an over-the-counter option. Proponents of OTC options point to their flexibility: Options can be tailored to suit the user's needs. In particular they can be written for a longer term. Most exchange-traded options have a maximum maturity of one year, and the vast bulk are for three or six months. Liquidity in certain options markets—notably currency and some interest-rate options—is also sometimes better in the OTC market than on the exchanges. In stock market options, the reverse is often true, at least for options on individual stocks.

Another issue that arises in comparing OTC versus exchange-traded options is the legal and tax position. In many cases, the tax treatment of an option varies depending on whether it is traded on a recognized exchange. Likewise the legal position regarding OTC options can be tricky (as in the case in the United Kingdom where the municipality, Hammersmith & Fulham, was found not to have the legal power to write OTC option contracts). By contrast, when dealing on an exchange, one's counterparty is the clearinghouse. For practical purposes, in normal circumstances, the question of credit risk does not arise.

Options are now traded on many different kinds of underlying instrument. Although an option on a future might seem more complex than an ordinary option, in fact, it is often simpler. The future consists of a single instrument with a fixed expiration date rather than, in some cases, a bundle of cash flows.

BASICS OF AN OPTION CONTRACT

An option is an agreement between two parties. One party grants the other the right to buy or to sell an instrument under certain conditions. The instrument may be a stock, a bond, a futures contract, an interest rate, or a foreign currency. The counterparty pays a "premium" for the privilege of being able to buy or to sell the instrument, without committing to do so. There are two basic types of options: puts and calls.

1. A *call option* gives the buyer the right to buy, or to "call away," a specified amount of the underlying instrument at the specified price during

a specified period. The price at which the instrument may be bought is the *exercise price* or the *strike price*. The last date on which the option may be exercised is the *expiration date*, or the maturity date.

2. A *put option* gives the buyer the right to sell, or put, to the writer a specified amount of the underlying instrument at the strike price until the expiration date.

The period during which the option can be exercised depends on its type—American or European. (These terms are relics of history, not geography: American options are traded in Europe, and vice versa.) Under an American option, the holder of the option has the right to exercise at any time before maturity. Under a European option, the holder may only exercise it at the time of expiration.

A call option is best described by a simple example. Suppose Bank A sells us a three-month European call option on the euro at a strike of EUR/US\$ 1.05, in an amount of EUR 10,000,000. This means that we have the right, in three months, to pay \$10.5 million to buy EUR 10 million. If the euro strengthens to, say, EUR 1.20 per dollar (so that it would cost us \$12 million to buy EUR 10,000,000 in the market), the option will have substantial value to us. Conversely, if, at the maturity of the option, the spot rate is EUR/US\$ 0.95, the option will have no value.

Let's put together some basic building blocks for analyzing options. Let's look at an option on sterling at \$2.00 per £1—a call option, American style—to see how the option would behave on the last day of its life. When spot sterling is trading in the market at, say, \$2.20, it would be possible to buy the option, exercise it at \$2.00, and sell at \$2.20. So the option will be worth at least \$0.20—the difference between \$2.00 and \$2.20. If the option costs less, one could buy, exercise, and sell for a net profit. And it will be worth no more than \$0.20—if it were worth more, anyone buying the option would take a loss (assuming we are trading in the final few minutes of the option's life). Conversely, if sterling were trading at \$2.10 at this time, the option would be worth \$0.10. If the pound were below \$2.00, the option would be worthless—you could buy sterling cheaper directly in the market than by exercising the right to buy at \$2.00.

We said that if sterling were trading at \$2.10 at the maturity of the option, it would be worth \$0.10. This difference between the currency price and the exercise price of the call option is often called its *intrinsic value*. Thus,

when sterling is at \$2.10, the option has an intrinsic value of \$0.10; at \$2.30, it has an intrinsic value of \$0.30. The only thing that affects intrinsic value is the gap between the price of the underlying instrument (in this case, sterling) and the strike price. Any excess premium over the intrinsic value of the option is called the *time value*, which is discussed more fully later.

- If the sterling's value is *above* the strike price, then the option will have intrinsic value and is said to be "in the money."
- If the sterling's value *equals* the strike price, then the option has no intrinsic value and is said to be "at the money."
- If the sterling's value is *below* the strike price, then the option again has no value and is said to be "out of the money."

OPTION PAYOFF DIAGRAMS

It is possible to draw a diagram showing the outcomes for different exchange rates at maturity—an option payoff diagram. Table 17.2 and Figure 17.1 show the results. This is the basic payoff profile of a call option, to which we will often return. At this stage, the key point to note is that there is unlimited profit potential as the pound rises and limited loss as it falls. (There will be a loss, not shown in the table: the loss is the amount of premium spent in buying an option that turned out to be worthless at expiration.)

Table 17.2 Intrinsic Value of Sterling Call

Call Option Payoff Profile—Strike 2.00	
Market Rate at Maturity	Intrinsic Value of the Option
1.6	0
1.8	0
2.0	0
2.2	0.2
2.4	0.4

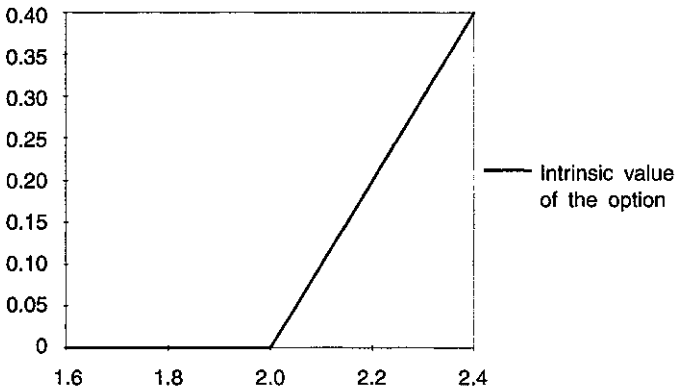


Figure 17.1 Intrinsic Value of Sterling Call at Expiration

We can do the same exercise for a put on the pound at \$2.00, as shown in Table 17.3. Again, we can draw the profile of the put in the last few minutes of its life (Figure 17.2). There is unlimited profit potential, this time as sterling falls, and limited risk of loss—the maximum loss will be the premium paid out.

Let's look at the position that would arise if instead of buying a call, we had sold, or written, a call. When we bought a call, we had the right but not the obligation to buy sterling at \$2.00. But in this case we have sold the call—we have the obligation to sell the pound at \$2.00. If sterling rises

Table 17.3 Intrinsic Value of Sterling Put

Put Option Payoff Profile—Strike 2.00	
Market Rate at Maturity	Intrinsic Value of the Option
1.4	0.6
1.6	0.4
1.8	0.2
2.0	0
2.2	0
2.4	0
2.6	0
2.8	0

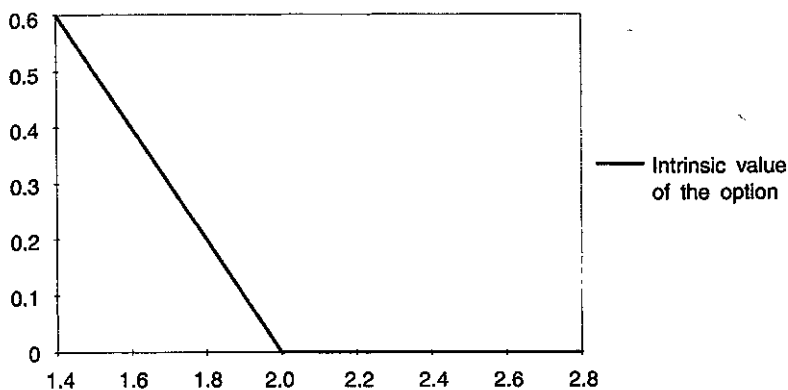


Figure 17.2 Intrinsic Value of Sterling Put at Expiration

above \$2.00, we must sell it to the party who bought the option instead of selling in the marketplace. So we will make a loss. The loss is unlimited: for example, if sterling rises to \$3.00, our loss will be \$1.00 per pound. If sterling, at the expiration of the option, closes below \$2.00, we will make a profit. Our profit will be the premium we charged for selling the option. Our profit is limited to the premium. So the writer of a call has unlimited risk, with a limited profit potential. We can see this in the diagram (Figure 17.3).

The same applies if we were to write a put (Figure 17.4). Why would anyone be crazy enough to write options, then? Well, writing an open (or “naked”) options position can be very risky, but it can be well rewarded in the shape of a substantial premium. After all, that is how insurance companies make money. They take risks in exchange for premium income. Also, there are hedging techniques that can reduce the risk.

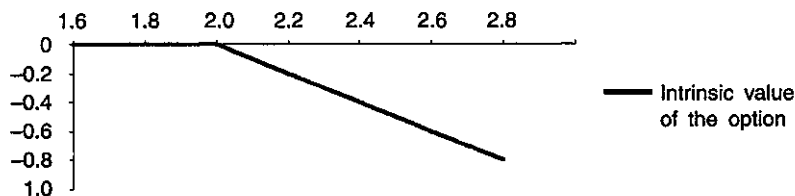


Figure 17.3 Profile of a Short Call Position

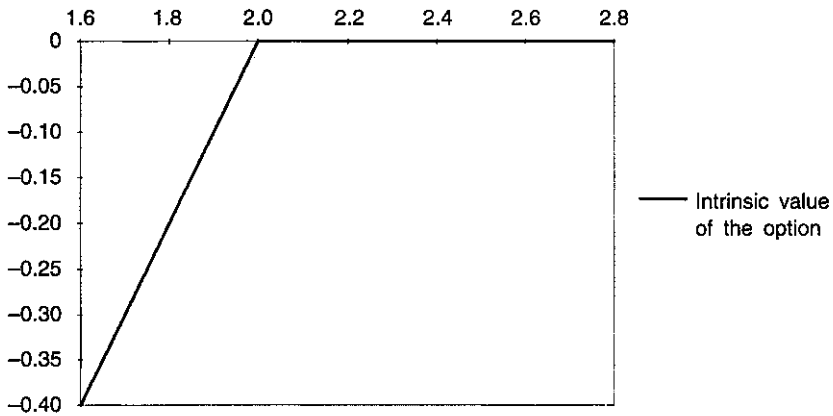


Figure 17.4 Profile of a Short Put Position

Finally, because we will be needing to combine positions later, it will be helpful to show a similar payoff diagram for the straightforward long and short positions. Figure 17.5 shows the payoff if we are long sterling at, say, \$2.00—our profit rises as sterling rises; as sterling falls, we start to take a loss. Likewise we can draw the payoff from being short.

These profiles—long the underlying asset (Figure 17.5), long the put or call, and short the put (Figure 17.4) or call (Figure 17.3)—are the basic building blocks of all options strategies. They can be combined in many different ways, some of which are discussed later in the chapter.

OPTION VALUATION

We come now to the theory of how to value options. Once again, it should be stressed that this is a black art—it is not a science. We mentioned earlier the case of NatWest Markets: the fact is that in pricing options there will almost always be room for disagreement about the assumptions being made in the option-pricing model. In the NatWest case, there was a clear difference between the prices being used internally and those quoted in the market, with the latter being widely available. Thus it was reasonable to say that NatWest's prices were "wrong." But in other cases, the market will be limited or illiquid, or indeed market traders may not have fully understood the instrument if it is highly specialized. So there is always scope for doubt about

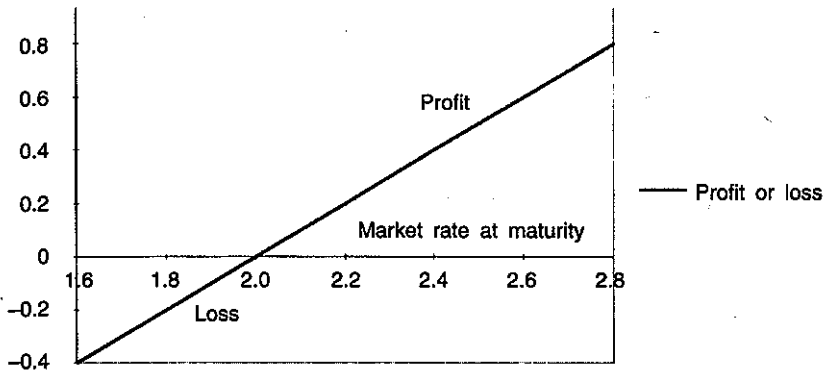


Figure 17.5 Payoff Profile of a Long Asset Position

the value of an individual option. This is because its value depends on an estimate of the future volatility of the underlying instrument. There will be a general market view of the appropriate level of volatility to be used; but if your estimate differs, then the option will be worth more or less to you.

The first, and most important, model used in options pricing was that developed by Fisher Black and Myron Scholes in 1973. The *Black-Scholes model* made four critical assumptions:

1. Prices may change rapidly but cannot “jump.” One can trade continuously in the market.
2. There is a risk-free rate of interest for borrowing and for lending from the current period until the expiration of the option.
3. Transactions costs and taxes are ignored.
4. The continuously compounded rate of return of the asset has a normal distribution—the asset price is log-normally distributed.

Given these assumptions, Black and Scholes showed that the price of the option would be determined by the following factors:

- The current price of the underlying instrument.
- The exercise price of the option.
- The remaining life of the option.
- The level of interest rates.
- The projected volatility of the underlying instrument.

Of these, all but the last are known at the time the option is priced. Thus, volatility is the key to options pricing.

In looking at the option's value, the first two factors are primary. This is clear if we look at the option on the day that it expires. Look at our earlier example of a \$2.00 call on sterling. (We will assume for the moment that interest rates in sterling and in dollars are identical.) On the day that the option expires, only the currency price and the strike price, or exercise price, of the option determine the option's value. The other factors have no bearing. We said that if sterling were trading at \$2.10 at the maturity of the option, it would be worth \$0.10. When sterling is at \$2.10, the option has an intrinsic value of \$0.10; at \$2.30, it has an intrinsic value of \$0.30. The only thing that affects intrinsic value is the gap between the price of the underlying instrument (in this case, sterling) and the strike price.

But in the period before the expiration of the option, there is another element in its price in addition to its intrinsic value. This is referred to as the *time value premium*. In general, the time value premium is found by the following formula for an in-the-money call option on an asset (sterling, in our example):

$$\text{Call time value premium} = \text{Call option price} + \text{Strike price} - \text{Asset price}$$

For example, sterling is trading at \$2.05, and the sterling October \$2.00 call is priced at \$0.08. The in-the-money amount (the intrinsic value) is \$0.05 (\$2.05 - \$2.00), and so the time value (price minus intrinsic value) is 3 (8 - 5).

The intrinsic value of the option is easy to calculate. The "fair value" of the time value premium is not so simple. It depends only partly on the time to maturity. It also depends on the volatility of the underlying asset and on interest rates. It will vary, too, according to how far in the money or out of the money the call option is.

If the call is out of the money, then the premium and the time value premium are the same. Let's say sterling is at \$2.05, and a sterling October \$2.10 call sells at \$0.04. The call has no intrinsic value by itself when the currency (at \$2.05) is below the striking price (\$2.10). So both the premium and the time value premium of the call are 4 points.

The option's time value premium decays much more rapidly in the last few weeks of its life than it does in the first few weeks. In fact, for reasons we will see later, the rate of decay is related to the square root of the time

remaining. To illustrate this we can draw a graph of the effect of time on an option's premium (the effect of "time decay" as it is often called). Figure 17.6 shows the effect of holding everything else constant. As the option comes closer to expiration, it loses value more and more quickly.

Another important point about time value is that it is always greatest for an option which is at the money. If the option is deep in or out of the money, its time value is very low. We can see why this is so if we think of the deal from the point of view of the option writer. Suppose we are quoting to write an option to sell sterling at \$2.10. Once the option is written, as we get closer to expiration, if sterling is near \$2.10, we will need to be thinking about buying some sterling. We need to buy to cover our commitment to deliver sterling at \$2.10. Now suppose there are 30 days to go on this option, and sterling is now at \$1.80. Then the risk of our having to deliver on this option is quite small—sterling is not very likely to rise 30 cents in 30 days. Equally, as one day passes and there are now 29 days to run, our risk will decline, but not by very much, because the risk was already small. So the fall in the premium we will charge will not be large. The effect of time value on the premium is small in these circumstances.

Conversely, suppose we are quoting the same option and sterling is trading today at \$2.40. The option is virtually certain to be exercised. We will buy sterling now to cover our position because we will almost certainly have to deliver. Again, if the maturity of the option that we are quoting were to be shortened by a day, our risk will not be much less. So the premium we charge will not fall much. Time value of a deep-in-the-money option is low.

It is when the option is at the money that our uncertainty is greatest. If

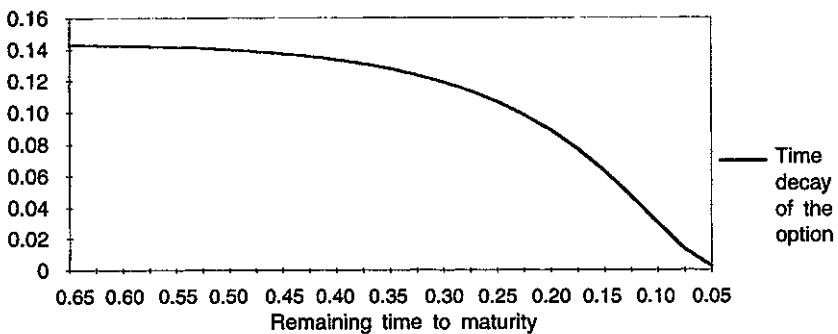


Figure 17.6 Time Decay

we are quoting a \$2.10 option for sterling and sterling is trading at \$2.10, then the market could go either way from now till maturity. In these circumstances, an extra day's life on the option really does have an effect on our risk. Time value is at its greatest when the option is at the money.

We can illustrate this: Figure 17.7 shows the value of the option premium at maturity and 30 days before maturity. The shaded area between the two lines is the time value of the option, and, as can be seen, the gap between the two lines is at its widest when the option is at the money.

THE BINOMIAL MODEL

Different writers of options in the market will price their options differently because they have differing views on future volatility. It is this that makes option pricing a bit of a black art. To add to the confusion, there are a number of different options-pricing models. The most widely known is that of Black and Scholes. The Black model is a variant of the Black-Scholes model and is suitable for options on futures. Other popular models are the Garman-Kohlhagen modification of Black-Scholes (widely used for currency options) and the Cox-Ross-Rubinstein model, or binomial model, which overcomes the problems the Black-Scholes model has in handling dividend payments

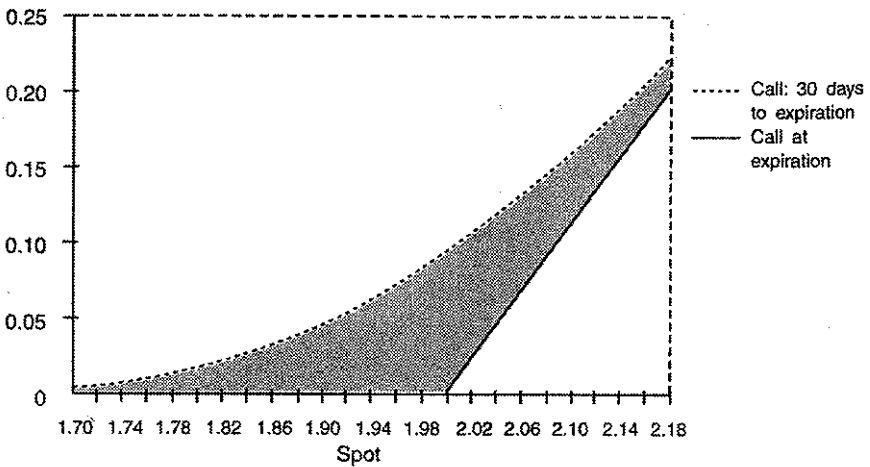


Figure 17.7 Time Value In, At, and Out of the Money

on underlying equities. The binomial and Black-Scholes models converge when trading is assumed to be continuous. In practice, bigger errors are likely to result from wrong forecasts of volatility than from minor variations in the underlying theoretical models. Of the models mentioned, the binomial is one of the most commonly used. It is also rather easier to explain intuitively, so we will start with it before moving on to the Black-Scholes model.

Let's start with an American call on sterling at \$2.00. Spot sterling today is trading at \$2.05. We'll call the exercise price of \$2.00 E , and the spot price S . Then $S - E = \$2.05 - \2.00 , or \$0.05; that is, if we buy the option and exercise today, the option will pay us 5 cents. So the call will be worth at least \$0.05 and probably more if there is any time to expiration. If we write the value of the call as C , we know we must have $C \geq S - E$. Also, because we know that we can choose to walk away from the option, its value can never be negative—we can never be harmed by owning it. So we know the value of a call will always be $C \geq 0$. In fact, we can write $C \geq [\text{Maximum of } (0, S - E)]$.

Can we make this more exact? One way to proceed is to start with the concept of a riskless hedge—a hedge that eliminates all risk.

The assumptions behind most riskless-hedge valuation models are as follows:

1. Prices may change rapidly but cannot “jump.”
2. There is a risk-free rate of interest for borrowing and for lending from the current period until the expiration of the option.
3. Transactions costs and taxes are ignored.

What we will do is set out a “binomial tree” showing the possible outcomes of the movement in sterling over time. At any point, sterling can move up or down. At each point along the branches of the tree, we will work out the fair price of an option on sterling, working back from the future to today. The approach was initiated by William Sharpe and developed further by Cox, Ross, and Rubinstein.

We assume a starting price for sterling of \$2.00. Then we assume that the price of sterling in each period can rise or fall by \$0.01—it is equally likely to rise or to fall. A three-period example is shown in Figure 17.8. At the start of the first period, we want to value a European call option. It has a strike of \$1.99. It expires after two periods (i.e., at the start of the third period). How do we set about this?

We begin by assuming, for simplicity, that interest rates in both currencies

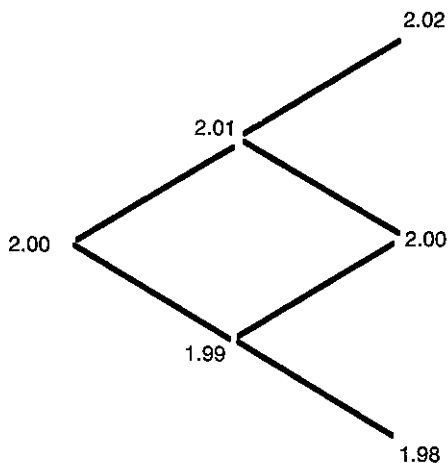


Figure 17.8 Sterling Binomial Tree

are equal. (This assumption is relaxed explicitly in the Garman-Kohlhagen model, which is widely used for pricing currency options; see below.) The next step is to consider the value of the option at expiration.

On expiration, sterling can be \$1.98, \$2.00, or \$2.02. And the option will be worth \$0.03 if sterling's price is \$2.02, \$0.01 if it is \$2.00, and nothing if it is \$1.98. Next, to get back from the third period to the second period, we use the concept of a riskless hedge. We set up a hedge such that we have no exposure to the market price of sterling.

Let us assume sterling's price is \$2.01 at the start of the second period. We want to find the option price. We do this by imagining a portfolio. It is long one pound sterling and short one call option on sterling with a strike of \$1.99.

At the start of the third period, the price of sterling could rise from \$2.01 to \$2.02 or fall to \$2.00. The option writer must deliver sterling at the strike price of \$1.99. So, at \$2.02, he or she will lose \$0.03. Likewise, if sterling falls to \$2.00, the writer will lose \$0.01. So at the start of the third period, whether the price moves up or down, the value of the portfolio will be \$1.99 ($\$2.02 - \0.03 or $\$2.00 - \0.01).

So there is no risk in this portfolio. It can earn no more than the risk-free rate. (If it did, arbitragers would borrow to invest in it and would drive down the return.) Likewise, it cannot earn less (there would be arbitrage in the opposite direction). So the rate of return on the risk-free portfolio must

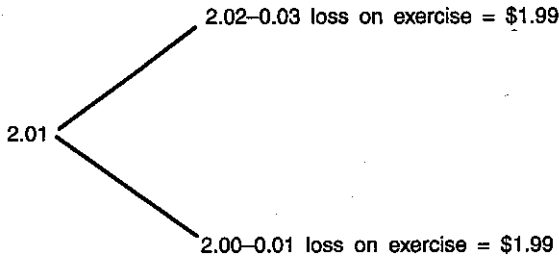


Figure 17.9 Portfolio Value if Sterling Is at \$2.01

equal the risk-free rate. Let us assume that the risk-free rate is 0.02% per period. Then the return on the portfolio will also be 0.02% per period.

We can now find a price for the option at the start of the second period, given the price of \$2.01 that we assumed earlier. We know the portfolio earns the risk-free rate. And we know it ends up worth \$1.99. So the starting value, or cost, of the portfolio must be \$1.99 discounted back over one period; that is, $\$1.99/1.0002$, or \$1.9896.

But we know also that the cost of the portfolio is \$2.01 (the price of the sterling) minus the premium on the option sold. Therefore, the option must earn $\$2.01 - \1.9896 , or \$0.0204. If it did not, the portfolio would not be worth exactly \$1.9801. Any other option cost would mean the risk-free portfolio does not earn the risk-free rate. *So, if the price of sterling at the start of the second period is \$2.01, then the value of the option must be \$0.0204.*

We can now use the same method to solve for a different price. What is the option price if the price of sterling at the start of the second period is \$1.99? In this case, we set up another portfolio. It now has one pound sterling plus two short calls.

We chose the number of calls to be two as follows. We ask: How many calls are needed to make the portfolio riskless? Or, how many calls will make the portfolio worth the same value whatever happens to sterling's price (whether it rises from \$1.99 to \$2.00 or falls to \$1.98)?

To find this, say K is the number of \$1.99 calls written. We know that if the price rises to \$2.00, we must deliver at \$1.99, and so each call will lose \$0.01. And if the price falls to \$1.98, there is no loss. So we want K such that

$$\$2.00 - (K \times \$0.01) = \$1.98 - (K \times \$0).$$

So $\$2.00 - \$1.98 = K \times \$0.01 - K \times \$0 = K \times \$0.01$, and so $\$0.02 = K \times \0.01 .

Solving for K shows that we need two short calls to make the portfolio riskless. (Before, we had $\$2.02 - (K \times \$0.03) = \$2.00 - (K \times \$0.01)$, and so $\$0.02 = \$0.02 \times K$ and hence $K = 1$.)

Now the price at the start of the third period can go from our assumed $\$1.99$ to either $\$2.00$ or $\$1.98$. At $\$2.00$, the option has a $\$0.01$ loss for a total loss of $\$0.02$ on the two options. At $\$1.98$, the option expires worthless. Thus, the portfolio will be worth $\$1.98$ next period, regardless of whether the price goes up to $\$2.00$ or down to $\$1.98$ ($\$2.00 - \0.02 or $\$1.98 - \0). So initial cost of the portfolio must be $\$1.98/1.0002$, or $\$1.9796$.

On our assumption, sterling costs $\$1.99$. So by the same reasoning as before, the two options must earn $\$1.99 - 1.9796$, or $\$0.0104$. So each option must be worth $\$0.0052$. We now know the option's value for the two possible prices of the second period (Figure 17.10).

There is one last step. We must work back to today. Suppose we set up a portfolio that is long one pound sterling, and short 1.32 call options. To find that number (1.32), we use the same approach as before. We say we must have $\$2.01 - \$0.0204K = \$1.99 - \$0.0052K$, so $\$0.02 = (\$0.0204 - \$0.0052)K$, and $K = \$0.02/\0.0152 , or 1.32.

In Table 17.4, we see that if the price of sterling goes up to $\$2.01$, the value of the portfolio will be $\$1.9831$. It will still be worth that if the price

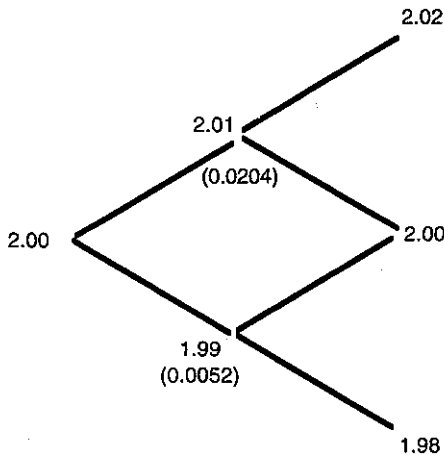


Figure 17.10 Sterling Binomial Tree: Second-Period Prices

Table 17.4 Portfolio Values (Long £1 Short 1.32 Calls)

Price of £	Short Call Position Value	Portfolio Value
2.01	1.32×0.0204	$2.01 - 0.0269 = 1.9831$
1.99	1.32×0.0052	$1.99 - 0.0069 = 1.9831$

of sterling falls to \$1.99. Therefore, the cost of the portfolio today must be its future value discounted back to today— $\$1.9831/1.0002$, or $\$1.9827$. But that cost must also equal \$2.00, the value of our holding of sterling today, minus the revenue from selling 1.32 calls. *So each call must sell for $(\$2.00 - 1.9827)/1.32$, or $\$0.0131$.*

We have at last worked back to answer our question. We have found the fair price for the option today if sterling is selling for \$2.00. Given the risk-free rate of interest and the set of possible future prices, \$0.0131 is the only possible answer. In principle, to solve for the fair value of longer-term options, all we need is a bigger set of possible prices. Then we can use the same method to find the current fair price of the option.

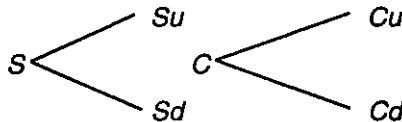
Summary

It may be helpful to summarize this process, as follows:

Suppose the price of sterling today is S . If the price rises, it will go up to S_u . If it goes down, it will go down to S_d . Consider a call option on sterling whose value today is C . The value will go up to C_u if sterling rises and fall to C_d if sterling falls.

We can draw the situation like this:

Sterling Call Price



We can think of the movements up and down as the branches of a tree. The time between steps in our tree is taken as one year. Our tree will look like Figure 17.8. Suppose we are at the first step in the process we went through earlier; namely we are at the start of the last period of the option's life (the third period) and sterling has risen to \$2.01. We now set up our hedged portfolio by saying that the portfolio value V_0 today is:

$$V_0 = S + hC$$

where h is the "hedge ratio." We want to find h such that

$$V_1 = Su + hCu = Sd + hCd$$

that is, the portfolio value after one step, V_1 , is the same if the price goes up or down. The previous equation implies that

$$H = \frac{-(Su - Sd)}{(Cu - Cd)}, \text{ or } \frac{-(2.02 - 2.00)}{(0.03 - 0.01)}$$

in our earlier example. (Remember that the option strike is \$1.99, and so its value at expiration will be \$0.03 if sterling is \$2.02 and \$0.01 if sterling closes at \$2.00.) In this case, $h = -1$: we would be short one call option and long one pound sterling to be risk-neutral. But if we set up this portfolio, we know that it is risk-free. We know that V_1 will always be the same. That in turn implies that

$$V_1 = V_0(1 + rt)$$

where r = the risk-free rate of interest and t is length of the step in terms of time. Earlier we defined our rate of interest as 0.02% per period, so here we set $t = 1$ because we have defined the rate of interest as a periodic rate.

Then $V_1 = 1.0002 \times V_0 = 1.0002 \times (\$2.01 - C)$

We can combine the two equations and rewrite them so that:

$$C = \frac{pCu + (1-p)Cd}{(1+rt)}$$

where we have simplified the result above by writing:

$$p = \frac{S(1+rt) - Sd}{Su - Sd}$$

In our example,

$$p = \frac{(\$2.01 \times 1.0002) - \$2.00}{\$2.02 - \$2.00} = \$0.010402 / 0.02 = 0.5201$$

So we can find C:

$$C = \frac{(0.05201 \times \$0.03) + (0.4799 \times \$0.01)}{1.0002} = 0.020402 / 1.0002 = 0.0204$$

as we saw before.

Then, as the chefs say, repeat as necessary, to get back to the starting value.

Notice all the assumptions *not* made in what we have done. We have made no assumptions about:

1. The probability of an upward or a downward move in the market.
2. The investor's degree of risk-aversion.

In other words, this model is applicable across all investors regardless of market conditions. It is this that has given it its generality and that makes it so useful. So it will be useful to explore the binomial a little further because various kinds of binomial tree are fundamental to pricing options in situations where the Black-Scholes model will not work—the binomial is a very powerful tool.

RISK-NEUTRAL TRANSITION PROBABILITIES

Something we glossed over a little earlier was the meaning of the term p in the formula in the summary in the preceding section. For most normal conditions, we have $0 < p < 1$, and so it rather resembles a probability. It is common to speak of it as the up-transition probability or the risk-neutral

transition probabilities. When using binomial trees, we create a risk-neutral world by choosing the transition probabilities to ensure that the expected value is equal to growth at the risk-free rate.

Assume that in our world the rate of interest is positive. We can see intuitively that if we are looking at an option on a risky instrument that pays no interest or dividend, then unless we expect the instrument to rise in value over time, we would never hold it. It would always be better to hold a risk-free bank deposit or bond, hence the requirement that the expected value of the instrument is equal to growth at the risk-free rate.

So although p is not strictly speaking a probability—because we started by saying we would make no forecast about the probability of a rise or a fall in the instrument—it must be set in such a way that it is consistent with a rise in the asset at a rate equal to the risk-free rate (often called the *drift*). This is consistent with making no forecast because p is not set subjectively. It is set in an objective manner to meet the condition that the asset must rise in line with the risk-free rate.

The approach adopted by Cox, Ross and Rubinstein¹ was to set the up probability (u) at $u = e^{\sigma\sqrt{t}}$ and the down probability (d) at $d = 1/u$. The transition probability p can be found from the formula

$$p = \frac{e^{\mu} - d}{u - d}$$

where μ is defined as the expected annual rate of return of the asset. Up to a very good approximation, these assumptions make the local volatility at each node of the tree equal to σ and the expected rate of return equal to μ .

Exhibit 17.1 European Binomial Option: A Worked Example

Suppose we have a foreign currency trading at 100 ($S = 100$), paying a rate of interest of 3% ($r_f = 0.03$); and in our world the risk-free interest rate is 10% ($r_d = 0.10$). We have estimated the volatility of the currency as 30% per annum ($\sigma = 0.3$) and we are interested

¹Cox, Ross, and Rubinstein, "Option Pricing: A Simplified Approach," *Journal of Financial Economics* (1979).

in a three-month option ($t = 0.25$ years) with a strike of 100 ($I = 100$).

We want to construct a binomial tree of price outcomes. We believe that the returns on the currency are normally distributed; so we want to construct the tree so that if its branches expanded to infinity, we would get a normal distribution. The returns on the currency are, we believe, *normally* distributed—in other words, symmetrically distributed. We have to define *return* properly.

If the currency starts at 100, goes to 110, and falls to 100 we get returns of +10% and -9.0909%, respectively—the returns are nonsymmetrical because in the second period the base is 110, not 100. We can get around this by defining the return as a logarithm: $\ln(110/100) = 0.0953 = 9.53\%$ and $\ln(100/110) = -0.0953 = -9.53\%$ (using the natural logarithm).

For a normal distribution with a variance of σ^2 measured over a period t , the variance is σ^2 . If we divide the period into n steps, the variance at each step is σ^2/n ; in other words the standard deviation (volatility) is $\sigma\sqrt{t/n}$. So if we divide our three-month period into, say, five subperiods, we have an applicable volatility of $0.30\sqrt{(0.25/5)} = 0.3 \times 0.223607$, or 0.067082.

So we define the return in each period on this asset as $\log(0.067082)$ or (if it falls in value) $\log(-0.067082)$. So the price change in each period is the antilogarithm of ± 0.067082 , that is, 1.0693838, or 0.935118 (say $UP = 1.0693838$ and $DOWN = 0.935118$).

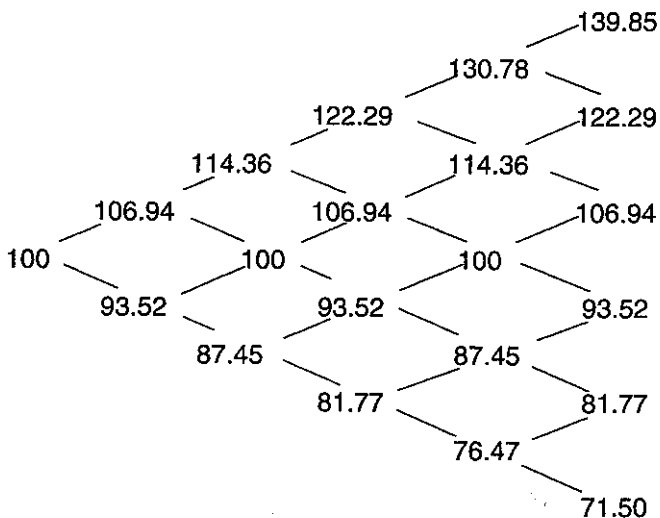
There is a probability p that the price of the asset will rise. Hence the probability of a fall is $1 - p$. Let us define $INT = r^{1/n}$, where $r = 1 +$ the domestic rate of interest, and INT can be thought of as the “periodic interest rate.” We also define $FGN = r_f^{1/n}$ where $f = 1 +$ foreign rate of interest, and so FGN is the “periodic foreign interest rate.”

Suppose today $r_d = 1.10$ and $r_f = 1.03$. Then $INT = 1.00478$ and $FGN = 1.00148$.

Then we can define $p = (INT/FGN - DOWN)/(UP - DOWN) = 0.50776$ in our example and $1 - p = (UP - INT/FGN)/(UP - DOWN) = 0.49224$.

Effectively, p is the probability of an upward move, and $1 - p$ is the probability of a downward move that would be consistent with the interest-rate environment that we have. Using all these assumptions, let us look now at what happens to the currency over the five periods we are considering:

Tree of Currency Price Movements:



In other words, in the first period, the price can move to 106.94 or 93.52; in the second, it can move from 106.94 to 114.36 or back to 100; and so on.

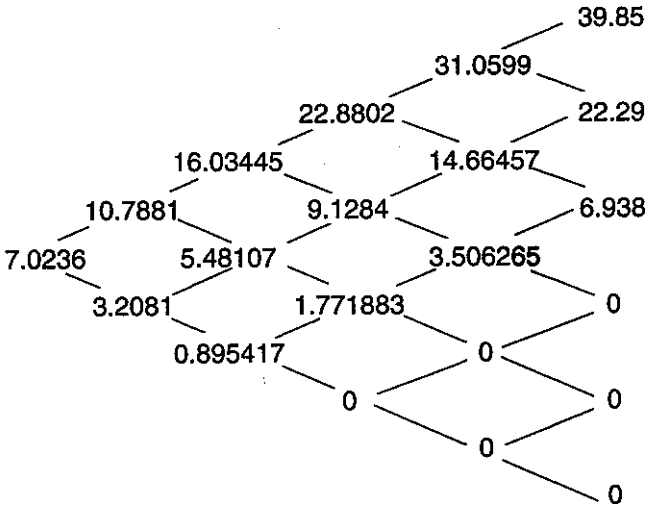
The next step is to consider the value of a call option on an asset that behaves like this. Suppose the call has a strike of 100. Then if the asset has reached 139.85, the call payoff is 39.85. If it has reached 122.29, the payoff is 22.29. Suppose now, we are in the fourth period: the asset price has reached 130.78. We know it can now go up to 139.85 or down to 122.29. What is the value of the call at that point?

It must be the present value of the expected outcome; that is, the present value of each payoff, weighted by the probability of the payoff. We have defined the probability of an UP move as 0.50776 and the probability of a DOWN move as 0.49224. We know that the payoffs are 39.85 and 22.29.

Therefore the value of the call at this point must be $[0.50776 \times 39.85 + (0.49224 \times 22.29)]/1.00478 = 31.06$.

We can repeat this process for each node of the tree, bearing in mind that the call is worthless for payoffs below the strike:

Payoff Tree:



So on these assumptions the option is worth 7.0236. Obviously, we have only considered the first five periods in the tree; in practice we would consider much larger trees.

STANDARD TREES AND FLEXIBLE TREES

An assumption we have made so far, implicitly, has been that the volatility at each node of the tree is equal. This is a common assumption, and the binomial tree constructed from fixed volatility assumptions is the standard approach. In a standard binomial tree, the up ratios, the down ratios, and the transition probabilities are the same at every node. The length of each time period is also the same. Flexible trees are so-called because very few restrictions are placed on the up and the down ratios and the transition probabilities of the tree. We only require that the tree be recombining; that is, at any time, an up move followed by a down move is exactly the same as a down move followed by an up move. In other words, the branches of the tree do not wander all over the place but rejoin. We will see later that flexible trees are becoming important tools in the pricing of options.

All this may seem far from the real world. After all, prices move all the time, not just once per period. Even worse, they can move to any one of many new values, not just two, as we have assumed. But if the reader is willing to accept our basic assumptions, his or her objections can be overcome by suitably changing the binomial model. Our model worked over three periods. If we divide these into infinitely short periods, we move toward continuous price changes. Now we have a very large number of observations. In these circumstances, we can generalize the model to become the Black-Scholes model, which we will do in a moment.

NORMAL DISTRIBUTION

Before we turn to the Black-Scholes model, we will look at the *normal distribution*. The normal distribution is well known in statistical theory: it is bell-shaped, symmetrical (Figure 17.11).

The normal distribution is important because it is quite a realistic picture of the distribution of a number of common occurrences. The reason for this is the Central Limit Theorem—once described as “one of the most remarkable in all mathematics.” The theorem says that no matter what the type of the underlying distribution, provided it has a finite variance, *it will approximate to the normal distribution for large samples*.

Most statistical distributions that are likely to apply in the real world have

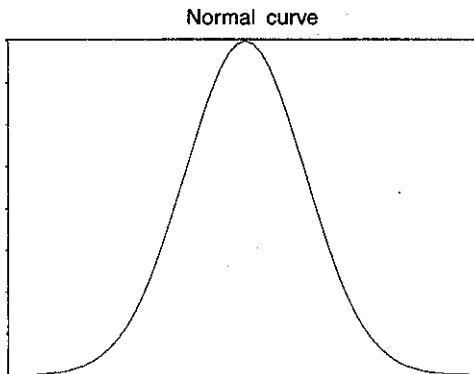


Figure 17.11 The Normal Distribution

finite variances. So that means that we can argue that, for sufficiently large samples, we are often justified in assuming that the underlying distribution of changes in the exchange rate (or whatever else we are writing an option on) is normal. More exactly, the standardized, continuously compounded rate of return of the asset (sterling, in our example) tends to approximate a normal distribution. Hence, the relative change in price (S^*/S) has a normal distribution, where S^* is the new price and S is the old. (So in fact the exchange rate itself will have what is called a “log-normal” distribution: its logarithm is normally distributed.)

Suppose we write an option on a currency whose price is 100. We know the price movements of the exchange rate over the past six months. These suggest its probability distribution is quite like a normal distribution. Over the past six months, the currency price’s *mean*, or average, is 100. Its *standard deviation*, or variability, is 12.

How do we find the probability that the currency’s price on maturity of the option is a given distance from the mean? We use the area underneath the curve between the mean and the price at maturity. How do we measure this area? The easiest way is by looking up a table for the “standardized normal” distribution (that is, the distribution of a normal variable with mean 0 and standard deviation of 1).

So the standardized normal distribution has to be applied to our currency. We do this by taking all the possible exchange rates. We subtract from them the mean, 100, and then divide the result by the standard deviation, 12. We have now standardized our exchange-rate distribution. In mathematician’s terms, we apply the transformation $[(x \text{ minus mean})/\text{standard deviation}]$. An example will illustrate this.

Let’s take the probability of the exchange rate being, say, 0% to 3% higher than the original price, that is, between 100 and 103. We take $x = 100$ and $x = 103$ and write $(x - \text{mean})/\text{standard deviation}$, or $(100 - 100)/12$, which equals 0, and $(103 - 100)/12$, which equals 0.25. We then find the probability that x is between 0 and 0.25 in the standard normal distribution by looking it up in the statistical tables for the normal distribution. Here it is shown by the area under the curve marked with the letter *A* in Figure 17.12. The area *A* is roughly 10% of the total area under the distribution curve. So the chance of the price being between 100 and 103 at maturity is 10%. The cost to the option seller of this event will average 1.5% (the average difference between 100 and 103).

Suppose we repeat this for each slice of 3 percentage points above the

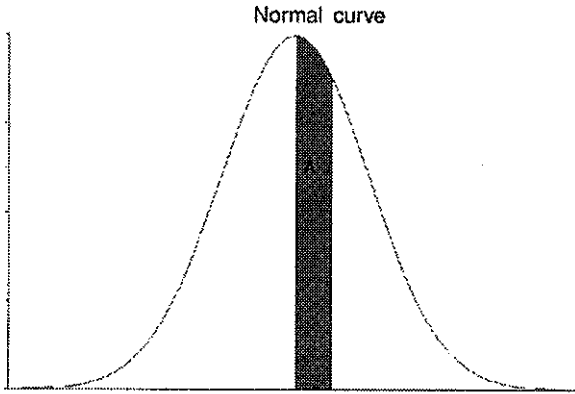


Figure 17.12 Possible Prices at Maturity: Standardized Normal Distribution

strike price. Then we will get a whole series of probabilities for each event, and each event has a cost, half way between the percentage points. We can weight each of these costs by the probability and get a total—say, 4.8%. So given this cost, the option seller will then decide how uncertain he or she feels about this estimated cost and, if necessary, add some loading for self-protection and then price the option accordingly.

In fact, what we have done here is add up the cumulative area under the normal curve—the technical term for this is the *cumulative normal density*.

BLACK-SCHOLES FORMULA

We have seen, in a general way, how the binomial model works and how it can be argued that, for large numbers of independent observations over time, the logarithm of changes in price, $\log(S^*/S)$, has a normal distribution (that is, the price has a “log-normal distribution”). The assumption of normality does agree with common sense: it says that small relative changes, either up or down, are very common, but large changes become proportionately less common. The normal distribution has a mean, μ , and variance, $\sigma\sqrt{T}$. If we consider the behavior of $\log(S^*/S)$ over T periods, we will find that over that time it has a mean μ and variance $\sigma\sqrt{T}$.

Now we can move on from the binomial model to the Black-Scholes model. Black-Scholes assumes that the price is log-normal, which as we have seen is usually reasonable—though not for interest rates, which we discuss

later—and this assumption gets us away from specifying a binomial-type path for prices. Instead we can set up a (fairly) simple formula. We can write the Black-Scholes formula like this:

$$C = N(d1)S - e^{-rT}N(d2)E$$

where C = Value of call option
 S = Spot price
 E = Exercise price
 $d1 = [\ln(S/E) + (r + \sigma^2/2)T]/\sigma\sqrt{T}$
 $d2 = d1 - \sigma\sqrt{T}$

$N(x)$ refers to the cumulative normal density. (We saw how to use $N(x)$ earlier in the section on the normal density.)

What this formula says is that the value of the call is equal to the expected value of what we will get from the call minus the expected cost. We can say that $N(d1)S$ is the expected value of the asset we will acquire under the call: we will get an asset with a value of S . That asset is weighted by a probability; $N(d1)$ is the probability we will exercise. (We will see later that $N(d1)$ is also the “delta” of the option.) And $e^{-rT}N(d2)E$ is the expected cost, in present-value terms, of having to exercise the option. And the call is worth the net difference between what we expect to get and what we expect to have to pay for it.

What are $d1$ and $d2$? We define $d1$ as $[\ln(S/E) + (r + \sigma^2/2)T]/\sigma\sqrt{T}$. What does this unwieldy beast mean? In a certain sense, $d1$ reflects the value of being able to exercise the option. Let’s start by thinking about it in the case of an at-the-money option. Here, $S = E$, hence $S/E = 1$. Now, $\ln(1) = 0$ (recall that “ln” is the *natural* logarithm not a logarithm to the base 10). So now, $d1 = (r + \sigma^2/2)T/\sigma\sqrt{T}$. It may help to rewrite this as two components: $rT/\sigma\sqrt{T} + (\sigma^2T/2)/\sigma\sqrt{T}$.

Let’s suppose that our option is in the amount of \$1. Then rT is the value we get by not buying \$1 of stock today, because we can keep the money in cash and earn interest. If we divide our period of time into units of $\sigma\sqrt{T}$, then we can say that $rT/\sigma\sqrt{T}$ is approximately the interest that is earned in that period (“approximately” because we are neglecting compounding). So that is the first part of $d1$. The second part arises from the volatility of the share. It can be simplified by dividing through by $\sigma\sqrt{T}$ to arrive at $\sigma\sqrt{T}/2$. Over the period T , a share with a volatility of σ is likely to make

an up or down move of $\sigma\sqrt{T}$. It is equally likely to go up or down. We are only interested in the payoff if it goes up—we can walk away from it if it goes down. Because there is a 50/50 chance of it going up, the expected profit, over our chosen subinterval of $\sigma\sqrt{T}$, is $\sigma\sqrt{T}/2$. So we can interpret $d1$ as the cash value of the interest earned by buying the option rather than the share, plus the payoff if the share goes up, over a specific interval of $\sigma\sqrt{T}$ in length.

All of this was on the assumption that we were at the money; clearly, if we are out of the money, the probability of achieving $d1$ is less. If we are in the money, the probability of achieving $d1$ is greater, and this adjustment is made by including the $\ln(S/E)$ component. To find the resulting probability, we then use the cumulative normal, $N(x)$, function.

Another way of looking at the Black-Scholes formula is to realize that Black and Scholes, in fact, adapted this formula from another field: an equation for heat transfer in physics. To illustrate this, assume you have a block of metal in a room that is at 20 degrees Celsius. If the block is heated until its temperature reaches 200 degrees, and then allowed to cool, the center of the block will stay hot for some time but then will begin to cool rapidly. (You can think of the market volatility today as the “heat” level.) If you plot this, you will see a pattern like that of Figure 17.6, which shows how time decay affects the price of an option.²

It may help to make this a bit more concrete. Suppose we have a one-year option (i.e., $T = 1$), the rate of interest is 10% (i.e., 0.10), the annualized volatility is 15% (i.e., 0.15), and the option is at the money so that $S = E$. Let us assume that the option is on a share with a current price of \$100. Then $rT = 0.10$ and $(\sigma^2 T/2) = 0.0225/2 = 0.01125$. Clearly $\sigma\sqrt{T} = 0.15$, and so we have $d1 = (0.10 + 0.01125)/0.15$, or 0.741667. We can use the Excel function NORMDIST (setting the function to have mean of 0 and variance of 1) or its equivalent in other spreadsheets, or look it up in a statistical book, to find that $N(0.741667) = 0.770855$, that is, there is a 77% chance that we will exercise a one-year at-the-money option on these assumptions if volatility is 15%. So the first term of the Black-Scholes value is 77.0855.

The second term is the discounted value of the exercise price multiplied

²This example is borrowed from Robert Tompkins, *Options Analysis*, 2nd ed. (Probus, 1994).

by $N(d_2)$. We know that $d_2 = d_1 - \sigma\sqrt{T} = 0.741667 - 0.15 = 0.591667$. Again we use Excel or our statistics book to find $N(d_2) = 0.722963$. We know that $e^{-rT} = \exp(-0.10)$, which again we can find from Excel or elsewhere to be 0.904837. So we know that the discounted value of the exercise price ($E \cdot e^{-rT}$) is 90.4837 and that the second component of the Black-Scholes formula is 0.722963×90.4837 , or 65.41641. This is the expected cost of exercising the option if it expires in the money.

So the value of the call is the difference between the expected payoff from exercising minus the expected cost of exercise: $77.0855 - 65.41641 = 11.66913$.

AMERICAN VERSUS EUROPEAN OPTIONS

We have said that an American option is one that can be exercised at any time until maturity and that a European option is one that can only be exercised at maturity. Common sense tells us that the American option must always be worth at least as much as the European: it conveys more rights and so must be worth more.

The question is “How much more?” The answer depends on the nature of the underlying asset. For instance, if the asset underlying the option is an equity that pays dividends, there can be circumstances in which it is optimal to exercise early. Likewise, for a currency option on a high-interest-rate currency—sterling—if the option is deep in the money, it may be worth exercising in order to get the high yield.

This will normally be true only if the option’s price does not itself reflect the value of the dividend due on the equity or the interest rate payable on the currency; that is, the market is not pricing efficiently. It can be shown that the right of early exercise is not in itself normally worth a great deal. It will almost always be better to sell an American option in the marketplace than to exercise it. The reason is that, until it expires, the American option will have some time value. In an efficient market, someone will always be willing to pay something for that time value.

There are three exceptions to this rule that it is better to sell than exercise: (1) for an American option on an instrument that is about to pay a cash flow—under certain conditions, early exercise may be worthwhile; (2) when dealing costs in the options market are high; and (3) when the option is so deep in the money that time value is negligible.

If dealing costs in the options market are high, then it may be cheaper to exercise the option than to incur the dealing cost by selling the option.

Likewise, we saw earlier that when an option is deep in the money, it will have almost no time value, and exercise may be the best choice. Suppose spot sterling is \$1.50; we own a three-month \$1.40 call worth \$0.10; that is, the call has no time value. Suppose three-month forward sterling is trading at \$1.45. Then we can exercise the option at \$1.40, and sell in the spot market at \$1.50, for a profit of \$0.10. If we still need sterling, we can buy forward at \$1.45. Alternatively, we can sell the option for \$0.10 and buy forward at \$1.45. In either case, the net cost of forward sterling to us is \$1.35.

There is one exception to this: the holder of an in-the-money option on a futures position who is hedging a futures position may find it optimal to exercise because of the difference between the margining procedures: the futures position is tying up variation margin, but the option position is not giving the benefit. This does not apply on the Chicago Mercantile Exchange (CME) or London International Financial Futures Exchange (LIFFE), where the two positions can be linked together. It is relevant, though, when we are considering two exchanges where we cannot offset.

VOLATILITY

The more volatile an instrument, the higher the associated option price. *Volatility* is a measure of how the price of the underlying instrument varies. The word *volatility* covers a multitude of possibilities. It could mean the volatility that we have deduced from other traded options ("implied volatility"), or it could mean our forecast of volatility. It could mean an estimate of volatility as derived from recent history. Unless otherwise stated in this book, volatility will be taken to refer to historic volatility, which is defined as the standard deviation (which we defined in Chapter 3) in price returns of the instrument underlying the option.

To be precise, the definition of *annual historic volatility* normally used in the options markets is:

$$\text{Volatility} = \sqrt{\text{Variance}\left[\log\left(\frac{P_t}{P_{t-1}}\right)\right]} \times 250$$

where $t = 1/n$; n is the number of trading days over which volatility is measured (we assume 250 trading days per annum). An alternative measure is to do the same calculation assuming a 365-day year, rather than trading days.

Measuring the volatility of an instrument in terms of its standard deviation gives us an idea of its likely trading range, all other things being equal. For example, if a currency priced at \$1.00 has an annualized volatility of 20%, then the most likely range of prices (i.e., within one standard deviation) by the end of the year is \$0.85 and \$1.20 (\$1.00 divided by 1.2 and multiplied by 1.2, respectively).

Let's take a call option on sterling with a strike price of \$2.10, when the currency is at \$2.00. If the expected volatility of sterling is 20%, there is a greater chance that the price will be above \$2.10 at the expiration of the option than if expected volatility is only 10%. The fact that there is a higher probability of large price falls is of no concern to the holder of a call option because the holder's loss is limited to the premium paid. So he or she will be prepared to pay more for an option on a currency that has an expected volatility of 20% than for an option on a currency with an expected volatility of 10%. Equally, the writer of the call option faces a greater risk on the more volatile currency and, therefore, will charge a higher premium to write it.

Estimating the future volatility of the underlying instrument is one of the hardest tasks in pricing an option. It is the only variable affecting the option premium that is not directly observable in the market when the option is priced. All we know at that point is what its volatility has been in the past. Conversely, once the option is priced (for example, an exchange-traded option where we can see the price at which the option last traded), we can work out what volatility is implied in the price, assuming we know the options-pricing formula that was used.

Finally, one key assumption of the Black-Scholes model is that volatility is known and constant during the life of the option. This is, of course, not possible in reality. Nor, in practice, do we find the market (apparently) using a consistent volatility across the whole range of strike prices. Rather, we find that the market has a range of volatilities, higher for out-of-the-money options and lower for at-the-money ones. This is called the "volatility smile," and we turn now to some problems in the concept of volatility.

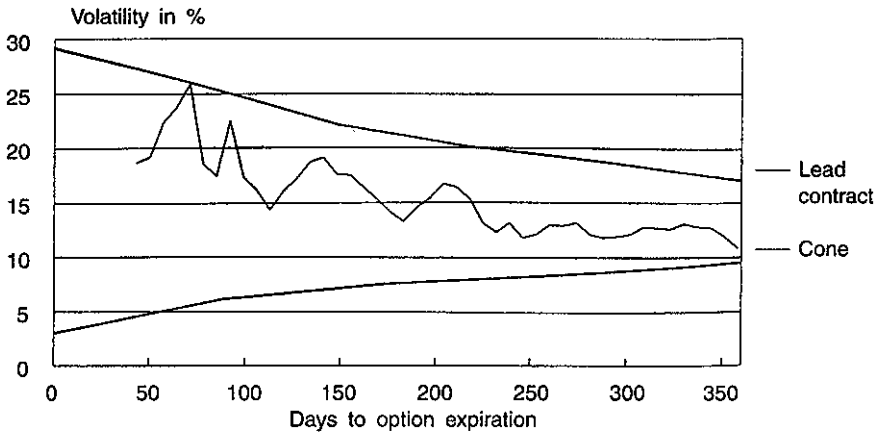


Figure 17.13 Volatility Cone

Volatility Cones

Given the critical importance of the volatility estimate in pricing an option, it may be worth spending some time thinking about how we should make that estimate. Often traders use gut feel or pricing in line with implied volatilities seen in the market. This may be satisfactory. The evidence in other markets is that spending huge sums of money or large amounts of time in building sophisticated forecasting models does not necessarily achieve performance improvements in proportion to the effort. One recent study concluded: "On a time-varying ex ante basis, the simpler the model, the better it performs . . . evidence from this study strongly supports the 'keep it simple' approach to forecasting."³ The same study recommended exponential smoothing and regression analysis as likely techniques for volatility forecasting.

A way of looking at volatility that many find helpful is the so-called volatility cone (Figure 17.13). This starts by considering the term structure of volatility. The smoothly curved lines represent upper and lower bounds of historical volatilities for trading horizons ranging from one month to one year. The data is drawn from the two previous years.

The resulting volatility cones show that short-term historical volatilities are substantially more variable than longer-term historical volatilities. This

³E. Dimson and P. March, "Volatility forecasting without data-snooping," *Journal of Banking & Finance* (1990).

can be seen in the greater distance between the maximum and minimum 30-day historical volatilities (shown toward the left of the graph) and the maximum and minimum 180-day historical volatilities (shown in the middle of the graph). The chart also shows the recent history of implied volatilities for the nearest contract (the lead contract) and the next (first deferred) contract. The solid line shows the past quarter's behavior of the current lead option, and the dotted line shows the past quarter's behavior of the current first deferred option. The left-most point of each line is the value of implied volatility for each of the contracts on the last trading day of the most recent quarter.

Volatility Smiles

A key problem in volatility estimation is that it is very common to find a skewed distribution of volatility when we observe the implied volatilities available in the market. This phenomenon became more obvious after the crash of 1987. Typically, out-of-the-money options are generally priced with higher volatilities. Usually the effect is somewhat symmetrical; but in equity markets particularly, the smile is more often what has been described as "a lop-sided leer." This phenomenon can be seen in Figure 17.14⁴ showing the leer for the UK equity market (FTSE options, August 1991).

Figure 17.15 shows the volatility smile for the March 1997 Euromark option contract on LIFFE⁵ and its evolution over time.

Implied Binomial Trees

In 1994, researchers from both sides of the Atlantic published studies that described the development of an options-pricing model that automatically incorporated the smile and the term structure effect seen in options markets.⁶ There were two approaches involved: (1) the implied volatility tree and (2)

⁴Data from R. G. Tompkins, *Options Analysis* (Probus, 1994).

⁵Many thanks to Bryan Eddery of LIFFE for supplying the data.

⁶B. Dupire, "Pricing with a Smile," *Risk* (January 1994); E. Derman and I. Kani, "Riding on a Smile," *Risk* (February 1994); M. Rubinstein, "Implied Binomial Trees," *Journal of Finance* (July 1994).

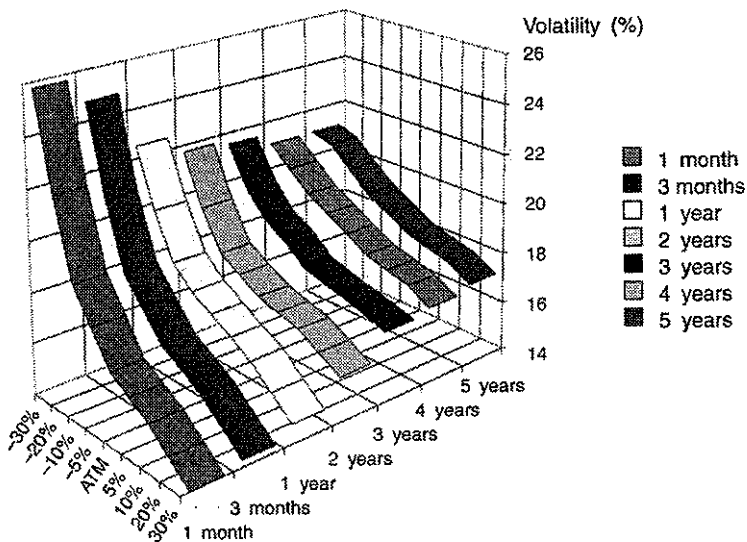


Figure 17.14 Volatility Smiles for FTSE Options

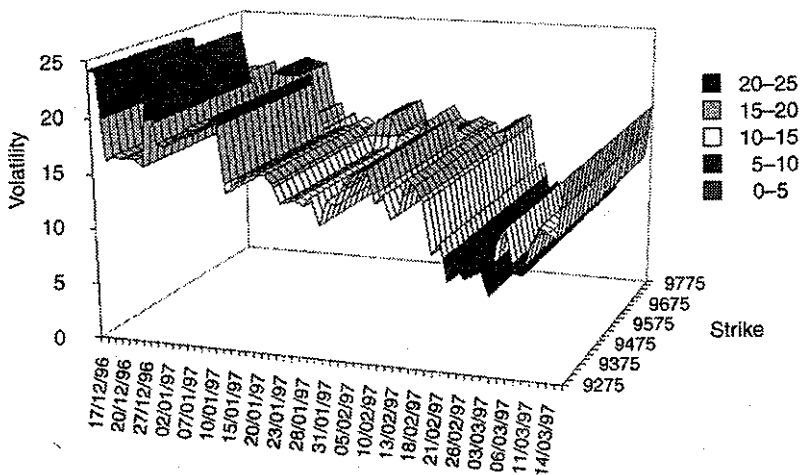


Figure 17.15 Volatility Surface for Euromarks, March 1997

the implied binomial tree. The first, in essence, takes observed option volatilities for future dates and uses them to construct the binomial tree. We can depict the outcome visually as if the tree were twisted to allow for differing volatilities at different nodes (Figure 17.16).

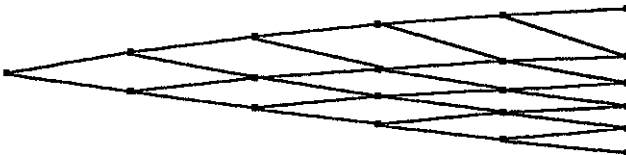
The second, the implied binomial model, starts with a given asset-price distribution for a particular future date and then builds a binomial distribution whose terminal distribution is equal to the given distribution. Where do we get this distribution from? Two possibilities suggest themselves: (1) deduce it from existing options prices; (2) take a specific set of market views. (In a sense, we are coming full circle here to the approach to options pricing before the risk-neutral Black-Scholes model was accepted; but this time we are imposing it on to a much more sophisticated framework.)

The implied binomial tree model has three steps:

1. For a given future date, set up a risk-neutral probability distribution for the asset.
2. Build a binomial tree whose last nodes end on the given future date and coincide with the distribution set up in step 1.
3. Use this tree to value options.

The third step is the same process as the one which we did earlier. The first step can be done, as mentioned, by working from a complete set of European option prices for some given forward date (obtained, if necessary, by interpolation/extrapolation from existing market data).

The implied volatility and the implied binomial tree approaches are potentially very powerful and flexible options-pricing tools. It seems likely we will see considerable development in this area.



Implied volatility model generates a twisted binomial tree.

Figure 17.16 Implied Volatility Tree

Volatility Indexes

At some point it seems likely that there will be a market in pure volatility; but it is some time in developing. In 1993, the Chicago Board Options Exchange (CBOE) introduced the CBOE Market Volatility Index. The CBOE Market Volatility Index, known by its ticker symbol VIX, measures the volatility of the U.S. equity market. It provides investors with up-to-the-minute market estimates of expected volatility by using real-time OEX index option bid/ask quotes. The VIX is calculated by averaging Standard and Poor's (S&P) 100 Stock Index at-the-money put and call implied volatilities. As yet, there has been little interest in trading a future or an option on the VIX. Similarly, EUREX has a volatility index but no derivative on that index. On the other hand, there is an active market in "volatility swaps" in the over-the-counter markets.

Measures of Option Risk and Sensitivity

In managing an options book, dealers pay attention to a number of risk measures. The most important are referred to as *delta*, *gamma*, *vega* (or *kappa*), and *theta*. Other measures sometimes referred to are *rho* and *lambda*. In this section we will consider how these risk measures apply to our old favorite, the \$2.00 sterling call. We will calculate them for a three-month option in an environment where the volatility is estimated at 20%, the domestic currency interest rate is 8%, and the foreign currency rate is 6%.

The *delta* of an option is the change in the price of the option that results from a change of one dollar in the price of the underlying asset. Delta varies between 0 and 1 (or 0% and 100%, depending how you want to express it). Figure 17.17 shows how delta rises from very low values when the option is out of the money to 1 when the option is deep in the money. At the point when delta reaches 1, the option is certain to be exercised, has no time value, and behaves like the asset itself.

We defined delta as the change in the option price for a change in asset price. That means that delta can be defined as the slope of the tangent to the option's price curve. Delta measures the sensitivity of the option's price to the underlying asset. The more in the money the option is, the more sensitive its price is to that of the asset. Conversely, for a deep-out-of-the-money option, even quite a large change in the asset price will have no effect.

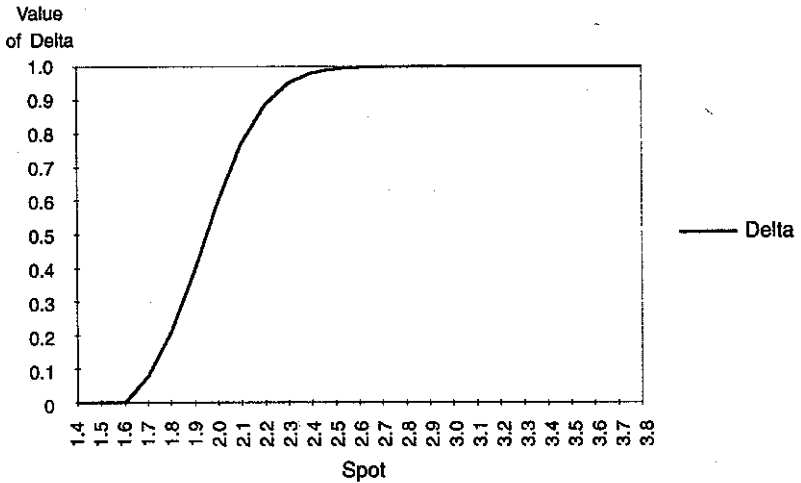


Figure 17.17 Delta

The question is sometimes asked: Why does delta change if volatility changes? The answer is: Because a change in volatility changes the shape of the premium/asset price curve, the slope of the curve (delta) changes.

Another way of looking at delta is to say that it measures the probability that the option will be exercised. When the option is deep out of the money, there is little chance that it will be exercised, and delta is zero. When the option is deep in the money, the option is almost 100% certain to be exercised, and delta will be one. When the option is at the money, the chances of exercise are 50/50, and delta will be around 0.5. The implication of this is that delta can be used as a measure of the exposure implied by an option position. Suppose we have written a call on \$100 million Eurodollar futures at 90.5 (an implied interest rate of 9.5%). Suppose the delta of the position is currently 0.25, that is, a 25% chance the option can be exercised against us. On a probability-weighted basis, therefore, our exposure is equivalent to being short \$25 million worth of Eurodollar futures at 90.5. Therefore, to hedge our position, we could buy \$25 million of futures. This is the concept of delta weighted hedging, which is widely used by many market makers in options.

The next important measure of option sensitivity is *gamma*. Gamma measures the sensitivity of delta to changes in the asset price and, thus is a measure of the stability of delta. The higher gamma is, the more rapidly

delta changes as the price of the asset changes. If we look again at Figure 17.17, we can see that delta does not change much as the asset price changes if the option is deep out of the money. Thus gamma is low. Nor does delta respond much to changes in asset price when the option is deep in the money. Again, gamma is low. Gamma is highest when the option is at the money. It is then that delta is moving most quickly. For the delta-weighted hedger, it is important to measure gamma. A high gamma means the hedge must be adjusted much more often: delta hedging a high-gamma position tends to be much more expensive. Gamma is highest when the option is at the money and when it is short-dated. It is lowest for long-dated out-of-the-money options.

Another way of looking at gamma is to say that it measures the curviness of the option premium curve. Just as delta measures the slope of the tangent to the curve at today's price, so gamma measures the curviness of the curve at that point. (In the language of calculus, delta is the first derivative, and gamma is the second derivative.) You might say that delta is the speed of change and gamma is the acceleration. Figure 17.18 shows the effect of gamma for different asset-price levels. (The curve ought to be smooth, but the spreadsheet used only had 10 different spot points in it.)

Offsets to gamma—ways of hedging our gamma exposure—would be to sell short-dated at-the-money options if we are long and to buy if we are

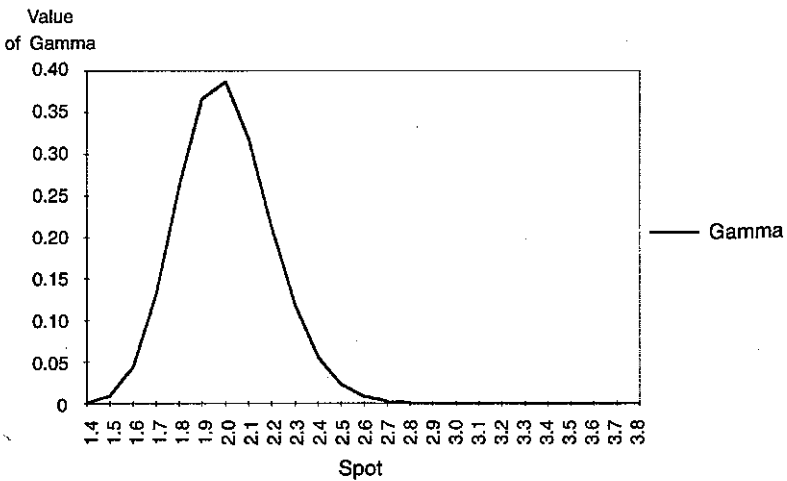


Figure 17.18 Gamma

short; we can avoid building up exposure to gamma by dealing in out-of-the-money far-dated options.

The next measure we must look at is called *vega* (or kappa or zeta or epsilon). This measures the impact on the option's premium of a 1% change in volatility. We said earlier that the more volatile the underlying asset, the more valuable the option on the asset will be. There will be a greater chance that the option could move in our favor during its lifetime. Vega particularly affects longer-dated options pricing.

Vega is at its largest for at-the-money long-dated options. If an option is deep-in or deep out-of-the-money, a change in volatility will not mean very much, whereas it could have a significant effect if the option is at the money. Likewise, vega is more important for a long-dated option because the longer time allows a greater chance for the option to move in the buyer's favor. Figure 17.19 shows the effect of vega for different asset-price levels. Offsets to vega are to write options if we are long of vega and to buy options if we are short; and if we do not want to build up vega, we should tend to deal in out-of-the-money options.

The fourth important measure of options sensitivity is *theta*. Theta measures the impact of time on an option's fair value. More exactly, it measures the effect of a shortening of 1 day in the option's life to maturity on the option

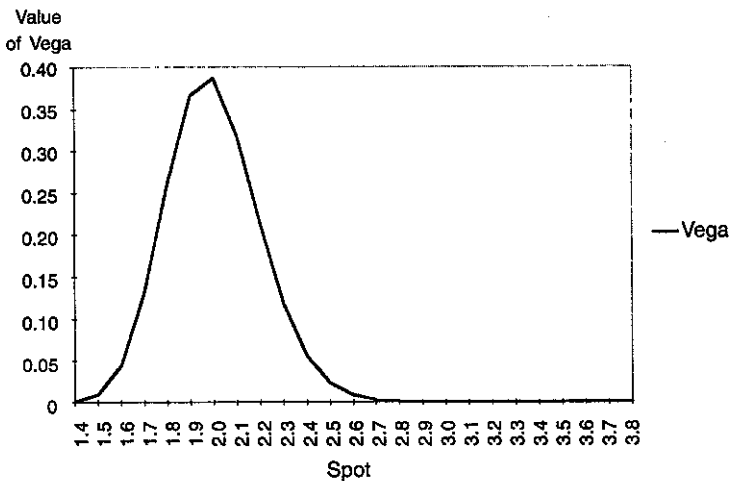


Figure 17.19 Vega

premium. We said earlier that early in an option's life the effect of time decay is not very large. It increases as the option's life shortens, and the reason for this is fairly clear: The percentage impact on the option's value of a 1-day shortening in its life is small if the option has 90 days to run, but much larger if it has only 1 day left. Also, theta has a bigger impact on at-the-money options. We saw earlier that time value for deep-in or deep-out-of-the-money options is small. Figure 17.20 shows how theta behaves for different price levels.

It may be of interest to consider delta, gamma, vega, and theta in three dimensions, that is, to plot them not only against changes in the spot but also over time from now until the maturity of the option. Figures 17.21–17.24 illustrate the situation.

We can see that delta starts off with the S-shaped curve described earlier, and then it sharpens to an almost vertical shape at expiration, reflecting the fact that at that point the option is either in or out of the money.

Note first that the delta diagram (Figure 17.21) was turned around compared with this gamma diagram (Figure 17.22) and its successors (Figures 17.22 and 17.23), so that the delta shape could be more easily seen. We can see from Figure 17.22 that gamma presents the biggest problems when we are very close to expiration and the option is at the money (a reflection of the nearly vertical delta line seen in Figure 17.21).

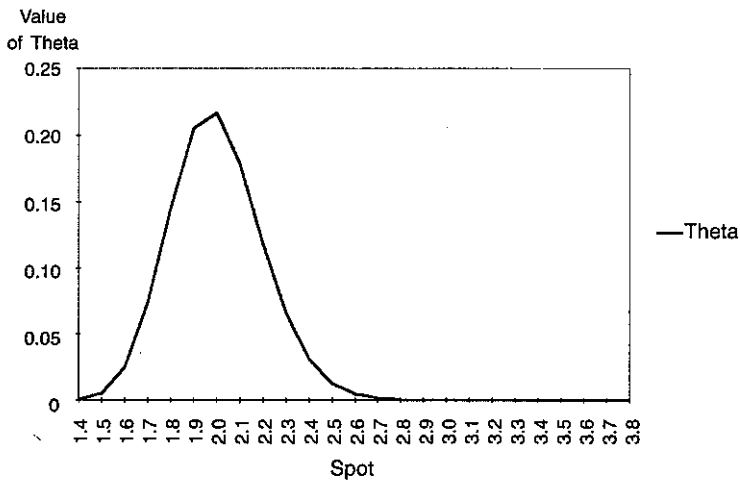


Figure 17.20 Theta

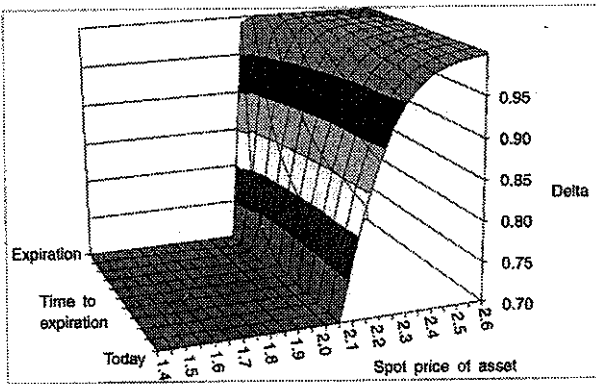


Figure 17.21 Delta against Spot Rate and against Time

Obviously, for volatility to have an impact, the market must have time in which to be volatile. As we get closer to expiration, therefore, vega has less influence. Likewise, if we are deep in or deep out of the money, a 1% change in volatility levels isn't going to make much difference.

In Figure 17.24 we can see that, for a given change in the time to expiration, theta has its largest effect on the option price as we are close to maturity. Finally, two other measures that are sometimes used are (1) rho and (2) lambda. *Rho* measures the sensitivity of the option's price to interest rates. It can be defined as the dollar change in the option's price for a 1% change

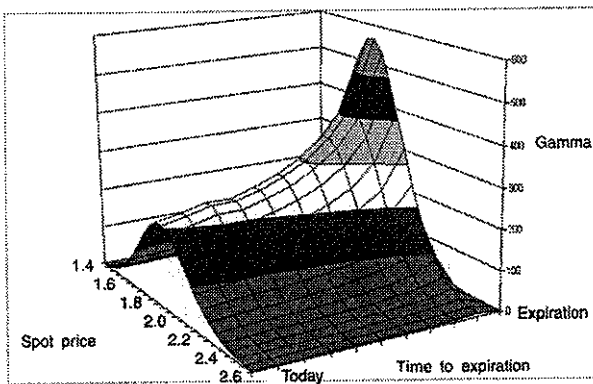


Figure 17.22 Gamma against Spot Rate and against Time

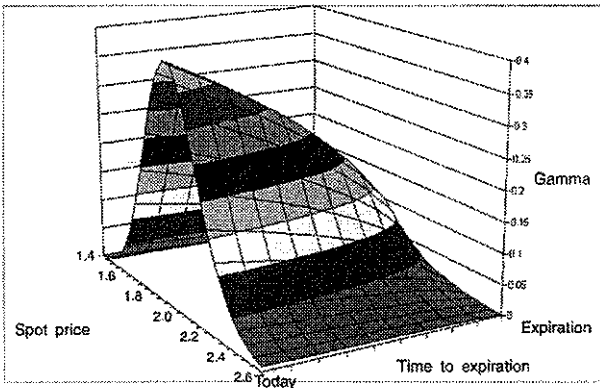


Figure 17.23 Vega against Spot Rate and against Time

in the rate of interest. Rho can be divided into two effects. The first is the effect of interest-rate changes on the price of the asset, which will be important if the option is on a bond or on a currency for forward delivery. The second is the effect of gearing, or leverage, on the option. The option gives the holder a claim on the asset, without having to finance its purchase. For example, I could buy an option on 1,000 IBM shares worth \$100,000; if the option costs me \$2,500, I have obtained effective control of \$100,000 of assets for \$2,500. My alternative would have been to borrow the remaining \$97,500

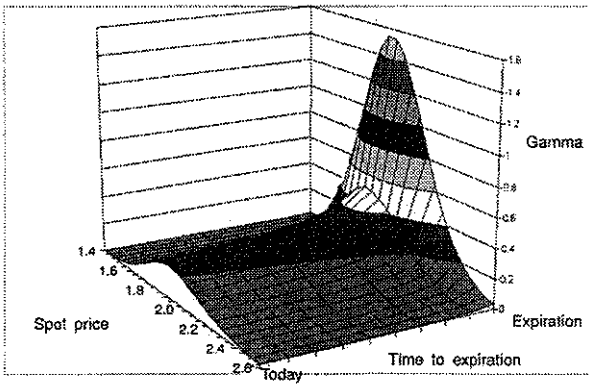


Figure 17.24 Theta against Spot Rate and against Time

to finance outright purchase of the underlying shares. Rho is not often important in assessing options, but it can be so, for example, in the case of long-dated currency options because in this case the forward exchange rates themselves are influenced directly by interest-rate movements.

Lambda is the percentage change in option price for a percentage change in stock price; effectively, it is the delta restated in percentage terms. (Economists would say that lambda is the elasticity of the option price with respect to asset price.)

BLACK-SCHOLES VARIANTS AND OTHER MODELS

Everybody agrees that the Black-Scholes model is incredibly useful. Everybody also agrees that it doesn't actually quite work in practice. Adjustments have to be made. Extensions have been developed to deal with specific technical problems with the Black-Scholes model: interest-rate options have to be looked at separately because it will not always be true that the price of the asset is independent of the risk-free rate of interest. The model needs to be modified to handle assets deliverable in the future (for example, for options on futures contracts); this variation gives the Black model. The Black-Scholes model is not well adapted for situations in which dividends or other cash flows are earned on the underlying asset; there is the possibility of early exercise in certain circumstances. In these situations, the binomial model discussed earlier would normally be used. Equity options models have to reflect the fact that dividends are normally paid in "lumpy" amounts. The Garman-Kohlhagen variant of the Black-Scholes model is used in the foreign exchange markets to allow for the impact of the interest rates of two different currencies. We now discuss some of these modifications.

Black Futures Option Model

In 1976 Fischer Black introduced a variant of the Black-Scholes model to deal with futures prices. In this model, the underlying asset price is replaced with the futures price, and both the futures price and the strike price are discounted to present value:

$$C = e^{-rt}[F \times N(d1) - E \times N(d2)]$$

$$\text{where } d1 = \frac{\ln(F/E) + (\sigma^2/2)t}{\sigma\sqrt{T}}$$

$$d2 = d1 - \sigma\sqrt{t}$$

t = Time to expiration (as % of a year)

F = Price of future

E = Exercise price of option

r = Risk-free interest rate for period t

N = Cumulative normal density

\ln = Natural logarithm

σ^2 = Variance of the rate of return

e = Exponential function

The Black model has a number of attractions: it is simple to use, and it handles assets due at a forward date. So it is widely used in practice in the financial industry, particularly for options on futures but also for interest rate caps (this will be seen in the next chapter).

Currency Options

We come now to consider currency options in more detail. One simple point should be made at the outset: Up to now, when we talk about an option, it has been quite clear what it is that the option is on. But now we have scope for confusion. Is a DEM/USD call a call on the deutschmark and a put on the U.S. dollar, or a call on the U.S. dollar and a put on the deutschmark? For exchange-traded options, this is not generally a real problem; but when quoting OTC options, it is very important for all parties to be clear on precisely what is meant.

Consider the following four methods:

1. Buy a June 15 JPY call struck at JPY 150 for 2%.
2. Buy a June 15 JPY call struck at JPY 150 for \$0.0133.
3. Buy a June 15 JPY call struck at \$0.0067 for \$0.0133.
4. Buy a June 15 USD put struck at JPY 150 for JPY 2.12.

All of these are quotations for precisely the same deal. Method 1 or 2 might be used in the OTC market in London or New York; method 4 might

be used by a Continental bank in the OTC market; method 3 is the one used in the exchange traded market. Which method is used depends on which is the base currency and which is the quoted; second, on whether the currency is quoted in indirect or direct terms (that is, JPY 150 per dollar or \$0.0067 per JPY); and, third, on whether the premium is quoted as an amount of currency or, as is common in the wholesale interbank market, as a percentage.

In an effort to reduce the potential for confusion, the Foreign Exchange Committee of the Federal Reserve Bank of New York in association with the Canadian Foreign Exchange Committee, the British Bankers' Association, and the Tokyo Foreign Exchange Market Practices Committee have produced a standard master document, the 1997 International Currency Options Market (ICOM) Master Agreement. A parallel, broader document has also been produced, the Foreign Exchange and Options Master Agreement (FEOMA). (These can both be downloaded from the Federal Reserve Bank of New York's web site www.ny.frb.org.)

Options pricing for currency options follows the same basic principle as for other options pricing. But there are several differences, of which the most important arise from the fact that there are now two sets of interest rates to consider, one in each currency. We know, therefore, that the forward exchange rate will be different from the spot rate. There are two sets of effects to consider:

1. The effect of the interest differential.
2. The effect of changes in the interest differential.

Let us look first at a situation in which spot sterling is trading at \$2.00 and three-month forward sterling is trading at \$1.95. Let us look at a three-month American call on sterling with a strike of \$1.95: the option is in the money because I can exercise at \$1.95 and sell at \$2.00. So the American call is worth at least its intrinsic value of \$0.05. But suppose the option were a European option: I can only exercise at expiration. The value, S , of the optioned asset is not the spot price but the forward price. In other words, the American call includes the forward points; the European call does not.

To allow for this, the following conventions tend to be used:

Foreign Exchange Option Conventions

<u>Higher-interest-rate currency</u>	<u>Low-interest-rate currency</u>
At-the-money calls struck at spot rate	At-the-money calls struck at forward rate
At-the-money puts struck at forward rate	At-the-money puts struck at spot rate

Garman-Kohlhagen Currency Options Model

In discussing the Black-Scholes model earlier, we glossed over an important fact: in a foreign currency option, there are two rates of interest involved: (1) the domestic and (2) the foreign. In 1983, Garman and Kohlhagen modified the Black-Scholes model to handle foreign currency options by allowing for this. Using the same notation that we had before, the Garman-Kohlhagen model for a European call is:

$$C = e^{-r_f T} S N(d1) - E e^{-r_d T} N(d2)$$

where r_f = the foreign interest rate

r_d = the domestic interest rate to the expiry date of the option

The first term reflects the fact that the spot rate is not the true price of the asset because we are dealing with a European call: the spot has to be converted into the equivalent of a forward rate. The definitions of the other terms are as before, except that $d1$ is rewritten:

$$d1 = \frac{\ln(S/E) + \left(r_d - r_f + \frac{\sigma^2}{2} \right) T}{\sigma \sqrt{T}}$$

By comparison, the original Black-Scholes formula was:

$$C = N(d1)S - e^{-rT} N(d2)E$$

We can if we choose rewrite the Garman-Kohlhagen formula in terms of forwards:

$$C = [FN(D1) - EN(D2)] e^{-rdT}$$

where

$$D1 = \frac{\ln\left(\frac{F}{E}\right) + \left(\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

and

$$D2 = D1 - \sigma\sqrt{T}$$

Using this rather simpler notation, we can also write the formula for a European put as follows:

$$P = [F\{N(D1) - 1\} - E\{N(D2) - 1\}]e^{-rdT}$$

Another way in which currency options differ from other options is that in the foreign exchange market, unlike most interest rate markets, there is a widely traded and liquid forward market. This means that the buyer or seller of an option has always the choice of comparing the option with the price available in the forward market; it also allows for the possibility of combining the two. These are the so-called "third-generation" products, which are discussed in the next chapter.

Interest-Rate Option Models

In many respects, by far the most difficult area of options is in the area of interest rates. It is here that much current research is being done, and a number of different models have emerged. The critical issue is that the underlying assumption in Black-Scholes is that the underlying rate of interest is constant. Clearly, this is useless when we are trying to price an option on a variable

rate of interest. A further problem is that in most cases, such as bond options, the underlying instruments are influenced not just by a single rate of interest but by the whole yield curve. In addition, if we are looking at a bond option, we have to face the fact that as the bond approaches maturity and its life shortens, its volatility decreases. So the Black-Scholes assumption of a constant volatility is also broken.

Most approaches are some form of the binomial model; we make some assumptions about the term structure of interest rates and then use those assumptions to generate a "lattice" of forward interest rate levels. The main differences among the models lie in the way the interest-rate process is specified, and this is set out in Table 17.8 for some of the better-known models.

In addition to the models cited in Table 17.8, there are a number of others (for example, Cox-Ingersoll Ross; Vasicek; Longstaff-Schwartz; Brennan-Schwartz) that have been developed and used by practitioners in certain circumstances.

Although there is no space here to discuss these in detail, at the risk of grossly oversimplifying, the issues at stake are (1) the underlying number of factors allowed to influence the term structure model, (2) the specification of the underlying volatility, and (3) the presence or absence of restrictions imposed to ensure that the resulting lattice is recombining.

Broadly, in a *one-factor model*, the process for the short-term risk-free interest rate involves only one source of uncertainty. The drift and the volatility are assumed to be functions of the interest rate but stable over time. These models include the Vasicek and Cox-Ingersoll-Ross models. *Two-factor models* usually involve a process in which a short rate and a long rate are modelled: for example, the Brennan-Schwartz model assumes that the short rate tends to revert to a long rate, which in turn follows a stochastic process. The Longstaff-Schwartz model is another example of this kind. The Heath-Jarrow-Morton (HJM) model can be thought of as a two-factor model, but it is capable of generalization to a multifactor approach.

The HJM model, however, produces trees that do not recombine. This presents practical difficulties, particularly if we are pricing path-dependent options. For a standard tree with n steps, we will have $n + 1$ terminal values. But when we have to consider all the possible paths through the tree, we have to deal with the fact that in an n -period tree there are 2^n paths. This means that in a 100-step tree, there are about 1.27 million trillion trillion paths. Put another way, if each human being on earth (say 5 billion people)

Table 17.9 Various Interest-Rate Process Models

Ho-Lee Model

$$dR = \theta t (dt) + \sigma dz$$

- where dR = Absolute change in interest rate
 θt = Mean of interest rate process as a function of time
 dt = Change in time
 σ = Volatility of absolute interest rate change
 dz = Standard random walk (Wiener process) with z a function of \sqrt{t}

Black-Derman-Toy Model

$$dR/R = \theta t (dt) + \sigma dz$$

- where dR/R = Proportional change in interest rate
 Other components are as in Ho-Lee.

Hull & White Model

$$dR = [\theta t + a(t) \times (b - r)]dt + \sigma dz$$

- where $a(t) \times (b - r)$ is an adjustment constant bringing the rate back to a long-term constant level r ("mean reversion")
 Other components are as in Ho-Lee.

Heath, Jarrow & Morton Model

$$dR(t,T) = a(t,T) + \sum \sigma(t,T) f(t,T) dz(t)$$

- where dR = Absolute change in interest rate which is a function of the time t of the option and of the maturity T of the underlying asset (typically a bond)
 $a(t,T)$ = Mean of interest rate dispersion process as a function of time
 $f(t,T)$ = Forward rate seen at time t for a period maturing at time T
 $dz(t)$ = Wiener process driving term structure movements
-

represented a path, we would need 254 million trillion planets to represent the total. That's a lot of heads to count, and much of the practical work on path-dependent options pricing is concerned with speeding it up. Now we add to the fact of huge numbers the fact that in the HJM model such a tree does not recombine. That means, essentially, that for each pair of nodes we do not go back to a single node; each node has two new nodes. We can see that the number of nodes starts to grow exponentially.

In practice, ways around this problem are found either by using techniques to speed the computation—control variate techniques, finite differences, and so forth⁷ or by making assumptions that lead to recombining trees and that limit the full generality of the HJM model.

⁷These are discussed in J. C. Hull, *Options, Futures & Other Derivatives*, 3rd ed. (Prentice Hall, 1997); P. Wilmott, J. Dewynne & S. Howison, *Option Pricing: Mathematical Models and Computation* (Oxford: Oxford Financial Press, 1993), amongst others.

18 Options Instruments

In Chapter 17, we looked at some of the concepts underlying options, their pricing, and the risks associated with options. In this chapter, we set out a review of the main option instruments that have been developed.

INTEREST RATE OPTIONS

Interest Rate Guarantee

We will begin this discussion with the *interest rate guarantee* (IRG). As the name suggests, an IRG gives an investor or a borrower a guaranteed interest rate. It is in essence an option to buy or to sell an interest-rate forward rate agreement (FRA) on a specified date at a specified rate, for a given price today. It is for one period only (multi-period guarantees are called *caps*, discussed next; hence an alternative name for the IRG is sometimes the “caplet”). The pricing calculation is discussed in the following section on caps. The interest rate guarantee as described here differs from the cap in only one point: under a cap, the interest payment is in arrears, whereas of course under the FRA it is paid in discounted form on the settlement date.

A typical example of an IRG would be a contract on three-month LIBOR (London Interbank Offered Rate) for \$10 million, expiration January 16, 2001, at a strike of 6.75%. Suppose that on January 16, 2001, the level of LIBOR is 9%. Then a client who had purchased the IRG would receive $(9 - 6.75)/100 \times \$10,000,000 \times 91/360$ or \$56,875. The pricing of the IRG is based on the Black model for futures (see the next section).

Caps and Floors

The market for caps and floors is an extension of the market for interest rate guarantees and also of the market in fixed-income options. The interest rate cap sets a maximum level, or *cap*, on a short-term rate index. The buyer of the cap is compensated if the index goes above a certain level, the strike level. Similarly, a *floor* provides a minimum rate on some index. Because most cap and floor agreements are private, it is difficult to estimate the size of the market. But the volume is certainly large.

A cap or floor contract is specified by the following:

1. *Underlying Index.* Caps and floors can be created on many indexes. For example, caps can be bought on one-, three-, or six-month LIBOR. Caps and floors have been set on the following indexes: LIBOR, commercial paper, prime, Treasury bills, certificates of deposit, and certain tax-exempt rates.

2. *Maturity.* This has ranged from 3 months to 12 years.

3. *Frequency.* This covers firstly the reset dates, on which the level of rates is compared with the strike level to find what payment needs to be made. Monthly, quarterly, and semiannual are the most common frequencies. Similarly, frequency refers to the payment dates.

4. *Strike Level.* Usually, one fixed level applies to the entire program, although the level can change over time in a predetermined way.

5. *Notional Principal Amount.* Like the strike level, the amount underlying the contract can be constant, or it can change over time.

A typical cap agreement could have the following terms:

Underlying index	Three-month LIBOR (as per Reuters LIBO screen)
Term of cap	3 years
Rate fixing	Quarterly
Strike level	8%
Payment	Quarterly, in arrears (actual/360 calculation basis)
Notional amount	\$30 million
Up-front fee	1.12% of par (\$336 thousand)

In this agreement, the writer of the cap would pay the owner of the cap in any quarter when three-month LIBOR was over the 8% cap level on the fixing date. As an example, if LIBOR were quoted at 9% on the fixing date, the payment would be: $(9/100 \times 92/360 \times \$30 \text{ million}) - (8/100 \times 92/360 \times \$30 \text{ million})$, or \$76,666.67. In this case, the writer would pay the holder of the interest-rate cap \$76,666.67. On the other hand, if LIBOR were at or below 8%, no payment would be made.

The pricing of the cap is based on the Black model for futures. This is a variant of the Black-Scholes model and is used when we are considering an asset to be delivered in the future. It is:

$$\text{where } C = e^{-rt}[F \times N(d1) - E \times N(d2)]$$

$$d1 = \frac{\ln(F/E + \sigma^2/2)t}{\sigma\sqrt{t}}$$

$$d2 = d1 - \sigma\sqrt{t}$$

t = time to expiration (as percent of a year)

F = price of future

N = cumulative normal

E = exercise price of option

r = risk-free interest rate for period t

Let us now consider the following interest-rate cap, which we will look at as a sequence of interest-rate guarantees, or caplets:

Date	May 25, 2002	
Cap strike rate	8.50	
Principal amount	£10,000,000.00	
Zero-coupon rates to:	Volatility (percent per annum):	
November 25, 2002	6.375	
May 25, 2003	7.25	12
November 25, 2003	7.75	11
May 26, 2004	8.00	10

We are considering a cap dealt on May 25, 2002, on £10,000,000. It has a strike rate of 8.5% on six-month sterling LIBOR; that is, if LIBOR rises

above 8.5%, we are paid the difference between LIBOR and 8.5% on £10,000,000. The first fixing will be on November 25, 2002, and our estimate of volatility of LIBOR for the period to May 25, 2003, is 12% per annum. We have zero-coupon rates for the various periods and estimates of the volatility for those periods. We now proceed to apply the Black model:

Let us look at the first period caplet (the term often applied to the components that, when added together, produce the value of the cap). What we are interested in is the forward rate for the period (i.e., the rate from November 2002 to May 2003) because that is the rate to which the cap will apply. Using the usual formula, we can calculate the forward rate for that period: it is 7.9861%. Supposing that we own an asset that paid the forward rate on £10,000,000 for the period in question, it would produce $7.9861\% \times £10,000,000 \times 181/365$, or £396,022.59. This is the value of F in the Black formula for C . If the asset paid the strike rate of 8.5%, it would produce $8.5 \times £10,000,000 \times 181/365$, or £421,506.85. This is the value of E in the Black formula for C .

So now we can write $\ln(F/E) = -0.062365$ (remembering that we use natural logarithms). Because we are concerned with the time to the rate fixing, not the maturity of the caplet, $t = 184/365$ years, or 0.50411 years. So now we can find $\sigma\sqrt{t} = 0.12 \times \sqrt{0.50411}$, or 0.085201.

Now we can find $d1$ and $d2$ in the Black formula, and we find that $d1 = -0.689373$ and hence $d2 = -0.774574$. Hence, consulting our normal distribution tables, or using the Excel function for this calculation, we can find that $N(d1) = 0.245294$ and $N(d2) = 0.219296$. As a result, we can now find the main body of the Black formula, $[F \times N(d1) - E \times N(d2)]$, which comes to £4,707.41. This is the future value of the caplet; we need to discount it back to complete the Black formula.

For the period in question, the value of the discount factor to the maturity of the caplet (1 year) e^{-rt} is $e^{-0.0725}$, or 0.93007. So the present value today of this caplet is £4,378.30. An alternative approach would be to discount not using the continuous time factor e^{-rt} but the bond market discount factor of $1/(1+r)^t$, in which case the discount factor works out to 0.932401 and the caplet value to £4,389.30.

To find the value of the cap as a whole, we repeat this process for the other two caplets for the six-month periods ending November 25, 2003, and May 26, 2004, to arrive at a final value for the cap as a whole of £42,046.04 (using continuous-time discount factors) or £42,254.00 (using period discount factors). Before worrying too much about the discrepancy between these two

prices, it may be helpful to realize that plugging in a volatility of 10.1% instead of 10% for the most distant caplet produces a continuous-time cap value of £42,222.70—in other words, any discrepancy caused by the choice of discount method is very likely to be swamped by errors in estimating volatility.

This point, indeed, recurs in different guises throughout any discussion of options. Arcane differences between pricing models are more than likely to be swamped by (1) difficulty in getting the right volatility and (2) market gapping and other structural hedge-management problems, which are likely to mean that the ex post cost of the option is radically different than the ex ante premium charged. “When an option trader sells a structure that is worth \$5 on his theoretical value sheets, he can expect, barring transaction costs, to manufacture it for somewhere between \$4 and \$6.”¹

One final point should be made on caps because it often trips up the unwary. If I buy a cap with a strike price of 8.5% and today’s LIBOR is 7%, then I might expect the value of the cap to increase if LIBOR jumps to 7.5%. The probability of LIBOR rising through the strike is greater. So the price of the cap should rise. But, provided that the only move is in the current six-month LIBOR, this is not, in fact, true. The reason is that the cap is an option not on the cash market rates, but on forward rates. If six-month LIBOR rises but one-year LIBOR remains the same, then the forward rate (LIBOR for six months, starting six months from now) will *fall*.

Suppose we refer to our previous cap. Suppose that six-month LIBOR rises to 7%; then we will have the results shown in Table 18.1.

The value of the cap has actually fallen by about 10% despite the rise in cash LIBOR. (On the other hand, if the forward rates had risen, the value of the cap would, of course, increase.)

Applications of Caps and Floors

Probably the most widespread use of caps is by borrowers who for some reason—because it suits their cash flows or because they have no access

¹N. Taleb, *Dynamic Hedging: Managing Vanilla and Exotic Options* (New York: John Wiley, 1997), p. 2.

Table 18.1 Impact of a Rise in LIBOR on the Cap Value

Date	May 25, 2002	
Cap strike rate	8.50	
Principal amount	10,000,000.00	
	Zero-Coupon Rates To	Volatility
November 25, 2002	7.00	12
May 25, 2003	7.25	11
November 25, 2003	7.75	10
May 26, 2004	8.00	
	Discrete Time	Continuous Time
Cap value	38,466.36	38,267.88
As % of principal	0.38%	0.38%

to the swap markets or perhaps because they are highly leveraged—prefer to pay an up-front premium in order to receive rate protection.

In some cases a useful way for a borrower to analyze the value of a cap—apart from pricing it using the Black-Scholes model or some similar option-pricing model—is to consider its all-in cost over the life of the cap deal, given a particular interest-rate outlook. Table 18.2 shows one such analysis of a quarterly cap on three-month LIBOR.

Here we have a \$100 million borrowing at LIBOR repaid after three years, plus a cap with a strike rate of 8.5%, costing 1.12% for three years, on an amount of \$100 million. The alternative is fixed-rate funding for three years at 8%. Our first step is to amortize the cost of the cap over the deal’s life. At 8%, this amortized cap cost comes to 0.11% per quarter.

Suppose that for the first period, three-month LIBOR is fixed at 6%. Then our borrowing cost is \$1.52 million, and there is no payment under the cap. Hence our all-in cost for the period is \$1.63 million. Now suppose that LIBOR jumps to 10% and remains there for the life of the deal. Our borrowing cost jumps to \$2.53 million per quarter, and we receive a payoff from the writer of the cap of \$0.38 million, making our net cost \$2.15 million plus the amortized cost of the cap, that is, \$2.26 million.

We can price the true cost of funds under this outlook as the internal rate of return (IRR) of the column headed “Net Cash Flow” in Table 18.2. This comes to 8.9% on a semiannual bond basis. In this case, therefore, we would

Table 18.2 Cap Payoff Value

Quarter	LIBOR Rate	Liability Cash Flow	Cap Payoff	Capped Cash Flow	Cap Cost Amortized at 8%	Net Cash Flow
0		-100.00				-100.00
1	6.00%	1.52	0.00	1.52	0.11	1.63
2	10.00%	2.53	0.38	2.15	0.11	2.26
3	10.00%	2.53	0.38	2.15	0.11	2.26
4	10.00%	2.53	0.38	2.15	0.11	2.26
5	10.00%	2.53	0.38	2.15	0.11	2.26
6	10.00%	2.53	0.38	2.15	0.11	2.26
7	10.00%	2.53	0.38	2.15	0.11	2.26
8	10.00%	2.53	0.38	2.15	0.11	2.26
9	10.00%	2.53	0.38	2.15	0.11	2.26
10	10.00%	2.53	0.38	2.15	0.11	2.26
11	10.00%	2.53	0.38	2.15	0.11	2.26
12	10.00%	102.53	0.38	102.15	0.11	102.26

have been better off to have fixed in the first place at 8% than to pay the cap premium because rates did not remain low for long enough to allow us to pay off the cost of the cap.

Table 18.3 shows that in this situation, LIBOR would have to remain at 6% for five quarters (15 months) for the cap to be a better alternative. Table 18.4 highlights a point that may not be immediately obvious: as far as the borrower is concerned, it does not matter how high rates go, once they go through the cap strike level. If instead of going to 10%, they go to only 8.75%, the borrower's smaller payoff is balanced by a smaller borrowing cost, so that the IRR of the entire deal is still 7.99%. All that matters is that LIBOR should go through the strike level; after that, it does not matter how high rates go. This, of course, is due to the cap's being an option, and thus a one-way bet. The converse, of course, is true for the writer of the cap.

Another way of looking at the break-even is to ask the question: Given that the LIBOR for the first period is fixed at 6%, what rate can be reached in period two and remain thereafter, so that we break even? As Table 18.5 shows, the answer is 7.53%. If rates go above 7.53%, and remain there, then we would have been better off taking fixed-rate funding. A quick and dirty approximation, incidentally, to this break-even rate can be found by taking the annual cap cost (0.44%) and deducting it from the fixed funding rate of 8%. The resulting figure is 7.56%—not far from the true rate.

As we saw in the previous chapter, puts and calls are related to each other through the price of the underlying security. In the case of caps and floors, the common denominator is the interest-rate swap. Let us assume a flat yield curve. Three-month LIBOR and a five-year interest rate swap are both at 8%. In this case, a five-year cap is equivalent to a five-year floor plus a commitment to pay the five-year swap rate of 8%. This holds true when both the cap and the floor are struck at the swap rate and if the fixed rate is paid on the same basis as is the floating rate. It can be shown that these positions will produce the same cash flows under any interest-rate movement.

For a rate above the cap level, say 10%, the holder of the cap will be paid the difference between LIBOR and 8% (i.e., 2%). The floor and swap combination produce the same cash flow. Because rates are above 8%, the floor by itself produces no income, whereas the swap entitles the holder to the difference between the 8% fixed outflow and the 10% LIBOR—2% again. For rates below the cap level, say 6%, the cap holder receives no payment.

Table 18.3 Cap: Time to Break-Even Point

Cap strike rate	8.50%	Payments per annum	4	Cap Cost		Net Cash	
Cap fee	1.12%	Amortized cap cost	0.11	Amortized		Flow	
Fixed funding	8.00%	IRR (semiannual bond equivalent)	7.99%	at 8%		Flow	
Term in years	3						
Quarter	LIBOR Rate	Liability Cash Flow	Cap Payoff	Capped Cash Flow	Cap Cost Amortized at 8%	Net Cash Flow	
0		-100.00				-100.00	
1	6.00%	1.52	0.00	1.52	0.11	1.63	
2	6.00%	1.52	0.00	1.52	0.11	1.63	
3	6.00%	1.52	0.00	1.52	0.11	1.63	
4	6.00%	1.52	0.00	1.52	0.11	1.63	
5	6.00%	1.52	0.00	1.52	0.11	1.63	
6	10.00%	2.53	0.38	2.15	0.11	2.26	
7	10.00%	2.53	0.38	2.15	0.11	2.26	
8	10.00%	2.53	0.38	2.15	0.11	2.26	
9	10.00%	2.53	0.38	2.15	0.11	2.26	
10	10.00%	2.53	0.38	2.15	0.11	2.26	
11	10.00%	2.53	0.38	2.15	0.11	2.26	
12	10.00%	102.53	0.38	102.15	0.11	102.26	

Table 18.4 Cap Payoffs: Effect of Small Rise in LIBOR

Quarter	LIBOR Rate	Liability Cash Flow	Cap Payoff	Capped Cash Flow	Cap Cost Amortized at 8%	Net Cash Flow
0	-100.00					-100.00
1	6.00%	1.52	0.00	1.52	0.11	1.63
2	6.00%	1.52	0.00	1.52	0.11	1.63
3	6.00%	1.52	0.00	1.52	0.11	1.63
4	6.00%	1.52	0.00	1.52	0.11	1.63
5	6.00%	1.52	0.00	1.52	0.11	1.63
6	8.75%	2.22	0.06	2.15	0.11	2.26
7	8.75%	2.22	0.06	2.15	0.11	2.26
8	8.75%	2.22	0.06	2.15	0.11	2.26
9	8.75%	2.22	0.06	2.15	0.11	2.26
10	8.75%	2.22	0.06	2.15	0.11	2.26
11	8.75%	2.22	0.06	2.15	0.11	2.26
12	8.75%	102.22	0.06	102.15	0.11	102.26

Cap strike rate 8.50% Payments per annum 4
 Cap fee 1.12% Amortized cap cost 0.11
 Fixed funding 8.00% IRR (semiannual bond equivalent) 7.99%
 Term in years 3

Table 18.5 Cap: Break-Even LIBOR

Quarter	LIBOR Rate	Liability Cash Flow	Cap Payoff	Capped Cash Flow	Cap Cost Amortized at 8%	Net Cash Flow
0	-100.00					-100.00
1	6.00%	1.52	0.00	1.52	0.11	1.63
2	7.53%	1.91	0.00	1.91	0.11	2.01
3	7.53%	1.91	0.00	1.91	0.11	2.01
4	7.53%	1.91	0.00	1.91	0.11	2.01
5	7.53%	1.91	0.00	1.91	0.11	2.01
6	7.53%	1.91	0.00	1.91	0.11	2.01
7	7.53%	1.91	0.00	1.91	0.11	2.01
8	7.53%	1.91	0.00	1.91	0.11	2.01
9	7.53%	1.91	0.00	1.91	0.11	2.01
10	7.53%	1.91	0.00	1.91	0.11	2.01
11	7.53%	1.91	0.00	1.91	0.11	2.01
12	7.53%	101.91	0.00	101.91	0.11	102.01

The holder of the floor plus the swap also has no net cash flow. The floor generates a positive cash flow equal to the difference between 8% and LIBOR—2%—which is just enough to cover the shortfall on the interest-rate swap between the fixed payment outflow of 8% and the floating payment received, 6%. At exactly 8%, none of the instruments produces cash flows.

SWAPTIONS (BLACK OR MARGRABE MODEL)

The *swaption* is an option on an interest-rate swap. The most common type of swaption is a European option on a bullet swap (that is, a swap with a fixed notional amount and a fixed term to maturity). If you buy an option on which the underlying asset is a swap on which you will receive a fixed rate, then you are said to buy the right to receive, or to buy a receiver's swaption; conversely, if you want to pay fixed, you are said to buy the right to pay or to buy a payer's swaption.

An example of an option to pay fixed would be the right to enter into a two-year swap where you receive six-month Libor and pay 9% annually on £10,000,000, where both the swap value date and the exercise date are in 12 months' time. What is the underlying asset of this option, and what is the strike price? We can argue that the person entering into the swap will be paying a series of fixed cash payments—the fixed rate—in order to obtain an underlying notional asset whose income stream will be six-month Libor. Hence, the strike price is the fixed payments due on the swap, and the underlying asset is the floating receipts on the swap. Because this is an option on an instrument for forward delivery, it is necessary to use the Black model, rather than the Black-Scholes model.

In order to use the Black model—or indeed any similar option model—to value the asset, we have to make the assumption that its value will be normally distributed; this assumption is, of course, not always true in practice. Interest rates tend to display “mean reversion,” so the calculated option price will usually be an approximation. The way in which the market usually handles this is by adjusting the volatility used to price the option.

Let us work out the price at which a market maker would write this swaption: the option period is one year, and the option is on a two-year swap with a notional principal amount of £10,000,000, with the market maker receiving fixed annually at 9% and paying LIBOR semiannually. Volatility

for a two-year swap starting in one year's time is estimated to be 11%. The sterling yield curve is as follows (using the one-year LIBOR rate and the swap rates for two and three years):

Date	%
January 12, 2001	7.75
January 12, 2002	8.25
January 12, 2003	8.50

The first step is to construct the implied zero-coupon curve and the annual "par yield curve." Bearing in mind that LIBOR rates are calculated on the basis of annual interest at maturity whereas the swap rates are semiannual rates, we get the following results:

True Annual Rates	Implied Zero-Coupon Curve (annual)
7.75	7.75
8.42016	8.4486
8.6806	8.7253

The second step is to calculate the swap rate on which the swaption will apply. This is a two-year swap, but it will not start until the exercise date of the swaption—one year from now. Hence we need the market rate for a two-year swap deferred for one year.

The underlying calculation principle is that the market maker, in order to hedge this transaction, would have to enter into a three-year swap starting from today, with a one-year swap in the opposite direction to lay off the risk for the first year, until the deferred swap comes into operation. For simplicity, we will assume the one-year swap is quoted on the basis of the true one-year rate in the immediately preceding list versus six-month LIBOR.

To calculate the deferred swap, we proceed as follows. We assume that the three-year swap, the one-year swap in the opposite direction, and the two-year deferred swap are all set up for the same dates and, thus, use the same LIBOR for the floating side. All of the floating-rate flows will net off against each other, and we will be concerned only with the fixed-rate flows. If we neglect bid-offer spreads for simplicity, we see that the present value (PV) of the deferred swap's cash flows must equal the PV of the three-year

swap's flows minus the PV of the one-year swap cash flows. In other words, the cash flows on both sides of the deal must be equal, in present-value terms.

One approach to this calculation is to calculate the PV of a basis point (PVBP) for the three-year swap. This is the PV of 0.01% paid semiannually for three years, valued at the three-year zero-coupon rate. Similarly we find the PVBP for the one-year swap (PV of 0.01% paid semiannually for one year, valued at the one-year zero-coupon rate). Therefore, we can derive the PVBP of the deferred swap by subtraction (because present value is additive).

The PV of the cash flows of the deferred swap must equal the PV of the longer swap minus the PV of the shorter swap, so the next step is to calculate the deferred swap rate from the formula:

$$\text{Deferred swap rate} \times \text{PVBP deferred swap} = \text{Long swap rate} \times \text{PVBP long swap} - \text{Short swap rate} \times \text{PVBP short swap}$$

Rearranging and inserting the appropriate rates, we find:

$$\text{Deferred rate} = 9.2812 = \frac{(8.7253 \times 2.5564) - (7.75 \times 0.9281)}{1.6283}$$

We now have the value of the underlying asset to which we should apply the Black model. This is a contract that gives us the right to pay 9% for two years in exchange for six-month LIBOR, starting one year from now, when the current implied forward swap rate for that period is 9.2812%. Applying the Black model gives us a valuation of £90,710.11 for this option—approximately 0.91% of the principal amount. If we consider the impact on the value of the swaption of various *parallel* yield curve shifts, we can see that if the whole yield curve shifts downward by 1%, the value of the swaption drops considerably, to rather less than 0.25% of the principal amount. Conversely, if the yield curve shifts upward by 2%, the swaption value rises to over 3.5% of the principal amount—over £350,000 in the case of a £10 million deal.

The emphasis on the parallel shift in the yield curve is aimed at keeping the analysis simple. In practice, the yield curve will usually shift in a nonparallel fashion. The effect on the swaption's value will depend on the exact shape of this shift and may not be intuitively obvious. In particular, if short-term rates rise faster than longer-term rates—as would be quite normal—the forward swap rate and, hence, the swaption value will *fall* rather than rise. Conversely,

a fall in short rates relative to long rates will increase the forward swap rate and, hence, the value of the swaption.

Finally, we should note the comparison with an interest-rate cap. The interest-rate cap gives you the right to receive LIBOR minus the strike or to pay nothing. The swaption, if exercised, may lead us at some point to pay out sums under the swap. Thus the swaption must always be worth less than an interest-rate cap for a corresponding period.

Swaptions became popular in the mid-1980s, when bonds with embedded put and call options began to be issued in significant numbers. Swaptions are commonly used to strip the options out of callable and puttable bonds.

EXOTICS

We come now to a large class of options that are generically referred to as *exotic options*. An exotic option can be broadly defined as an option that redefines one or more of the conditions of the “standard” options previously discussed. For ease of reference, exotic options in this chapter will be grouped into two main classes, with subgroups:

1. *Path-Independent Options*. Options for which it does not matter how the option has moved during the course of its life. These subdivide into:
 - Options for which the standard terms of an option in terms of payoff, time of premium payment, and so on, are varied.
 - Compound options—options on options.
 - Multifactor options—options whose value depends not on just one asset but on two or more.

2. *Path-Dependent Options*. Those options whose value is influenced not just by the condition of the market on the expiration date, but also by how it behaved during the life of the option. In some cases (such as binary barriers), this class includes variants of the path-independent class.

It should be stressed that this remains a rapidly developing field, so the following treatment is not guaranteed to be comprehensive. In many cases adaptation of instruments to specific markets may make them appear different, and of course it is in the interests of investment bankers to proclaim the novelty of the instrument they are marketing.

PATH-INDEPENDENT OPTIONS

We begin with options that consist of a variation of the standard terms of the option instrument in regard to exercise date, premium payment, and payoff style, but for which the path traversed by the underlying asset during the life of the option makes no difference to the payoff.

Bermudan Option

A *Bermudan option*, as the name implies, lies between a European and an American option. Unlike an American option, it does not permit a continuous right to exercise the option. But it does permit the option to be exercised on specific dates before expiration, unlike a European option. A typical application of the Bermudan option would be in the fixed-income markets. A 10-year bond may be callable in the September of the last five years of its life. An investor owning the bond might be interested in an option that allows her to replace the bond if it is, in fact, called during these periods; but she might be unwilling to pay the full cost of an American option because this gives unnecessary “extra” cover. The pricing of the option will normally be found by using a binomial approach. We evaluate the option at those nodes in the binomial tree where the possibility of exercise could occur. Having found all those nodes at which exercise is possible, we discount back to today’s probability-weighted value for the option.

Forward Start (Delayed) Option²

Among the simplest of the exotic options is the *forward start option*. This is an option that is paid for now but that will start some time in the future. Consider an option that starts at time t_1 and matures at time t_2 . Suppose it is on a non-dividend-paying equity whose current price is S , and whose price at time t_1 is S_1 . We can see from the Black-Scholes formula that the value of an at-the-money call option is proportional to the stock price. So

²See J. C. Hull, *Options, Futures and Other Derivatives* (Englewood Cliffs, NJ: Prentice-Hall, 1997), Chapter 18.

the value of the option at time t_1 is therefore cS_1/S , where c is the value today of an at-the-money option with a life of $t_2 - t_1$. Using risk-neutral valuation, the value of the forward start option today is:

$$e^{-rt_1} \hat{E}(cS_1/S)$$

where \hat{E} denotes expectations in a risk-neutral world. We already know c and S , and in a risk-neutral world $\hat{E}(S_1) = Se^{rt_1}$. So it follows that the value of the forward start option is c . It is the value of a normal at-the-money option whose life is $t_2 - t_1$. If the underlying asset pays interest or dividends at a rate d , then the value of the forward start option becomes ce^{-dt_1} .

Practical applications of the delayed option might include situations in which a compound option might be used, and delayed options have been built into employee-compensation option structures (where the option is only made available to employees if they are still at the firm). Delayed options have also been used by fund managers creating guaranteed-return funds or using so-called "90/10" structures. In the latter case, the fund manager invests 90% of the fund in cash or in a low-risk instrument and 10% in options or warrants. At the expiration of the operation, if clients are satisfied, they may wish to roll over into a new 90/10 fund; but, of course, the option-pricing levels at that later time are unknown today. If today's volatility levels are low and if the fund manager believes that the bulk of the 90/10 fund will be rolled over, it might make sense to buy forward options to cover the rollover.

BINARY/DIGITAL OPTIONS

Binary (or *digital*) *options* are among the simplest kind of exotic options—at least, as far as pricing is concerned. Hedging is a different matter. These options are a straight bet that an underlying market will finish above or below the strike price at expiration. The payoff of this event is a fixed amount, regardless of the level of the underlying asset. These binary or digital options come in two basic varieties: (1) all-or-nothing and (2) one-touch. (I shall use the terms digital and binary interchangeably throughout.)

1. The *all-or-nothing* option only pays out if the underlying asset finishes in the money at the expiration of the option.

2. The *one-touch* option pays out as long as, at some time during the life of the option, the underlying price rose above the strike price.

Such options permit the construction of a number of interesting investor instruments, such as “range notes.” Aside from their use in the construction of range notes, binaries are often used by foreign exchange traders either in situations where they see a rate jump or, conversely, in quiet markets. As an example of the former, in early 1997, a number of Indonesian firms were reported buying European-style out-of-the-money double-binary options on the rupiah; a typical trade might have involved an option that paid off 2.5% on the notional amount of the trade if the rupiah depreciated to between IDR 2490.8 and IDR 2538.7 against the dollar (a depreciation of 4% to 6% compared with the then spot of IDR 2395) within the following 12 months. If the rate did not jump sharply, then the option did not pay off. (History shows that they would indeed have been profitable, given the later collapse of the rupiah.) Conversely, many trades have been done on the basis that, provided the exchange rate remained within a given range, the option pays off.

Thus, these options have many uses. But for the writer of the option, they pose a tough hedging challenge because of the all-or-nothing payout. As we come close to expiration and as the option swings above and below the trigger level, the payout switches from zero to positive, triggering huge swings in delta. A delta of 1,000% would not be uncommon (whereas for a normal call option, delta ranges between 0% and 100%, or 0 to 1). A large digital option transaction presents a very large risk to the writer—hedging these instruments is the option trader’s equivalent of Russian roulette. One possible approach is to take the “actuarial” view. We build up a book consisting of many trades with as wide a spread of strikes as possible. In that case, although around each strike there will be huge swings in the delta, across the book as a whole the risk is averaged down to manageable levels.

We begin by considering the simplest form of digital options, which are path-independent—they pay out at expiration according to whether the asset is above or below the strike, and they pay out a fixed amount.

All-or-Nothing Options

Of the types of binary option, the easier to price by far is the *all-or-nothing digital*. What we are interested in pricing with the all-or-nothing digital is the expected value of the asset (for the asset-or-nothing call) or of the cash

value of the strike price (for the cash-or-nothing call). We already know these from the Black-Scholes model:

$$\begin{aligned}\text{Asset-or-nothing call} &= S \times N(d1) \times e^{-dT} \\ \text{Cash-or-nothing call} &= E \times N(d1) \times e^{-rT}\end{aligned}$$

where S , $N(d1)$, and T are as defined in the Black-Scholes model in Chapter 17, d is the dividend earned on the asset in continuous time, and r is the rate of interest.

The Binary Family Tree³

It is possible to construct a “family tree” of binary options, according to whether they are path-independent or path-dependent; whether they pay out at expiration or when a barrier is hit, or when a barrier is hit provided they are above or below a given strike level (the latter two categories sometimes being referred to as “binary barriers”). Barrier options are discussed separately later in the section Path-Dependent Options, but we give here for background the family tree for path-independent binary options.

We can see from the family tree in Figure 18.1 that path-independent digitals are the building blocks for two specific types of exotic option. The first, the so-called “supershare,” was proposed by N. Hakansson⁴ in 1976. A firm would buy a portfolio of shares and issue against it supershares that would pay off at expiration as follows: Provided the portfolio value lies between a lower bound V_d and an upper bound V_u , the investor receives a given share of the portfolio; otherwise the investor receives nothing. In other words, the investor buys an asset-or-nothing call struck at V_d and sells an asset-or-nothing call struck at V_u .

The second exotic built from these binaries is the so-called “gap” option, for which the payoff is of the form: 0 if $S \leq E$ (i.e., if the asset finishes below the strike, we receive nothing) and $S - X$ if $S \geq E$ (i.e., if the asset finishes above the strike, we do not get the normal call payout of $S - E$ but $S - X$, where X is the “height” of the gap, $X - E$). Obviously, if we

³The discussion and diagram in this section follows M. Rubinstein and E. Reiner, “Unscrambling the Binary Code,” *Risk* (October 1991).

⁴N. Hakansson, “The purchasing power fund: A new kind of financial intermediary,” *Financial Analysts Journal* (November–December 1976).

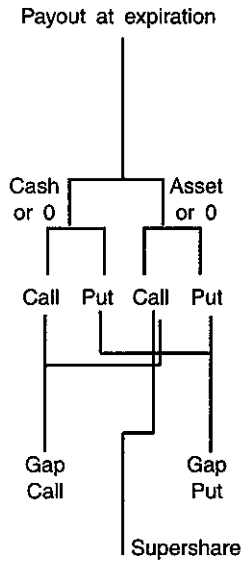


Figure 18.1 Path-Independent Binary Options (Payout at Expiration)

set X equal to E , the gap options revert to standard calls and puts. Other types of binary—binary barrier options—are discussed later.

More recently, there has been a yet further extension of this concept⁵ to the concept of the *bivariate cash-or-nothing*. This is an option that pays out a fixed amount when the prices of two assets are between predetermined limits at expiration. It is clear that the concept could be extended to multivariate (rainbow) cash-or-nothing options and to barrier binary options.

The digital option has been extended to the interest-rate market via a variant of the capped FRN using a digital cap. This is an FRN (floating rate or nothing) that pays a floating rate subject to a cap; if the rate is above the cap, it pays nothing. (Compare the traditional capped FRN, for which the investor would receive the cap rate.) For example, the coupon might equal $(\text{LIBOR} + 60) \times (\% \text{ of time LIBOR is less than } 9.5\%)$. Because the penalty to the investor is much higher if the cap is breached, the value of the cap is much greater to the seller. Thus, for the same price (usually expressed as the extra margin over LIBOR), a digital cap FRN will normally have a much higher cap level than the traditional capped FRN.

⁵R. Heynen and H. Kat, "Brick by Brick," *Risk* (June 1996).

Pay Later (Contingent Premium) Options

Pay-later options are options for which no premium must be paid unless the option is exercised. But the option must be exercised if the underlying asset is equal to or greater than the strike price of the option. This is true even if that means the intrinsic value received is less than the premium payable.

The key advantage of the pay-later option to the option buyer is that no premium is ever payable if the option expires out of the money. The pricing of the option is actually quite simple. Suppose we are looking at a pay-later call. The buyer gets a standard call option but has also sold to the option writer a digital all-or-nothing option, in which the digital premium is set equal to the premium of the standard call, so the net cost is zero. We adjust the size of the digital call to achieve this. As a result, the formula is:

$$\text{Pay-later call} = [S \times N(d1) \times e^{-dT} - E \times N(d1) \times e^{-rT}] - \{(R[S \times N(d1) \times e^{-dT}])\}$$

where R = the quantity of the asset-or-nothing option that is sold such that the premiums of the ordinary call and the asset-or-nothing option are identical.

Compound Options

A *compound option* is an option on an option. The most common use is in the foreign exchange markets in the so-called “tender-to-contract” situation. This is a scheme designed to help corporations bidding for contracts overseas. They know that if they win the contract, they will have foreign currency exposure that they will need to hedge; on the other hand, if the contract is not won, they will have no exposure.

Schemes have been devised to meet this kind of situation: One choice is to write a compound option—an option contract giving the right to buy an option at some future date on certain terms. Another choice is to charge the full premium for the underlying option on day one, subject to a partial refund of the premium if the tender fails to win the contract. In exchange for the right to obtain the partial refund, the option buyer gives up the right to exercise the option independently of his or her success in the underlying tender; that is, if the tender fails, then the option cannot be exercised.

The value of a compound call-on-call option was first formally defined

by R. Geske⁶ and extended by M. Rubinstein.⁷ If we consider a currency compound option, we can write the value of a call-on-call as:

$$CaCa = S \times e^{-R_f t} N_2(x; y; p) - E_2 e^{-R_d t} N_2(x - \sigma\sqrt{t}; y - \sigma\sqrt{t}; p) - E_1 e^{-R_d t} N(-x + \sigma\sqrt{t})$$

- where E_1 = exercise price for “mother” option
- E_2 = exercise price for “daughter”
- $CaCa$ = the premium for the call-on-call
- S = spot exchange rate
- R_f = foreign interest rate
- R_d = domestic interest rate
- σ = volatility of underlying currency
- t = expiration date of compound option (the “mother” option)
- T = expiration date of underlying ordinary option (the “daughter” option)
- N_2 = bivariate normal density
- $N(\)$ = cumulative normal (univariate) density

$$p = \sqrt{t/T}$$

$$x = \frac{\ln\left(\frac{S}{S^*}\right) + \left[R_d - R_f + \frac{\sigma^2}{2}\right]t}{\sigma\sqrt{t}}$$

$$y = \frac{\ln\left(\frac{S}{E_2}\right) + \left[R_d - R_f + \frac{\sigma^2}{2}\right]T}{\sigma\sqrt{t}}$$

Again, to put the rather formidable piece of algebra in context, one can compare the simpler binomial pricing approach for a call-on-call.

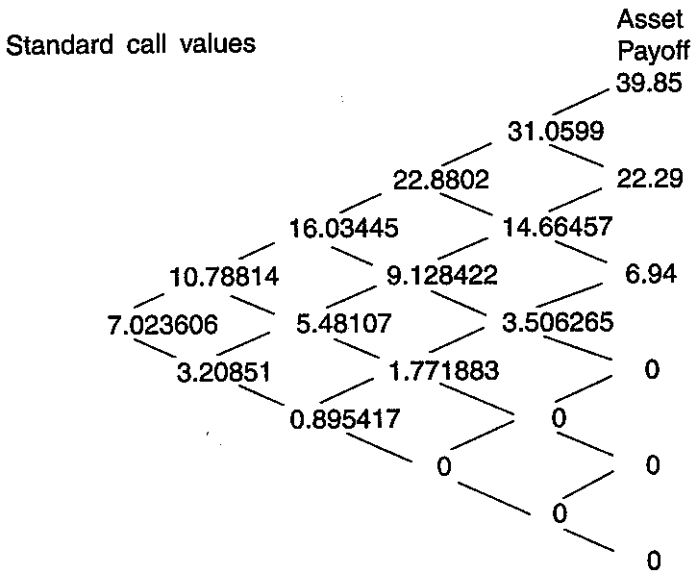
We start from the basic case in Exhibit 17.1 and we will apply it to the call-on-call.

⁶R. Geske, “The Valuation of Compound Options,” *Journal of Financial Economics* (1979).

⁷M. Rubinstein, “Double Trouble,” *Risk* (September 1995).

Exhibit 18.1

We have already devised the pricing tree earlier for a standard European call using a five-step underlying asset tree where $\sigma = 0.3$, $t = 0.25$, $r = 1.10$, $d = 1.03$, $S = 100$, $X = 100$, $UP = 1.06938$, $DOWN = 0.935118$, $INT = 1.00478$, $FGN = 1.00148$. Given these variables, the asset tree produces payoffs of 39.85, 22.29, and so on; and given these payoffs, we can find the following call values:



Now let us consider a call on this call. Say the strike level of the call-on-call is 8.00, and its maturity $t(c)$ is 0.15. We know that the underlying call is valued over five steps and a total maturity of 0.25, so that each step is 0.05 apart. Because the call-on-call has a maturity of 0.15, this is equivalent to three steps: so the payoffs on this call will be the values of the underlying call after three steps. These values are 22.88, 9.13, 1.77, or zero. Because the strike of our call on the call is 8.00, its payoffs will be 14.88, 1.13, or zero.

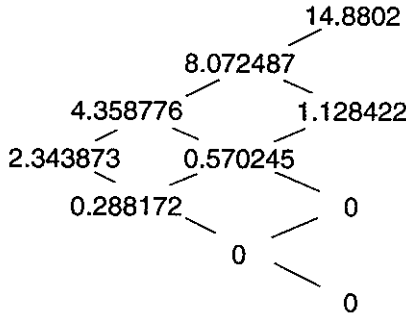
To value the call-on-call at the previous step, we proceed as we would for a normal call: the value is the present value of the expected payoffs of the call. The only difference here is that instead of payoffs

on the underlying asset, we are looking at payoffs on a call on the asset.

The volatility and other parameters are unchanged, so we know that the probability of an UP move is 0.50776, and that the probability of a DOWN move is 0.49224.

Now we can value the call-on-call, using the same procedures as we would for a normal call: $C = [(0.50776 \times 14.88) + (0.49224 \times 1.13)]/1.00478 = 8.07$.

What is the value today of this call-on-call? We can work back through the nodes to arrive at the following tree:



Notice that we are paying 2.34 to buy a call on another call with a strike of 8; that is, our total cost if we exercise the right to buy the second call will be 10.34, which compares with the standard call quoted above of 7.02.

The purchase of an option on a cap (sometimes called a *caption*) or an option on a floor (*floption* or *floortion*) is an example of the compound option concept applied to the interest-rate arena.

Chooser (“As-You-Like-It”) Options

The *chooser option* is an option that allows you to choose later whether it is a put or a call! The most typical application would be to a situation in which a trader anticipates an extreme market move but is uncertain of the direction. The reliance on extreme volatility is illustrated by the fact that these options first came into prominence at the time of the Gulf War, in conditions of extreme volatility in oil markets. In fact, a chooser is very similar to a straddle. The difference is that at some point the buyer must

choose between the put and the call. Therefore, the chooser will be worth less than the straddle: putting that another way, the chooser is a cheaper way to buy volatility than the straddle is.

The key features of chooser options include:

- The buyer of the chooser decides on the first maturity date (the choice date) whether the option is to be a put or a call.
- The selected option expires on the second maturity date.
- In a typical structure, the choice feature can be cancelled at any time until the choice date.
- *Standard chooser options* have the same strike and expiration dates for the two options.
- *Complex choosers* allow the call and the put to have different expiration dates and strike prices.

The payoff of the chooser option at the choice date is the greater of the call option or the put option values on that day. We receive the better of the call or the put. Another way of looking at this is to argue that buying the chooser gives us the better of

1. A call on the asset at strike price S and exercise price E for the whole period of the option (i.e., to final maturity). OR
2. A put on the asset when the asset price is $Se^{-d(T-t)}$ and the put strike is $Ee^{-r(T-t)}$, where d is the dividend earned on the asset, t is the time to the choice date, and T is the time to final maturity.

In that case, the chooser call value is:

Chooser =

$$S \times N(x)e^{-dt} - EN(x - \sigma\sqrt{T})e^{-rt} - S \times N(-y)e^{-dt} + E \times N(-y + \sigma\sqrt{T})e^{-rt}$$

where T = the time to final maturity
 t = the time to choice

$$x = \frac{\ln(Se^{-dt} / Ee^{-rt})}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2}$$

$$y = \frac{\ln(Se^{-dT} / Ee^{-rT})}{\sigma\sqrt{t}} + \frac{\sigma\sqrt{t}}{2}$$

Note that y is almost the same as x , but $\sigma\sqrt{t}$ is substituted for $\sigma\sqrt{T}$.

A moment's thought will suggest that the value of the chooser must increase with the length of time that we are given in which to choose. Consider five Black-Scholes standard chooser options⁸ on foreign currency, all with current underlying asset price $S = 100$, strike price $E = 100$, time to expiration $T = 1$ year, domestic interest rate = 10%, foreign currency interest rate = 5%, and underlying volatility = 30%. Then we can find the following chooser values:

t	Value
0	13.39
0.1	15.17
0.2	16.50
0.5	19.28
1.0	22.46

In the case where $t = 0$ (we have no time to choose), the chooser's value is the same as the call option. In the case where $t = T = 1$ (we have a complete choice throughout the life), the chooser is equivalent to a straddle, and its cost will equal the straddle's cost. In between, as we can see, the chooser's value rises with the length of time available to us to make our choice.

Power Option

The *power option* allows the holder the payoff of a standard option but with the value of the underlying asset raised to some power, for example, LIBOR squared. Obviously, the power option is of most interest to the gambler looking for action. However, the pricing is actually not too strange.

If the underlying asset S is log-normally distributed (i.e., returns from S are normally distributed), then S^n will also have a similar distribution. If we

⁸This example is lifted from M. Rubinstein, "Options for the Undecided," *Risk* (April 1991).

consider the Black-Scholes world, we assume that the asset follows the normal geometric Brownian motion that is described by $dS/S = \mu + \sigma dz$. So $dS = \mu Sdt + \sigma Sdz$.

We can then set out the implied stochastic process for the general case S^n , which gives us:

$$d(S^n) = \left[n\mu + \frac{1}{2} \sigma^2 n(n-1) \right] S^n dt + [n\sigma] S^n dz$$

In the case where the payoff is squared, for example, giving $n = 2$, we have

$$d(S^2) = [2\mu + \sigma^2] S^2 dt + [2\sigma] S^2 dz$$

Here, therefore, we have to replace the standard drift term in the Black-Scholes world, μ , by $(2\mu + \sigma^2)$ and the volatility, σ , by 2σ . Substituting these values into Black-Scholes will give us the pricing for the power option.

Note that the impact of the power option on the payoff comes not just from the power factor but also from the impact on volatility—in the case of a squared payoff, the impact of volatility is doubled.

Option to Exchange One Asset for Another (Margrabe Option)

The formula for the value of an option to exchange one asset for another was originally developed by William Margrabe in 1977. The formula is:

$$C = X_1 N(d_1) - X_2 N(d_2)$$

where C = value of the call option

$$d_1 = \frac{\ln(X_1 / X_2) + (\sigma^2 / 2)t}{\sigma \sqrt{t}}$$

$$d_2 = d_1 - \sigma \sqrt{t}$$

$$\sigma^2 = \sigma_{x_1}^2 + \sigma_{x_2}^2 - 2\rho_{x_1 x_2} \sigma_{x_1 x_2}$$

- σ_{x_1} = volatility of first asset
 σ_{x_2} = volatility of second asset
 ρ_{x_1, x_2} = correlation between first and second assets
 t = time to expiration as a percent of a year
 X_1 = price of first asset
 X_2 = price of second asset

Although this might seem complex, it is in fact simply Black-Scholes with two changes: (1) the fixed exercise price has been replaced by the price of the second asset, X_2 ; (2) the volatility is the combined volatility of the two assets, which is calculated by allowing for the correlation between them. We can obtain Black-Scholes from Margrabe by changing the numéraire.

This option-pricing model is relevant in a number of cases, notably those in which we consider the “better of two,” or rainbow options, to which we now turn.

Rainbow Options

The so-called *rainbow option* allows the investor to receive the best-performing asset among a set of assets. For example, the investor might buy an option that gives the best of the Standard & Poor’s (S&P) 500, the Financial Times Stock Exchange (FTSE) 100, and the DAX. In the case of a two-factor option (e.g., the better of the FTSE 100 and the DAX), we have a simple option to exchange one asset (the under-performing asset) for another (the better-performing asset). This is, of course, the Margrabe option just discussed.

When more than two assets are involved, the pricing cannot readily be calculated by means of a closed-form solution, and pricing is normally done by means of a Monte Carlo simulation or a similar technique.

Spread Options

A moment’s thought suggests that holding an option on the better of two assets is equivalent to holding one of the assets and holding an option on the spread between the two assets. Thus, where the Margrabe option can be used, it can be applied to the spread option also.

Of course, in situations where Margrabe/Black-Scholes is not applicable,

such as interest-rate yield spreads, one could seek to model the spread itself as an asset. This approach would need to contend with the fact that, unlike a normal asset, it would be quite possible for a spread to go negative. Closed-form formulas for spread options (apart from the Margrabe applications) are not generally available, and we have to resort to numerical methods.

Quanto Options

A *quanto option* is one in which the payoff depends both on an underlying price and on the size of the exposure as a function of the underlying price. The term comes from the phrase “quantity-adjusted option.” The most typical application is for a fund manager. Suppose we are a U.S.-based investor considering the purchase of French shares. Suppose we buy 100,000 at a price of EUR 8 per share. Our initial cost is EUR 800,000. Suppose we sell forward EUR 800,000 against dollars for one year to protect ourselves against currency risk. After a year, we look at the position and find that the shares have gone up to EUR 12. The value of the position is now EUR 1,200,000. But our hedge was only for EUR 800,000; we are underhedged. The quanto option aims to solve this problem.

There are four basic versions of the quanto (we consider a call quanto):

1. A foreign equity call struck in the foreign currency. This is the simplest case—the payoff is simply the standard call option value converted at the current exchange rate.

2. A foreign equity call struck in the domestic currency. In this case, we have the option to exchange a domestic strike price for the foreign equity. This is a variant of the Margrabe option to exchange one asset for another.

3. A fixed-exchange-rate foreign equity call. This is a little trickier. In thinking about this version of the quanto, it helps to think of the French stock⁹ as behaving like a dollar-denominated stock that pays a dividend yield (which we will assume to be continuous) of $r_d - r_f + q - \rho\sigma_S\sigma_X$

⁹For a more formal discussion, see, e.g., J. C. Hull, *Options, Futures and Other Derivatives*, 3rd international ed., pp. 299–301 (Prentice Hall).

where r_d = U.S. domestic interest rate
 r_f = Foreign (French) interest rate
 q = dividend yield on French stock
 ρ = correlation between the French stock price and the French franc exchange rate
 σ_S = volatility of the French stock price
 σ_X = volatility of the French franc exchange rate

We can then plug this into our standard option-valuation models and proceed accordingly.

4. An equity-linked foreign exchange call. This type of quanto is in effect a fixed exchange rate foreign equity put, with the roles of the equity and the exchange rate reversed; hence we can apply the technique just used for the fixed exchange rate foreign equity call.

Basket Option

The basket option consists of an option on a set of underlying assets. Typical uses might be by a portfolio manager who holds, say, Shell, Citibank, and Toyota in his portfolio. He could buy put options on each, or he could buy an option on a basket holding the three. Typically, the basket will be cheaper as long as the underlying assets are not perfectly correlated. This is because their volatilities will tend to offset each other and the volatility of the basket will be less than that of its parts. Another common use of the basket option is to hedge a group of currencies (e.g., a portfolio manager might hedge his exposure to all European currencies by buying a basket option on those currencies).

Various approaches to valuing basket options have been taken. One approach is to argue that the value of the portfolio is likely to behave log-normally, rather than the value of the underlying assets, and then to apply the standard formulas. Another approach is to calculate the weights of the components of the basket, calculate their correlations, derive a composite volatility for the portfolio, and then apply Black-Scholes to the portfolio. Still another way is to argue that with an Asian option we monitor one asset n times, whereas with the European basket option we monitor n assets one time (at expiration); provided we fudge the correlations, we could apply modifications of Asian option-pricing models (discussed in the next section).

The most common approach seems to be to assume arbitrarily that the basket will follow a log-normal distribution whose volatility is defined by the volatilities of its component parts.

PATH-DEPENDENT OPTIONS

We turn now to options whose value is determined in part by the path that the asset price has taken during the life of the option. In general, these are much more difficult to value, and some form of numerical method is generally needed, though in some cases closed-form formulas have been developed.

Asian (Average) Options

The Asian option is an average-rate option. There are two kinds of average-rate option: (1) fixed strike and (2) floating strike. The former is by far the most common. It cash settles on the expiration date according to the difference between the strike rate and the average exchange rate over the option's life. Average-rate options are a valuable hedging tool for many corporates whose risk is not on large cash flows on particular dates, but on smaller cash flows on a regular basis. The premium for an Asian option will normally be substantially less than for a European or an American option because the volatility of the average is much less than the volatility of the asset. This is another attraction for the corporate hedger.

If the underlying asset price S is assumed to be log-normally distributed, the geometric average of S is also log-normally distributed, and an analytical formula for the Asian option can then be calculated. Unfortunately in the real world most client applications revolve around arithmetic, not geometric, averages. The arithmetic average of the log-normal does not produce tractable results. Various pricing methods are used, most of which attempt to track the bias between the log-normal distribution and that of the arithmetic average. One well-known approach¹⁰ seeks to calculate the mean and the variance of the probability distribution of the arithmetic average exactly; we then

¹⁰A. Kemna and A. Vorst, "A Pricing Method for Options Based on Average Asset Values," *Journal of Banking and Finance* (March 1990).

assume that the distribution of the average is the log-normal distribution with the same mean and variance.

The average strike (“floating strike”) variant of the Asian option sets the strike price of the option to the average price of the asset during the option’s life. The payout is the difference between this strike and the asset price on the expiration date. Another variant is the “flexible Asian” option. For these options the observations that count for the average do not all get the same weight. This might be of interest, for example, to a firm whose euro cash flows to be hedged back into dollars are heavily concentrated in, say, months 1, 7, 9, and 11 of any given year.¹¹

Another variant can be seen in the interest-rate cap market, where the cap payout is not based on the normal quarterly payout against three-month LIBOR but is taken over the year as a whole such that a payment is made only if LIBOR is above the strike during the year as a whole on a cumulative basis. Suppose that we have a 6% cap and the LIBOR fixings are 5%, 7%, 8%, and 5% over the year. On a normal cap we would receive 0%, 1%, 2%, and 0% for a total of 3%; on this variant we would receive 1%. It thus provides cheaper cover for a firm that is aiming to meet an annual, budgeted, interest cost without being unduly concerned whether any given quarter is above or below the set level.

Barrier

An important and popular class of path-dependent options is the *barrier option*. There is no doubt that the barrier option market has grown substantially, but there are no hard figures on this. One recent estimate is that it has grown from \$123 billion in 1992 to over \$2,000 billion in 1996.¹²

As an example, a *down-and-out barrier option* expires prematurely if the exchange rate falls below a certain level during the life of the option. Thus a \$1.9500 call with a down-and-out feature at \$1.8500 (the out-strike) will become valueless if the rate at any time falls below \$1.8500. Down-and-out options may be attractive to option sellers; and because conventional options involve no risk of premature expiration for the buyer, down-and-out options are always cheaper than the corresponding European option. *Up-and-away* options are the converse: they expire prematurely if rates ever exceed

¹¹See P. G. Zhang, “Flexible Arithmetic Asian Options,” *Journal of Derivatives* (1995).

¹²H. Hsu, “Surprised Parties,” *Risk* (April 1997).

a specified level. *Range options* expire prematurely if rates ever move outside a specified range. A \$1.7500 call with a trading range of \$1.65/1.85 will expire valueless if sterling falls below \$1.6500 or rises above \$1.8500. Conversely, *outside trading range options* expire valueless unless rates have been both sides of a specified range. A \$1.7500 call with an outside trading range of \$1.65/1.85 is valueless at maturity unless rates have been both below \$1.6500 and above \$1.8500 during the life of the option.

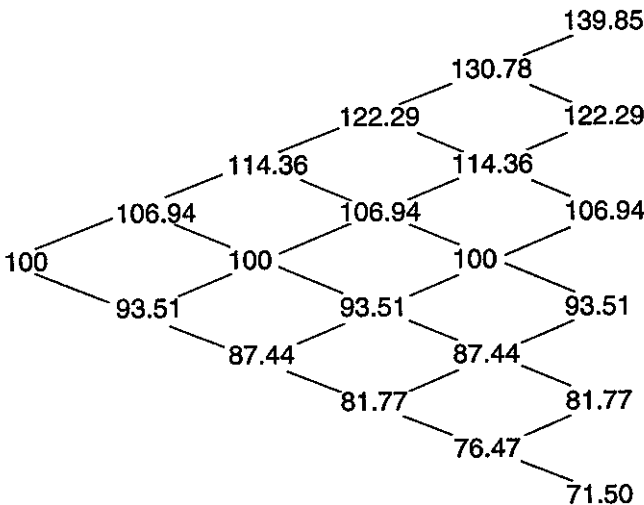
It is theoretically possible to construct a closed-form valuation model for barrier options, but the mathematics is nontrivial and in practice a binomial approach is a reasonable substitute.

Exhibit 18.2 Barrier Option

As an illustration of the barrier concept we will present the following simplified example. It builds on the same example as was used earlier in this chapter.

We consider a down-and-out option on a currency using the same underlying variables as before, so we have $\sigma = 0.3$, $t = 0.25$, $R_d = 1.10$, $R_f = 1.03$, $S = 100$, $X = 100$, $UP = 1.06938$, $DOWN = 0.935118$, $INT = 1.00478$, and $FGN = 1.00148$. We have the same underlying asset (currency) tree as before:

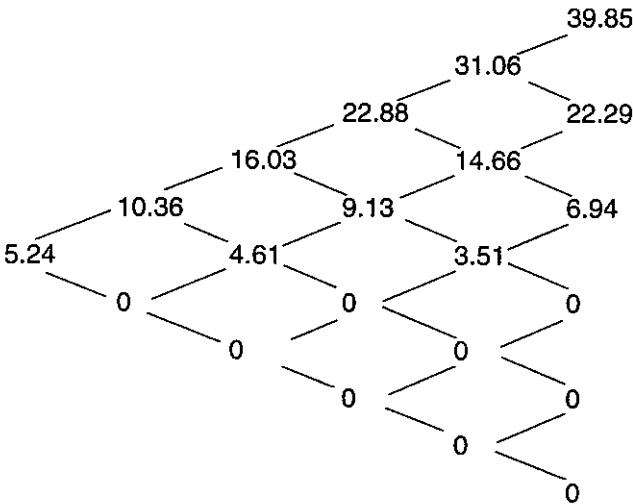
Currency Tree



Now we want to price a down-and-out call on this currency. This is a call option that is cancelled if at any point the underlying currency touches 95. We can apply the same principles as before: the value of the option is the present value of the probability-weighted average of the payoffs. Hence, in the fourth period, when the currency's value is at 130.78 (so that we know that the payoffs will be either 139.85 or 122.29), the value of the down-and-out is 31.06—the same as the value of an ordinary call because we have not gone below the 95 threshold, nor can we in the next period.

But if the currency's value in the fourth period is at 100 and the next step down into the fifth period would be to 93.51, then the value of the barrier would be breached. The option would expire worthless.

So we allow for those points where the option would disappear. Then we can construct a tree of option prices by discounting back the probability-weighted average of each pair of outcomes (just as we did earlier in this chapter, except some of these outcomes are zero). We will produce the following tree:



As this example shows, the pricing of a barrier option is quite simple in concept (though the practicalities of devising realistic trees are not quite so simple).

A variant of the standard barrier option (indeed, one could say, a constituent part of the standard barrier option) is the *binary barrier option*. Figure 18.2 shows a “family tree” of path-dependent binary barrier options, drawn from the same source¹³ as the family tree of path-independent binaries included earlier (Figure 18.1).

As can be seen from the tree, there are at least 28 different variants of the binary barrier option (some of which are given different names in the market, e.g., up-and-out and up-and-in calls are sometimes called reverse knockout options). Space does not permit a full discussion, but the interested reader is referred to the original article by Rubinstein and Reiner. In this section we will simply pick out some key items.

Consider, for example, the option labeled (13) in the diagram, which is a down-and-in cash-or-nothing call that pays out a sum X at expiration if the asset price S has fallen below the barrier level H at some time but at expiration S is greater than E , where E is the strike level—otherwise it pays nothing. The option labeled (15) in the diagram is a down-and-in asset-or-nothing call that pays off S if at expiration S is greater than E , provided that S has fallen below H at some time—otherwise it pays nothing.

Suppose we go short (13), where X is set equal to E . In other words, we sell an option where we must pay E if at expiration S is greater than E , provided S has fallen below H at some time. Suppose at the same time we buy (15). Suppose that during the life of the option, the barrier is breached— S falls below H —so that the two options “knock in.” Now, if at expiration S is greater than E , we will receive S but must pay E . A moment’s thought will convince us that by selling (13) and buying (15), we have in fact created a down-and-in call option. Figure 18.2 shows how the other barrier options can be created by using binary barriers as building blocks.

We have talked throughout rather glibly about the barrier without addressing the question of how it is measured. A particular problem with barrier options, notably in the currency markets but also elsewhere, has been that if the option is close to the barrier as it comes to expiration, market makers will often try to push the market through the barrier level. A related point is the period during which we monitor the barrier: standard documentation in the foreign exchange markets often specifies that trading hours run from 6 A.M. Monday in Sydney to 5 P.M. Friday in New York.

¹³M. Rubinstein and E. Reiner, “Unscrambling the Binary Code,” *Risk* (October 1991).

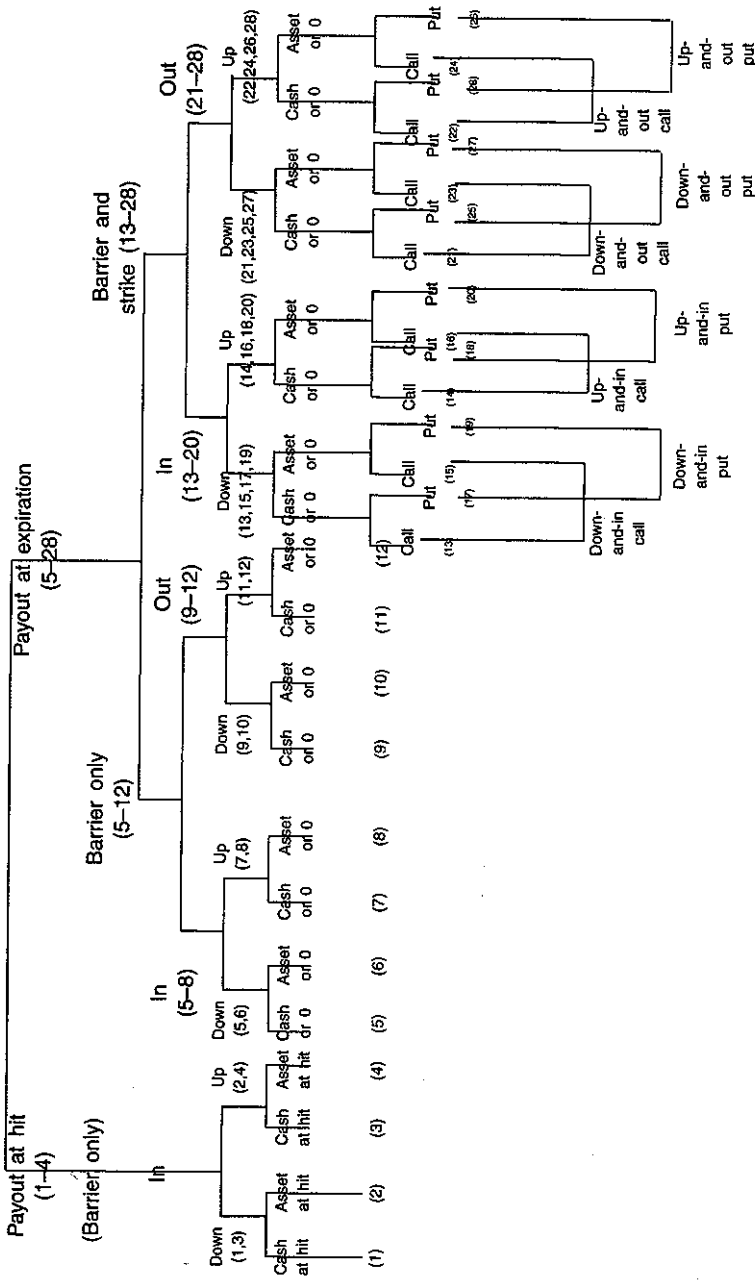


Figure 18.2 Path-Dependent Binary Options. Source: M. Rubenstein & E. Reiner, "Unscrambling the Binary Code," *Risk*, October 1991.

Another issue is whether the documentation specifies that the barrier is hit if a price is traded or if a price is quoted on a screen. The latter situation, obviously, lends itself to manipulation. Recent standard documentation developed by the British Bankers' Association and the New York Federal Reserve's Foreign Exchange Committee requires actual transactions to be the basis of a barrier event.

A related point is the frequency with which we check whether the barrier is hit. In currency markets where there is continuous worldwide trading (e.g., dollar/mark, dollar/yen), it is fairly easy to check continuously; not so for a Krone/yen barrier or for a barrier on a swaption. In the latter case, it has been shown¹⁴ that the price of a daily observed barrier might well be 10% higher than for a continuously observed swaption—a contract that is theoretically available but not in fact practicable.

These binary options have played an important role in certain markets, notably in the range instruments traded in interest-rate and foreign exchange markets. Range trading became very fashionable when the market seemed directionless and volatilities were high.

In the most straightforward version, the *range binary option*, investors receive a payout of several times the premium paid, but only if the underlying exchange or interest rate remains within a preset range. More exotic variants were often embedded in bonds and warrants—these create products that allow daily accrual of interest on days when the range conditions are satisfied. In some cases, accrual is stopped once the range is broken. In other cases, accrual is restarted after a range breach if the underlying subsequently trades back inside the range.

To give an idea of the scope for leverage in range trades, in mid-1996 foreign exchange products were being structured that gave 8:1, 10:1, and even 15:1 payoffs on a straightforward double-knock-out structure. There were more complex versions: Bankers Trust's Quattro product gave four ranges: if an investor was correct on all four ranges, his or her payoff was eight times the premium. Even if only one range remained unbroken, the Quattro holder received double the premium. Although these instruments are highly leveraged, they limit losses to the premium paid. This differentiates them from more conventional bets on low volatility such as the sale of straddles, which expose the holder of the position to unlimited risk. That

¹⁴F. Cheuk and T. Vorst, "Breaking Down Barriers," *Risk* (April 1996).

said, holders of notes in which these options are embedded can lose significant amounts of their principal if the bonds are not accruing and are sold before maturity.

Foreign exchange dealers learned this the hard way in 1995 and 1996. Deals were struck when volatilities on European cross-rates were close to or at all-time highs. This pushed the price of binary range products down dramatically because it seemed likely that the ranges would be broken. Subsequent sharp falls in volatility (e.g., deutschemark/lira volatility fell from around 15% in early 1995 to nearer 5% by the end of 1996) meant that the ranges were not breached. Furthermore, the popularity of the product with both institutional investors and corporate hedgers, who used the range option in place of vanilla options to reduce hedging costs, exacerbated dealers' problems. Prices fell below the levels at which they covered hedging costs as dealers competed for business. Moreover, the scramble to hedge positions once it became clear that the downward trend in volatilities was permanent forced down volatility. Option holders made huge profits, and underhedged option dealers took significant losses. At least three major banks cut their exotic foreign exchange teams after the event, though no confirmation was forthcoming that these moves were linked to the range-trading debacle.

Demand for range binary options was also driven by demand from corporate treasurers who saw them as a cost-effective hedging instrument. In combination with vanilla options or forwards, range binaries can be used to create cheap and even self-financing hedges. If a company is long dollars and wants insurance, it can buy a dollar put and a range option on the relevant exchange rate. If volatility falls, then the value of the put will fall, but the value of the range option will rise. The put may expire worthless, but the range may pay out, funding or partly funding the put premium.

Range options can also be used as a substitute for forwards to create what some banks call the range bonus forward (inaccurately, because no forward contract exists, only an option contract). Instead of buying an outright forward, a treasurer can decide to take some of the forward points and use them to buy a range option. Suppose the forward dollar/euro outright is 1.07, and spot is 1.08. The hedger could take one euro of premium to buy a range position that produces, say, four euros of windfall profit if the view is correct.

In the interest-rate markets, path-dependent caps and floors such as knock-ins and knock-outs have been quite widely used, again because of the premium

reduction. A borrower might look at, say, a knock-in LIBOR cap with a strike of 7% and a trigger of 6%. As long as rates are below 6%, no cap exists. Once rates rise above 6%, the seller's liability begins: a cap is created, with a strike of 7%.

The buyer of such a cap might think she is not much at risk to rising interest rates when LIBOR is below 6%. She might believe, however, that an interest rate rise past 6% suggests a strong rising trend. The cap buyer makes no upfront payment, but she pays the seller if LIBOR rises past the trigger of 6%. Obviously, as with all contingent premium options, the premium paid—if it is paid—is a good deal more than the premium for a conventional cap. Once the cap is knocked-in, however, the cap purchaser is protected if interest rates rise past 7%.

Another variant that has been offered in the market is the up-and-out cap with a refundable premium. This is a cap with a predetermined range whose lower limit is the cap's strike and whose upper limit is the level above which the protection disappears. If the cap disappears, the buyer is refunded the premium payable for that period.

At each fixing, the floating reference rate is compared to the established limits. There are three possible outcomes:

1. The market rate is below the strike: no payment made.
2. The rate is in the predetermined range: the seller pays the buyer the interest differential between the market rate and the strike rate.
3. The rate is above the knockout level: the cap is deactivated. No interest differential is paid, but the seller reimburses that part of the premium that applies to the period.

The product thus represents an intermediate solution between a standard cap and a standard up-and-out cap.

Look-Back Option

The *look-back option* gives the buyer the right to "look back" over the period of the option and deal at the best possible rate during that period. Of course, the buyer is charged a sizeable premium for this right. Consider a three-month sterling look-back call, traded with spot initially at \$1.7500. If sterling falls continuously over the three months to, say, \$1.7000, the option will

be at the money on expiration. If sterling rises continuously, the option will behave as a \$1.7500 call. If sterling is volatile, falling to, say, \$1.6500 before returning to \$1.7500 at expiration, the option behaves as a \$1.6500 call. Because the look-back option will always expire in or at the money, the premium will always be greater than for the at-the-money spot European option.

There are two main types of look-back options available: (1) the "standard" look-back and (2) the "extrema" look-back. The valuation of a standard European look-back (SLB) can be done by means of a closed-form formula:¹⁵

SLB =

$$\left[S e^{-rT} N(a_1) \right] - \left[S e^{-rT} \frac{\sigma^2}{2(r-q)} N(a_1) \right] - S_{\min} e^{-rT} \left[N(a_2) - \frac{\sigma^2}{2(r-r_f)} e^{Y_1} N(-a_3) \right]$$

where

$$a_1 = \frac{\ln(S/S_{\min}) + (r - r_f + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$a_2 = a_1 - \sigma\sqrt{T}$$

$$a_3 = \frac{\ln(S/S_{\min}) + (-r + r_f + \sigma^2/2)}{\sigma\sqrt{T}}$$

$$Y_1 = \frac{-2(r - r_f - \sigma^2/2)\ln(S/S_{\min})}{\sigma^2}$$

r_f = the foreign interest rate (in the case of a currency look-back or in the case of an equity), the continuously payable dividend; S_{\min} = minimum level reached by S during the life of the option

Although the look-back formula looks formidable, and at first blush it might seem difficult to hedge an instrument that guarantees to pay out the best possible price, in fact the hedging is (in principle) not too difficult. At

¹⁵See, e.g., J. C. Hull, *Options, Futures and Other Derivatives* (Prentice-Hall, 1997), and the references cited there.

the start of the transaction, we buy a call option—assuming we have sold to the client a look-back call that was struck at the money. If the market falls, we sell that call and buy a new at-the-money call. In this way, we always own a call that we have bought at the bottom of the market. The costs of this hedging are high because we lose money every time we sell a hedging call that is out of the money; and the bid-offer spreads are higher if we hedge in this way. So, the look-back option will be expensive, as one would expect anyway, for an instrument that is guaranteed to pay out at maturity (unless the minimum falls on the last day of the option). A common rule of thumb is to estimate the look-back as costing double the standard call option.

The second formulation of the look-back option, which is less common, is the extrema look-back. Suppose we have an extrema look-back call with a strike level of E and a previously observed maximum value of the underlying of V . Let M be the maximum value observed from now, the date of trading the option, to its expiration. Then if E was fixed below V , the extrema payoff is the better of $V - E$ or $M - E$. If E was fixed above V and if M is below E , the payoff is zero. In other words, the look-back payoff here considers the extreme value not just during the life of the option but also during some earlier period; and it pays off the better of the already observed maximum or any new maximum (less the strike).

Another variant is the partial look-back option—the buyer is allowed to select a subperiod of the option's life to look back over.

Cliquet/Ratchet Option

The *cliquet option* was first popularized in France, hence the name. The option was introduced in the form of bonds with payoffs linked to the CAC-40 stock market index, and it was widely marketed to retail customers as well as to professional investors. The cliquet allows the option's strike price to be reset at a set number of dates (usually annually) to the current asset price. Any positive intrinsic value is locked in at that point. From the investor's viewpoint, this is a very attractive structure. In effect, the option gives us the right to lock in any profits at regular intervals before we buy back into the market at the new market level. One could think of it as the equivalent of a tax-driven "bed-and-breakfast" deal where the investor automatically crystallizes any capital gains.

An example would be the FFr 300 million Credit Lyonnais Guernsey issue, issued in June 1992, maturing July 17, 1996. Here the bond coupon was set at a minimum of 0% and a maximum of 18% linked to the performance of CAC-40 index—the initial level set at FFr 1,913 on June 17, 1992. The cliquet options allow the CAC strike to be reset every year, which is attractive to investors. They can lock in gains accrued to date, whereas if the index falls, investors can buy a call at a lower strike. Even if the index has not risen above the initial strike of FFr 1,913 by the bond's maturity, investors will have received income every year that the index rises. If the index fell in any one year, they would receive no coupon, and the next year's strike would be reset at the lower level. In this structure, the rise in the index is paid out in the form of bond coupon during the life of the deal; in other structures, the payment is made at maturity.

Pricing and hedging of the cliquet structure is surprisingly straightforward. If we consider the bond just mentioned, we have four successive coupons to be paid out, the value of which is fixed by the cliquet. After the first year's call option—for which the pricing is, of course, already known—we have three successive one-year call options that will be struck at the money when they come into existence. These are none other than forward, or delayed-start options; earlier in this chapter, we found their value to be the same as that of a call struck at the money today for a one-year maturity.

Ladder

A variant of the cliquet says, "Instead of refixing the strike every year, we fix it when the market has risen a given percentage." This is called a *ladder option*, which is a special case of the look-back call. In a ladder option, we can look back only at certain points: the "rungs" of the ladder. As the number of rungs increases toward infinity, so the ladder starts to resemble a look-back. Many ladder options have been combined with zero-coupon bonds to achieve the combination of a guaranteed minimum return plus the locking in of a rise in the market.

An example might be a bond for which the investor is guaranteed the return of his or her assets at maturity, plus the ability to lock in to a rise of 50% and 75% from today's levels. Clearly, if the market only rises 49%, a look-back option would have been a better bet; but in return for taking

this risk, the investor can buy the ladder option more cheaply. The hedging of a ladder option is a combination of normal puts/calls and knock-out puts or calls.

An example of the application of the ladder was the issue by ABN Amro Bank in 1993 of 4,000 ladder-call warrants on 100 units of the European Options Exchange (EOE) Index, exercisable December 17, 1993, at NLG 280. These warrants had barriers every 10 points from 290 to 320, which guaranteed cash settlement in Netherlands guilder (NLG) at the higher of the maximum barrier reached and the final EOE index level.

The pricing of the ladder option is not so easy as that of the cliquet option because a closed-form solution is not yet available. However, we can replicate the behavior of a ladder by a suitable combination of barrier and conventional options, as the following example demonstrates.

Exhibit 18.3 Ladder Option Bond

We wish to issue a bond whose redemption value gives the investor a payout like that of a ladder call option on the NLG, with one rung set at 115% of the current NLG level. If at maturity the NLG were to be below today's level, the investor simply gets the original principal back. If at maturity the NLG is between 100% and 115% of today's level—say, 108% of today's level—and has never been above 115%, the payout is the increase. In this example, the investor would receive 108%.

However, if *at any time* the NLG traded above 115% of today's level, the investor is guaranteed a payout of 115%—even if the NLG has subsequently collapsed to, for example, 90% of today. If the NLG settles above 115%, for example, at 125%, then the investor gets 125% of the principal amount back.

We could hedge our position as follows:

1. We buy a call option on the NLG at a strike of 100% of today.
2. We buy a long put spread; that is, we sell a put with a strike of 100% of the NLG, and we buy a put with a strike of 115%.
3. We sell an up-and-output (U&O) put spread; that is, we buy an up-and-out with a strike of 100% and an "out" of 115%, and we sell an up-and-out put with a strike of 115% and an "out" of 115%.

We consider the payoff of this package on the following assumptions (rungs):

1. NLG settles at 80, never having touched 115%.
2. NLG settles at 80, having touched 115%.
3. NLG settles at 125.

Outcome	Rung 1		Rung 2		Rung 3
	Not touched 80	Touched 80	Not touched 100	Touched 100	Touched 125
Call	0	0	0	0	25
Put spread:					
-Put	-20	-20	0	0	0
+Put	35	35	15	15	0
Short knock-out put					
+U&O @ spot	20	0	0	0	0
-U&O @ rung	-35	0	-15	0	0
Total payoff	0	15	0	15	25

As we can see, this package of options has provided an exact hedge of the ladder structure required.

Shout

The *shout option* is another twist on the cliquet/ladder concepts. In this case the strikes on the option are set not at fixed dates as with the cliquet, nor at fixed market levels as with the ladder, but at the option of the buyer. When the buyer wants to fix the strike, he "shouts" to the writer.

The pricing of the shout option assumes rationality on the part of the shouter. It will be rational to shout only if the intrinsic value of the option obtained thereby is greater than zero. More precisely, it is rational for the buyer to shout if the expected value of the option obtained is greater than the expected value of the option obtained without shouting (i.e., if the buyer does not expect the market to fall further, if a buyer of a shout call option). It should be noted that this decision is very closely similar to the decision

on whether to exercise an American call option, and rather similar valuation methods are required—we set up a binomial tree and “prune” it in line with the “rational shout” behavior.

The shout is cheaper than the look-back because it requires the buyer to take the risk of shouting at the wrong moment. But if the buyer calls the market well, he or she gets the same payoff as that for a look-back.

Comparisons

It may be of some help if we pause at this point to draw some comparisons. Figures 18.3, 18.4, 18.5, and 18.6 compare various exotic options on sterling at a strike price of \$1.75 when the current spot rate is also \$1.75—the options are at the money. Each option is for one year, with the assumed sterling interest rate at 6.375% and the dollar interest rate at 5.75%. Where barriers apply, they are taken, for down-and-out/in and up-and-out/in as \$1.70 and \$1.80, respectively. For touch options, the same levels are used. The fixed

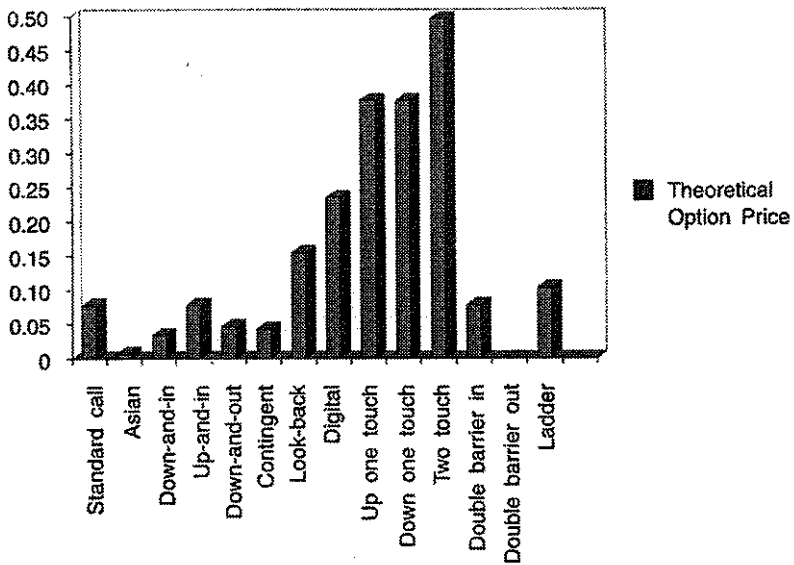


Figure 18.3 Premiums for Various Exotics

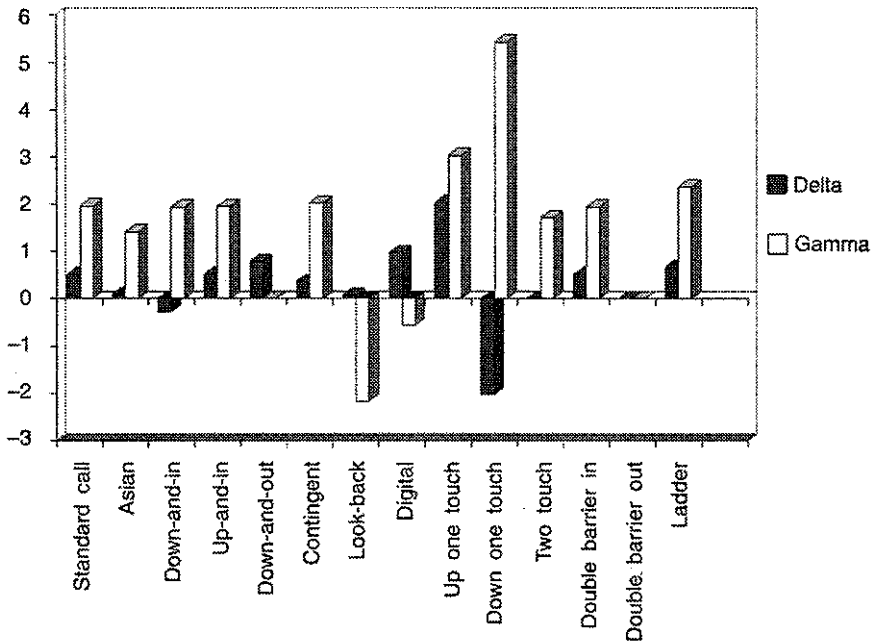


Figure 18.4 Delta and Gamma

payoff used for digital and touch options is 0.5. The ladder option is assumed to have rungs at \$1.80 and \$1.85.

It should be very firmly stressed that these comparisons are extremely rough-and-ready because inevitably they are snapshots of dynamic instruments. This applies particularly to the digital and the barrier options, where delta and gamma are extremely volatile around the strike and the barrier.

OPTION HYBRIDS

Forward Contracts with Embedded Options

In practice, most of these products were developed in order to allow corporate treasurers or fund managers to use options without appearing to do so. This avoided the need for lengthy explanations to a board or to trustees whose

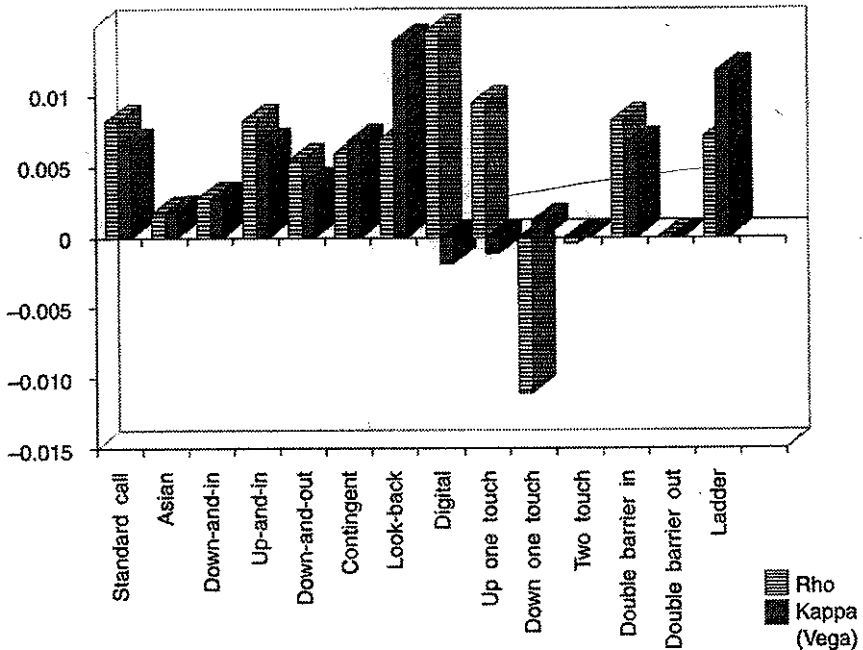


Figure 18.5 Rho and Vega

grasp of the advantages of options might be rather limited. In some cases, banks also used these products in order to conceal from their customers the true costs of the product they were buying. In most cases it is usually cheapest for the customer to buy the component parts separately. However, where there are regulatory or tax advantages, the third-generation products may be useful. For example, in the United Kingdom, the Inland Revenue took the view that an option was a wasting asset, therefore losses on options purchased were not tax deductible. A loss on a forward exchange contract, however, was allowable. Thus combining the forward and the option allowed for better tax treatment.

We will look at three kinds of third generation product: (1) the break forward, (2) the range forward, and (3) the participating contract. (Unfortunately the marketing departments of many banks, in an effort to make the bank's product seem different, have dreamed up many different names for these products. Thus break forwards have been called a Boston option, a FOX [forward with optional exit], and so on.)

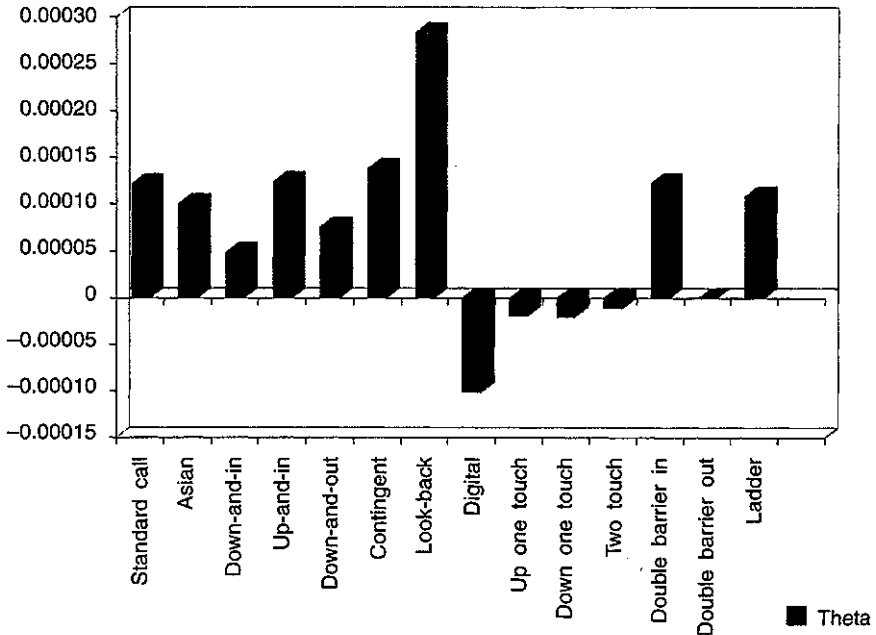


Figure 18.6 Theta

The *break forward* is a forward contract combined with a call or a put. For example, a corporate customer requires to buy forward sterling value June 15. Today is March 15; the interest rate to June 15 is 10%. The forward rate is \$1.65 for June 15, and the \$1.60 June 15 put costs \$0.036. The bank will offer to sell forward to the customer at a certain rate, with a “free” put at \$1.60. How is that forward rate determined? The bank will protect itself by buying forward sterling to sell to the customer and by buying the \$1.60 puts. It will fund the cost of the premium paid today on those puts at 10%. So the funded put costs $0.036 \times [(1 + 10\% \times 91/265)] = \$0.0009 + \$0.036$, or \$0.0369. The bank offers to sell forward at $\$1.65 + \0.0369 , or \$1.6869 (instead of the \$1.6500 available in the market), with a “free” put at \$1.60. The corporate customer buys forward at \$1.6869. If sterling is below \$1.60 at maturity, the customer exercises the put. Say sterling is at \$1.55; then the customer will exercise the put (crystallizing a loss of $\$1.6869 - \1.6000 , or \$0.0869) and will buy in the market at \$1.55. The next total cost to the customer will be $\$1.5500 + \0.0869 , or \$1.6369. But

that will still be less than the \$1.6500 that the customer would have paid if he or she had simply covered forward.

The *range forward* is an extension of the break forward to give an upper and a lower limit. Outside the range of those limits, the customer is protected. Inside the range, the customer is exposed. Suppose again our corporate customer wants to buy forward sterling value June 15. As before, today is March 15; the interest rate to June 15 is 10%, and the forward rate is \$1.65 for June 15. As before, the \$1.60 June 15 put costs \$0.036; the \$1.90 June 15 call costs \$0.042. The bank offers to sell to its customer at whatever the June 15 spot rate turns out to be. The offer is subject to a maximum of \$1.90 and a minimum of \$1.60, and the trade will be adjusted by a set amount representing the bank's fee for the deal. The customer knows he or she will not have to pay more than \$1.90 (plus fee). In exchange, the customer gives up the hope of profiting below \$1.60.

What is happening is that the bank effectively sells a call to the customer and buys a put from the customer. It sells the call for \$0.042, buying the put for \$0.036, for a net cost to the customer of \$0.006. This cost is funded for 91 days at 10% for an all-in cost at maturity of \$0.0062. So the final deal includes a fee of \$0.0062 added to the rate at which the contract is traded. A variant of this approach is to adjust the strike prices of the upper and the lower limits so that the net premium payable is zero.

Participating contracts are an interesting variation. In the break forward and the range forward deals, the cost to the customer is varied by changing the strike levels of the option. This can also be done by setting a particular strike and then varying the cost by varying the proportion of the deal's size. Once again, the corporate customer requires to buy forward sterling value June 15; today is March 15; the interest rate to June 15 is 10%, and the forward rate is \$1.65 for June 15. The \$1.70 June 15 put costs \$0.08, and the \$1.70 June 15 call costs \$0.05. The bank offers to sell forward to customer at \$1.70—an above market rate—but it will share 37.5% of its profits on the deal with its customer.

That share is decided by the ratio of the costs of the call to that of the put: 37.5% is given back because the call costs 62.5% of the put (0.05 versus 0.08). Suppose the deal is for £62,500,000, and the exchange-traded puts and calls that the bank uses to hedge its position are for £62,500 each. The bank will hedge its upside risk by buying 1,000 calls and will fund this by selling 625 puts, for no net outlay of premium. If sterling falls, it has sold

at \$1.70 to the customer, but it will profit from the fact that it has sold only 625 puts; this profit is available to be passed on to the customer. (Obviously in real life the percentage will be adjusted to allow the bank a profit.)

The range forward uses puts and calls with different strikes to arrive at a premium of zero, or close to it; the participating contract uses the same strikes but adjusts the amount of the deal on one side to achieve the same result.

EMBEDDED OPTION SWAPS

An enormous variety of possible swaps can be created by embedding in the swap some type of option, for example, a swap in which the client pays six-month LIBOR and receives six-month LIBOR plus a spread of, say, 110 basis points. In exchange, the client accepts that if LIBOR touches a certain level, then the coupon for the period is forfeited. These “one-touch swaps” were popular for a period in 1994, for example.

Another possibility might be the look-back basis swap. With these structures, the client pays the highest LIBOR fixing in the reset and receives LIBOR set at the start of the period plus a spread. In a two-year deal with six-month resets, for example, the client might receive six-month LIBOR plus 120 and pay the highest daily six-month LIBOR rate in each six-month period.

Swaps with Built-In Options

There is a substantial market for swaps with various types of option built in. As an example, one investment bank in November 1996 was offering the following swap, which essentially was designed to act as a “play” on convergence within the European currencies that it was expected would enter the European Monetary Union. The swap consisted of the following two-year trade: the client would pay FRF three-month PIBOR (Paris Interbank Offered Rate) and receive $(\text{FRF three-month PIBOR} + 0.64\%) \times n/Q$, where n = number of days that FRF three-month PIBOR is greater than DEM three-month LIBOR and Q = exact number of days in the quarter.

The risk in this swap, of course, is that the German interest-rate level might rise above the French. If this were to occur, then the client would

pay three-month PIBOR and receive nothing. The underlying option is a cross-currency binary interest-rate option.

Participating Swaps

One variant of the swap is the *participating swap*. This is designed for floating-rate borrowers who wish to hedge against an increase in money market rates and who think rates are unlikely to drop below a certain level. The swap fixes a borrowing rate, but it allows borrowers to benefit from any decline in rates within a range determined at the start of the transaction. For example, the swap might be for five years at a fixed rate of 7%, with a range of 4% to 7%. If rates fall below 4%, the borrower pays the fixed swap rate of 7%. But if rates are between 4% and 7%, the borrower pays a floating rate. If rates are above 7%, the borrower pays the fixed swap rate of 7%.

This product is an interesting alternative to the standard swap for a floating-rate borrower who is willing to pay a fixed rate slightly higher than that of a standard swap in return for the chance to benefit from a fall in rates within the given range.

UNITED CURRENCY OPTION MARKET

In 1982, the Philadelphia Stock Exchange (PHLX) pioneered listed options on currencies (standardized contracts). More recently, it has developed a marketplace known as the United Currency Option Market (UCOM). This trades three types of option:

1. It trades *standardized currency options* on eight major currencies and two cross-rate pairs, with American- or European-style exercise; maturities can range from two weeks to as long as two years, with a choice of midmonth or month-end expiration.
2. It trades *Virtual Currency Options* ("3-D," or Dollar-Denominated Delivery) contracts. The 3-D euro option, for example, is a cash-settled euro option that automatically settles in U.S. dollars. They were designed to allow investors to trade currency options without the need to establish foreign

currency accounts or international bank lines. The investor merely pays or receives the difference between the strike price and the settlement value. The 3-D is a European-style option with maturity ranging from one week to nine months.

3. It trades *customized currency options*. The trading mechanics are very similar to those for FLEX options on the Chicago Board Options Exchange (CBOE) and elsewhere. Request for Quotes (RFQ), quotes, and trades are published as text messages over the Options Price Reporting Authority (OPRA). The issuer and guarantor of all these options is the Options Clearing Corporation (OCC).

Any two currently approved currencies, including the U.S. dollar, may be matched for trading. Either may represent the base or the underlying currency; for example, US\$/JPY (strike prices expressed in U.S. dollars per Japanese yen) or JPY/US\$ (strike prices expressed in yen per dollar); GBP/EUR (strike prices expressed in pounds sterling per euro) or EUR/GBP (strike prices expressed in euro per pounds sterling). A total of 100 possible currency pairs are available for trading. Contract size for the currency pairs is determined by the underlying currency. Exercise style is European.

A participant may trade a customized currency option with either a standard expiration date (termed a "standard-expiry option") or a customized date (termed a "custom-dated option"). Standard-expiry options and custom-dated options have distinct exercise and assignment processes. Standard-expiry options conform to existing exercise and assignment practices for all standardized contracts.

Custom-dated options follow a unique exercise and assignment process on expiration:

1. 8:00 A.M. (Eastern Time)—Trading ceases in expiring custom-dated options.
2. 10:00 A.M. (Eastern Time)—Window closes for exercise instructions in expiring custom-dated options. OCC will then disseminate a preliminary indication of the percentage of open interest exercised in each series.
3. 10:15 A.M. (Eastern Time)—Custom-dated options expire, and final assignment notification based on a pro rata assignment process begins.

19 Risk Issues

Within the financial services industry, there are at least three separate groups with unique ways of looking at risk: (1) investment managers, (2) insurers, and (3) banks. They have historically looked at risk with quite different eyes. The current trend, though, is for these three to blend together as different areas of the industry come closer together.

Investment managers typically start from a “modern portfolio theory” perspective. The basic elements of modern portfolio theory were laid down by Harry Markowitz in 1952. He defined *risk* as the uncertainty, or variability, of returns. This risk is usually measured by the standard deviation of expected returns about the mean. (For those familiar with financial options, the standard deviation is referred to in that market as *volatility*. For those unfamiliar with them, the concepts of standard deviation and correlation are defined in Appendix A.)

Markowitz pointed out the importance of correlation—or the lack of it—in reducing overall portfolio risk. If a portfolio contains various securities, but the prices of those securities move closely in line with each other, there will be little effect on the variability of a portfolio’s expected rate of return. Effective diversification is only achieved if the portfolio is composed of securities that do not vary in a similar way. If this is so, then the variability of the portfolio’s rate of return—its risk—is much less than the risk of the components. From this insight came the thought that portfolio return can be increased, for the same level of risk, by diversifying.

The first sign that this type of thinking has begun to affect the way the banking regulators look at risk is to be seen in the European Union’s Capital Adequacy Directive (CAD) provisions for risk weighting on securities holdings,

in which separate factors are applied for risk that is specific to an individual issuer and for market risk as a whole. After a long debate, the Basle Committee rules (discussed later) have also been amended to allow for the effects of diversification.

Insurance companies, by contrast, look at risk in a very different way when they insure risks. Insurance companies expect disasters to happen. The problem resolves itself into (1) predicting the frequency and the cost of the disasters, so as to charge the right premium, and (2) making sure the firm has enough capital (or reinsurance) to survive whatever Fate may hold in store.

An example of the use of this pricing approach to risk in bank trading activities is the pricing of options. When writing an option, the market maker often cannot hedge the risk by buying a matching option (or, if he or she can, the cost might well be enough to swallow the profit). Usually, options prices quoted by a market maker will reflect the expected stream of losses that will arise from “dynamic hedging” of the option position. To this will be added whatever profit margin is needed. Here the market maker is acting as a true insurer: the hedging costs are the unpredictable reinsurance costs.

Banks' risk measurement, historically, has been driven by the approach of the lending banker. The amount lent to each client is added up, and the total is considered the total amount at risk through loans. To this would be added the credit equivalent (however measured) of forward foreign exchange contracts and other off-balance-sheet exposures. However, in recent-years, the measurement of exposure has become more dynamic and is increasingly being influenced by the other risk-management approaches just discussed and by their successors, notably the concept of value at risk (VAR), which is discussed later. The experience of the near-collapse of Long-Term Capital Management discussed at the end of the next section also heightened awareness of the linkages between market risk and credit risk.

GENERAL CONTROL OF RISK

Everything in this book, in one way or another, is about taking a risk to earn a return. But uncontrolled risk can be disastrous. The next three chapters are about measuring and controlling various risks. This chapter discusses some of the general concepts involved. There are many possible ways to

classify risk. One way is to split risk into name, liquidity, credit, legal, country/political, control, and market. Market risk can be subdivided into forced-sale risk, interest risk, exchange risk, basis risk (or correlation risk), volatility risk, and risk of change in shape of the yield curve.

An important general point needs to be made at the start. Traditional risk controls consisted largely of fixed limits. For example, a forward exchange dealer might be told, "You must not have an exposure greater than \$15 million in the one-year maturity and \$10 million in the two-year maturity." Over the past decade, however, the tendency has been to move toward a more sophisticated and flexible approach. The 1990s saw the introduction of the concept of *value at risk* (see later section Market Risk), and the tendency has been to move to control exposures with reference to this or related concepts, coupled with a growing emphasis on "stress testing." These concepts are discussed further later.

But before getting into the details, we start by pointing out that a very large part of risk control has to do not with systems or procedures but with basic common sense. This means looking through the procedures to think about the real world and recognizing that that world has imperfections.

Sophisticated tools are useless unless the basics are right. The golden rule here is that *rigid rules are no substitute for a good relationship with the dealing and the backup teams*. But there are obvious basics, the first of which is separation between the dealing room and the back office. This should prevent unauthorized dealing from being concealed by inadequate back-office procedures. The risk is that (as at Barings in 1995) an unauthorized position loses money and is "doubled up" in the hope of turning around.

In this context, a truism that bears repeating is that the test of a dealer is not how much profit he or she makes but his or her ability to take losses early rather than to hang on until too late. Certain banks set profit goals for traders, who are then given incentives or are pressured to meet or to exceed the goals. There is a risk that this policy can lead to overtrading. Another sensitive area is the question of requests to deal at rates that are "away from the market." This may sometimes be needed to help a broker. The broker is then expected to repay the "points" (away from the market price) he has "borrowed." But the use of points can also be a sign that a dealer is beginning to try to conceal a position that is going sour. It is also important to make sure that too much business is not directed toward one broker or one bank.

There are many other ways in which Murphy's Law¹ can apply. Many banks came to appreciate foreign exchange settlement risk more clearly after the 1974 collapse of I.D. Herstatt, a German private bank that tried to sell short more sterling than most banks ever see (it was a good idea, but a year too soon). The Bundesbank made the mistake of closing Herstatt's doors at 4:30 P.M. in Frankfurt while New York was still open, so that the deutchemark (DEM) side of trades settled, but not the U.S. dollar side. In foreign exchange, time-zone considerations matter.

Another basic—making sure that there is an independent check on dealers' activity by ensuring separate confirmations to an independent back office—was neglected by Volkswagen AG (VW). In its 1986 results, this firm made provisions for DEM 382 million of foreign exchange losses: the foreign exchange manager and at least one other employee entered into fake foreign exchange contracts with the National Bank of Hungary in cooperation with an external currency broker. The fraud came to light when the Hungarian National Bank said that documents that VW thought covered forward foreign exchange deals were false. On at least one occasion, the deals were done at a rate 26 pfennigs off the current market rate, which itself should have been a red flag.

An unthinking application of formal rules led to considerable embarrassment at County NatWest in 1987. A Scotsman whose previous claim to fame had been as a successful worm farmer became involved in option trading when his son was hired as an equity salesman by National Westminster Bank's investment banking subsidiary, County NatWest. During the first nine months of 1987, all went well. The father's option turnover during that period exceeded 8 million, generating commissions for County NatWest of over £100,000 and an income for the worm breeder of £250,000, much of which had been generated by writing put options on the U.K. stock market index (the Financial Times Stock Exchange—FTSE—index contract). By mid-October 1987, he had written about 50% of the outstanding January 1988 puts on the FTSE index. On October 19, 1987, to use *Variety's* immortal words, "Wall St. laid an egg." The puts shot up in price, and the loss incurred by County NatWest in respect of margin calls that could not be met was over £3 million. The worrying point is that before the crash, County NatWest's compliance department had questioned their employee regarding his trading activities

¹"Whatever can go wrong, will go wrong."

with his father and was given a clean bill of health. No one looked beyond the legal issues to consider the market risk implicit in a private individual's controlling 50% of an option series.

The collapse of Orange County, California, in 1994 illustrated the danger of using a high degree of leverage (in this case through the repo market) to invest in sophisticated but illiquid structured notes. As with Long-Term Capital Management (discussed shortly), a heavy price was paid when the markets became illiquid.

A spectacular disaster in 1995, the collapse of Barings, reflected a serious failure of control and understanding by senior management. A rogue trader claimed to be carrying out large arbitrage positions in the futures markets and reported high profits, but all losses were being dumped in a suspense account. No one queried the size of the suspense account, nor the huge margin calls that were being made, partly because the trader also had supervisory responsibility over the back office—a basic breach of the control regime.

The near-collapse of Long-Term Capital Management (LTCM) in October 1998 illustrated another important truth. The firm was highly sophisticated, numbering among its management no less than two Nobel Prize winners, Merton and Scholes, with a high degree of expertise in derivatives. It ran a sophisticated hedge fund the collapse of which was due to a worldwide “flight to quality” after the Russian default in August 1998. As the market moved against Long-Term Capital Management, they needed to liquidate positions. The size of the positions pushed the market against them, and because of the high degree of gearing/leverage, this in turn resulted in further collateral being demanded by their counterparts. This required further liquidation of positions. The moral here is that sophisticated systems are no defense against a sudden drying up of market liquidity.

Name Risk

Because so many things can go wrong, when outsiders assess another institution, they think first in a general way about that institution's standing and reputation: the “quality of the name.” Risk to the firm's name is the most important, though the most nebulous, risk. Any institution that hopes to do business must have a good reputation. Once that is lost, confidence of counterparties will no longer be available, and the firm will find it impossible to deal in the markets.

We can break down the risk further: moral hazard and overexposure. If an institution's employees engage in criminal or immoral activities, the reputation of the institution will be at risk. An isolated instance of such conduct, however, as at Volkswagen, can be a great deal less damaging than the other type of main risk, namely overexposure in the market. If an institution is thought to be over trading, counterparties will become much more careful about the degree of credit they are willing to grant it. Thus, most banks and other corporations active in financial markets will normally have controls on the extent of trading activity that are expressed not merely in terms of position risk but also in terms of total transaction volume, or "name in the market."

In the foreign exchange market, for example, a limit on the total foreign exchange book is normally set. It is necessary to have some control on the volume of activity to prevent overtrading and to keep total exposure under reasonable control. Normally the aggregate book would be defined as all outstanding foreign currency contracts (purchases plus sales, spots plus forwards) with customers, banks, branches, and subsidiaries. Interest arbitrage spot and forward contracts with counterparties should be included; but if interest arbitrage transactions are generated internally within a dealing room (say, between subsections of the room), these ought to be excluded. They do not put the bank at risk in the outside world. A similar limit would apply to the total outstanding volume of the Eurocurrency and domestic currency book. At the same time, these limits cannot be too small: a bank will need a certain reputation in the marketplace. If the firm has not dealt in the market for the past seven years, it cannot expect an instant response from the market when it telephones for a price.

Liquidity Risk

Liquidity risk flows from the basic fact that even a profitable business can still go bankrupt if it does not have enough cash on hand to pay its immediate bills. Most banks that collapse do so because of liquidity problems rather than solvency problems. The collapse of Continental Illinois in 1984, for example, followed revelations of severe losses on its energy-lending portfolio. But that in itself was not enough to push the bank into difficulties. What really caused the problems was that the news about the losses caused counterparty banks in the Eurodollar market (Continental's prime funding

source) to cut back on their interbank lines of credit. It was the drying up of liquidity rather than the solvency problem that caused Continental to get into difficulties. The two are often related, but an instructive comparison can be made with Bank of America, which also experienced heavy losses during the 1980s. Unlike Continental, Bank of America also had a very large retail deposit base, which was much more stable than the international wholesale market on which Continental depended for its funding. Thus, it remained liquid throughout its crisis and was able to survive. Orange County and LTCM illustrate another facet of this problem: the potential cost of trying to bale out of large positions when the market is nervous and illiquid.

Banks will normally control liquidity risk by monitoring their funding ladders, which track the maturity of liabilities against maturity of assets. Corporate treasurers similarly seek to ensure that they have, at a minimum, sufficient committed lines of credit from their banks for sufficient maturity to overcome any short-term funding pressures. Investors and hedge funds often monitor their liquidity risk (at least in equity markets, where data is easily available) by reckoning their positions in terms of the number of days' trading in the given security.

Credit Risk

Credit risk is an obvious and fundamental risk for any bank. Lending will mostly be controlled by a set of counterparty limits fixed in relation to the counterparty's perceived credit worthiness. It is not the function of this book to discuss traditional lending exposure. But other activities—notably forward commitments such as forward foreign exchange, forward rate agreements, and swaps—also imply credit exposure. There is a need to assess the overall picture.

Extensive discussions in this area led up to the issue in December 1987 of a proposal by the Bank for International Settlements (BIS), which represented the first initiative aimed at regulating bank capital adequacy on a global basis. The BIS proposal is focused primarily on credit risk—it laid down a two-tiered capital standard measured against risk-weighted assets. The risk weightings were defined in terms of credit risk equivalent. They are discussed in more detail in Chapter 22 on credit and related risks.

There is a fundamental point to be made: Strong ratios need not mean strong banks. The collapse of the British bank, Johnson Matthey, was a case

in point. To quote the British Bankers Association: “like many of the fringe banks before it, it boasted ample capital ratios and would have passed the statistical tests of most prescriptive systems with flying colors. Its problems stemmed from loan concentration, poor loan quality and gravely inadequate management systems.” The U.S. thrift industry provides a raft of similar examples.

In the foreign exchange and money market area, a number of subsidiary questions arise in that the credit risk on some of these instruments is not always clear. Credit risks in foreign exchange occur in two areas. The first type of risk is on outstanding forward contracts. Suppose a customer went bankrupt after doing a forward sale of euro to a bank. The bank would have to buy forward euro to replace those that it would have been receiving from the customer. The bank is at risk because the rates might have moved against it. This is often called replacement risk. A loss is caused by a counterparty’s default coupled with an unfavorable movement in the forward exchange rate between the currencies concerned.

Suppose that Bank X does a deal to sell US\$ 1,000,000 and buy ¥ 150,000,000 for delivery in 365 days’ time. The forward exchange rate is US\$ 1 = ¥ 150. If the counterparty, Bank Y, defaults the following day, Bank X would have to replace the contract with another to ensure that its books remain balanced. If the 364-day forward rate is now US\$ 1 = ¥ 140, then Bank X would have to pay US\$ 1,071,429 instead of US\$ 1,000,000 in order to receive the same ¥ 150,000,000, and it would incur a loss of \$71,429.

Measuring the bank’s true exposure in some of these markets—particularly options markets—is extremely difficult. There is no magic formula that can be simply applied. The BIS formula is essentially arbitrary, although it reflects the best judgment of a group of experienced central bankers. The measurement of risk in these areas has a large element of judgment. These issues are discussed in Chapter 21.

An important aspect of control of credit risk is the ability to reduce gross exposures by properly arranged netting schemes (discussed later in this chapter).

Legal Risk

There are two main areas of *legal risk*: (1) the set of risks applying to existing businesses and (2) the set of risks applying to new products. The former

obviously are more general in application and would include at least the following risks:

1. *Documentation Failure.* Inadequate documentation (or adequate, standard documentation that has not been properly completed—a very common failing) presents significant legal risk if it were needed to support a court case.

2. *Recharacterization Risk.* This is the danger that a transaction of one kind (e.g., a sale and repurchase of a bond) might be held by the court to be another kind (e.g., a security loan) with different tax or legal implications. Similarly, certain kinds of artificial derivatives structures devised to escape tax have sometimes failed in their aim because of this risk.

3. *“Ultra Vires” Risk.* There is the risk that the entity with whom we are transacting is not legally able to undertake the trade. The best-known example of this in recent years perhaps is the U.K. municipalities that escaped from loss-making, interest-rate-swap obligations by claiming that they never had the legal power to do the trade. Although most companies will normally be held by the courts to be able to do most kinds of financial operation, there may be ultra vires risk in some countries if the documentation is not signed by the appropriate person; and unincorporated bodies (such as some universities in the United Kingdom, pension funds, and in some cases possibly mutual funds) present special risks.

Country/Political Risk

International operations involve a number of risks (e.g., expropriation by hostile governments), but in our context the primary concerns would probably be the following:

1. *Jurisdiction Risk.* The risk arising from doing business in certain countries or with counterparties from those countries. As an example, consider a forward foreign exchange transaction with a bank in country X, with whom your own country enters into a dispute. Transactions between the two

countries might be unexpectedly frozen (e.g., the United Kingdom and Argentina in 1982, the United States and Libya in 1986, transactions with Iraq in 1990, and so on).

2. *Transfer Risk.* A specific kind of jurisdiction risk, namely the risk that the country with whom you are dealing is unable to find sufficient foreign exchange to honor its obligations. Even though your counterparty is able and willing to pay, it may be prevented by the foreign exchange shortage. Examples include the Philippines in 1983 (which came to court in the United States—*Wells Fargo Asia Ltd. v. Citibank NA*, 936 F 2d 723) and numerous African and Latin American countries at various times.

3. *Pure Political Risks.* The risk that might arise when dealing, in our own country, with a domestic entity that for some political reason finds itself in difficulty. An example of this from the swaps market was the U.K. local authorities (municipalities) who were able to walk away from losing positions by claiming that they should never have been able to take them on in the first place because they were illegal (*ultra vires*). (This was, in part, legal risk.) In a similar case, Orange County, California, after its disastrous losses from interest-rate derivatives in 1994, sued Merrill Lynch to seek to get out of its obligations by claiming that it had been misled, despite the fact that its Treasurer had knowingly entered into the transactions involved and that its political supervisors had gratefully accepted the excess profits from previous years.

4. *Supranational Risk.* Related risk exists when dealing with a group of apparently highly respectable counterparts, governments. As a collective, they may walk away from obligations to which an individual government might have been induced to respond. The International Tin Council (ITC) was set up by 22 tin-producing and consuming governments (including Japan, Germany, and the United Kingdom). They signed the treaty that created the Tin Council and gave it their support: bankers doing business with the ITC were assured that it had the backing of these governments. In October 1985, the ITC defaulted on debts of £900 million. For a long time, it had been buying up tin in the market in an attempt to stabilize the price, but the selling pressure became too great.

Brokers who bought tin on the London Metal Exchange on behalf of the ITC were left with a metal that lost almost half its value. Banks lost money

as the value of ITC loan collateral fell. But when the governments were asked to step up to support the organization, the only reply was the sound of hands being washed. The creditors sued, and the British Court of Appeal held that the governments were not liable for the ITC's debts. The moral is that a government's verbal assurance isn't worth the paper it's written on, to adapt Sam Goldwyn's phrase—even if this assurance is given by Germany, Japan, or the United Kingdom.

In general, dealing with any political entity is fraught with inherent risk. The Biblical saying sums it up: "Put not thy trust in princes."

Control Risks

The next set of risks can be called control risks. Two main components are (1) systems risks and (2) fraud. *Systems risks* are best illustrated by the plight of the Bank of New York in 1985. The bank is one of the largest clearing banks for trading in U.S. Treasury bonds. In the process of installing a sophisticated new system, it failed to test the system adequately in advance. The result was that the system broke down during its early operations. The bank thus acquired the unfortunate distinction of having to arrange probably the largest single overnight borrowing facility in history: \$24 billion from the Federal Reserve. It goes without saying that such an occasion can be both expensive and embarrassing. The same occasion highlights the potential scale of risk arising from a foul-up in settlements. These are discussed in Chapter 22.

Fraud is always a possible risk for any dealing operation. However, standard procedures, if properly followed, will normally eliminate most possible fraud before it can become significant. Three classic types account for the majority of fraud experienced.

1. The dealer makes a loss and then hopes to "trade his way out of trouble." Further losses result, and the dealer now begins to conceal the size of the loss. Often the next step is to "double up" in the hope of retrieving the position quickly, and the losses run out of control. This pattern has been seen in disasters such as Lloyds Bank, Lugano; Fuji Bank, Singapore; Daiwa Bank, New York; and Barings, Singapore. It will be noticed that this type of problem often occurs in an operation that is some distance from head office. It is often easier for the dealer to cover up losses in a smaller branch.

2. The dealer conceals losses or inflates profits, operating in collusion with an outside party. This outside party verifies the prices indicated to the back office by the dealer to support the dealer's manipulation of the profits. Examples include the options fraud at ABN Amro in New York in 1991, which cost them \$70 million.

3. The dealer arranges with an outside party such as a broker that profitable trades are to be booked to his personal account and unprofitable trades to the account of his employer. Examples include the fraud at Volkswagen referred to earlier.

The proper operation of standard procedures would have prevented almost all of these frauds. Concealment of trades is usually achieved by arranging for the dealer to receive confirmation of the trades rather than an independent back office, hence the importance of ensuring that confirmations are handled only by the back office. Similarly, the manipulation of position revaluations, while perhaps more difficult to detect in markets such as OTC options, can be prevented by ensuring that the back office obtains prices from genuinely independent sources.

Thus at minimum, these key principles should be observed:

1. Confirmations should never be handled by the dealer.
2. Back office personnel should operate completely independent of the dealer and should get market prices from an independent source.
3. The back office should report via an independent reporting line to a senior manager in the organization, preferably at Board level.

MARKET RISK

Specific aspects of market risk will be discussed in detail in the next chapters, covering interest-rate risk and foreign exchange risk. As a general comment, however, it is worth saying that there are four basic components of market exposure: (1) the level of rates; (2) the shape of the yield curve (or in forward foreign exchange, the relative shape of two yield curves); (3) volatility exposure, for options; and (4) basis risk between different markets.

There are a number of different ways of approaching the estimation of market risk. The two key factors determining the approach selected are the

user's response to two questions: (1) Can we accept the assumption of normality—is it reasonable to assume that market movements follow the normal distribution? If so, statistical tools can be employed; if not, scenario techniques will be needed. (2) Does the value of the position change linearly with changes in market prices? If not (as is typical for options positions where market movements are not very small), simulation techniques will be desirable.

There are four possible combinations of answers:

1. If the answers to both questions 1 and 2 are yes, then it is possible to estimate risks by using standard measures of risk such as duration and convexity (see Chapter 20) and to estimate portfolio risk as a whole by using estimates of correlations of market rates and prices.
2. If the answer to both questions is no, then we are forced to use scenario analysis combined with simulation techniques.
3. If the answer to question 1 is no and to question 2 is yes, then we will probably want to use scenario analysis alone.
4. If the answer to question 1 is yes and to question 2 is no, then a combination of statistical tools and simulation techniques will be required.²

For a major international institution the portfolio will almost certainly behave in a nonlinear fashion, because a significant options involvement is likely. Very probably a combination of statistical tools and simulation techniques will be used. The scenarios used in simulations are often a mixture of observed rate and price changes from selected periods in the past and judgment calls by the practitioner. One possible approach is to select a historical period judged to reflect current markets; another is to project forward recent observed data.

A combined approach—sometimes referred to as “Structured Monte Carlo”—would be first to generate consistent sets of scenarios based on historical volatilities and correlations or on the implied volatilities and correlations observed from the options markets. The second step would be to generate scenarios of expected changes from these volatilities and correlations. The process is summarized in Figure 19.1.

²Borrowing *RiskMetrics* (JP Morgan, 1994) terminology, the first case would be Delta Valuation; the fourth would be Full Valuation with simulations.

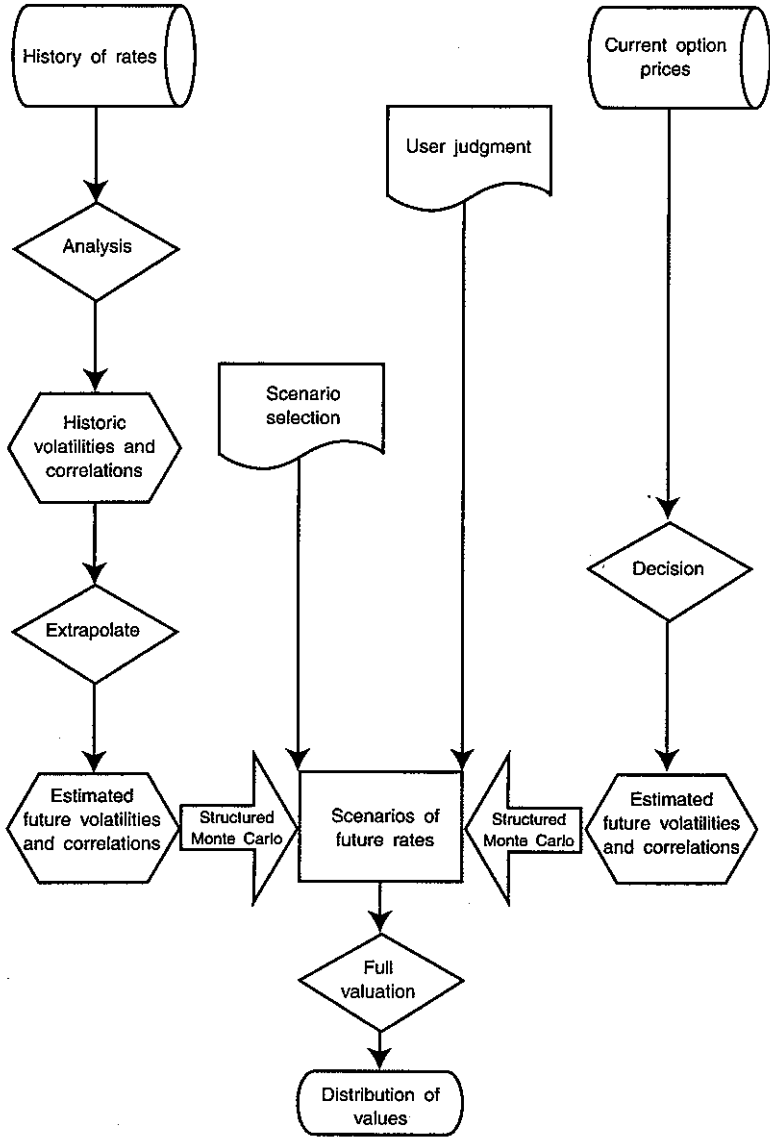


Figure 19.1 Structured Monte Carlo

Before discussing regulatory control of market risk, we need to outline recent developments in thinking about how to measure market risk. A major change in the market's way of looking at these risks took place with the introduction of *RiskMetrics* by JP Morgan in 1994. The significance of *RiskMetrics* was not so much the popularization of the value-at-risk (VAR) approach—many other banks had evolved equally sophisticated measurement methods—as the free availability to the market as a whole, for the first time, of a transparent methodology and data set.

One of the biggest weaknesses of VAR is that it requires a defined holding period. Of course, this is in some ways a strength because it requires us to focus on how long we expect to hold the position. But in illiquid markets it becomes a weakness because the length of the holding period becomes uncertain. This was vividly highlighted by LTCM in 1998. Despite this, the VAR framework has undoubtedly provided a good general framework for dialogue between the market and the regulators.

The basic RiskMetrics approach is to assume that changes in prices and yields of financial instruments are normally distributed. Given this assumption, volatility can be expressed in terms of the distribution of changes' standard deviation from the mean. The RiskMetrics approach has been to use 1.65 standard deviations as its measure of risk, which encompasses 95% of occurrences.

The RiskMetrics approach's assumptions imply two key consequences:

1. By setting a confidence level of 95%, we say that we are prepared to accept a 5% chance that the market will move beyond our parameters; that is, on 1 day in 20, the market will move more than we predicted.
2. We accept the risk that in reality the exchange rate moves in a nonnormal manner; as mentioned elsewhere, there is a good deal of evidence that many rates evidence "fat tails," implying that the number and the size of large changes is higher than that forecast by a normal distribution.

The question of whether normality is an appropriate assumption has been the subject of extremely extensive debate in academic and financial communities for some years. There is evidence that some financial series, notably exchange rates, are "leptokurtic"—they have fat tails. On the other hand, many would argue that there is not yet sufficient evidence to suggest that

this discrepancy is large enough to justify abandoning the assumption of normal distribution.

The RiskMetrics approach defines *market risk* firstly in terms of *absolute* market risk: the estimate of total loss expressed in currency terms (e.g., dollars at risk). Market risk can also be defined in terms of *relative* market risk; this concept, more relevant to the investment management community, measures the risk of underperformance against a benchmark index.

Secondly, RiskMetrics defines market risk in terms of time horizon. *Daily earnings at risk* (DEaR) is defined as the expected loss over a one-day horizon; VAR measures the potential loss over a longer horizon, such as one month.

The original version of RiskMetrics based its estimates of volatility and correlations on historical data. This was a methodological choice. The RiskMetrics approach therefore was to use exponentially weighted moving averages of historical rate movements. This ensured not only that the volatility estimates respond quickly to market shocks, but also that they gradually revert back to more normal levels. More recently, apparently, greater emphasis has been laid on historical simulations—doubtless reflecting lessons learned from the Asian crisis of 1997 and the Russian default of 1998.

RiskMetrics: Details

In this section, we discuss RiskMetrics in more technical detail. We also address some criticisms that have been made by other market participants.

There are two steps to the RiskMetrics process. First, all positions are marked to market (valuation), and, second, the future variability of the market value is estimated (simulation). Trading items are valued at their current market value as quoted in liquid secondary markets. To value transactions for which, in the absence of a liquid secondary market, no market value exists, the first step is to map them into equivalent positions, or to decompose them into parts for which secondary market prices exist. RiskMetrics treats the most basic part as being a single cash flow with a given maturity and credit rating of the obligor. This mapping into individual cash flows is a feature of RiskMetrics that is not always accepted by other market participants. Figure 19.2 summarizes the process.

This approach can handle most categories of instrument except those that

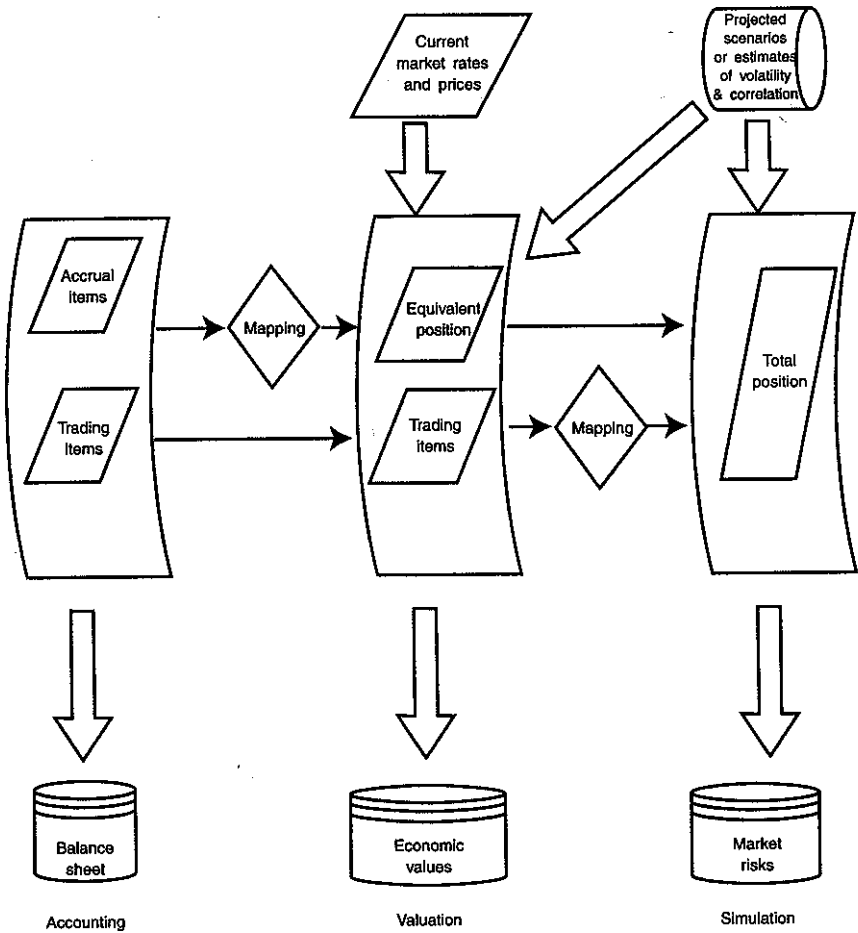


Figure 19.2 The VAR Process. *Source:* JP Morgan, RiskMetrics Technical Document, 3rd ed., p. 10.

do not have a liquid secondary market and that contain option components. For the valuation of items in those categories, an options-pricing model and expected volatilities and correlations are required, hence the diagonal arrow at the top of the diagram.

The core of RiskMetrics is (1) a method of mapping positions, forecasting volatilities, and correlations, and estimating risk; (2) a daily updated set of

estimated volatilities and correlations of rates and prices in most major financial markets.

Briefly, RiskMetrics assumes that returns on assets are normally distributed (where *return* is defined as the natural logarithm of the price today divided by the price yesterday). An *adverse move* is defined as a daily change in either direction (up or down) that is not expected to happen more than 10% of the time; that is, an adverse move is equivalent to 1.65 standard deviations, given the assumption of normal distribution of returns. It is expected that declines and rises larger than 1.65 standard deviations will occur 5% of the time.

As mentioned earlier, RiskMetrics defines two time horizons: (1) DEaR, which measures maximum estimated losses on a given position that can be expected to occur over a single day with 95% probability, and (2) VAR, which measures maximum estimated losses in market value of a given position that can be expected to be incurred until the position can be neutralized or reassessed.

Morgan argued that the 95/5% level is appropriate because: "RiskMetrics is a risk measurement tool designed for management use. In management it is important that you can observe and check your estimates frequently. The 5% cutoff implies that you should observe a loss greater than the estimated DEaR about every 20 business days. If you had chosen the 1% cutoff, you would have to wait on average 100 days for a confirmation that the estimate reflects reality. Regulators have a different perspective; they look to define capital levels necessary to support any losses that could happen."³

Use of VAR Models

Clearly, VAR has many benefits in comparison to other risk-management methods. However, there are a number of practical problems. A comparative study⁴ applied eight common VAR methodologies to three hypothetical portfolios. For the same portfolio, the calculated VAR ranged from a base level (as an index) of 100 to 1,400.

³RiskMetrics Technical Document, 3rd ed.; p. 28.

⁴T. S. Beder, "VAR: Seductive but Dangerous," *Financial Analysts Journal* (September-October 1995).

The types of calculation performed were:

No.	Simulation Type	Data Base/	
		Correlation Assumption	Holding Period
1	Historical	Previous 100 trading days	1 day
2	Historical	Previous 250 trading days	1 day
3	Monte Carlo	Historical, RiskMetrics correlations	1 day
4	Monte Carlo	Historical, Basle correlations	1 day
5	Historical	Previous 100 trading days	2 weeks
6	Historical	Previous 250 trading days	2 weeks
7	Monte Carlo	Historical, RiskMetrics correlations	2 weeks
8	Monte Carlo	Historical, Basle correlations	2 weeks

The three portfolios were (1) a long position in 2-year and 10-year U.S. Treasury strips; (2) a long position in the Standard & Poor's (S&P) 500 equity index contract plus long and short options on the same contract; (3) a combination of the first two portfolios. The results of the VAR calculations are shown in Table 19.1.

Thus for Portfolio 1, the VAR ranged from 0.20% of the portfolio to 2.87%—the highest measure of risk is 14 times the lowest. For Portfolio 2, the VAR ranged from 0.69% to 3.95%—a variation of rather more than fivefold. For the combined Portfolio 3, the range is from 0.48 to 3.41, or a sevenfold variation.

VAR and Optionality

VAR is, by definition, a single number that evaluates reported risk at a given confidence level. As such, it is not well adapted to handling situations in which options play an important part in the portfolio. In this case, resort must be had to other approaches. The most common approach is scenario analysis. This is discussed in the next section. There is, however, another

Table 19.1 VAR as Percentage of Portfolio

Portfolio 1	95% Confidence	99% Confidence
1	0.49	0.67
2	0.83	1.29
3	0.63	0.88
4	0.68	0.97
5	0.20	0.82
6	1.70	2.14
7	1.82	2.61
8	2.00	2.87

Portfolio 2	95% Confidence	99% Confidence
1	0.69	1.26
2	0.91	1.30
3	0.85	1.07
4	0.91	1.18
5	2.31	3.48
6	3.89	3.94
7	3.92	3.95
8	3.93	3.95

Portfolio 3	95% Confidence	99% Confidence
1	0.48	0.73
2	0.74	1.08
3	0.57	0.77
4	0.80	1.08
5	1.24	1.71
6	2.56	2.89
7	2.51	3.00
8	2.97	3.41

Source: T. S. Beder, "VAR: Seductive but Dangerous," *Financial Analysts Journal*, Sept.-Oct. 1995, pp. 14, 18, 21.

issue here: the adequacy of the models used to value the options under different scenarios.

It is both right and inevitable that different firms should use different option-pricing models. That is, after all, what makes a market work: differences of opinion about prices. However, it may be of interest to report

the results of an exercise carried out by the Bank of England.⁵ This was an exercise in which the Bank of England asked 40 banks and securities firms to price a variety of over-the-counter option and swap products. The survey divided the products into two groups: (1) those to be priced using market rates at 4 P.M. on the specified day (February 6, 1996) and (2) those to be priced using rates specified by the Bank of England. The results are shown in Table 19.2, which shows the standard deviation of the price and the delta of the instrument. (In other words, the prices and the deltas quoted by each firm in the sample were aggregated, and the standard deviation of the sample was calculated.) These have been standardized by quoting them as a percentage of the price (e.g., if the standard deviation of the price of the instrument were £600 and the price itself were £60,000, then the standard deviation as a percentage of the price is shown in the table as 1%).

The results of this survey make interesting reading. They highlight the consistency of pricing available in the foreign exchange market as against the bond market: bond options are by far the least consistently priced, followed by the collar pricing. This was not because the products were particularly exotic, but because there were differences in estimating the yield curve and its volatility. The Bank of England authors (Weston and Cooper) comment, delicately:

“Fewer respondents used a unified framework for valuing caps, floors, swaptions, and bond options than expected. Many used the cap model, which implies that forward interest rates are log-normal, while using bond option and swaption models that imply forward bond prices are log-normal. This was surprising, as this approach does not help manage the risks across these products.” (p. 27)

Stress Testing

For the reasons cited earlier, VAR models are by no means perfect risk management tools. Furthermore, as the Asian crisis in 1997 and the Russian default in 1998 illustrated, even a sophisticated VAR model will not necessarily cover extreme outcomes, and for this it is advisable to have a systematic program of stress testing of the risk portfolio. Obviously, for stress testing

⁵Reported in *Risk* (February 1996), pp. 23–27.

Table 19.2 Results of Bank of England Survey

Instrument	Price	Delta	Sample Size
American equity straddle	6%	14%	20
European equity straddle	6	27	20
Equity digital option	6	33	19
Equity quanto option (a)	9	7	5
Equity quanto option (b)	1	2	4
Equity quanto option (c)	2	4	12
American FX option	2	2	31
Interest-rate collar (a)	26	26	18
Interest-rate collar (b)	10	9	14
Interest-rate collar (c)	10	9	12
Interest-rate collar (d)	6	8	15
Swaption straddle	3	85*	32
Bond option	38	39	17
European FX option (a)	0	4	24
European FX option (b)	1	3	8
European FX option (c)	1	4	5
FX barrier option (a)	4	3	14
FX barrier option (b)	20	71	19
Asian FX option (a)	1	3	7
Asian FX option (b)	1	3	13
Asian FX option (c)	1	2	8
Asian FX option (d)	1	2	3
Forward starting swap (a)	4	3	34
Forward starting swap (b)	3	2	17
Swaption (a)	1	4	27
Swaption (b)	1	7	12

Equity quanto option (a) priced at the money with the strike and the spot rate of the S&P assumed to be 450; (b) priced at the money with the strike and the spot rate of the S&P assumed to be the current S&P level; (c) priced away from the money with the strike at 450 and the spot rate of the S&P assumed to be the current S&P level.

Interest-rate collar priced (a) as a single "collarlet" three months forward for a period of three months; (b) as a single "collarlet" six months forward for a period of three months; (c) as a single "collarlet" three months forward for a period of six months; (d) priced as a collar with two fixings each for a three-month period.

Table 19.2 (continued)

European FX option priced (a) as a dollar put using yield curve data provided by Bank of England; (b) as a dollar call using yield curve data provided by Bank of England; (c) as a dollar put using own yield curve data.

FX barrier option priced (a) as a down-and-out option, sterling call; (b) as an up-and-in option, sterling put.

Asian FX option priced (a) as a sterling call assuming flat volatility; (b) as a sterling put assuming flat volatility; (c) as a sterling call assuming term structure of volatility; (d) as a sterling put assuming term structure of volatility.

Forward starting swap priced (a) using own discount factors and yield curve given by Bank of England; (b) using discount factors and yield curve given by Bank of England.

Swaption priced (a) using own discount factors and yield curve given by Bank of England; (b) using discount factors and yield curve given by Bank of England.

*High figure caused partly by some banks quoting the delta as zero rather than attempting to quantify it.

Source: S. Weston and S. Cooper, "Bank Checks," *Risk* (February 1996), pp. 23-24.

to be effective, by definition, it must consider nonstandard situations. However, the U.S. Derivatives Policy Group "Framework for Voluntary Oversight" recommended certain minimum standards in respect of specified market movements, which may be of interest to those considering the design of appropriate stress tests. The parameters were chosen to be large moves relative to an overnight time horizon, as follows:

1. Parallel yield curve shifts of 100 basis points up and down.
2. Steepening and flattening of the yield curves (2s to 10s) by 25 basis points.
3. Each of the four permutations of a parallel yield curve shift of 100 basis points concurrent with a tilting of the yield curve (2s to 10s) by 25 basis points.
4. Increase and decrease in all three-month yield volatilities by 20% of prevailing levels.
5. Increase and decrease in equity index values by 10%.
6. Increase and decrease in equity index volatilities by 20% of prevailing levels.

7. Increase and decrease in the value of foreign currencies by 6% in the case of major currencies and by 20% in the case of other currencies.
8. Increase and decrease in foreign exchange rate volatilities by 20% of prevailing levels.
9. Increase and decrease in swap spreads by 20 basis points.

Clearly, the specific levels proposed could be argued. But in general, for an overnight move, these do seem to represent a fairly sensible starting point for a framework for routine stress testing. It remains the case, however, that for a stress test to have value, it must deal with the unexpected. Obviously by definition we cannot predict the next *unexpected* event—who would have predicted that an earthquake in Tokyo would bring down a British firm trading in Singapore? Who could have predicted that a default in Russia would require the Federal Reserve to organize a bailout of a hedge fund? But the nine parameters set out above could be considered as a starting point for stress testing.

CORRELATION RISK

One of the merits argued for VAR is that it takes explicit account of “risk diversification”—the VAR of a widely spread portfolio will typically be less than that of positions of comparable size focused into one market. At the same time, the degree of diversification depends critically on the degree of or lack of correlation between markets. There is, therefore, a correlation risk implicit in this approach.

But during major market events, such as the Russian default in 1998, correlation changes sharply. Table 19.3 illustrates the extent to which earlier correlations drawn from normal experience became unreliable in a crisis.

Also, many products currently traded mean that the trader incurs correlation risk—examples included so-called diff swaps and quanto equity options. Because these products involve a principal amount that varies in line with one of the risk factors, the two risks cannot simply be split out (as the interest risk could be stripped out of a forward FX position, for example). Instead, a firm’s trading desks need to coordinate their activities by setting up formal links between trading units and between trading units and global risk managers. This level of coordination has not been needed for traditional instruments. Also, large banks’ books can include thousands of individual trading

Table 19.3 Correlation Breakdown

Relationship	Historical Correlation	Correlation during Crisis	Crisis Event	Crisis Date
Peso/\$ vs 1-mo CETES	0.30	0.80	Mexico	12/94
GBP/\$ vs 1-mo. GBP LIBOR	-0.10	0.75	ERM	9/92
GBP/DEM vs 1-mo. GBP LIBOR	-0.10	0.60	ERM	9/92
Junk bonds vs U.S. equities	0.20	0.80	'87 crash	10/87
U.S. equities vs U.S. 10-yr bonds	-0.10	0.65	'87 crash	10/87
JGB 10-yrs vs U.S. 10-yr bonds	0.20	0.80	Iraq/Kuwait	8/90
Oil vs U.S. 10-yr bonds	0.20	0.75	Iraq/Kuwait	8/90

Source: R. Bookstaber, "Global Risk Management: Are We Missing the Point?" *Journal of Portfolio Management* (Spring 1997).

positions across multiple trading desks in several countries. To arrive at a firmwide estimate of risk, most of these banks rely on summary statistics of each trading position. They then add up these summary statistics to arrive at the risk of the entire firm. Because traditional measures of risk do not properly reflect the risk of a portfolio that contains correlation products, these summary statistics can mislead decisions at the corporate level.

Also, correlation risk is greater in the illiquid currencies of emerging markets, where large changes in interest rates and exchange rates can occur overnight. More important for correlation products, such changes can happen simultaneously, for example, in 1994, the Mexican peso/U.S. dollar exchange rate, the Mexican equity markets, and Mexican interest rates changed dramatically and all at once.

Also, if we have a position in a correlation product, we must find a counterparty who is willing to take on the exact exposure of the original contract; otherwise, we may have to hedge the exposure dynamically. Therefore, if liquidity for correlation products dries up, we may be forced into dynamically hedging exposures that we would like to eliminate but cannot.

To address these potential problems, the first step is to identify the presence of correlation risks in a portfolio. Two approaches might be taken:

1. Each variable to which a portfolio is exposed may be “shocked” individually. Then we can compare the sum of these changes in market value with the changes when the variables are shocked simultaneously. If the change in value from the simultaneous shock differs from the sum of the individual shocks, the portfolio has correlation risks.

2. Ex post profits and losses and model-predicted profits and losses may be reconciled. A risk manager could look into the cause of profits or losses in excess of predictions by analyzing discrepancies between model prices and market prices. Such excess returns could arise if correlation risk is being measured by traditional risk management tools.

Once these risks are identified, the second step is for the risk manager to use a simulations-based approach to measure price risk. Because this process is so involved, a simulations-based approach seems sensible only for firms that do a lot of business in correlation products. Such firms will probably find it useful to develop multiple simulation methods to make sure that their risk estimates are robust to alternative specifications.

Regulation of Market Risk

The authorities have been actively involved in supervision of market risks by financial institutions for many years, but the original Basle Committee Rules of 1988 covered only credit risk. They were extended in 1995 to cover market risk. Briefly, the committee proposed two methods of measuring market risk: (1) the “standardized” approach, using an elaborate matrix of specific percentages, and (2) the “internal-model” approach. The latter is permitted only if banks meet certain qualitative criteria. Provided these are met, banks may calculate the VAR using their own internal models: the calculation must use a 99%, one-tail confidence interval, a 10-day holding period, and a historical observation period of at least one year. The capital requirement is defined as the higher of: (1) the previous day’s VAR measured as just specified, or (2) an average of the daily VAR measures on each of the preceding 60 business days multiplied by a multiplication factor.

The multiplication factor will be set by individual supervisors on the basis of their assessment of the quality of the bank’s risk management system, subject to an absolute minimum of 3. The committee agreed that banks should

be required to add to this multiplication factor a “plus” directly related to the ex post performance of the model (e.g., it could be derived from the outcome of “back-testing”).

Work is under way at the time of writing to reconsider the whole Basle framework; but the subject is highly controversial, and it is uncertain how long the revision process will take.

Netting

As mentioned earlier, one method of reducing credit risk on market counterparties is to net off gross exposures down to smaller net figures. It is clear that the effectiveness of this process depends critically on the legal soundness of the documentation involved. Also, there are a numbers of ways in which netting can be implemented, the discussion of which follows. We can divide into two broad categories: (1) bilateral netting in its various forms and (2) multilateral netting.

Bilateral netting is netting which takes place between the same counterparties. If counterparty A buys 1,000 shares of XYZ from counterparty B, and then sells 950 shares to B, the “net” result would be that counterparty B would have to deliver 50 shares of XYZ to A, against the net cash amount due. This type of bilateral netting is widely used, particularly in over-the-counter markets such as foreign exchange or swaps. Bilateral netting can take the form of payment netting, close-out netting, or netting by novation.

Payment Netting

Payment netting (also sometimes known as “obligation netting”) is the combination of all trades (or, in money transfer systems, money movements) between two counterparties on a given date, with a single net payment worked out in each currency (see Figure 19.3). This process is sometimes referred to as “bilateral payment netting” because it takes place between two counterparties. For example, if a bank does 25 trades in dollar/yen with the same counterparty all of which settle on the same day, it makes only one netted payment instead of 25. The net payments are worked out at some pre-agreed time, typically the day before value date (although it is possible to agree net payments on the value date, depending on the currency and time zone).

The bank and the counterparty continue to confirm all deals on a daily

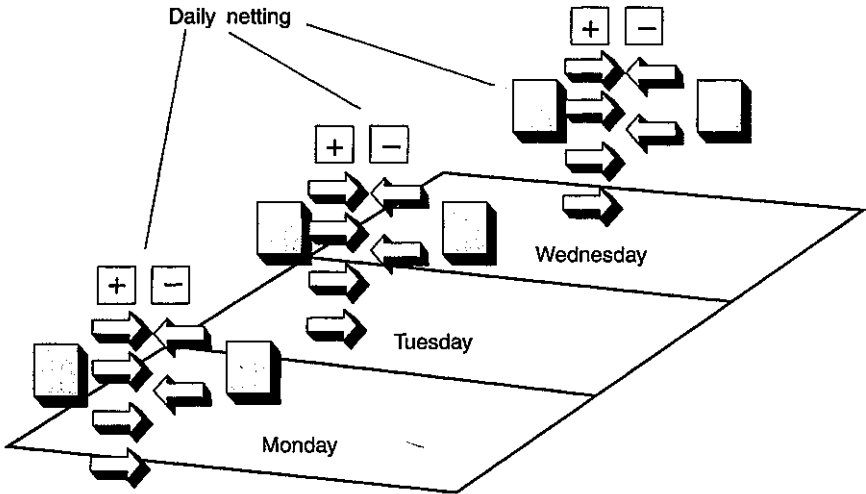


Figure 19.3 Payment Netting

basis either directly or through a system that helps support bilateral payment netting. The operational process of payment netting may be supported either by an informal agreement or, preferably, by a legal agreement. The agreement may be a simple one-page agreement that only supports payment netting, or it may be included in a master agreement (see chapter end) that incorporates close-out netting of any unsettled contracts at the time of default.

Close-Out Netting

In contrast to payment netting, *close-out netting* requires counterparties:

1. To settle all obligations that have been contracted but are not yet due.
2. To settle on a net basis.
3. To settle as soon as a close-out event occurs (e.g., one of the parties goes bankrupt).

However, as illustrated in Figure 19.4, if a close-out event does not occur, the trades are settled normally, that is, gross (unless there is a separate payment netting agreement). So close-out netting does not, in itself, imply payment netting.

One difference between close-out netting and payment netting is that close-out netting operates across all currencies that have been used in transactions

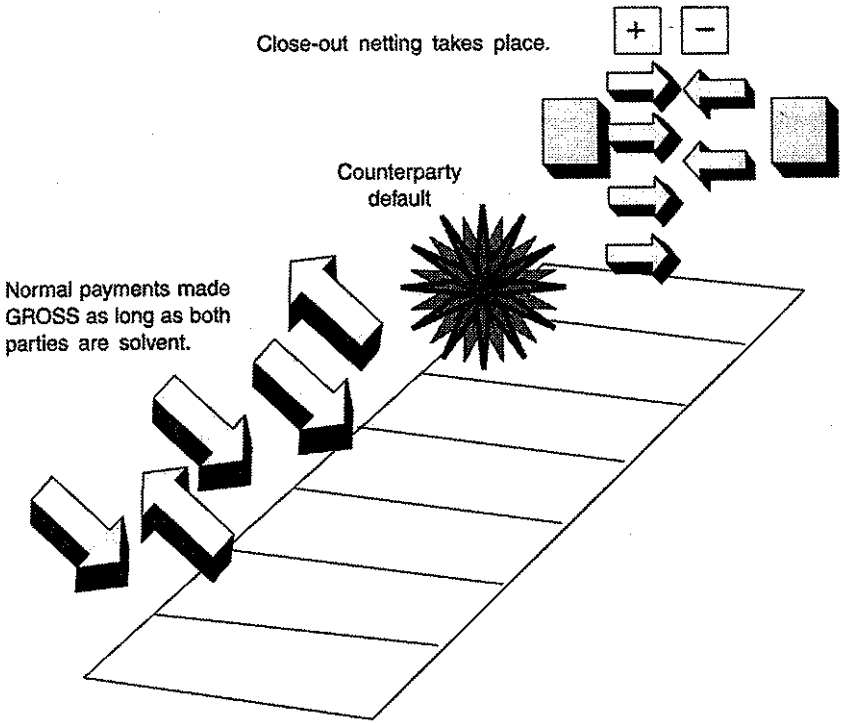


Figure 19.4 Close-Out Netting

between the two parties. A second difference between them is that payment netting does not net the obligations to pay. It simply nets the cash movement. Hence payment netting does not reduce the legal gross obligation to a net figure. Close-out netting does so—provided it is correctly documented.

Regulators recognize properly documented close-out netting as giving enough protection for banks to be allowed to report their counterparty exposures on a net basis for capital adequacy requirements. Two common documents for this purpose are the International Foreign Exchange Master Agreement (IFEMA) and International Swaps and Derivatives Association (ISDA) documents (discussed at the end of this chapter).

Novation Netting

Novation netting occurs immediately when two parties enter into a nettable transaction. In contrast, payment netting occurs just prior to settlement. On

value date, no difference exists between the payment amounts that would be calculated under novation netting and those that would be calculated under payment netting.

“Netting by novation” agreements provide for individual forward contracts to disappear when they are confirmed. They are replaced by new obligations forming part of a single agreement. Amounts due under a new contract will be added to running balances due between the two parties in each currency at each future value date. This reduces the size of the payments to be made on each value date; and it reduces their number to one per currency traded. In some markets, banks may be able to achieve a reduction of more than 50% in local payments in all currencies, in terms of both value and volume.

By merging all of the transactions into a single agreement, covering the running accounts, the credit exposure on the counterparty can be reduced to a single net amount. The process is illustrated in Figure 19.5.

This single net amount can be stated as the discounted present value of the sum of mutual future payments. It can also be stated as the discounted present value of the net unrealized gains and losses on all of the obligations included in the netting contract.

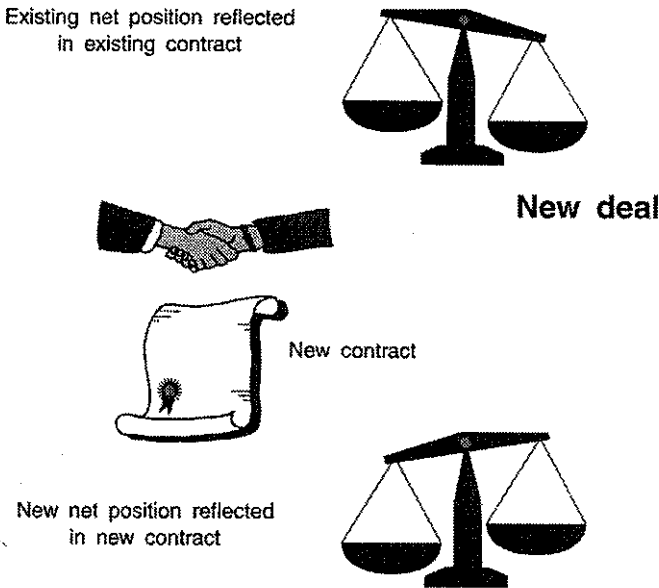


Figure 19.5 Netting by Novation

In jurisdictions where it is legally enforceable, novation netting removes any chance of “cherry-picking” in a bankruptcy because all of the remaining net payment obligations constitute a single contract. (“Cherry-picking” occurs when the liquidator of a bankrupt company selects only the profitable transactions for performance and defaults on the unprofitable transactions, forcing the nondefaulting party to pay in gross.)

The 1988 Capital Accord of the BIS permitted recognition of the benefits of netting by novation of foreign exchange contracts having a term of more than 14 days and governed by a master agreement. The July 1994 amendment to the Capital Accord permitted banks that met all of the criteria contained in the Capital Accord, and any additional conditions required by their local supervisors, to recognize the benefits of close-out netting for capital reporting purposes. Another advantage of close-out netting arises because, like payment netting, novation netting only affects payments in the same currency due on the same date. By contrast, close-out netting operates across all currencies. Accordingly, where close-out netting is enforceable and cherry-picking is no longer a risk, netting by novation is less important as a means of netting presettlement exposures.

Master agreements (see chapter end) work in a similar way to novation, except that the individual transactions are not blended into running accounts but retain their specific terms so that they can be assigned or terminated individually. Master agreements can provide for netting on certain value dates and usually provide for netting on certain events of default (close-out netting—discussed earlier).

Netting+

In foreign exchange markets, some banks advocate the use of tom-next swaps (see Chapter 12) to reduce bilateral settlement exposure. This mechanism has been given the name “Netting+.” On the day before value date, counterparties enter into a set of tom/next swaps to offset each bilaterally netting non-U.S. dollar cash flow due on value date. This cuts out delivery of any non-U.S. dollar amounts. The net amount to be settled will be a single net U.S. dollar amount equal to the net profit or loss on all transactions being settled via Netting+. By doing a swap from tomorrow to the spot date, the market positions created by the “tom” sides of the individual currencies’ swaps are offset. Payment obligations arising from the “next” part of the swaps will be aggregated and netted against any other payment obligations arising for the same value date and will in turn be offset by another set of

tom/next swaps. Netting+ excludes regularly traded “tom” deals because these are usually done for funding purposes and thus require delivery.

Let us look at an example: At cutoff time on December 1, two Netting+ counterparties determine that on December 2, Party A owes DEM 500 to Party B, and Party B owes US\$ 322 to Party A. Under Netting+, they will do a tom/next swap: Party A buys DEM 500 from Party B for U.S. dollars for value December 2, and sells DEM 500 to Party B for U.S. dollars for value December 3 at current market rates. The deutschemark cash flows for December 2 are netted down to zero (no mark delivery), and the residual U.S. dollar cash flow remains to be paid by one party to the other. (If for example, the December 2 leg of the tom/next swap was done at 1.5625 (i.e., for US\$ 3,201), Party B will pay 2 to Party A.)

Payments related to the “next” part of the tom/next swap are combined with all other cash flows due December 3. These combined cash flows will in turn be offset by a new set of tom/next swaps, and so on. Before they enter into tom/next swaps for Netting+ purposes, the counterparties must agree on:

- A source and time for setting the rates to be used.
- A cutoff time for calculating the amounts to be swapped.
- The currencies to be settled via Netting+. (Currencies that are infrequently traded are not appropriate for the Netting+ settlement mechanism.)

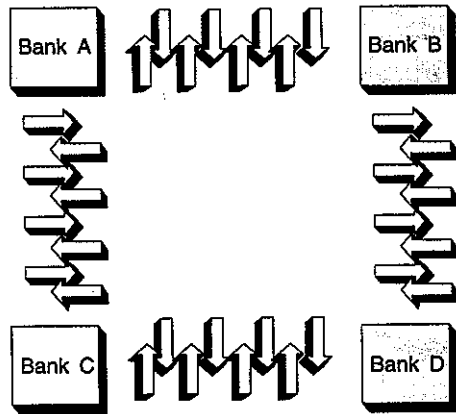
The details of a Netting+ arrangement may be documented as an amendment to a master agreement or may be agreed by an operational letter agreement. Because the size of a Netting+ swap can grow over time, it may also be a good idea to agree to a maximum limit, which if reached will cause the parties to close out all, or a portion of, the swap. Netting+ is an attractive way to cut out settlement risk because it needs no capital investment, collateral, counterparty substitution, third-party agent, or membership criteria. It may be done manually or in an automated system.

Multilateral Settlement Netting

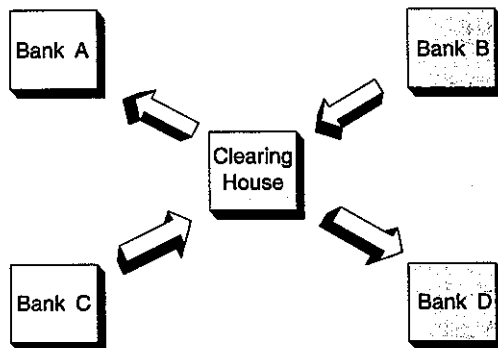
Multilateral netting systems work by adding up each member’s bilateral net positions with each of the other members. This produces a single multilateral “net-net” position. Usually, the netting is conducted through a central entity, which is legally substituted for the original counterparty to each trade. If

so, the net-net position will in fact be a bilateral net position between each member and the central counterparty (see Figure 19.6).

Using bilateral netting, whereby we agree with each counterparty to net down each currency's transactions to a single payment, the final payment can be netted down to a single figure for each of the n currencies involved. So for each counterparty, we make/receive n payments. If we have N counterparties, then the total payments involved are $N \times n$. On the other hand, if we were using a multilateral system, with only one central counterparty, then the total number would only be n .



Multiple gross payments between banks . . .



are reduced to single net transfers to/from the clearing house

Figure 19.6 Multilateral Netting

Suppose instead of bilaterally netting by currency we agree with each counterparty to net all currencies down to a single net amount. In that case we have only one payment per counterparty. Then our total number of payments is N . In this case, whether bilateral netting is more efficient than multilateral depends on whether N is greater than n or n is greater than N .

Here is an example: Suppose Bank A has to settle the following deals on a particular day:

Pay US\$ 1,650,000, receive £1,000,000 from Bank B.

Pay ¥149,000, receive US\$ 1,000,000 from Bank C.

Then it would have to pay away one U.S. dollar amount for the first contract and receive U.S. dollars for the second contract. If all three banks were members of a multilateral clearinghouse, then both of Bank A's contracts would be with the clearinghouse. Bank A's payment flows would change from gross flows to net flows as follows:

Pay US\$ 65,000 to the clearinghouse.

Pay ¥149,000 to the clearinghouse.

Receive £1,000,000 from the clearinghouse.

Applying this approach to deals done with a large number of a bank's major counterparties produces a large reduction in payment flows. For example, a bank doing 300 deals a day, involving 24 currencies, would have to make 300 payments and receive 300 payments if they are not netted at all. If all the counterparties were members of the clearinghouse, then the bank would make or receive a maximum of only 24 items in total—one for each currency involved. Payments traffic—and risks and costs—would be reduced by 96%.

Some banks are members of multilateral payment netting systems such as CHIPS (Clearing House Interbank Payment System). These usually provide for the netting of payments in a single currency. If a member cannot settle its net debit position, the resulting shortfall is shared between the system members. In these payment netting systems, members are exposed to settlement risks with respect to payment orders sent to them by other members. Suppose a system member defaults on its settlement obligations, and suppose this exposure is to be allocated among the surviving members on the basis of their bilateral positions with the failed firm. Then surviving members' share

of the payment orders sent by the failed firm would represent the remaining members' exposure. It is the sending of payment orders by others that creates the exposure under the loss-sharing arrangement. Hence it is this activity that other members need to be able to limit.

Because banks cannot directly control the payment-sending activities of other banks, the normal approach is for them to set bilateral limits on the number of messages they will accept at any one time from each other system member. Then the system as a whole has a loss-sharing formula, which allocates losses among system members according to the size of their bilateral limits with the failed party.

Although multilateral netting systems clearly reduce overall exposure, they may not reduce the exposure of an individual member, but increase it. This could happen if a member, with whom we have not traded, defaults. If the rules of the multilateral netting system provide for loss-sharing among the members, we would find we had a loss even though we had not traded with the bank concerned. Clearly, a good deal depends on the precise loss-sharing arrangements of the system concerned.

Legal Documentation for Settlement Netting

Master Agreements. To make effective bilateral netting agreements, proper documentation is needed. A typical approach is to sign a master agreement with each counterparty. The master agreement should clearly define:

- The terms under which netting occurs.
- The method of calculating exposure.
- The process by which the agreement will take effect.

When a counterparty defaults, it may demand payment on all contracts that are profitable to it and refuse to pay on those that are unprofitable (sometimes called cherry-picking). If this happens, the nondefaulting party may be left with a larger than expected loss. A master agreement makes sure that the counterparty remains responsible for all existing contracts and not just those it chooses to accept.

Market Standards. Several documents have been developed that act as market standards. They have provisions that should satisfy relevant accounting and regulatory standards, provided there is a legal opinion that the agreements are legally enforceable in the relevant jurisdictions. These are:

- ISDA Master Agreement (1987 or 1992 version).
- IFEMA Agreement covering spot and forward currency transactions.
- International Currency Options Market (ICOM) Agreement covering currency options.
- Foreign Exchange and Options Master Agreement (FEOMA) for foreign exchange and options.

The ISDA Agreement has the advantage that it covers a range of instruments, but it also has the corresponding disadvantage that it is more complex. The IFEMA and ICOM agreements have the advantage of being relatively simpler but the disadvantage that they are designed purely for foreign exchange.

20 Money Market Risk and Interest-Rate Risk

Money market risk is fundamental to the operations of a bank. It consists of two parts: (1) funding risk and (2) interest risk. *Funding risk*, or liquidity risk, arises from the danger of lending long and borrowing short. *Interest risk* arises from the effect on profit or loss of changes in interest rates.

LIQUIDITY

In setting up liquidity policy, a bank—or any firm—first needs to think of the times when it might need cash and of its reliance on marketable assets and liquid claims on others. It will have to look at the safety of the assets if there is a general market crisis. Second, it has to make sure it can finance any immediate or expected need for cash.

As far as protection against crisis, banks' usual policy is to buy government securities or prime certificates of deposit (CDs) of first-class banks to provide a cushion of assets that are readily marketable. These assets can then be sold for cash if the bank has an urgent need for them. This assumes that these are institutions whose credit standing will be untouched in a crisis. Therefore, the bank will be able to sell the assets without incurring a great loss. This is, of course, only an assumption; but it is the only practical one that can be made. If Armageddon comes, there will be little that even the most farsighted treasurer could do to protect his or her bank.

The second line of defense will be standby arrangements made between banks. If one of the parties to the standby arrangement falls into difficulties,

the counterparty will provide funds to help. The third line of defense is the "lender of last resort": the central bank of the country in which the headquarters of the bank are located. The Basle Concordat of 1975 among the major central banks of the world began to lay the foundations for supervision of international banking operations. At the same time, there was to some extent an implicit acceptance of a lender-of-last-resort function for international banks' operations. However, the Banco Ambrosiano affair in 1985, when Italy and Luxembourg disagreed, and the Bank of Credit Commerce International (BCCI) affair in 1991 showed that there are limits to certain central banks' willingness or ability to interpret the Concordat in a broad way.

Liquidity, or funding, risk is caused by a mismatch in final maturity dates. A lending with a final maturity date of one year, funded by a one-month deposit, causes a liquidity risk for the remaining eleven months. The bank cannot be certain of laying its hands on the money for the next eleven months. In an extreme case, if a bank becomes so illiquid that it cannot fund itself from day to day, it must close down.

Funding risk and interest risk are closely connected, but quite distinct (Figure 20.1). Suppose a lending has a maturity of one year, but it is based on a three-month roll-over. If it is funded by a three-month deposit, the funding risk remains for the last nine months. The interest rate risk is nil for the current three months. And it is cut out in future each time the bank funds the three-month rollover with a three-month deposit. But if the three-month rollover lending is financed by a six-month deposit, there is not only a liquidity risk but also an interest risk. The interest rate that the bank might earn for the last three months before the next rollover date is uncertain (because the rate will only be set at maturity of the first three-month lending). These two different risks can only be measured on separate ladders because the same item can put the bank at risk in two different periods. A five-year loan funded by a three-month borrowing would cause a five-year funding risk, but the interest risk will be covered every three months. If rollover business is an important part of a bank's total book, it may need a separate interest-rate ladder.

Problems can arise even when the bank's book is totally matched. Suppose a trader borrows one-year funds at, say, 8% in the expectation that rates will rise, but instead rates fall sharply soon after the borrowing. The trader decides to minimize further loss by covering the position at 6%. As far as liquidity and interest mismatch are concerned, the trader is exactly matched; but there is a built-in loss in his or her position that needs to be detected.

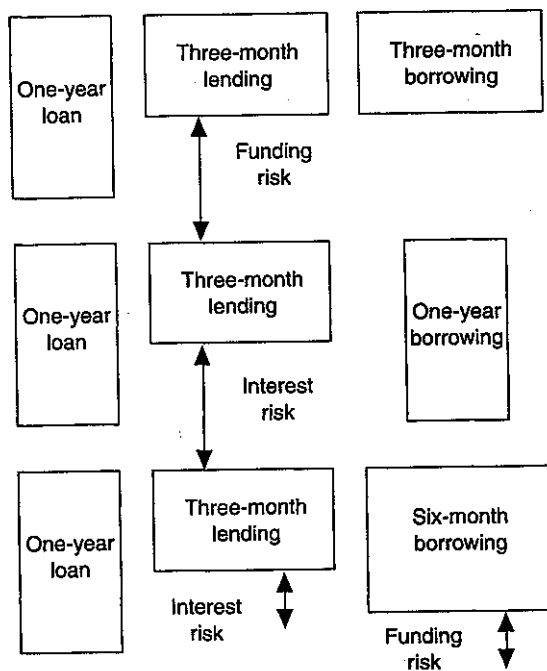


Figure 20.1 Interest versus Funding Risk

MONEY MARKET MATURITY LADDER

A deposit maturity mismatch ladder will normally be essential. The methods used will depend on the business of the bank. An example might be as follows: Separate ladders are made up for local currency liabilities and assets and for foreign currency liabilities and assets by each currency. Maturities are split into time bands on the basis of time left to maturity (not the original life of the deal, nor the next rollover date). The time band used is (1) the first date at which call or notice deposits can be required to be repaid; (2) the due dates of bills of exchange, promissory notes, or CDs; (3) the last repayment date of a government stock or similar security; (4) the agreed repayment dates for time deposits; or (5) the agreed repayment date for each installment of a medium-term loan. Table 20.1 shows what the effect of this might be.

We see that call assets in local currency exceed liabilities. The opposite situation occurs in the foreign currency book. So the net final mismatch is negative at 4,733 in accounting currency terms. In both local and foreign

Table 20.1 Deposit Mismatch Ladder

Period	Local Currency Mismatch			Foreign Currency Mismatch			Final Mismatch			
	Liabilities (1)	Assets (2)	-P (3)	-C (4)	Liabilities (5)	Assets (6)	-P (7)	-C (8)	-P (9)	-C (10)
Call and Savings	(2,322)	6,460	4,138		(8,982)	111	(8,871)	(9,624)	(4,733)	(5,531)
One-seven days	(4,045)	4,000	(45)	4,093	(6,998)	6,245	(753)		(798)	
Eight days-one month	(14,743)	14,762	19	4,112	(3,159)	9,217	6,058	(3,566)	6,077	546
One-two months	—	220	220	4,332	—	4,590	4,590	1,024	4,810	5,356
Two-three months	—	3,093	3,093	7,425	—	8,444	8,444	9,468	11,537	16,893
Three-six months	(22,281)	20,328	(1,953)	5,472	(36,314)	18,648	(17,666)	(8,198)	(19,619)	(2,726)
Six-nine months	(4,713)	2,439	(2,274)	3,198	(7,498)	1,799	(5,699)	(13,897)	(7,973)	(10,699)
Nine-twelve months	(2,345)	3,440	1,095	4,293	(6,119)	4,892	(1,227)	(15,124)	(132)	(10,831)
Overdraft ^a	—	24	24	4,317	—	1,725	1,725	(13,399)	1,749	(9,082)
One-two years	(5,005)	7,395	2,390	6,707	(3,847)	5,621	1,774	(11,625)	4,164	(4,918)
Two-three years	(654)	1,240	586	7,293	(320)	488	168	(11,457)	754	(4,164)
Three-four years	(3,760)	6,064	2,304	9,597	(92)	2,120	2,028	(9,429)	4,332	168
Four-five years	(698)	8,369	7,670	17,267	—	—	—	(9,429)	7,670	7,838
Longer	—	7,975	7,975	25,242	—	—	—	(9,429)	7,975	15,813
Capital and infrastructure	(20,316)	4,503	(15,813)	9,429	—	—	—	(9,429)	(15,813)	nil
Totals	(80,882)	90,311	9,429	—	(73,329)	63,900	(9,429)	—	nil	nil

Note: P = this period, C = cumulative.

^aTreated as 12-month loans.

currency, this mismatch is slightly increased by a net borrowing in the one-to-seven-day period, whereas in the eight-day-to-one-month period, the position is dominated by a large overlent position in the foreign currency book. This brings the cumulative final mismatch to an overlent position. This runs up to the three-to-six-month period, and from there on, the bank is overborrowed up to the three-year period.

The maturity mismatch ladder will need to be supplemented by various items of other information. For example, the treatment of overdrafts (if any) will be influenced by the extent to which some of them are "hard core," that is, being used as a permanent borrowing. In setting up Table 20.1, we assumed that, in practice, overdrafts are not repayable on demand, but they need to be treated as 12-month assets. Hardcore overdrafts ought properly to be treated as even longer-period assets. It is also important to include information on other commitments. If we do, we can see the bank's exposure if customers were to use all existing facilities in a crisis. Undrawn money market lines or overdraft facilities can cause large potential extra exposure. Contingent liabilities under standby arrangements, documentary credits, or acceptances also need to be measured.

Also we cannot judge the bank's overall position without knowing what mismatch the local central bank will accept. And we need to know from the ordinary interest income and expense-accounting procedure whether the book is currently profitable and how vulnerable the book is to sudden shifts in interest rates—the interest-rate risk.

INTEREST MISMATCH LADDER

For this purpose, an interest-rate mismatch ladder will be needed. This classifies balances by the time for which the interest rate is fixed, rather than by their final maturity. So a loan repayable after five years and rolled over at a six-month rate would be shown in a five-year band in the deposit maturity mismatch ladder and in the six-month band in the interest mismatch ladder. Table 20.2 shows an interest mismatch ladder in its simplest form.

Table 20.2 shows where the bank is most at risk from sudden interest-rate movements. In this case, for example, the bank is overlent in the Euromarket in all periods beyond three months. As a result, a sudden rise in certain interest rates would make much of the longer-term book unprofitable until the fixed-rate assets had run off.

Table 20.2 Interest Mismatch Ladder

Interest-Rate Period	Euro		Local Currency		Net
	Liabilities	Assets	Liabilities	Assets	
Noninterest bearing	1,100	—	22,795	12,171	-11,724
At variable rates (notice up to seven days)	4,255	300	2,000	24	-5,931
Fixed rates up to three months	19,846	13,421	22,958	20,688	-8,695
Three–twelve months	31,422	35,347	31,174	36,775	+9,526
One–two years	6,111	8,481	6,455	7,227	+3,142
Two–three years	3,980	5,054	640	1,625	+2,059
Three–four years	377	1,905	3,680	4,049	+1,897
Four–five years	849	1,150	680	2,520	+2,141
Five years plus	79	148	—	6,232	+6,301
	68,019	65,806	90,382	91,311	-1,284

A more-refined interest-rate mismatch ladder would take into account the interest rates at which the deals were originally done. We can find the weighted averages for outstanding contracts on the ladders for placings (assets) and raisings (liabilities) by time blocks. We will take into account the amount, the number of days from report date to maturity date, and the rate. For example, suppose the placings maturing in a given one-month time block on a ladder at report date were US\$ 2 million maturing in 5 days at 12%, US\$ 3 million maturing in 10 days at 11½%, and US\$ 5 million maturing in 28 days at 11%. Then the weighted average for the placings in that time block could be calculated as shown in Table 20.3. We can see from this

Table 20.3 Weighted Average Rate per Block

Contract	Amount	Days	Product 1	Rate	Product
1	2	× 5	= 10	× 12	= 120
2	3	× 10	= 30	× 11.5	= 345
3	5	× 28	= 140	× 11	= 1,540
			180		2,005

Note: Weighted average rate for time block is 2,005/180, or 11.14%.

example that the effect of the US\$ 5 million deal at the lower rate of 11% has tended to pull down the weighted average rate for the time block.

An example of this technique can be seen in Table 20.4. This is a simplified balance sheet of a domestic money market dealing room. Short-term operations are broken down into overnight, call and notice, one-week, and one-month. Thereafter monthly time blocks are used up to the one-year period, after which the division is into years. We can see that the overnight operations are running at a profit, but the call and notice and one-week periods are both generating a loss. Apart from these, though, and the seven-month, ten-month, and three-year operations, all the other time blocks are showing a profit. Notice that the row labeled "Cumulative mismatch" is cumulated from the furthest date and not the nearest date on the ladder. The reason for this is to prevent long-term problems from being hidden by short-term cosmetics. Suppose the bank were heavily overlent in the longer periods, such as the two-, three-, or four-year, but were very much overborrowed in the shorter periods. Cumulating from the near end to the far end might give the idea that the bank is overfunded for most of the earlier part of its book and that the overlending in the far periods was adequately financed. It is simply a matter of presentation, and cumulating in another way may be better in other circumstances.

MORE SOPHISTICATED TECHNIQUES

Looking at this position becomes more complex when we consider derivatives. We need to add in the exposure that might arise from futures, options, and swaps. Conceptually, swaps are identical to a purchase or a sale of a fixed-rate asset coupled with a sale or a purchase of a floating-rate asset (putting that another way, a fixed-rate lending funded by a floating-rate borrowing, or vice versa). Swaps raise no new issues of principle in reporting terms once they are properly identified.

Futures positions likewise are fairly straightforward: the crucial point is to ensure that positions are properly reported to include not only the margin amounts but also the underlying exposures. Once this is done, the underlying exposure is again conceptually identical to a position in the underlying asset for the total underlying amount and can be treated accordingly. (Some complications arise from the question of basis risk and, for deliverable instruments, the question of properly identifying the cheapest to deliver: but broadly speaking, the risk is fairly clearcut.)

Table 20.4 Domestic Money Position

	Over- night	Call and Notice	One Week	One Month	Two Months	Three Months	Four Months	Five Months	Six Months
<i>Raisings</i>									
Banks	87	31	66	222	102	37	6	8	24
Commercials	15	130	39	31	53	21	16	3	4
CDs	—	—	5	28	35	24	12	15	29
Branches and subsidiaries	18	16	17	28	36	7	3	2	4
Subtotal	120	177	127	309	226	89	37	28	61
Average cost	11.63	11.60	12.07	12.21	12.49	12.56	12.50	12.66	12.64
<i>Lendings</i>									
Reserves	110	—	—	—	—	—	—	—	—
CDs	—	—	—	—	17	18	14	6	11
Banks	34	4	40	51	51	55	86	26	26
Commercials	10	—	74	41	41	38	5	—	—
Branches and subsidiaries	4	—	16	57	57	11	7	5	16
Other lendings	—	—	10	—	—	9	—	—	—
Subtotal	158	4	140	149	166	131	112	37	53
Average yield	11.87	11.40	11.85	12.67	12.99	12.59	13.42	13.12	14.19
Period mismatch	38	-173	13	-160	-60	42	75	9	-8
Cumulative mismatch	24	-14	159	146	306	366	324	249	240

Options raise other issues. Up to now, revaluing our positions was fairly simple: we took an assumed level of interest rates, applied them to the book, and reached a figure for profit and loss. We can do this also, of course, for the options positions. But that does not capture all the dimensions of risk. There are at least three dimensions to options risk: (1) market movements, (2) changes in volatility, and (3) time. Changes in each of these variables can impact our profit and loss. People seek to handle this extra complexity in different ways, but probably the most common approach is to try and undertake some form of "sensitivity analysis" that shows the impact of changes in the different variables on profits and losses.

The methods set so far for measuring interest-rate risk are those that would be applicable for a bank with straightforward money market deposit operations. However, in recent years, banks have also become much more active in medium-term interest-rate risk through the development of the interest-rates swap market. The measurement of interest-rate sensitivity in the medium-term market poses different questions.

Seven Months	Eight Months	Nine Months	Ten Months	Eleven Months	Twelve Months	Two Years	Three Years	Four Years	Five Years	Five Years
1	8	1	20	1	1	1	4	—	—	—
3	13	—	1	—	—	3	—	—	—	—
2	2	12	11	1	2	—	5	—	—	—
13	2	3	2	1	1	—	5	24	—	—
19	25	16	34	3	4	4	14	24	—	—
13.64	12.40	13.50	12.24	12.01	12.50	13.35	13.33	12.04	—	—
—	—	—	—	—	—	—	—	—	—	—
14	19	26	15	7	11	20	1	5	1	2
9	14	15	27	6	16	—	9	28	—	2
—	—	11	—	—	—	4	—	2	—	—
4	10	1	3	1	—	—	—	1	—	—
—	7	—	—	—	14	28	37	14	7	—
27	50	53	45	14	41	52	47	50	8	4
13.55	13.12	13.57	11.98	12.85	13.17	13.41	13.11	13.71	14.07	13.30
8	25	37	11	11	37	48	33	26	8	4
248	240	215	178	167	156	119	71	38	12	4

All through this chapter, we have implicitly ignored the fact that one dollar receivable in five years time is worth less in practice than one dollar receivable today. The time value of money is critical to measuring the interest-rate risk of a bank's medium-term swap book and also of its securities trading activity. The duration of the bank's exposures is also critical. (These concepts are defined later in this chapter.)

It will be desirable to have some sense of the duration and the convexity of the firm's overall interest-sensitive positions. As a general rule, though, it would probably make more sense to focus on specific "books" than on the bank's balance sheet as a whole because there will be so many complex internal offsets that the balance sheet as a whole may have little meaning in terms of interest-rate exposure. Furthermore, single measures such as duration have very little meaning at this broad level of aggregation. Providing that adequate computer systems are available (and if they are not, some other risk-control questions arise rather quickly), it would be desirable to construct interest-risk scenarios showing the impact of a change in the level of rates;

a change in the slope of the yield curve (particularly important for forward positions such as forward rate agreements, forward-forward deposits, and interest-rate futures); changes in the volatility of interest rates (which would affect the valuation of interest-rate options, caps, collars, and floors); and changes in basis risk (for example, the impact of a change in the spread relationship between LIBOR (London Interbank Offered Rate) and U.S. Treasury bills or between U.S. Treasury bonds and Eurobonds).

Finally, it is worth mentioning that some institutions have begun to apply Monte Carlo simulation techniques to their interest-rate exposure; the Monte Carlo technique is discussed in more detail in Chapter 19 where we see how it can be used to assess swap exposure.

INTERNAL PRICING

The treasurer of a bank will have to cope with widely varying regulations from country to country. In addition, he or she has many internal control problems with which to contend. One of the most widespread of these is the so-called “transfer pricing” issue. The question here is intimately related to the whole question of centralization versus decentralization. Because, in general, most banks centralize their treasury functions, transfer pricing is a fairly widespread problem, which comes up both in foreign exchange and in deposit business. The transfer pricing issue is most clearly seen in foreign exchange. In the event that a customer calls for a price, he or she will very often be routed either through a branch or through a “corporate desk.” The branch or the corporate desk will then get a market price from the professional market foreign exchange dealers. The issue is whether the customer desk or the branch should be given a “turn” or “loading” and so be able to show a profit for its efforts. It is important that some recognition be given to whoever has done the work to produce the business. At the same time, the problem is that by adding the extra loading, the overall quotation may be out of line with the competition.

A similar but more complex problem arises in deposit business. For a lending that is linked to some clearly defined rate such as LIBOR, the question of transfer pricing is relatively straightforward. The dealers will lend the money to the office making the loan at LIBOR, and the loan-producing office will then add a margin on which the office and the customer have

previously been agreed. It is then reasonable to say whether the trading room has funded itself successfully by comparing the average funding cost with the LIBOR rates used for on-lending. The issue here is relatively simple because a rate like LIBOR is defined for set periods such as one month, two months, three months, and so on.

The question becomes more complex when we look at loans that are linked to base, or prime, rate. In general, such loans are repayable on demand, theoretically at least, although on occasion they may be made available for a fixed period. For theoretically overnight lendings, it seems clear that the right cost-of-funds measure is an overnight interest rate. But these can move very sharply, whereas a bank's prime rate is normally rather "sticky" in its movements. So the dealing room can experience unexpected profits or losses that have little to do with its own skill in funding the bank's book but have much more to do with the desire of the bank's management to keep its prime rate stable. There is no simple answer to this problem. All one can suggest is that one should consider the overall structure of a bank's book and select the interest rate that seems most appropriate for measuring cost of funds. Then one should stick with it, making due allowances for short-term distortions that may arise as a result of market conditions.

LOAN PRICING

The issue of transfer pricing is closely connected with the overall issue of loan pricing. This is by no means purely a responsibility of the treasurer because the lending and marketing personnel of a bank will also be concerned. However, because the aim of loan pricing is to ensure a viable overall balance sheet, the treasurer has to be concerned that loan pricing is appropriate—pricing must not be so aggressive that it leads to a rapid expansion of lending and a ballooning of the balance sheet to the point where capital and other ratios are breached; on the other hand, it cannot be so conservative that no business is ever done. At least three problems are relevant: (1) average pricing versus marginal pricing, (2) pricing of reserve asset costs, and (3) required return on bank capital.

The "average versus marginal" cost argument sometimes occurs when lending officers want to adjust the cost-of-funds formula used in loan pricing to reflect the fact that a bank has access to so-called free balances. These

balances will be in the form of current accounts obtained through the branch network, travelers' check float, or other cheap sources of funds. The crucial point is that such free balances are inherently limited in supply. As the bank's balance sheet expands, so they must support a larger and larger volume of business.

Figure 20.2 is based on the assumption that there is a fixed pool of free balances available to a bank and that additional funds have to be raised in the marketplace at the going interbank rate. This rate tends to rise against the bank as its bidding for funds increases, because other banks become increasingly less willing to lend to it. As the volume of business expands beyond the crossover point Z, we see that if the bank still prices its loans on the average cost of funds, it is starting to incur a loss. The average cost of funds to it is more than the average yield. For each new loan that it puts

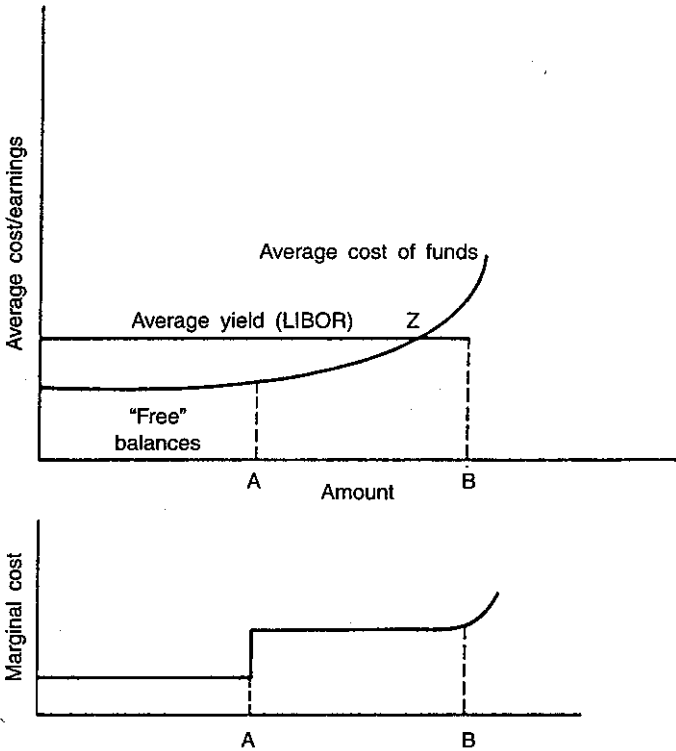


Figure 20.2 Average versus Marginal Cost of Funds

on the books, it is increasing its losses because the yield of the loan is below the cost of the funds.

A second issue is the pricing of reserve asset costs. The issue doesn't really come up if a loan is linked to prime rate. These rates generally take into account the average cost of holding reserve assets against lendings. The problem occurs when a bank is making a lending linked to a money market rate, such as LIBOR. In the Euromarkets, reserve costs can be ignored. But in domestic markets, they need to be included when pricing a loan of this kind. It may be argued that reserve costs should be borne by the depositor, but this would be hard to justify to the depositor and would create problems in pricing, for the term of the deposit is quite likely to be shorter than that of the loan and possibly shorter than the term of the reserve asset, if, for example, this is a government security. Also, and more important, banks compete with many institutions for funds; not all these institutions have reserve costs.

The reason for charging the reserve asset cost to the lendings is as follows. A bank's holding of reserves is usually based on eligible liabilities. Interbank lending in the money market is generally offset (in most countries) against interbank liabilities to work out the total of eligible liabilities. So, in general, interbank lending has no reserve cost, whereas customer lending creates a need for reserve assets. The exact formula for calculation of reserve asset costs is laid out in Chapter 13.

A related issue is the required return on bank capital. Risk is measured by weighting all assets by a given series of coefficients. A risk-asset ratio is then calculated, which is defined as the ratio of the adjusted capital base to weighted risk assets. This is defined in accordance with the norms set out by the Bank for International Settlements (BIS) and other regulators.

Suppose that the risk-asset ratio were 10% and that the capital base of the bank were 100 units. Then the capital available will support weighted assets of 1,000 units. An expansion of customer lendings (which are weighted at 1.0) of 100 will therefore increase risk weighted assets by 100. This will need an increase of 10 units in the capital base. According to the overall cost of capital, the loan pricing would need to be adjusted. If the cost of capital is 10%, then approximately 1% has to be charged into the price of the loan (minus any assumed earnings on capital). An expansion of money market lendings, though, needs less capital to support it, so the capital cost factor will be lower.

BALANCE SHEET RATIOS AND LOCAL REGULATIONS

In addition to varying regulations and internal control problems, the treasurer of a bank has a third area of concern: the control of the size and the structure of the bank's book. He or she has to match them to the volume of activity in various markets and to the amount of capital available to support the total book. In a multicurrency bank, this matching can cause complications. The bank will probably want a certain ratio of capital to total balance sheet and will, in fact, generally be required to do so by law or by custom. For example, in Germany, the Bundesaufsichtsamt für das Kreditwesen (Federal Banking Supervisory Authority) and the Bundesbank have jointly laid down certain "Basic Principles" that essentially limit a bank's total lending and investments to 18 times capital. But in a multicurrency bank, maintaining such a capital ratio can cause problems unless the capital itself is distributed in proportion with the different currencies of the balance sheet.

Suppose a German bank, with a capital denominated purely in euro, wanted to maintain a 5% capital ratio but had half of its balance sheet in U.S. dollars because of Eurodollar operations. Then a fall in the euro of 10% would force the bank to raise an extra 5% of its existing capital (assuming that it had already been at its limits). But the alternative of selecting capital denominated in different currencies according to the proportions that they currently hold in the balance sheet is not entirely satisfactory. It makes it difficult for the bank to switch the composition of its balance sheet from currency to currency according to its business needs.

The treasurer also needs to ensure that the bank complies with the local regulations of the central bank. Typically, these will cover foreign exchange positions, liquidity requirements, and exchange control compliance, where applicable.

INTEREST RISK

We have touched briefly on interest risk, which we now need to discuss more fully. The simplest kind of interest risk arises in normal money market operations where we take funds for say six months at, say, 7% and lend them for three months at 7.5%. We face the risk that interest rates in the three-month period may be lower than expected. A simple measure of this

risk can be found by constructing interest risk ladders to parallel the funding ladders discussed earlier.

In recent years, however, it has become customary for banks to think in terms of the concept of interest-rate duration as a measure of interest risk. The concept is particularly relevant where banks are undertaking longer-term operations in deposits, forward rate agreements (FRAs), or interest-rate swaps—indeed the origin of the concept was in the bond market.

Duration, Convexity, and Reinvestment Risk

We saw in Chapter 7 how to work out a bond's price. *Duration* is a measure of the bond's "length," and hence its riskiness, which takes the interim interest payments into account. Duration is the weighted-average number of periods until cash flows occur, where the weights are the present value of the cash flow, expressed as a percentage of the price of the bond.

It may help to understand duration if we start with the simple case of a U.S. Treasury zero-coupon bond. This is a bond that pays no annual interest: the investor's return comes from buying the bond at a discount to its face value. Let's take a four-year zero-coupon bond that has a yield of 10%. What is its duration? In this case, there is only one cash flow, which occurs in time period 4, and only one weight, which on this occasion must be 1. So the duration of the zero-coupon bond is 4 years and is equal to its maturity.

The next step is to look at a coupon-bearing bond. Let's start with a \$100 bond that pays an annual coupon of 10% and has a two-year maturity. One way of looking at this bond is to argue that in fact it is a portfolio of two bonds. One, which matures in a year's time, is a zero-coupon bond worth \$10. The second, which matures in two years' time, is a zero-coupon bond worth \$110. Following the logic we just used on our four-year zero, the duration of the first bond is 1 and of the second is 2.

The combined duration of the "portfolio" is obtained by adding these together. But we need to allow for the fact that one "bond" is much smaller than the other. The way to do this is to weight them by their present values in cash terms. If we use a discount rate of 10% for the present value sums, then we see that the present value of \$10 due in one year is \$9.0909; the present value of \$110 due in two years is \$90.90909. Thus the present value (price) of the coupon bond is the total of the present value of its cash flows, \$99.99999, say \$100, and our weights are 0.0909 and 0.9090, respectively.

Hence the duration is $(1 \times 0.0909) + (2 \times 0.9090)$, which comes to 1.9089, or 1.91 years.

Notice that the coupon bond's duration is shorter than its maturity. Duration is only equal to maturity for zero-coupon bonds. For all coupon-bearing bonds, duration will be less than the maturity. One other point to note is that, unlike the bond's maturity, its duration varies with the level of interest rates because of the changes in present value arising from a change in the discount rate. If we had used 11% as the discount factor in the present value calculation we just did, the duration would have come out to be about 1.88.

The full formula for duration is:

$$D = \frac{\sum_{t=1}^n \frac{t \times C_t}{(1+r)^t}}{\sum_{t=1}^n \frac{C_t}{(1+r)^t}}$$

where t = period number, C_t = cash flow at time t , r = market yield on the bond.

We can rewrite this more simply: the bottom line is the price that we would pay for the bond today, call it P . We can define the individual weights on the top line as

$$W_t = \frac{C_t}{(1+r)^t P}$$

Then we can write:

$$D = \sum_{t=1}^n tW_t$$

Some people may find it helpful to think about duration in more visual terms. A helpful way of looking at duration was given in a paper by R. W. Kopprasch.¹ Figure 20.3, based on that paper, shows the cash flows and

¹R.W. Kopprasch, "Understanding Duration and Volatility" (Salomon Brothers, September 1985).

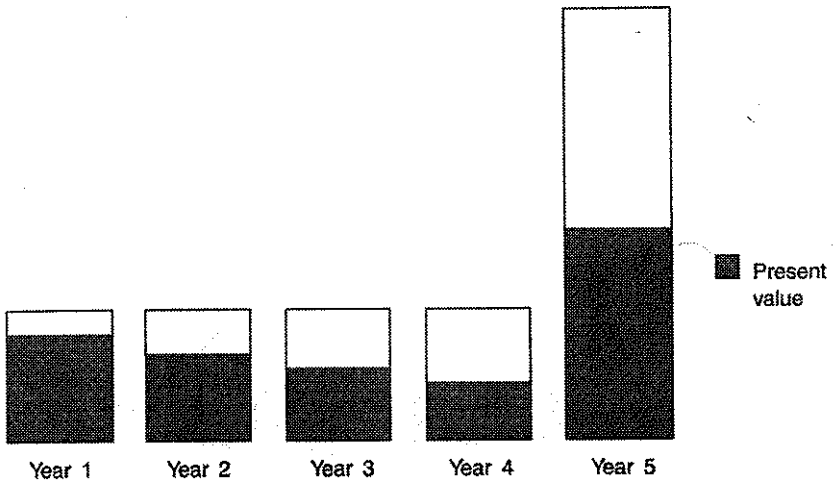


Figure 20.3 Cash Flows and Present Values of Five-Year Bond

present values of a five-year 12% bond. The shaded area of each cash flow represents the present value of that cash flow.

We can imagine that Figure 20.4 is a series of tins resting on a seesaw. The size of each tin is the cash flow due; the water in the tin is the present value of the cash flow. The distance between the centers of each cash flow container represents the amount of time between the cash flows; that is, each tin is one period apart.

If an investor were looking at this five-year bond on a coupon date, the first tin would be one period away from the start. The second would be two periods away, and so on. The duration would be the distance from the investor to where we could put a fulcrum and balance the whole system (see Figure 20.4). It is the bond's "center of gravity."

Looking at duration in this way makes it clear that the duration of a zero-coupon bond equals its maturity. Because there is only one cash flow, the fulcrum must lie at that cash flow. For all other bonds, the duration is less than the maturity. For if there are intervening cash flows, the fulcrum cannot be at the end of the seesaw and still balance it.

The definition of duration that we have been using is sometimes called *Macaulay duration*, after the man who invented it. There is a related concept called *modified duration*, which is the Macaulay duration divided by $(1 + r)$. (We need to be sure that r is correctly defined as the periodic yield. If r is 10% per annum, we would write 1.10; if it were a semiannual yield,

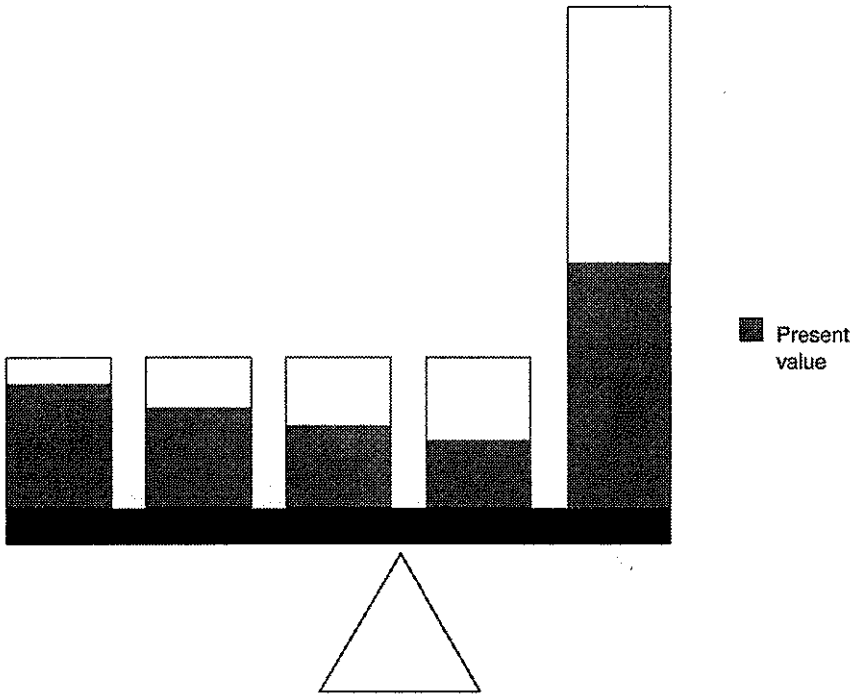


Figure 20.4 Duration: The Fulcrum of the Cash Flows

we would write 1.05.) Modified duration (MD) turns out to be a very good measure of the riskiness of the bond. It approximates very closely the percentage change in price as a result of a one-basis-point rise in yield; that is, it shows how vulnerable the bond's value is to interest-rate movements.

$$MD = \sum_{t=1}^n \frac{tW_t}{(1+r)}$$

Let's go back to our four-year zero-coupon bond, yielding 10%. In that case, its current price will be \$68.30 per \$100 face value due in four years' time. That price is found by the standard present value (PV) calculation, which here is fairly simple: $PV = \$100/(1+r)^4$.

What would the price of the bond be at a yield of 10.01%? From the same formula, we can find the price as \$68.28. What is the percentage change in price for a one-basis-point rise in yield? If we work out the prices of

the bonds very precisely, we will find that at 10%, the price is \$68.30135; at 10.01%, the price is \$68.27651; and the percentage difference, expressed as a percentage of the original price of \$68.30135, is -0.036% . The percentage change in price is 3.6 times as large as the change in yield. In other words, for a change in yield of 0.01%, the value of the bond changes by $0.01\% \times MD$, the modified duration. Therefore, modified duration gives a measure of the volatility of the bond. Hence, it is usually referred to as “volatility” in the U.K. bond market, rather than as “modified duration,” which is the U.S. term.

This is one of the chief practical uses of duration: as a measure of the volatility of a bond. To be precise, modified duration is a measure of the percentage volatility of the full price (that is, including accrued interest) of a bond, given small changes in interest rates. It can be looked at in graphic terms as the slope of the bond’s price-yield curve (Figure 20.5).

Modified duration as a measure of percentage volatility is only valid for small changes in yield. For larger changes, one must consider the security’s *convexity*. (The term comes from the price-yield curve for a normal bond, which is convex.) Mathematically speaking, the convexity is the second derivative of the price-yield curve:

$$C = \frac{10,000}{P} \times \frac{\delta^2 P}{\delta Y^2}$$

where P = dirty price of bond (i.e., including accrued interest), Y = periodic yield (e.g., semiannual), and C = convexity.

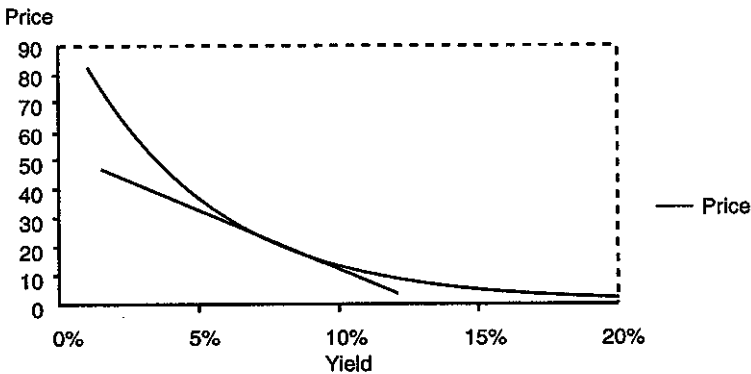


Figure 20.5 Duration: The Tangent to the Price-Yield Curve

A less formidable formula, which is a practical approximation, is to define P_p and P_m as the price of the bond if yields rise and fall, respectively, by one basis point. Then

$$C = \frac{10^3 \times (P_p + P_m - 2P)}{P}$$

Key-Rate Duration

A refinement of the concept of duration was introduced by T. S. Y. Ho, among others² in the shape of key-rate duration. This concept focuses on the idea of analyzing interest-rate risk with respect to sectors of the yield curve. The duration of a bond is measured with respect to one key portion of the yield curve. Thus, one might consider duration in relation to the 10-year zero rate. A variant of this is to consider duration in relation to on-the-run Treasury bond yields, sometimes called “key Treasury rate duration.”

The concept of key rate is relevant, for example, in relation to the analysis of structured notes that carry embedded in them risks derived from changes in the shape of the yield curve. The analysis of the duration of a structured note is not as simple as the duration of a Treasury bond or any “normal” straight bond. The exact calculation will vary enormously, depending on the structure of the bond concerned. What follows is an attempt to explain a possible line of approach.³

The duration of a Treasury bond is dependent on the yield used to discount the cash flows involved. We may therefore call it the *discounting rate duration*. But the performance of a structured note may be dependent on some other interest rate. We may have, for example, a \$10 million bond whose redemption value, or coupons, may be set by the five-year Swiss franc swap rate. The bond value is then linked not just to U.S. interest rates but also to Swiss franc rates. We will call this second duration the *index rate duration*—the sensitivity of the bond’s price to changes in the underlying index, which here

²T. S. Y. Ho, “Key Rate Durations: Measures of Interest Rate Risks,” *Journal of Fixed Income* (1992).

³This section draws on the treatment given by S. Y. Peng and R. E. Dattatreya, *The Structured Note Market* (Chicago: Probus Publishing, 1995), which should be consulted for a fuller discussion of the issues involved.

is the Swiss franc rate. We could also define the concept of *composite duration*, or *net duration*, which is the composite of the two underlying durations.

As an example of risk measurement on a structured note, we will consider a three-year Euro-medium-term note issued by FNMA. The note pays an annual coupon defined as: [10-year Constant Maturity Treasury (CMT) rate minus 12-month LIBOR] plus 2%. (The CMT rate is a rate for 10-year Treasury bonds, which is, as it were, constantly updated. It reflects the current yield on new 10-year Treasury bonds.)

The first step is to see that, as is typical with many structured notes, we have two durations to look at. The first is the conventional duration, or *discounting duration*, which is the impact on the price of the bond of a change in the yield of the instrument whose yield we use to value the cash flows of the bond. With a conventional bond, the cash-flow-valuation yield is the yield on the bond. That yield reflects the rate at which money can be invested or reinvested during the life of the bond. But with this bond, the yield definition is exotic. We cannot be sure that at any time in the three-year life of the bond we can invest money at (10-year CMT-12 month LIBOR) + 2%. So we will use the three-year Treasury bond yield to value the cash flows. A change in the three-year Treasury yield will change the value of the FNMA note, and the impact of that change will be reflected in the discounting rate duration.

The second duration to look at is the *index rate duration*, which is the impact on the bond price of changes in the index rate(s) that define the coupon of the bond. With a conventional bond, the coupon is the coupon, and this sensitivity does not arise. But with this bond, we have two variable items. (1) The CMT coupon is refixed annually as the then-current 10-year Treasury bond yield, and (2) LIBOR will also vary each year.

Let us deal with the LIBOR component first. It is possible to convert from a stream of LIBOR coupons to a fixed swap rate. (This is set out in Chapter 16.) Normally the LIBOR is a six-month LIBOR. But we can often construct the swap against 12-month LIBOR for no additional cost. Thus the stream of 12-month LIBOR coupons embedded in the FNMA note can be treated as being equal, for interest-risk purposes, to the three-year swap rate (because three years is the underlying maturity of the note). This in turn is equal to the three-year Treasury yield plus or minus some spread (which over a three-year period can be assumed not to vary very much). In this case the LIBOR flows are being deducted from our coupon. It is as if we were paying LIBOR to receive a three-year Treasury rate. So the value of the LIBOR stream is

equivalent to being long a three-year Treasury bond. If we assume an interest-rate level, for the purposes of this example, of 5%, then the duration of the position is about -2.75 (negative, because rising yields imply falling prices).

Next we consider the CMT component. At this point we need to look at the key-rate duration of the various parts of the CMT component. The present value of the coupon income represented by the CMT component is the sum of the current 10-year Treasury coupon plus the 10-year Treasury coupon fixed a year from now plus the 10-year coupon fixed two years from now. Each of these must be discounted at the appropriate rate for that cash flow. So we can write:

$$\text{PV of CMT coupons} = \frac{T_{10,0}}{(1+r_1)} + \frac{T_{10,1}}{(1+r_2)^2} + \frac{T_{10,2}}{(1+r_3)^3}$$

where $T_{10,1}$ = the 10-year rate fixed a year from now, $T_{10,2}$ = the rate fixed two years from now, and $(1+r_2)$ = the discount factor applicable to a cash flow to be received two years from now.

We have no way of knowing what the 10-year Treasury rate will be one year from now. But we do know the forward 10-year rates built into the current Treasury bond yield curve. So we know what the current market forecast of those rates is. We can find the market's forecast of what the 10-year Treasury rate will be by looking at today's 1-year rate and today's 11-year rate. Similarly we can find from the 2-year rate and the 12-year rate what the implicit forecast is for 10-year yields starting 2 years from now.

This calculation is laborious, though of course it can be done by computer software. For the purposes of this example, let us note that in the present case, the length of time until the forward starts (1 and 2 years) is small in relation to the maturity of the bond (10 years). In this case it is more or less fair to assume that the forward rate is close to the rate on the final-maturity bond; that is, the 10-year rate for 1 year forward is close to the yield on the 11-year bond, and the 10-year rate 2 years forward is proportional to the yield on the 12-year bond. This simplifying assumption is made only for the purpose of exposition.

Now we can argue that the CMT component of this bond consists of three sets of yields: They are roughly equivalent to the 10-, 11-, and 12-year Treasury bond yield. The effect of a change in the 10-year bond will be slightly greater than that of the 11-year bond because that yield is received

a year from now, whereas the 11-year (i.e., the CMT 10-year due to be fixed next year and paid the following year) is received in 2 years.

We have now worked out how to find the three key-rate durations (KRDs) of the 10-, 11-, and 12-year bonds. The KRD of the 10-year bond is the impact of a one-basis-point change in the 10-year-bond yield. The effect of this change will last for one year (because next year, the coupon will be refixed). So the total effect is one basis point. The one basis point will be received in one year's time. Discounting it at our previously assumed rate of 5%, we get the present value of this change to be 0.96. Because a rise in the yield will benefit us (remember that we have separated out the effect of changing the discount rate into the discount rate duration), the sign of the KRD is positive, making it +0.96. Similarly, for the 11-year KRD, we need the impact of a one-basis-point change for one year, received in two years' time. The present value of this at 5% is +0.91. For the 12-year KRD, we need the present value of a one-basis-point yield for one year, received three years from now. This comes to +0.85.

We can summarize the position in Table 20.5.

In aggregate, therefore, we can say that this note has a duration of -5.5 with respect to any change in the three-year Treasury bond. Roughly speaking, a 1% rise in three-year-bond yields will cost us 5.5%. But a rise in the 10-, 11-, or 12-year yields would help us. Therefore, the note is a bet on the yield curve steepening (we want the three-year rate to fall and the 10-, 11-, and 12-year rates to rise).

Graphically, we have the depiction of the situation shown in Figure 20.6.

If we assume a parallel shift across the whole curve, the duration is $-2.75 - 2.75 + 0.96 + 0.91 + 0.85$, or -2.78, about the same as that for the straight three-year note.

Table 20.5 Components of Key Rate Duration

Component Index Rate	Index 10-year CMT	Key Rate for Index	KRD
		T_{10}	0.96
		T_{11}	0.91
		T_{12}	0.85
	12-month LIBOR	T_3	-2.75
Discounting Rate	Treasury rate to maturity	T_3	-2.75

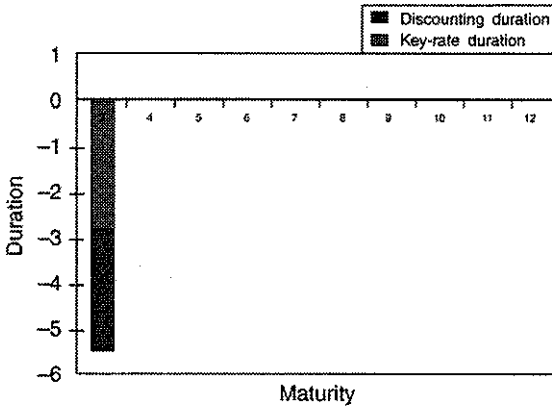


Figure 20.6 Key-Rate Duration and Discount Duration

Limitations of Duration and the Concept of Convexity

Although convexity can be used to correct one major limitation of duration, there are other more subtle but more severe limitations of both duration and convexity. Duration and convexity work well for single-bond portfolios but most actual situations involve multiple-bond portfolios. Consider a simple portfolio consisting of equal amounts invested in one bond with duration of 5.0 and another with duration of 10.0. The overall duration is 7.5. If the yields on both bonds change by an equal number of basis points (and letting the yield change be small to ignore the convexity problem), duration will accurately give us the change in value of the portfolio and enable us to immunize. But parallel shifts in the yield curve are not particularly common. Also, in global bond portfolios, a basis point change is more probable in some currencies (e.g., the lira) than in others (e.g., the Swiss franc). Duration says nothing of the probability of a change; it only measures the effect of a change. For this we need to incorporate our interest-risk measures in a broader approach such as value-at-risk, discussed in Chapter 19.

21 Measurement and Control of Foreign Exchange Risk

In this chapter we look at the measurement and the control of foreign exchange risk. The basis of the risk is common to both banks and corporations, but because foreign exchange trading and position matching are fundamental to a bank and ancillary to the industrialist's business, which may entail quite different operating exposures, the corporate's foreign exchange management may need to be quite different.

We start first by looking at it from the bank's point of view, because this is the simplest. Generally, banks do not have to worry, at the trading level, about taxation or about noncash items. Then we go on to think about some of the problems faced by industrial and commercial corporations in foreign exchange, beginning with how its exposure is to be measured. We explain the effect of taxation, and we then look at the U.S. Financial Accounting Standards (FAS) Board's Statement 52 on accounting for foreign exchange rate changes, together with some more recent pronouncements such as FAS 133.

The following sections look at some of the options open to the corporation in managing its exposure. We begin with some of the organizational issues: choice of trading philosophy and the question of whether to centralize. This leads to multinational netting systems. Then we look at other methods of exposure reduction—nonfinancial and financial. Nonfinancial steps include choices relating to production, pricing, and marketing. Financial steps include choice of borrowing currency, currency swaps, and similar arrangements.

EXCHANGE BOOK AND EXCHANGE LADDER

Let's start with some of the concepts used in the control of a bank treasury. The first is the *exchange book*, which is the total of all outstanding exchange contracts in any one currency at any one time. The size of the total book is found by adding up all the outstanding contracts in all currencies and expressing the total in terms of a single common currency—usually the local currency or the U.S. dollar.

Next is the *foreign exchange ladder*, which registers every purchase and every sale of a currency in maturity date order. An example is set out in Table 21.1. This bank's book is long overall of EUR 100,000. It has sold EUR 1 million in the one-month period against a purchase in six months; bought EUR 2 million in the two-month period against a sale of EUR 2 million in three months; and bought EUR 500,000 in the one-year period against EUR 500,000 sold in the two-year period. Because its positions do not balance exactly in every period, this bank has a mismatch, or gap, position. Therefore, it is vulnerable to rate movements against it. If the euro spot price falls, this bank will lose on the spot position. And if the forward dollar discount/euro premium should rise in the two-year maturity compared with the one-year, it would lose money on the EUR 500,000 one-year position against the two-years position.

Management will aim to control the risks by setting a mismatch limit for each period. Suppose that the two-year mismatch limit was only EUR 250,000, but that the spot limit was EUR 2,000,000. Then the dealers might have to

Table 21.1 Euro Ladder

Period	In (+)	Out (-)	Net	Cumulative (from far end)
Spot	+100,000	0	+100,000	+100,000
One month	0	-1,000,000	- 1,000,000	0
Two months	+2,000,000	0	+2,000,000	+1,000,000
Three months	0	-2,000,000	- 2,000,000	-1,000,000
Six months	+1,000,000	0	+1,000,000	+1,000,000
Twelve months	+500,000	0	+500,000	0
Twenty-four months	0	-500,000	-500,000	-500,000
Total	+3,600,000	-3,500,000	+100,000	

cut down the two-year position and might do it by making a swap of EUR 250,000; they would sell spot and buy forward to bring the new two-year figure back to the limit. Or, if the spot limit were full but they had room in the six-month band, they might bring part of the position back to the six-month period.

REVALUATION

The *exchange position ladder* is a key tool for management of the bank's position, but of itself, it is only a record of what deals were done. It gives us no information about the current profit of the deals. In order to know that, banks will revalue their foreign currency "book" from time to time. The profit or the loss is taken to the bank's profit-and-loss account. Let's look at a U.S. bank that is dealing U.S. dollars against euro. The way its euro exchange ladder might look is shown in Table 21.2. This, though, does not tell us if we are making money on the deals. Let's ask ourselves, What would happen if the bank were required to go out of business tomorrow? That is, at what prices could we liquidate these contracts? Suppose that we take today's prices for the various periods involved and apply them to the current book. Table 21.3 shows how the position might look.

As we can see, the overall book now shows a loss. There is a small profit in the spot position, because the Swiss franc (CHF) has strengthened to 1.49. But where the bank had paid a premium of CHF 0.08 for its six-month against one-month swap, it would now only earn a premium of 0.02 for reversing the deal. Where it had sold three-month Swiss francs for a nil premium against

Table 21.2 CHF Position Equivalents

Period	CHF Amount	Original Rate	Original USD Equivalent
Spot	100,000	1.50	-66,666.67
One month	1,000,000	1.51	-662,251.66
Two months	2,000,000	1.45	-1,379,310.34
Three months	-2,000,000	1.45	1,379,310.34
Six months	1,000,000	1.43	-699,300.70
Twelve months	500,000	1.39	-359,712.23
Two years	-500,000	1.26	396,825.40

Table 21.3 Swiss Franc Position Revalued

Original Period	Currency Amount	Original Rate	USD Equivalent	Current Rate	Current Value	Profit/loss
Spot	100,000	1.50	-66,666.67	1.49	67,114.09	447.43
One month	-1,000,000	1.51	662,251.66	1.48	-675,675.68	-13,424.02
Two months	2,000,000	1.45	-1,379,310.34	1.47	1,360,544.22	-18,766.13
Three months	-2,000,000	1.45	1,379,310.34	1.46	-1,369,863.01	9,447.33
Six months	1,000,000	1.43	-699,300.70	1.46	684,931.51	-14,369.19
Twelve months	500,000	1.39	-359,712.23	1.41	354,609.93	-5,102.30
Two years	-500,000	1.26	396,825.40	1.31	-381,679.39	15,146.01
Totals	100,000		-66,602.54		39,981.67	-26,620.87

two months, it would now have to pay a premium of 0.01 to reverse the swap. There is a small profit on the one-year deal against the two-year deal because the two-year was sold at a premium of 0.13 against the one-year. The bank would have to pay only 0.10 to reverse the swap.

The benefit of the revaluation is that it gives current information about which positions are profitable and which are turning into loss. The example we looked at was simple. It assumed that the various contracts outstanding were for the "standard" maturity dates. A bank will normally have nonstandard forward contracts as well. Assuming that the process is computerized, it will be possible to produce interpolated rates for every single date and to revalue every contract. For practical reasons, it might be easiest to consider contracts to be matched if they fall within the same calendar week, the same semimonthly period, or even the same month, depending on how close they are to today and on how precise we need to be.

As discussed in the interest-rate section in the previous chapter, a full picture would include the effect of futures, options, and swaps. Similar considerations apply to the foreign exchange risk of these items as in interest-rate risk (the credit risk on currency swaps is different, however, as discussed in Chapters 16 and 22).

MEASUREMENT OF EXPOSURE IN THE CORPORATION

In many ways, the measurement of exposure in the corporation is intrinsically more complex than in a bank. In the banking case, we are concerned with purely monetary assets and liabilities; in the corporation, the asset to be

hedged may consist of a trading receivable, or it may consist of a fixed asset such as property that forms part of the corporation's balance sheet. Equally, the bank's trading operations will usually be subject to a fairly uniform tax treatment because its profits and losses on foreign exchange will (normally) be part of its ordinary income. This is often not so for an industrial or commercial corporation.

There are many different measures of exposure that have been applied to corporations. Economic, transaction, translation, and operational exposure are all terms that have been used at various times. The broadest, perhaps, is *economic exposure*, which has been defined as the impact of exchange rate changes on discounted cash flow of a company at a specified future date.

Two other widely used measures are transaction exposure and translation exposure. They are used by the Financial Accounting Standards Board (FASB) of the United States, which in 1975 published its Statement Number 8, now generally referred to as FAS 8. In brief, *transaction exposure* concerns actual transactions in foreign currencies, whereas *translation exposure* deals with the valuation of overseas assets.

Finally, another measure that is widely used is consolidated after-tax exposure. This, as the name suggests, looks at the translation component and the tax effect of the transaction component of the exposure from a consolidated after-tax viewpoint. This concept of after-tax exposure is often used by corporations with a centralized exposure management function.

The choice of definition is controversial. FAS 8, the first definitive statement of its kind on this subject, ran to over 20,000 words, much of it devoted to justifying the Board's decision. But it was subjected to intensive international criticism. After six years of debate, some of the main principles of FAS 8 were abandoned, and a new statement, FAS 52, was published.

FAS 52 AND FAS 133

Briefly, FAS 52 switched away from the approach of FAS 8 toward the so-called "net investment approach"—each foreign branch, division, or subsidiary was looked on as a net investment of the parent. So the parent's exchange risk was related to the business as a whole and not to individual assets and liabilities. FAS 52 lays down this policy: "The assets, liabilities, and operations of a foreign entity shall be measured using the functional currency

of that entity. An entity's functional currency is the currency of the primary economic environment in which the entity operates; normally, that is the currency of the environment in which the entity primarily generates and expends cash." (FAS 52, para. 5)

Once the functional currency for a foreign entity is determined, its accounts must be cast in terms of the functional currency. If its accounts are not maintained in the functional currency, remeasurement into the functional currency is required (FAS 52, para. 10). The accounts are then translated into the reporting currency of the parent, in the following manner:

All elements of financial statements shall be translated by using a current exchange rate. For assets and liabilities, the exchange rate at the balance sheet date shall be used. For revenues, expenses, gains, and losses, the exchange rates at the dates at which those elements are recognized shall be used.

If an entity's functional currency is a foreign currency, translation adjustments result from the process of translating that entity's financial statements into the reporting currency. Translation adjustments shall not be included in determining net income but shall be reported separately and accumulated in a separate component of equity. (FAS 52, para. 12 and 13)

FAS 52 transferred the impact of translation adjustments from the profit-and-loss account to the balance sheet. It removed erratic fluctuations in income at the price of erratic fluctuations in the balance sheet.

Although the broad framework of FAS 52 remains in place, it has been modified by a number of later developments, notably FAS 107, *Disclosures about Fair Value of Financial Instruments*, and most recently FAS 133, *Accounting for Derivative Instruments and Hedging Activities*, issued in 1998.

A *derivative instrument* is defined in paragraphs 6 to 11 of FAS 133 as a financial instrument or other contract that possesses all of the following three characteristics:

1. It has (1) one or more underlyings and (2) one or more amounts or payment provisions or both. Those terms determine the amount of the settlement or settlements and, in some cases, whether a settlement is required.
2. It requires no initial net investment or an initial net investment that is smaller than would be required for other types of contracts that would be expected to have a similar response to changes in market factors.

3. Its terms require or permit net settlement; it can readily be settled by a means outside the contract; or it provides for delivery of an asset that puts the recipient in a position not substantially different from net settlement.

FAS 133 requires that a firm recognize all derivatives as either assets or liabilities in the statement of financial position and measure those instruments at fair value. If certain conditions are met, a derivative may be specifically designated as (1) a hedge of the exposure to changes in the fair value of a recognized asset or liability or an unrecognized firm commitment, (2) a hedge of the exposure to variable cash flows of a forecast transaction, or (3) a hedge of the foreign currency exposure of a net investment in a foreign operation, an unrecognized firm commitment, an available-for-sale security, or a foreign-currency-denominated forecast transaction.

The accounting for changes in the fair value of a derivative (that is, gains and losses) depends on the intended use of the derivative. The first case is a derivative designated as a hedge of a recognized asset or liability or a firm commitment (referred to as a "fair value hedge"). In this case the gain or the loss is recognized in earnings in the period of change together with the offsetting loss or gain on the hedged item. The effect is to reflect any impact on earnings if the hedge is not effective.

The next case is a derivative designated as hedging the exposure to variable cash flows of a forecasted transaction (referred to as a "cash flow hedge"). Here the effective portion of the derivative's gain or loss is initially reported as a component of other comprehensive income (outside earnings) and subsequently reclassified into earnings when the forecasted transaction affects earnings. Again, if the hedge is not effective, the ineffective portion of the gain or loss is reported in earnings immediately.

The third case is a derivative designated as hedging the foreign currency exposure of a net investment in a foreign operation. Here the gain or the loss is reported in other comprehensive income (outside earnings) as part of the cumulative translation adjustment.

For a derivative not designated as a hedging instrument, the gain or the loss is recognized in earnings in the period of change.

Under FAS 133, a firm that elects to apply hedge accounting is required to state at the start of the hedge the method it will use for assessing the effectiveness of the hedging derivative; and it must state the measurement approach it will use for determining the ineffective aspect of the hedge. Those methods must be consistent with the firm's approach to managing risk.

Under FAS 133, we may not designate a nonderivative financial instrument as a hedge of an asset, a liability, an unrecognized firm commitment, or a forecasted transaction. The exception is that a nonderivative instrument in a foreign currency may be designated as a hedge of the foreign currency exposure of an unrecognized firm commitment denominated in a foreign currency or a net investment in a foreign operation.

The following example illustrates some of the foreign-currency hedge concepts (tax considerations are ignored):

Exhibit 21.1 Foreign Currency Hedge Concepts under FAS 133

In October 2001, company XYZ expects to buy goods from the United Kingdom in October 2002 at a cost of £200,000. The actual dollar cost will depend on the spot exchange rate in October 2002. XYZ enters into a forward-exchange contract to receive £200,000 and to pay \$320,000 in October 2002 (i.e., we deal off an outright of \$1.60). XYZ designates the forward contract as a hedge of the likely obligation to pay £200,000 in October 2002. It assesses hedge effectiveness by comparing the entire change in the fair value of the forward contract to changes in the cash flows of the likely transaction.

As expected, XYZ buys the goods in October 2002 and has to pay £200,000. Suppose the spot exchange rate in October 2002 is £1 = US\$ 1.70, and accordingly, the forward contract has a gain of \$20,000.

XYZ would record the following journal entries to apply cash flow hedge accounting under FAS 133:

- October 2001
No entry is recorded because the forward-exchange contract is at market.
- October 2002
 1. Raw materials inventory \$340,000
Accounts payable \$340,000
(To record the receipt of raw materials for £200,000 at the spot rate of £1 = US\$ 1.70)
 2. Forward exchange contract \$20,000
Other comprehensive income \$20,000
(To record the change in the fair value of the forward contract)

3. Cash \$20,000

Forward exchange contract \$20,000

(To record the net cash settlement of the forward-exchange contract)

XYZ fixed its raw-materials cost at £1 = US\$ 1.60 (\$340,000 actual purchase price less \$20,000 gain on the forward-exchange contract). The gain on the forward contract that is accumulated in other comprehensive income will be reclassified to earnings at a later date, when the inventory is sold and earnings reflect this.

**INVENTORY, FIXED ASSETS, AND
LONG-TERM BORROWING**

Up to now we have concentrated on transaction and translation exposures only from current assets and liabilities. In the process certain complications have been glossed over. The first of these is inventory. Under FAS 8, FAS 52's predecessor, the U.S. FASB permitted corporations to value inventory in two ways. They could value at current exchange rates if inventory was valued at current cost or at historic exchange rates if inventory was valued at historic cost. But the borrowings to finance the inventory were generally valued at current exchange rates. It was possible to get some odd results. Suppose the currency of the country in which the inventory was held began to appreciate. Suppose the inventory were valued at historic cost. The exchange value of the inventory would be held at the old rate while the value of the borrowing rose. The company would seem to lose money.

A similar distortion arose in the case of fixed assets, and this case points up wider issues. Take the case of a U.S. company buying fixed assets in Home, which has the Home currency (HC) as its currency. Suppose that during that year, inflation in Home runs at 100%, while there is no inflation in the United States. Suppose that in year 1, US\$ 1 = HC 100, and in year 2, US\$ 1 = HC 200. In year 1, the U.S. company buys a machine in Brazil costing HC 10,000, that is, US\$ 100. At the end of year 2, the valuation in historic terms is HC 10,000 = US\$ 100.

In current terms, the machine's value has fallen to US\$ 50 because of the fall in the exchange rate. But the Home price of such a machine, owing

to the 100% domestic inflation, has doubled from HC 10,000 to HC 20,000. So if the U.S. company were to replace the machine in year 2, its cost in U.S. dollar terms would be US\$ 100. In this case, measuring the value of the machine at the current exchange rate understates its value to the company. The domestic price-level change has exactly offset the exchange-rate movement.

In the converse case, take a Home company investing in the United States. In year 1, the home company buys a machine worth US\$ 100 for HC 10,000. At the end of year 2, the valuation of the machine is still US\$ 100 because there has been no inflation in the United States. Valued at the historic exchange rate, this produces a value of HC 10,000. In current terms, though, the machine's value of US\$ 100 translates to HC 20,000. The price arrived at in current terms is the same as the price that would apply to the purchase of a new machine. A new machine will also cost US\$ 100, there having been no inflation.

In the case of a U.S. company investing in Home (an investment in a soft currency area) the historic rate is the more appropriate measure of the fixed asset. The apparent loss to the company from the exchange-rate movement would be fully offset by the domestic price-level change. In the reverse case (the Home company investing in the United States, a hard currency area), the exchange-rate movement is not offset by any change in the domestic price level, so the current basis of translation gives the more sensible result.

These examples oversimplify the position. If both countries are inflating at different speeds, neither the current nor the historical method will be completely accurate. In general, it will tend to be true that the historic basis will give the more accurate result for investments in weak currencies, whereas the current basis is better for investments in strong currencies. (These problems are especially acute in hyperinflationary countries, which FAS 52 essentially treats as if they were being accounted for under the old FAS 8 rules.)

But even this qualified conclusion is subject to further qualifications. Most important, the Home/United States example implicitly assumes that the "right" way of valuing the asset at the end of year 2 was by comparing it with a replacement. For most purposes, what matters to the company is not the replacement cost, but the amount of local currency income that the asset can produce. We may be right to assume that a fall in the exchange rate of a country where the asset is held will later be offset by a rise in the domestic price level. This would help the asset to produce future income. Then it would be fair to assume that the value of the asset to the company will remain

constant. In this case, the historic measurement will be appropriate. The crucial assumption, though, is the ability of the asset to keep its income-generating capacity in "real" terms. If the Home devaluation were accompanied by price controls, the real value of the machine in our example would have fallen.

Another area of complication is the question of translation exposures on long-term borrowings. In the case of investment in fixed assets, the exchange risk is a bit unreal. The corporation does not have to put up hard cash if exchange rates move. But in the case of foreign currency borrowings, which have to be repaid, the position is very different. "Cheap" Swiss francs (CHF) borrowed for 10 years in 1965 at CHF 4.3730 per US\$ 1 would have cost around 80% more to repay in 1975 at CHF 2.6200. If these changes were not reflected in the balance sheet of the company, serious distortions would arise in assessing the company's ability to repay its debts.

But suppose the franc borrowing was to finance a franc fixed asset. Revaluing the borrowing at current exchange rates while leaving the franc asset at the historic exchange rate could produce significant distortions as well. Even though the fixed asset in Switzerland might not conveniently be saleable to repay the franc borrowing, it does exist and may provide security for a further franc borrowing with which to refinance the old borrowing, or it may generate a Swiss franc cash flow sufficient to service the borrowing.

CASH VERSUS INCOME VERSUS ACCOUNTING

Finally, we need to look at the conflicts among the various types of exposure management strategy. A hedge in the foreign exchange market has an impact on cash flow, net after-tax income, and accounting gains or losses. The cash, income, and accounting gain/loss impact will vary according to whether the company decides not to hedge, to hedge on a before-tax basis, or to hedge on an after-tax basis. Each of these strategies (if the hedge is properly done) will cut out the impact of exchange-rate fluctuations on one of the three variables (cash, net income, or accounting gain/loss).

However, each strategy will also add to the impact on the other two variables. If all other things are equal, we can say that the accounting gain or loss is likely to fluctuate most with no forward cover and least with cover arranged on a before-tax basis. Net after-tax income is most volatile with no cover and least if the hedge is on an after-tax basis. In contrast, the cash

flow effect of translation exposure is nil if it is left completely unhedged, greater if cover is taken on a before-tax basis, and greatest if hedged on an after-tax basis.

A further potential problem is where the hedging should be done. This is linked to the question of centralization discussed next, and also to the existence of exchange controls in the countries involved. For example, a U.S. corporation with an Indian subsidiary might not be able to instruct its Indian subsidiary to hedge against possible translation exposure because of Indian exchange controls. The U.S. company would have to do the hedging operations itself in the U.S. market and accept the consequent cash flow and income implications. Again, a Swiss subsidiary might be able to do the hedge, but it might not be able to sustain the possible cash flow or income impact.

IMPLEMENTING EXPOSURE MANAGEMENT

Having discussed how exposure is measured, we come now to the question of what to do about exposure. This raises a number of issues, but perhaps the most pervasive is the organizational effect of exposure management. The issue surfaces in two particular ways: (1) corporate foreign exchange trading policy and (2) the role of a central treasury. But these in themselves mesh in with many other aspects of a corporation's management style.

Perhaps the most basic question is about the corporation's trading aims. In some firms, a high-level decision has been made to lay down general guidelines for foreign exchange trading policies. In others, there is a general style clearly understood in the treasury area. In others again, the policy is just to respond to events. As exchange rates have become more volatile, the risk of large losses has greatly increased. So it would be sensible for a set of formal guidelines to be worked out if this has not yet been done. At least the exercise will help all concerned decide whether the present policies meet the firm's needs. Professional bank dealers deliberately take positions that open up foreign currency exposure to make a profit from them. Some corporations do the same. At the opposite extreme are those companies who feel, "Our business is making widgets, not trading in currency." For each company, the right answer will depend on its size and on the scale of its international business.

A conservative view would be that the shareholders are entitled to expect

the management of the company to put itself in a position to manage its foreign exchange problems, but this view does not authorize that management to behave like a bank. This view might see it as acceptable currency management to leave open a foreign exchange exposure that has arisen in the normal course of business. But opening up an exposure deliberately, on the other hand, would be speculative and accordingly not acceptable.

Many others take a more aggressive approach. The right answer for each company must lie in its own circumstances and skills. The crucial point is that clear guidelines should be laid down by senior management to those who carry out the company's transactions.

A second issue that has to be examined is the extent to which far foreign exchange trading should be centralized. The drawback to central control is that it can create a central bureaucracy that is removed from day-to-day problems. A central treasury function can also curb the freedom of the individual profit centers if they lose control over their cash. Also, if the operating divisions no longer have responsibility for their exposure, they may take more risks. (An obvious example is a salesperson pressured to invoice in an undesirable currency.) The group as a whole can suffer because the central treasury has drained foreign exchange skill from the operating units.

But there are arguments in favor of centralization. First, it helps to justify better facilities. The most obvious is direct telephone lines to foreign exchange dealing rooms in the banks. A direct line gives a much faster response from the banks. It also makes it easier for the corporation to get simultaneous quotes from two or three banks, which is essential for a fair comparison. Second, a centralized treasury can ensure that the firm gets the best rates. It can put together "marketable" amounts. Third, centralization also makes it easier to match exposures. In general, it is a waste of money if one subsidiary is buying yen while another is selling yen. By the same token, centralization can be a great help to cash management on an international basis. Fourth, it helps to concentrate the foreign exchange skills that would otherwise be scattered. This gives scope for full use of the company's information sources and skills.

If the firm decides to centralize, it has to decide how to set the exchange rates within the company. Again, this depends on the volume of foreign currency business done. In some companies, it may be simplest for the central treasury to issue a regular circular telling the units the rates applying for the month or quarter to come. Or it may be best for the central treasury to act like a bank to the rest of the company. When a division has made

a commercial contract, the exposure is passed to the central treasury by a "deal" between the division and the center.

Various rates may be used for this deal. First is the rate at which the center later covers in the market. This kills any suspicion by the division that it is being "robbed" by the center. But it will probably cause delay because the center may not cover the deal at once. And it may not be possible to match up the deals exactly. Second is the spot rate on the day that the deal is passed from the division to the center. But if the contract is for a future date, the division may ignore the forward premium, or discount, on the currency in its pricing. This will harm the group's overall pricing and exposure. A better rate is that for the date that the underlying cash flow will take place. Once the center has bought the currency from, or sold it to, the division, it is the center's job to turn the trade at a profit in the marketplace.

For a multinational treasury, there is an obvious problem in centralizing exposures between countries. Legal, fiscal, and other factors may prevent this.

PRODUCTION, PRICING, AND MARKETING STRATEGIES

The choice of production location implies an exchange exposure. It may not be obvious to a U.S. firm that is exporting 10% of its output that by locating its production in the United States it has made an exchange-rate decision. But, in a converse situation, Volkswagen during the 1970s came to realize that by exporting to the United States from Germany, it was making itself vulnerable to deutschemark revaluations. No amount of hedging in the forward market could offset this basic economic exposure. As a result, Volkswagen ultimately decided to locate some of its production in the United States.

It is possible to be exposed to the movement of a currency without producing in that currency's country or selling to that country. For example, sales of jet engines by Rolls-Royce in Britain to India are affected by movements in the dollar. In the world jet engine market, there are effectively only three major players: General Electric, Pratt & Whitney, and Rolls-Royce. Because General Electric and Pratt & Whitney are American, the market prices are in dollars. Rolls's profit margins, therefore, are vulnerable to movements in sterling against the dollar, as the company found during the late 1970s.

Another important concern in the area of pricing and marketing is the

question of invoicing currency. In the example just mentioned, Rolls-Royce's choice of invoicing currency was fixed by market conditions. In other cases, companies producing in a country with a weak currency have chosen to invoice in a strong currency, such as the Deutschmark or the U.S. dollar, to protect the value of their receivables.

In general, therefore, exporters try to use their own currency as currency of invoice. This lets them protect themselves against exchange-rate fluctuations. But there have been periods—notably, for example, in the United Kingdom during the prolonged weakness of sterling—when exporters switched their invoices into stronger currencies. That gave them flexibility. They could profit from the devaluation of the domestic currency, or they could cover forward in the foreign exchange market or borrow foreign currency against the foreign currency receivable.

The choice of invoice currency is dictated not only by financial considerations, but also by what the salesperson can persuade the buyer to accept (or vice versa if the goods are being imported). At this point, exposure management touches the commercial thinking of the firm. The exposure management team needs to know the commercial pressures in the marketplace where the salespeople are working. It is equally important for those selling the company's goods to know the risks to which they may commit the company if they accept a change in invoicing currency.

The greatest flexibility, of course, lies in the choice of invoicing currency in trade within a multinational group. If the exporting parent sells in its own domestic currency to its subsidiary, then the subsidiary has the exposure. Alternatively the parent can invoice in the subsidiary's currency and keep the exposure at home. The latter case generally gives more flexibility. Exceptions to this rule would make sense if the parent company's domestic currency were expected to be weak relative to the subsidiary's. Then, provided the subsidiary's profits were taxable at a lower rate than the parent's, invoicing in the parent's currency and shifting profits to the subsidiary might be desirable. A second exception is in the converse case, where the parent's currency is expected to be strong and the parent's tax rate is lower. In this case, parent currency invoicing might be desirable.

The price of this flexibility is complexity at the center. In addition, flexibility could be hampered by exchange controls. Suppose a U.S. company with a low domestic tax rate has a French subsidiary that is paying high taxes. The dollar is expected to appreciate against the French franc. The parent decides to invoice its sales to France in dollars. The exposure is passed to

the French subsidiary. But suppose French regulations forbid forward cover more than two months in advance of delivery of the goods. Suppose the goods are shipped on 180 days' credit. Then the French subsidiary is exposed to movements in the franc for four months until they can take cover. The uncertain impact on local profitability may be demoralizing. In this situation, it might be better to invoice in francs and to handle the exposure centrally.

CHOICE OF BORROWING CURRENCY

A second obvious method of reducing exposure is to consider the choice of currency for borrowings. Suppose a U.S. corporation has a British subsidiary that has net assets. It can hedge these assets through forward sales of sterling in the foreign exchange markets or by borrowing sterling and selling it spot. Or it can instruct the U.K. subsidiary to build up its sterling borrowings and pay down its foreign currency borrowings or to remit the proceeds to the parent, to the point where the net currency asset position is eliminated. Or, if there were a net liability position in sterling (under FAS 8), the U.S. parent might have lent the British subsidiary dollars, letting it pay off some of its sterling borrowings to bring the net position back to zero.

But these operations depend on freedom from exchange controls. And there may be other problems. Funds may not be available from local financial institutions for a sufficiently long maturity. Building up local borrowings, or paying them down, may not be convenient because of balance-sheet limitations or loan covenants, as well as possible exchange control problems. Hence various other techniques have been developed to reduce exposure. These are the so-called back-to-back and parallel loans, currency swaps, and simulated currency loans. Of these, probably the most widespread are currency swaps, discussed in Chapter 16.

22 Credit and Settlement Risk

Books have been written on the subject of credit risk. This chapter does not show how to analyze the credit quality of a counterparty; rather it briefly explains the controls that have been imposed by regulators in the major countries under the aegis of the Bank for International Settlements (BIS). Then we will discuss settlement risk and clearing systems.

MEASUREMENT OF CREDIT RISK

The BIS has set up a two-tier capital standard measured against risk-weighted assets: Tier 1 is defined as fully paid in shareholders' equity and retained earnings; Tier 2 includes subordinated debt, loan loss reserves, preferred stock, and certain hybrid instruments.

Although a great deal of investment banking ingenuity has been expended on the creation of Tier 1 or Tier 2 capital, we are concerned here much more with the definition of *risk-weighted assets*, the denominator of the capital ratio. Precise definitions vary according to the central bank involved, but the following outline is drawn from the Solvency Ratio Directive of the European Communities, which covers a wide range of countries. The procedure used is as follows—all assets (and off-balance-sheet exposures) are allocated a weighting, according to the following categories:

- *Zero Weighting.* Cash; claims on or guaranteed by Organization for Economic Cooperation (OECD) and on the European communities; claims

on other central governments and central banks denominated and funded in the national currencies of the borrowers or guaranteed by the borrowers; all claims secured by OECD central government or central bank securities or European Community securities, or cash.

- *20% Weighting.* Claims on or guaranteed by the European Investment Bank (EIB) or multilateral development banks; claims on or guaranteed by OECD regional governments or local authorities; claims on or guaranteed by OECD credit institutions or, in the case of non-OECD credit institutions, similar claims with a maturity of one year or less; claims collateralized by securities issued by the EIB or by multilateral development banks; cash items in the process of collection.

- *50% Weighting.* Loans secured on residential mortgages, prepayments, and accrued income.

- *100% Weighting.* All other assets, including tangible assets, except for those where provision is made for them to be deducted from the bank's capital.

The treatment of off-balance-sheet items depends on whether the items are interest-rate and foreign exchange risks, or other risks. Interest and foreign exchange risks are treated as follows: *Interest-rate contracts* are defined to include single-currency interest-rate swaps, basis swaps (floating/floating swaps), forward rate agreements, interest-rate futures, interest-rate options purchased, and other contracts of a similar nature. (Interest rate futures are included only if they are not traded on recognized exchanges where they are subject to daily margin requirements.) *Foreign exchange contracts* are defined to include forward foreign exchange contracts (excluding those with an original maturity of 14 calendar days or less), cross-currency interest-rates swaps, currency options purchased, currency futures, and other contracts of a similar nature. (Currency futures are excluded if they are traded on recognized exchanges and subject to daily margin requirements. Interest-rate and currency options sold are excluded because once the premium is paid, the obligation is only one way, from the credit institution to its customer.)

Where there is a separate bilateral contract for novation, recognized by the national supervisory authorities, between a credit institution and its counterparty under which any obligations to each other to deliver payments

in their common currency on a given date are automatically amalgamated with other similar obligations due on the same date, the single net amount fixed by such a novation is weighted, rather than the gross amounts involved.

Off-balance-sheet items must first be grouped according to the risk categories:

- *Full Risk.* Guarantees having the character of credit substitutes, acceptances, endorsements on bills not bearing the name of another credit institution, transactions with recourse, irrevocable standby letters of credit having the character of credit substitutes, outright forward purchases of assets, asset sale and repurchase agreements where they are treated as off-balance-sheet, forward deposits, unpaid portion of partly paid shares and securities, and any other items classified as full risk by the appropriate authority.

- *Medium Risk.* Documentary credits issued and confirmed, warranties and indemnities and guarantees not having the character of credit substitutes (including tender, performance, customs, and tax bonds), certain asset sales and repurchase agreements, irrevocable standby letters of credit not having the character of credit substitutes, undrawn credit facilities with an original maturity of more than one year, note issuance facilities and underwriting facilities, and other items classified by the central bank as carrying medium risks.

- *Medium/Low Risk.* Documentary credits in which the underlying shipment is collateral, other self-liquidating transactions, and other items characterized by the central bank as carrying medium/low risk.

- *Low Risk.* Undrawn credit facilities that have an original maturity up to and including one year or that may be canceled unconditionally at any time without notice; other items also classified by the central bank as carrying low risk.

The weighting attached to the full-risk items is 100%, medium-risk is 50%, and medium/low-risk is 20%; the value of low-risk items is set at 0%. The off-balance-sheet items are then weighted in accordance with relevant weightings to arrive at an on-balance-sheet equivalent.

For the interest-rate and foreign exchange contracts listed, subject to the

consent of their supervisory authorities, credit institutions may use one of two methods: (1) the mark-to-market approach or (2) the original exposure approach.

The *mark-to-market* approach proceeds as follows:

1. All outstanding contracts are marked to market with their current replacement cost. The total of all contracts with positive values is obtained (that is, all of those contracts for which the other side of the deal is showing a loss and might walk away from the deal).

2. A figure for potential future credit exposure is added. To obtain this, the notional principal amounts or values underlying the contracts are multiplied by the following percentages:

Residual Maturity	Interest-Rate Contracts (%)	Foreign Exchange Contracts (%)
1 year or less	0%	1%
More than 1 year	1/2%	5%

3. The sum of the current replacement cost and potential future credit exposure is multiplied by the risk weightings allocated to the relevant counterparties as outlined earlier.

The *original exposure approach* has two steps:

1. The notional principal amount of each contract is multiplied by the percentages given below:

Residual Maturity	Interest-Rate Contracts	Foreign Exchange Contracts
1 year or less	1/2%	2%
Over 1 year, up to 2 years	1%	5%
Each additional year	1%	3%

2. The original exposure is multiplied by the risk weightings allocated to the relevant counterparties as outlined earlier. (In this approach, in the case of interest-rate contracts, credit institutions may, subject to the consent of the supervisory authorities, choose either original or residual maturity.)

SIMULATIONS OF RISK

As discussed in Chapter 19, the recent tendency has been to move away from formula-type risk measurement of the kind just discussed, which is now generally used mainly by smaller, less-sophisticated institutions or companies. Given that the type of risk we are discussing here is replacement risk, which is essentially dependent on unpredictable future movements in market rates, there is of course no single guaranteed-to-be-correct measurement method. The value-at-risk method is very generally applied across market portfolios to give us a snapshot of the potential risk of our aggregate current positions. In order to estimate the likely future-credit-risk profile of a given market position, however, we need to focus on the likely future path of rates and how the structure of the specific instrument is likely to perform over time. One widely used approach is the so-called Monte Carlo simulation.

This simulation method was invented by John von Neumann, who wanted to model extremely complex systems. It represents a solution using not intellectual subtlety, but the brute force of the computer. In essence, what we do is calculate many scenarios using a random-number generator. For a sufficiently large number of scenarios, the results can be analyzed statistically, and an accurate assessment of risk can be made. It is like a man who is playing with loaded dice. He knows that they are loaded but not the results they will give. If he throws the dice often enough and analyzes the outcome, eventually he will be able to make a very good estimate of the probability of any given face of the one die turning up on the next throw. Of course, he is still just as uncertain as before; but now he knows the probabilities. The same situation occurs when we have run all our simulations. We are just as uncertain as we were before any simulations were run, but now we should have a fairly good idea of the odds against us.

To take a specific example, consider a Monte Carlo simulation applied

to an interest rate swap.¹ A single interest-rate path will be built up over the life of the transaction. Starting from the level of rates at the time the swap starts, the level of rates at the next period (for example, next year) is set by the start level plus (or minus) a change. The level of rates two periods from now is set from the next-period rate plus (or minus) a change, and so on, until we have created a chain of interest rates for every period in the swap's life.

Monte Carlo simulation models calculate these interest-rate changes by using an assumed-probability-distribution function for interest rates and a random-number generator that kicks the process off randomly. For the distribution function, most people use the so-called "log-normal" distribution. This implies that changes in the logarithm of the interest rate are distributed normally. Using the logarithm implies that we assume that percentage changes in the rate, rather than the rate itself, are normally distributed. That accords with common sense: if a rate is 20%, it is quite likely to move to 21% (a 1% change on 20% is a 5% swing); if a rate is at 3%, a 1% rise would be seen as large (a 1% rise on 3% is a 33.33% swing). The log-normal assumption is widely used, for example, in the Black-Scholes option-pricing model (see Chapter 17).

Using this log-normal assumption implies several things:

1. There is no underlying trend in interest rates. In each period, rates are as likely to rise as they are to fall.
2. The change in next period's rate is independent of previous changes.
3. The change within a period depends on the assumed standard deviation of the log-normal distribution (that is, the volatility of the interest rate). Volatility is an assumption that we have to make before we run the model.
4. The scale of interest-rate movements over the life of a swap consisting of several periods increases with the number of periods. This is a feature common to most Monte Carlo models and could be called "diffusion."

When we assume a level for volatility, we in effect set global constraints on how far interest rates can move in the future. To be more precise, the

¹The following discussion is adapted from M. Ferron and G. Handjinicolau in R. J. Schwartz and C. W. Smith (eds.), *The Handbook of Currency and Interest Rate Risk Management* (New York: New York Institute of Finance, 1990).

log-normal distribution—the chance of a value lying within one standard deviation of the mean—is roughly 84%. The chance it will be within two standard deviations is 98%.

Suppose that rates now are 9% and that we guess volatility at 20%. Then one standard deviation will be $9\% \times 20\%$, or 1.8%. So there is an 84% chance that interest rates in the next period will be between 7.2% and 10.8%. Likewise, there is a 98% chance they will be within 5.4% and 12.6%.

Now let's think about the longer term. We said earlier that as the length of the swap grows, so does volatility. More specifically, the diffusion (the increase from the starting level of volatility) for a log-normal distribution is a function of the square root of time elapsed since the start of the process. Thus, in our example, at the end of the second period, there is an 84% chance that interest rates will be between 6.5% and 11.5% (one standard deviation two periods from now is equal to $9\% \times 20\% \times \sqrt{2}$) and a 98% chance that interest rates will lie between 2.5% and 30%.

In modeling the default risk on an interest-rate swap, we shall make the following assumptions:

1. The risk is always positive; that is, the replacement cost is equal to its mark-to-market value or to zero if that value would mean a gain to the other party (we assume we are always cherry-picked by the other party).
2. The timing of default is random: there is equal likelihood of default occurring at any time during the life of the swap.

On these assumptions, the credit risk is equal to the average of the expected replacement costs at each point in the future.

The credit risk will reflect two opposing forces: (1) the amortization effect and the (2) diffusion effect. The amortization effect results from the fact that as time passes and payments are actually exchanged without default, the credit risk on the swap falls toward zero. The diffusion effect results from the fact that as time passes, interest rates have a greater chance of moving from their starting levels.

Figure 22.1 shows the results of a Monte Carlo simulation for the credit risk of a "plain vanilla" 9% 10-year swap, assuming a 20% volatility of interest rates. It will be seen that the profile of the credit risk is humped, with maximum exposure occurring about two years after the start date. On the day of the swap, the credit risk is zero (because it could be replaced

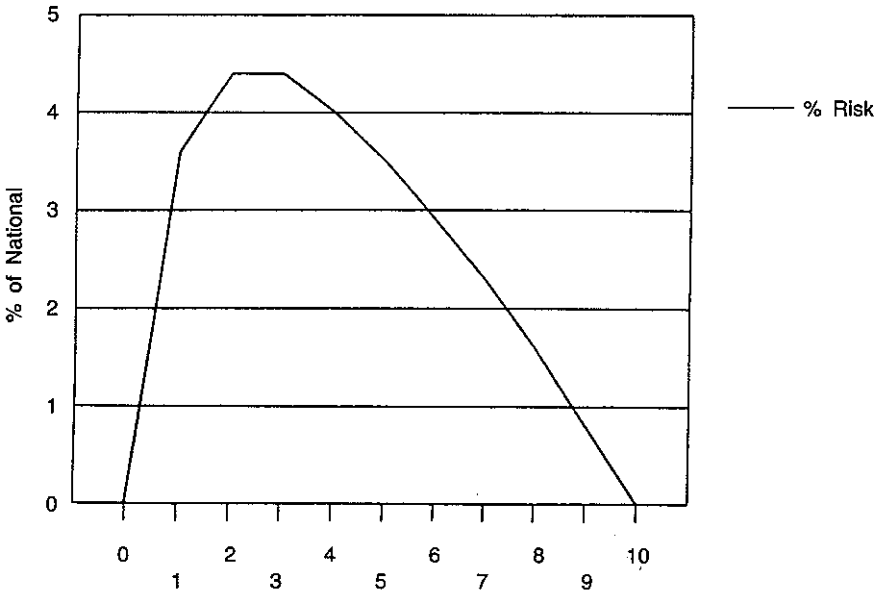


Figure 22.1 Expected Swap Replacement Cost 9% Ten-Year Plain Vanilla Swap

immediately with another swap at the same rate), but as interest rates begin to move, the risk rises; against that, the amortization effect kicks in as time moves on.

DANGERS OF RISK FORMULAS

There are several ways to assess risk. The risk assessment methods laid down by the BIS are those that have been agreed on by the supervisors. That is not to say that they are perfect; in some ways, they are dangerous. The mechanical application of formulas to credit risk is never appropriate. Each case has to be looked at in the light of the precise structure of the deal to make sure that all cash flows have been properly captured in the credit analysis. The risk on a deal involving forward Saudi riyals, where one side settles on Friday and the other on Saturday (see Chapter 9), is very different from a forward dollar/mark deal, for example, where both sides will settle on the same day (but even there, there is a time-zone risk).

Another example is the formula applied for swap risk. It needs to be carefully applied with regard to the actual cash flows involved. In some swaps, the interest payment varies; that is, interest might be paid by one party quarterly, and by the other party only semiannually. In this case, the party paying out funds quarterly has a greater risk than the semiannual payer. Suppose A pays \$5 million quarterly to B, in the expectation of being paid six-month LIBOR (London Interbank Offered Rate) by B. If, after a quarterly payment, B defaults, then A has paid out \$5 million that is lost, in addition to any "replacement cost" of replacing the swap. In this case, the BIS factors would need to be adjusted upward to allow for the cash flow pattern.

In drawing up its regulations, the BIS had to grapple with the fact that the credit risk implied by market activities is fundamentally different from that in normal lending activities. Thus, for example, a bank that lends money to an industrial company will do so in the knowledge that, if its credit analysis has been inadequate or if economic conditions turn unfavorable, it will lose 100% of its loan, together with any interest accrued but unpaid thereon. Depending on the strength of its security and on the efforts of any liquidator or administrator, some or all of the loan may be recovered in due course in a "work-out" situation.

But the credit risk implied by market risk is quite different. Unlike a loan to an industrial company, the amount of credit risk is not known for certain on day one. It will depend on market conditions. Suppose a bank contracts to buy forward from company A the sum of GBP 10 million at \$1.90. The bank knows that in one year's time, it is contracted to pay out \$19 million and to receive GBP 10 million. It will cover its position by a matching deal in the forward exchange market at, say, \$1.9100. Thus, it is contracted to receive GBP 10 million, paying away \$19 million, and to pay away GBP 10 million in exchange for \$19.1 million, for a clear fixed profit. But suppose that after three months, company A goes bankrupt. The sterling that was due to be delivered, now due in nine month's time, will no longer be forthcoming. So the bank must go into the market to buy sterling, otherwise it will have an open forward exchange position, which could be highly risky. Suppose that sterling is now at \$1.70 for delivery in nine months' time. Then the bank would have a profit; it now must pay away only \$17 million to get the GBP 10 million that it is contracted to hand over in exchange for \$19.1 million. Conversely, if sterling were at \$2.00, the bank would be on a loss because to get its hands on the GBP 10 million, it must now pay \$20 million, and it will still receive only \$19.1 million.

Therefore, the credit risk implied by a forward exchange deal with a customer is not “hard,” but “soft”; that is, bankruptcy of the counterparty could conceivably give a profit to the bank. (In practice, however, this is most unlikely. It is likely that the liquidator or the administrator of a failed company would try to insist on retaining the existing forward foreign exchange contract if it were profitable for the company and try to walk away from it if it were not—the so-called cherry-picking problem.)

Similar problems apply to any of the other interest or foreign exchange contracts that we are discussing, such as interest-rate swaps. In every case, the true credit risk cannot be measured in advance. Thus, the BIS formula, like any other possible credit-risk-measurement method, is essentially a guess at the unknowable. It is critically important for those who are managing the risks involved to be clearly aware that simply because a formula has been laid down by the BIS does not make that formula the best possible method or the only method of measuring true counterparty exposure.

SETTLEMENT RISK

In Chapter 19, mention was made of the settlement problems that led to the Bank of New York’s urgent need for an overnight overdraft of US\$ 24 billion. No more-vivid illustration is required to show how settlement problems have the potential to bring an institution to its knees—though it should be added that the Bank of New York survived “with a little help from its friends.”

The authorities are well aware of the risks involved. Currently the Basle Committee is looking at these and related issues under the rubric of “operational risk”; and in due time one could expect to see a new framework for capital requirements in this area.

Because of the importance of settlement systems for international financial markets, central banks have spent much time analyzing them. The first step was that in 1990 a report prepared by a group under Alexandre Lamfalussy of the BIS laid down a set of standards for cross-border and multilateral netting systems. These were as follows:

1. Netting schemes should have a well-founded legal basis under all relevant jurisdictions.

2. Netting scheme participants should have a clear understanding of the impact of the particular scheme on each of the financial risks affected by the netting process.

3. Netting scheme participants should have clearly defined procedures for the management of credit risk and liquidity risks that specify the respective responsibilities of the netting provider and the participants. These procedures should also ensure that all parties have both the incentive and the capabilities to manage and to contain each of the risks they bear and that limits are placed on the maximum level of credit exposure that can be produced by each participant.

4. Multilateral netting systems should, at a minimum, be capable of ensuring the timely completion of daily settlements in the event of an inability to settle by the participant with the largest single net debit position.

5. Multilateral netting systems should have objective and publicly disclosed criteria for admission that permit fair and open access.

6. All netting schemes should ensure the operational reliability of technical systems and the availability of backup facilities capable of completing daily processing requirements.

We begin by taking a closer look at the credit risk implicit in foreign exchange settlements, a subject that has been the subject of much recent work at the BIS and elsewhere.

CREDIT RISK

Settlement failures can present a significant counterparty credit risk. The classic example is the collapse of Bank Herstatt in 1974. In this case Herstatt was closed by the German authorities at 4 P.M. Frankfurt time. As a result, those who had paid deutschemark to Herstatt to settle U.S. dollar/deutschemark trades lost their money. This was because the New York CHIPS (Clearing House International Payment System) immediately froze Herstatt's account (at 10 A.M. New York time). Hence the dollar countervalue was never paid.

Other examples of similar collapses were the failure of BCCI in July 1991 and the bankruptcy of Barings in 1995.

It is clear that the impact of a settlement failure is not limited to the credit risk. Foreign exchange settlement risk also has a liquidity dimension. If a bank does not receive the currency it has bought when it falls due, it will need to cover this shortfall. It will need financing in that currency. In fact, even if the bank is able to withhold the currency it was due to deliver, it will still have a liquidity shortfall in the currency bought.

A recent study of this issue by the BIS² set out the following definition of *foreign exchange settlement exposure*: "A bank's actual exposure—the amount at risk—when settling a foreign exchange trade equals the full amount of the currency purchased and lasts from the time a payment instruction for the currency sold can no longer be cancelled unilaterally until the time the currency purchased is received with finality."

To develop a practical method for measuring exposure, the BIS report suggested classifying a trade into the following categories:

Status R: Revocable. The bank's payment instruction for the sold currency either has not been issued or may be unilaterally cancelled without the consent of the bank's counterparty or any other intermediary. The bank faces no current settlement exposure for this trade.

Status I: Irrevocable. The bank's payment instruction for the sold currency can no longer be cancelled unilaterally. This is either because it has been finally processed by the relevant payments system or because some other factor (e.g., internal procedures, correspondent banking arrangements, local payment-system rules, laws) makes cancellation dependent on the consent of the counterparty or another intermediary. Yet the final receipt of the bought currency is due some time from now. In this case, the bought amount is clearly at risk.

Status U: Uncertain. The bank's payment instruction for the sold currency can no longer be cancelled unilaterally. Receipt of the bought currency is now due, but the bank does not yet know whether it has received these funds with finality. In normal circumstances, the bank expects to have received

²*Settlement Risk in Foreign Exchange Transactions* (Basle: BIS, 1996).

the funds on time. However, because it is possible that the bought currency was not received when due (e.g., owing to an error or to a technical or financial failure of the counterparty or some other intermediary), the bought amount might, in fact, still be at risk.

Status F: Fail. The bank has established that it did not receive the bought currency from its counterparty. In this case, the bought amount is overdue and remains clearly at risk.

Status S: Settled. The bank knows that it has received the bought currency with finality. From a settlement-risk perspective, the trade is considered settled and the bought amount is considered no longer at risk.

Figure 22.2 illustrates this simplified description of the settlement process.

Clearly, the times involved in each stage vary from bank to bank. But the exposure can be measured. For banks that can always identify their failed payments and final receipts promptly, current exposure will be the sum of status F and status I trades. For banks unable to identify failed trades promptly, the exposure will be unknown. It will be at least the sum of status F and status I trades plus some part of the status U trades.

The BIS did a survey of market practices. It found that for most of the banks surveyed, the minimum foreign exchange settlement exposure of an individual spot or forward trade (the status I period) was between one and two business days. Furthermore, it can take from one to two business days for many banks to establish actual receipt of the currency (the status U period). As a result, the settlement exposure can often be more than three business days—plus any intervening weekends and holidays.

Banks can incur settlement risk no matter which currency they buy or sell. Even where the currency bought is settled before the currency sold, the buying bank might have to give irrevocable instructions for delivering the currency sold before the currency bought settles.

This situation reflects the fact that most settlement systems were designed mainly to be efficient rather than to control settlement risk. Automation in the form of “straight-through processing” has provided many benefits. But the price of this is that it can create a situation in which a bank or its correspondent cannot cancel unexecuted payment instructions even before settlement day.

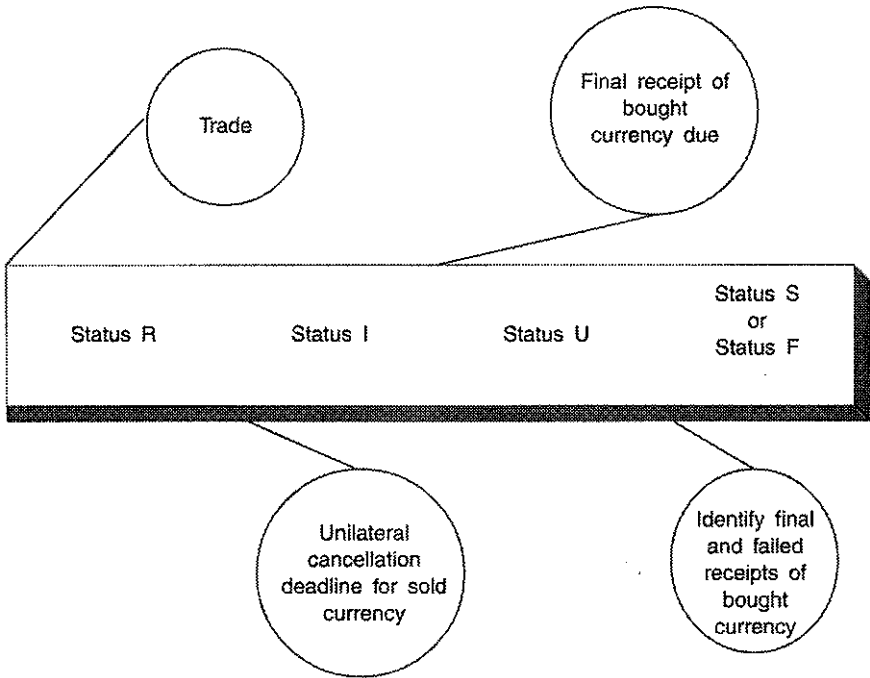


Figure 22.2 Foreign Exchange Settlement Process: Changing Status of a Trade. *Source:* “Settlement Risk in Foreign Exchange Transactions” (Basle: BIS, March 1996), p. 34.

In 1994, the New York Foreign Exchange Committee published a report on settlement risk that defined “best-case” foreign exchange settlement practices as those that would give a bank the following capabilities:

- To cancel its payment instructions unilaterally up until the opening time on settlement day of the local large-value transfer system.
- To identify its final and failed receipts immediately on finality of the local large-value transfer system.

There is also scope for at least some market participants to reduce the amount at risk during the settlement process via netting arrangements. These were discussed in Chapter 19.

UNITED STATES CLEARING SYSTEMS

The two main clearing and settlement systems relevant to the international markets in the United States are (1) the Fedwire service provided by the Federal Reserve Bank and (2) the Clearing House Interbank Payment System (CHIPS) operated by the New York Clearing House Association. Fedwire is used principally for domestic payments, whereas over 70 percent of CHIPS payments are dollar-denominated international payments. Fedwire is normally used for interbank overnight loans, interbank settlement transactions, corporate-to-corporate payments, and settlement of security transactions (via the Fedwire security system, see later section). In contrast, CHIPS is used to settle foreign exchange transactions and eurodollar placements.

Over 11,000 depository institutions use Fedwire. Approximately 7,000 of these are connected to the Federal Reserve via local data communication networks. Fedwire transfers are actually accounting entries effected on the books of the Federal Reserve. The sending bank authorizes the Federal Reserve to debit its account and to credit the account of the bank that is to receive the transfer.

Compared with other cashless payments, Fedwires are unique in that the Federal Reserve treats them as final and irrevocable payments; that is, once the Federal Reserve has delivered an advice of credit to the receiving depository institution, it will not reverse the credit. Because of the significant credit exposures implied, the Federal Reserve implemented a program to reduce payment-system risk in 1985. A notable feature has been the decision to charge for daylight overdrafts by the minute, thus giving firms an incentive to control carefully their use of unsecured credit from the Federal Reserve.

The CHIPS System

The New York Clearing House Association runs CHIPS, one of the largest payment systems in the world; it handles U.S. dollar transfers for the foreign exchange and Eurodollar markets.

CHIPS is a private-funds transfer network with no central bank support; and as a result, all risk is borne by the participants. To control these risks CHIPS has a number of safeguards. The first was bilateral limits, introduced in 1984. These let a member limit its exposure to other members. Each member is to indicate whether it is willing to receive payment messages from

each other member. If it is willing to receive payment messages from a member, it must set a limit on the maximum net dollar amount it is willing to receive from that member.

CHIPS checks all payment messages against bilateral limits. If a payment message would cause a member to exceed the bilateral limit that the receiving member has set for it, CHIPS will not allow the message to be released. CHIPS members may adjust bilateral limits at any point during the operating day and during the 20 minutes before the system opens for payment-message processing.

At the close of a normal business day, each settling member that is in debit must send a Fedwire for that amount to the CHIPS settlement account at Federal Reserve Bank of New York (FRBNY). After all debtors have paid, CHIPS will send Fedwires to the creditors.

Federal Reserve Book-Entry System

The Fedwire book-entry securities system services all marketable U.S. Treasury securities, many federal agency securities, and certain international agency securities. Of these, the most important for our purposes, because of their role in the repo markets, are Treasury notes and bonds.

Treasuries settle through the Fedwire book-entry securities system, which is operated by Federal Reserve banks. The Fedwire book-entry securities system is a real-time delivery-versus-payment (DVP) gross settlement system that requires the immediate and simultaneous transfer of securities against payment. Depository institutions that maintain funds accounts at a Federal Reserve bank are eligible to maintain book-entry securities accounts at a Reserve bank, as are certain nondepository institutions, subject to certain settlement restrictions.

Another important settlement vehicle for Treasuries, particularly for repo market participants, is the Government Securities Clearing Corporation (GSCC). This was established to provide a netting mechanism for the clearance and the settlement of U.S. government securities in both the primary and the secondary markets for Treasury securities.

Participants in the clearance and settlement of Treasury securities include the Federal Reserve, GSCC, members of GSCC referred to as Comparison members and Netting members, and clearing agent banks (banks that settle on behalf of members). GSCC and each of its members has a designated

clearing agent bank that operates through the Fedwire book-entry for securities system.

UNITED KINGDOM

Money Transfer Systems

In the United Kingdom, large-value payments are primarily handled by the Clearing House Automated Payment System (CHAPS) system. In addition, separate payment arrangements support the Central Gilts Office and the Central Money Markets Office.

The CHAPS system includes 16 banks, including the Bank of England. These are the settlement banks. There are also around 400 institutions with CHAPS participant status, which by virtue of agency agreements with settlement members can have CHAPS payments addressed directly to themselves via their agency account.

In the second quarter of 1996, the CHAPS system became a real-time gross settlement system. Each payment instruction generated creates in turn a settlement request, which is sent to the Bank of England. If the sending bank has sufficient funds on its account, the Bank of England will settle the transaction. It will then return a confirmation to the sending bank. As soon as this confirmation is received, the main message containing the whole payment details will be released automatically to the receiving bank. The latter will know that it has received final and irrevocable payment.

The ability of banks to process payments through the CHAPS system is constrained by their availability of funds on the settlement account. To allow for the smooth flow of payments through the CHAPS system under Real-Time Gross Settlement (RTGS), the Bank of England provides CHAPS banks with additional intraday funds by same-day repo agreements (interest-free).

Central Gilts Office

The Central Gilts Office (GCO) operates from 8:30 A.M. to 2:50 P.M. It is in the process of being merged with CREST (see later section). Instructions can only be input on the day of settlement; most trades are for next-day

settlement. Delivery of the stock is effective in real time once the seller has input the details and the buyer has positively accepted, provided the seller has sufficient stock on its account. At the moment when the CGO transfers stock from the account of the seller to that of the buyer, an unconditional and irrevocable obligation by the buyer's settlement bank to pay the seller's settlement bank is created. Thus the system is a version of a Model 2 DVP (delivery-versus-payment) system.³

The European Settlements Office

The European Settlements Office (ESO) is a system that handles settlements of instruments denominated in ECU (European Currency units), and presumably it will handle euro settlements in due course. The ESO is linked to Euroclear and Cedel and thus allows members access to all ECU securities issued into these entities. Deliveries against payment must be input by 11:30 A.M. Deliveries input after that time for same-day settlement must be free of payment. Same-day settlement is not possible for delivery to counterparties in Euroclear or Cedel. Such deliveries must be input by close of business the previous day. Forward-dated deliveries can be input up to one year ahead. As soon as the essential details of the trade input by both parties have been automatically matched by the system and providing that the buyer has sufficient funds and the seller has sufficient securities, transfer takes place on a real-time basis. Transfers are final and irrevocable. When the securities move, an *assured payment* (i.e., an irrevocable and unconditional instruction to the buyer's bank to pay the seller's) is created.

The Central Money Markets Office

Membership in the Central Money Markets Office (CMO) is open to all London money markets institutions. Currently around 60 firms are members,

³The BIS report "Delivery Versus Payment in Securities Settlement Systems" (Basle: BIS, September 1992) defined three models by which delivery of securities might be linked to payment: Model 1, where both securities and funds are settled on a gross trade-by-trade basis; Model 2, where securities settle gross throughout the day and funds settle net at the end of the processing cycle; and Model 3, where both securities and funds settle on a net basis at the end of the processing cycle.

with 200 participating indirectly through agency arrangements with CMO members. The CMO provides a central depository for money market instruments and an electronic book-entry transfer system that caters for a variety of sterling bearer instruments. Processing is continuous between 8:30 A.M. and 4:45 P.M. Deliveries against payment, however, cannot be accepted after 3:45 P.M.

When the CMO transfers instruments from the seller's account to the buyer's account, an instruction to the buyer's settlement bank is generated simultaneously. These instructions (unlike their counterparts in the CGO) are not assured, i.e., they are not irrevocable and unconditional.

Crest

CREST has been designed to handle the purchase, sale, loan, and repo of U.K. and Irish equities and corporate bonds and depository receipts. Securities in CREST are transferred continuously in real time against an irrevocable and unconditional payment obligation. It is in the process of taking over the functionality of the CGO.

CREST is a mechanism for holding and transferring shares and other securities in dematerialized (electronic book-entry) form. Thus, it maintains a record of all its members' eligible holdings of stock in computer book-entry form. It responds to electronic messages from members to transfer stock from one CREST account to another. It authenticates the origin and the content of messages it receives, compares the instructions input by the buyer and the seller, and matches them. It checks the availability on the settlement day of stock and cash in CREST members' accounts and moves the stock from the seller's account to the buyer's account. The buying member's bank will be instructed to pay the selling member's bank. It will be unconditionally obliged to do so, thus ensuring effective delivery versus payment (assured payment). Finally, CREST will notify the stock's registrar, who will have undertaken to register all valid transfers within two hours of the transfer in the system. As a result, the contents of a member's accounts in CREST and on the register will mirror each other.

CREST also provides a mechanism for providing collateral for stock borrowing, known as *deliveries by value* (DBV). It resembles the current arrangements in the Central Gilts Office. With this DBV mechanism, securities offered as collateral are actually delivered to the lender (as distinct

from previous arrangements within Talisman, where a floating charge was taken over securities that remained in the borrower's possession).

JAPAN

The primary clearing system in Japan with which we are concerned is that run called by the Bank of Japan, called BOJ-Net. The BOJ-Net consists of two major parts: (1) the funds transfer system and (2) the securities transfer system. In April 1997 the Bank of Japan announced that it will convert BOJ-Net to real-time settlement by the end of the year 2000.

Settlement for funds transfers resulting from the Bank's market operations for bonds and bills and the Bank's payments/receipts related to treasury funds and Japanese government securities (e.g., payment of principal and interest), most of which are currently made by designated-time settlement, will be effected by "simultaneous settlement."

The Bank of Japan will provide intraday credit to cover a liquidity shortfall for individual participants in the form of fully collateralized intraday overdrafts. Interest will not be charged on intraday overdrafts, but if the funds are not repaid by the end of the business day, a considerable penalty interest rate will be applied.

Settlement of participants' net positions stemming from privately operated clearing systems—the Bill and Cheque Clearing System, the Foreign Exchange Yen Clearing System (FEYCS), the Zengin System, and the Tokyo International Financial Futures Exchange (TIFFE)—will be effected on an RTGS basis through a settlement account each system will open at the Bank.

The Bank also intends to abolish designated-time settlement (currently at 3 P.M.) for government bond settlements, which will make RTGS the only mode of settlement for Japanese Government Bonds (JGBs) over the BOJ-Net JGB transfer system by the end of the year 2000.

Other systems operational in Tokyo include the Tokyo dollar clearing, which provides a local Tokyo clearing system for dollar transactions. Dollar settlements work, in general, as follows: First, settlements are made by transferring funds between the dollar deposit accounts that participants hold with the same Tokyo branch of the U.S. bank, for example, Citibank. Second, the net settlement balances in the Tokyo branch are transferred to the New York head office and settled through CHIPS.

TARGET

The Trans-European Automated Real-Time Gross Settlement Express Transfer (TARGET) is the interbank funds-transfer system that has been set up to handle large-value transfers of euro. It links together the domestic RTGS systems of each country in the European Union (including the United Kingdom and other countries that are not members of the European Monetary Union).

Domestic RTGS systems are interconnected by common infrastructures and procedures called the *Interlinking system*. Within TARGET (as shown in Figure 22.3), the Interlinking system is composed of a telecommunications network, linked in each country to a local interface, called the national *Interlinking component*. These components transform the presentation of payment data from the national standard to the Interlinking standard and vice versa.

As an example, suppose that Deutsche Bank wishes to make a payment in euro to BNP in Paris. Deutsche send a message through the German EIL-ZV system, which transmits it via the German Interlinking system to the French Interlinking system. The latter then transmits it to the French TBF system, which in turn transmits the message to BNP.

TARGET operates as an RTGS system. Payment orders will be processed one by one, continuously. If there are sufficient funds on the sender's account,

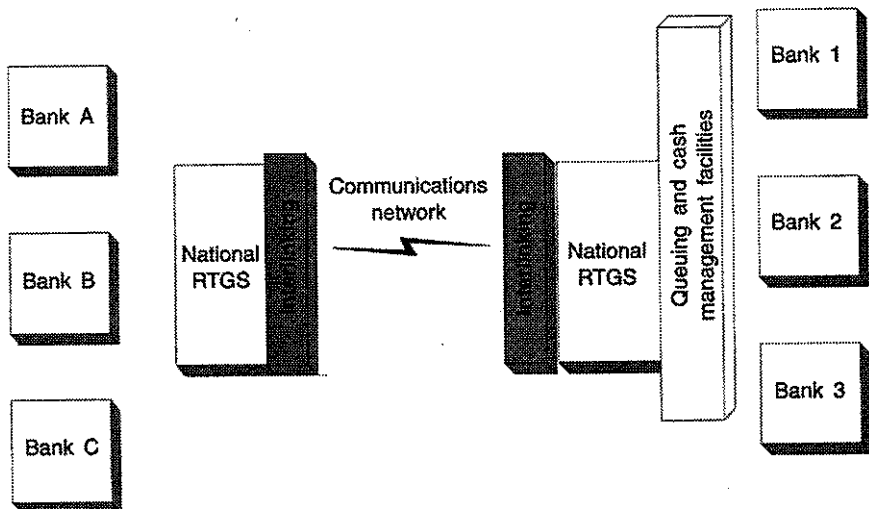


Figure 22.3 TARGET Structure

it will provide immediate and final settlement. In other words, the account of the receiving institution will never be credited before the account of the sending institution has been debited. As a result, the receiving bank will always know that funds received through TARGET are unconditional and irrevocable.

TARGET also operates as a vehicle for cross-border large-value net settlement systems, such as the Euro1 clearing system provided by the ECU Banking Association (discussed next). Basically, TARGET sits on top of national RTGS systems, and so each national RTGS system will keep its existing characteristics.

EURO BANKING ASSOCIATION: EURO CLEARING SYSTEM

In December 1996, the Euro Banking Association (EBA) announced its plans regarding the development of a commercial euro payment system, building on the existing ECU network.

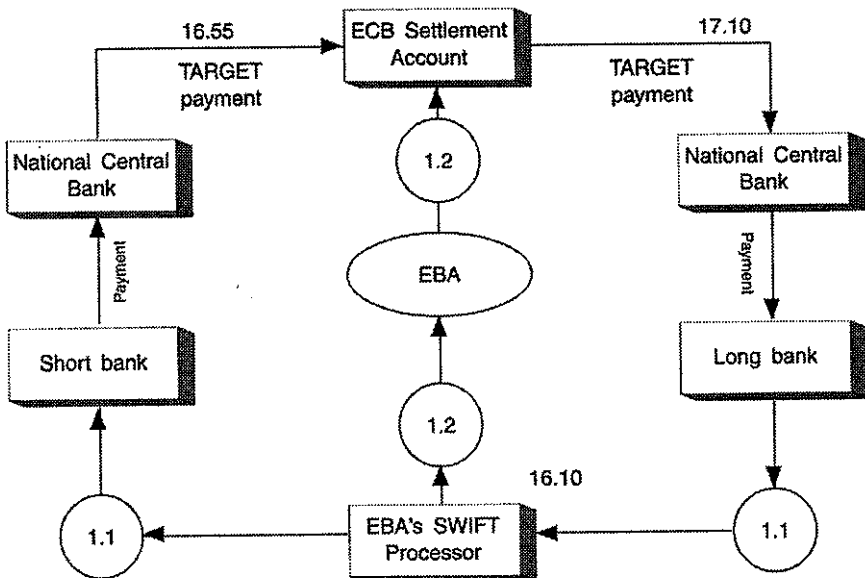
In Euro1, a member bank sends a SWIFT (Society for Worldwide Interbank Financial Telecommunications) payment message, which, using SWIFT's FIN-Copy service, will be identified as an EBA payment and copy to the central EBA processor (also operated by SWIFT). See Figure 22.4. Here the payment will be assessed against the relevant sending and receiving bank limits. Assuming that no limit breaches would result, the payment is processed and sent on, via the SWIFT network, to the receiving bank. Any payment that, if processed, would cause a limit to be breached is held in a queue until such time as other processed payments create the necessary room under the limit. As part of the EBA's real-time monitoring of member banks' net positions and queues, there is a facility for invoking a "circles processing" procedure. Each member bank has both a multilateral debit limit and a credit limit, which represent the maximum amount single obligation or claim of the member toward the community of all other members under the Single Obligation Structure.

The legal structure of the EBA system needed to accommodate the insolvency laws of all relevant legal jurisdictions. The EBA solution is the *Single Obligation Structure*, which can be seen as the legal description of a payment system whereby payment obligations are agreed, from the outset, to be on a net basis. The balance established for each participant at each

time a payment order is transmitted through the system constitutes the valid and enforceable payment obligation or claim of each participant toward the community of all other participants. Payment of the balance is due at an agreed cutoff time.

During the entire period from the first payment instruction a participant sends or receives on a particular day until the settlement of the net amount payable by or to such participants, there will only ever be one single payment obligation or claim of that participant. Because the Single Obligation Structure does not rely on set-off or novation of gross bilateral payment obligations, it is understood that it withstands the legal challenge of multilateral netting or bilateral netting in those jurisdictions where netting is not fully recognized.

Because from a legal perspective, the Single Obligation Structure does



SWIFT information messages:

1.1 Individual end-of-day balances sent to each bank

1.2 All end-of-day messages sent to EBA and ECB

Short bank: bank with debit balance

Long bank: bank with credit balance

Times are latest deadlines (CET) on a normal operating day.

Figure 22.4 Euro1 Structure. *Source:* Bank of England, "Practical Issues Arising from the Introduction of the Euro" (December 1998).

not rely on the gross amount of payment instructions sent and received between the relevant participants, this also means that, conceptually, the structure does not allow for an unwinding of payment instructions that have been processed by the system. As part of the process of demonstrating to the European Central Bank (ECB) that the system complied with the Lamfalussy risk standards, the EBA has obtained legal opinions that show that the structure (and the way that it is elaborated in the system rules) is legally binding and enforceable in all relevant jurisdictions.

FRANCE

Large-value payments in France are made through the Transferts Banque de France (TBF) system. TBF opens at 7:30 A.M. Banks may send messages at any time during the day by using the SWIFT network. The message is received by the Centrale des R glements Interbancaires (CRI), which transmits the message details to the TBF system. The latter then sends back notification of rejection, settlement, or queuing to the CRI. The CRI then sends this back to SWIFT, where the message is then forwarded to the receiving bank. The TBF accounting day is provisionally closed at 5:30 P.M. after which time each settlement account holder receives the balance of its settlement account, and all operations still in the queue are rejected. The TBF system is then reopened for an adjustment period with transfers to cover positions. The accounting day is finally closed at 6:30 P.M. after the last cash file from SICOVAM, the French securities depository, has been recorded to allow intraday repurchase agreements to be repaid.

The French system is highly sophisticated—in many ways more so than the U.S. systems—in that there is an intimate link between TBF and Relit Grand Vitesse (RGV), the securities settlement system, which is operated through SICOVAM. In July 1995 an agreement was implemented between the Banque de France and SICOVAM under which the Banque de France acquired 40% of SICOVAM's capital.

RGV offers real-time matching, settlement, and reporting cycles, operating 22 hours out of 24 for matching purposes. It delivers settlement finality as follows: SICOVAM continuously calculates each participant's purchasing power on the basis of cash positions with RGV; securities available as collateral, whether on account or in the course of processing; and (where appropriate) collateral and guarantees outside the system.

If a participant does not have enough cash to settle a securities transfer

during the course of the day, the Banque de France will be able to initiate repurchase agreements automatically to guarantee finality of payment and to eliminate intraday cash shortages. All of these repos must be settled by the end of the day. Thus RGV and TBF are very closely intertwined.

TBF is an RTGS system; the French market also operates a net system, the *Système Net Protégé* (SNP), a large-value net settlement system protected according to the Lamfalussy standards, by which payment becomes final only after end-of-day netting and settlement of balances via the TBF system.

GERMANY

The Bundesbank operates a large-value payment system that is a real-time gross settlement system, the EIL-ZV. Since January 1992, the EIL-ZV has been accessible via electronic link originally called the *Elektronischer Schalter* (ELS—"the electronic counter"). (Since the arrival of the euro, the name has been changed to "Euro Link System.") Originally, the EIL-ZV was designed as a decentralized system: the various branches of the Bundesbank each had a computer acting as a node in the network. The last cutoff time for urgent transfers is 2 P.M.

In addition, it operates an electronic net settlement system, EAF2. This system is used primarily for same-day clearing and settlement of interbank payments (e.g., money markets and foreign exchange market transactions). Payments from abroad play an important role, as can be seen from the fact that on U.S. bank holidays, turnover in EAF2 falls to 10% to 20% of normal turnover and virtually doubles thereafter.

EAF2 operates in two phases: (1) from 8 A.M. to 12:45 P.M. and (2) from 1 P.M. to 2:15 P.M. The first phase operates in 20-minute cycles. It is based primarily on the principle of using income payments as cover for outgoing payments, by offsetting them against each other as far as possible in each cycle.

The first step is that each participant decides a maximum sender amount for each bilateral counterparty. This amount is transferred to special blocked accounts at the Bundesbank and is assigned to the counterparty as security.

In each cycle, offset payments involved become final immediately, as under a gross settlement system, but no booking on an account of the Bundesbank takes place. Payments that are not offset are subsequently carried over into queues for the next processing cycle. This system has the advantage

that receiving institutions know that they have received with finality. But because the funds are not credited to a Bundesbank account yet, the liquidity is only available for covering outgoing payments in subsequent delivery cycles within the same bilateral relationship.

As a result, about 70% of the payments going through the system are final by 10:30 A.M., with the use of relatively small amounts of liquidity as compared with the normal gross settlement system (around DEM 2 billion to 3 billion, or only about 0.5% of the averaged delivered value of DEM 600 billion).

At the end of phase 1, all participants' bilateral positions are cumulated into a single debit and credit balance and booked on the Bundesbank account. At the same time, the original blocked amounts are unblocked. At this stage, central bank money is redistributed between the participants and can now be used freely.

At the start of phase 2 (1 P.M. to 2:15 P.M.), there is a multilateral clearing and settlement of payments that did not get offset in phase 1. If there are any outstanding debit amounts arising from this first multilateral clearing, the maximum volume of residual payments that can be cleared and settled is determined by an appropriate algorithm. Payments that are regarded as uncovered after this calculation are temporarily deferred to a second multilateral clearing and settlement. Participants are granted a 45-minute period to obtain cover. If the second multilateral clearing and settlement cannot be made to balance, individual payments are withdrawn and treated as revoked payments. Thus the EAF2 is always completed, and there is no possibility of unwinding, thus reducing systemic risk.

The system for securities settlement in Germany is operated by the central securities depository, Deutsche Börse (DB) Clearing. This holds 98% of bonds and almost all shares issued in Germany. It currently runs three securities batch-processing cycles. The first takes place on the evening before settlement date and the other two on settlement date. Under the TRUST project, the ultimate aim is for DB Clearing to operate in real time.

CANADA AND AUSTRALIA

The Canadian Payments Association (CPA) came into being in December 1980 with the objective of establishing and operating a national clearing and settlement system. The CPA runs its Automated Clearing Settlement System (ACSS), which began in 1984. Membership of the system consists of two

levels: (1) Direct Clearers and (2) other members. Direct Clearers represent themselves directly in the clearing-and-settlement process and act as clearing agents for other deposit-taking institutions. The settlement process begins at approximately 8:30 A.M. Ottawa (Eastern) time when certain regular transactions affecting Direct Clearers are carried out via the ACSS. These include government payments to and from the Direct Clearers. At 9:30 A.M., the preliminary net clearing gain or loss of each Direct Clearer is available to the institution from the ACSS. Until 11:00 A.M., bilateral adjustments take place to handle corrections. Shortly after 11:00 A.M., the final net gains and losses are available from the ACSS. At 1:30 P.M., Ottawa time, the Bank of Canada obtains each Direct Clearer's "national standing" and adjusts the balances of the Direct Clearers on its own books. At approximately 4:00 P.M., Ottawa time, following any final adjustments and any necessary central bank advances, the bank establishes the closing balances of each Direct Clearer as at the end of the previous day. Final settlement, therefore, takes place retroactively.

The Canadian Depository for Securities was federally incorporated in 1970. It provides services for the clearing and the settlement of securities transactions, which principally involve equity share transactions. Recently, however, money market instruments have been included, such as Treasury bills, banker's acceptances, bearer deposit notes, commercial paper, provincial and municipal notes, term deposits, and guaranteed investments certificates.

Clearing in Australia is managed by the Clearing House Committee, which consists of representatives of the major trading banks. Funds that have been cleared at the clearing house become eligible for the banks' exchange settlement accounts with the Reserve Bank. By 9:30 A.M., the Reserve Bank relays details of banks' exchange-settlement balances to market participants. It also advises the market of its expected activities in open-market bond operations.

Much money market clearing is handled through Austraclear. Austraclear was founded in 1984 as the central securities depository for bills of exchange, certificates of deposit and promissory notes, and fixed income securities, operating on a delivery-versus-payment basis.

SWIFT

In 1973, the Society for Worldwide Interbank Financial Telecommunications (SWIFT) was founded. It first went live on a limited basis in Europe in 1977

and was then extended to North America and the Far East and in 1984 to the Middle East. It is a computerized message switch whose major advantage is that it has a strict format requirement for messages. This allows banks to interconnect it to other computer systems such as CHIPS or Fedwire.

SWIFT is a key component of the international financial architecture because in addition to its original role as an interbank payment messaging system, it also operates the TARGET system and Euro 1, which were discussed earlier. It also plays an increasingly important role in securities messages and electronic trade confirmation in the securities markets.

CONTINUOUS LINKED SETTLEMENT

In 1997 a company called Continuous Linked Settlement Services Limited (CLSS) was set up to develop and build a continuous linked settlement (CLS) system for the settlement of foreign exchange trades. It will operate as a holding company with headquarters in London and a subsidiary, CLS Bank (which will be an Edge Act bank headquarters), in New York. The CLS Bank will hold the settlement account with a central bank for each currency in which it settles. Settlement members will pay CLS Bank through the local RTGS payment systems, and it will pay out settlement proceeds through these payment systems. The use of central bank accounts and RTGS payment systems ensures that inward and outward payments are secure and final.

The CLS Bank will operate multicurrency accounts for each settlement member. It will credit a member's account when it receives a payment from the member, debit/credit the account when it settles a transaction for the member, and debit the account when it pays out settlement proceeds. Because members can have debit positions (in effect, overdrafts) on their currency subaccounts, settlement can be completed on behalf of a member before the member has paid in all the funding to cover the settlement. However, CLS Bank will ensure that even though some subaccounts may be in debit, these will always be covered by surplus positions in other currency subaccounts at all times, so that CLS Bank does not have a credit risk to the member.

The critical point about CLS Bank is that it will operate a payment-versus-payment system: currencies will be exchanged simultaneously within the bank. Suppose a member is due to settle a payment of \$11 million against EUR 10 million. Its account will be debited with the \$11 million only if the EUR 10 million can be credited to it from the other member's account.

The way in which this will work is that CLS Bank will be advised of payments to go through the system by its members before the settlement date. From this information, it will work out a schedule according to which members must pay in funds to cover any short positions. Note that, in the interests of efficient use of liquidity, members will not necessarily be required to pay all the money in immediately but will be able to pay during the course of the funding period, which at the time of writing is fixed at 7 A.M. to 12 P.M. CET (Central European Time).

When payments are received, CLS Bank will be notified and will credit the member's account. It will settle as many transactions as possible from the waiting queue. It will then calculate how much of members' available long balances can be paid out, while ensuring that members still maintain a positive net overall balance on their accounts and that the CLS Bank has sufficient funds.

The CLS process will move between these tasks every few minutes, taking in payments as they arrive, settling transactions from the queue, paying out, taking in new payments, and so on, repeatedly through the processing cycle. In effect, it will operate as a continuous process, continually trying to settle remaining transactions and paying out available settlement proceeds as fast as possible.

Appendix A

Basic Statistical Concepts

Many of the modern techniques of risk management use statistical concepts. So in this section we will cover the minimum required for you to be able to understand value at risk and related ideas. We cover, in this section, the concepts of *the mean, standard deviation, variance, covariance, correlation, the normal distribution, and confidence intervals*. Each one of these ideas is fairly simple on its own, but joined together, they become some powerful tools for sophisticated risk management.

MEAN AND STANDARD DEVIATION (VOLATILITY)

Let us take five firms that ship goods by road. We want to analyze their losses due to accidents, theft, and so on. To do this, we take a sample journey for each firm and find that the results (losses) are: \$10, \$20, \$30, \$50, and \$90. The mean, or average, loss is $(10 + 20 + 30 + 50 + 90)/5$, or \$40.

But often we need to know how much variation there is between the firms—how reliable is the average of \$40? We need a measure of the variability of the data. Two common measures are the *variance* and its square root, the *standard deviation*. (The standard deviation is often called “volatility” in financial markets.) To find the variance, we work as follows. We have worked out the mean loss of \$40. For each shipment, we work out the deviation from the mean (designated X). Because the deviation may be positive or negative and, hence, would cancel if added up, we first square the deviations before adding them.

X	$(X - \bar{X})$	$(X - \bar{X})^2$
10	-30	900
20	-20	400
30	-10	100
50	10	100
90	50	2,500
		<u>4,000</u>

For technical reasons to do with the sample size, we divide the total of 4,000 by $(n - 1)$, where n is the number of observations. Thus we arrive at a figure for the variance of $4,000/4$, or 1,000. But this is in units of dollars squared. This is not very meaningful. Because the standard deviation is the square root of the variance, it is measured in more understandable units. In this case, $\sqrt{1,000}$ equals \$31.62. If you think about it, the standard deviation turns out to mean exactly what it says—the typical, or standard, deviation that you might expect to see in the data.

Figure A.1 illustrates the five items of data and their deviation from the average. The figure also shows the typical, or standard, deviation up or down of \$31.62. This gives an idea of how variable the underlying data is.

The formal definitions are as follows:

- Sample mean: $\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$

where $\sum_{i=1}^n x_i$ means “Add up $x_1, x_2, x_3, \dots, x_n$ ” and n is the number of items in the sample.

- Sample variance: $\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}$

- Sample standard deviation (i.e., square root of variance): $\sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}}$

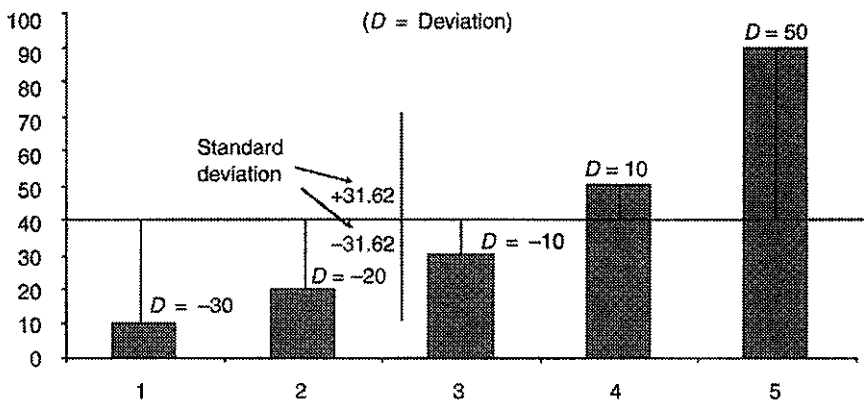


Figure A.1 Mean and Standard Deviation

NORMAL CURVE

The *normal distribution* is a very well known statistical distribution. This is because, given enough observations, very many distributions tend toward the normal. Hence it is important in financial markets as well as in many other areas of statistics.

Take a simple example as follows. A conventional six-sided die is tossed n times. We note the total of the dots as T . If we toss the die only once, T may take the values 1, 2, 3, 4, 5, or 6. For any given one of these numbers, the probability it will turn up when we throw is $1/6$. This produces a uniform distribution, which has mean 3.5 and variance 2.916. It is plotted in Figure A.2. The normal distribution, with the same mean and variance, is also shown. Clearly, the two probability distributions are quite different.

Suppose we now toss the die twice— $n = 2$. Now T may take the values 2, 3, . . . , 12. Now the probabilities are $1/36$, $2/36$, $3/36$, $4/36$, $5/36$, $6/36$, . . . , $1/36$, that is, the chance of throwing a total of 2 is the probability of throwing 1 each time. We know this is $(1/6) \times (1/6)$, or $1/36$. But we can throw a total of three in two ways: by throwing 2 and 1, or 1 and 2. Hence the probability that $T = 3$ is $2/36$. We can throw 4 in three ways: 1 and 3, 3 and 1, or 2 and 2. Hence its probability is $3/36$; and so on. This distribution, with mean 7 and variance 5.83, is plotted in Figure A.3, together with a normal distribution having the same mean and variance. They look more like each other than before.

Similarly, when $n = 3$, we get a probability distribution with a mean of

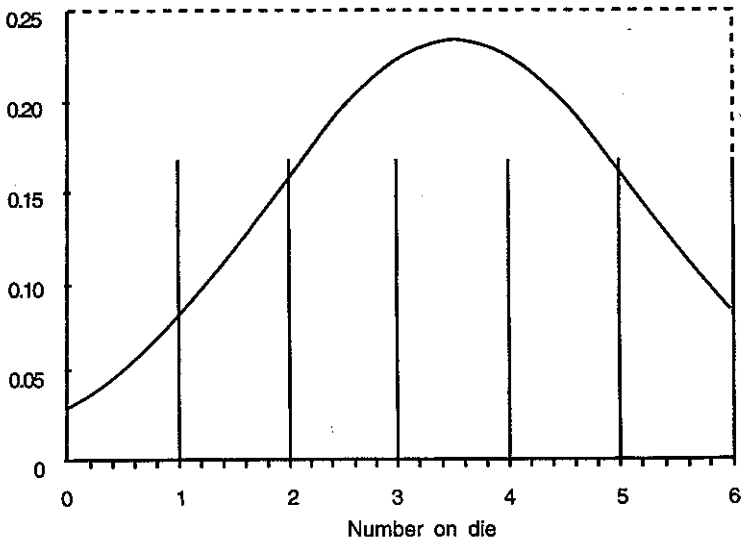


Figure A.2 Normal Distribution versus Throw of Die

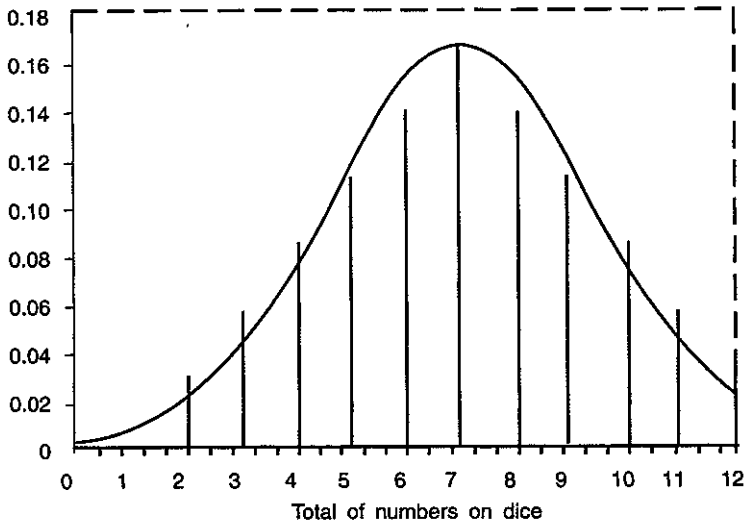


Figure A.3 Normal Curve and Two Throws

10.5 and variance 8.75, and in Figure A.4 we plot the normal distribution having the same mean and variance. Here the resemblance between the two distributions is quite noticeable.

This example was chosen because the two distributions converge quickly. But the same process holds good, even if it happens more slowly, for many statistical distributions. Hence the great importance of the normal distribution in statistics. If we have large numbers of items in a sample—for example, of percentage changes in exchange rates or claims under motor insurance policies—it is often practical to assume that they are normally distributed.

COVARIANCE AND CORRELATION

Often we want to know how two sets of data are related. A common measure of this is the covariance of the two sets of data. Suppose two stock markets, A and B, show the following percentage returns, measured over 100 periods:

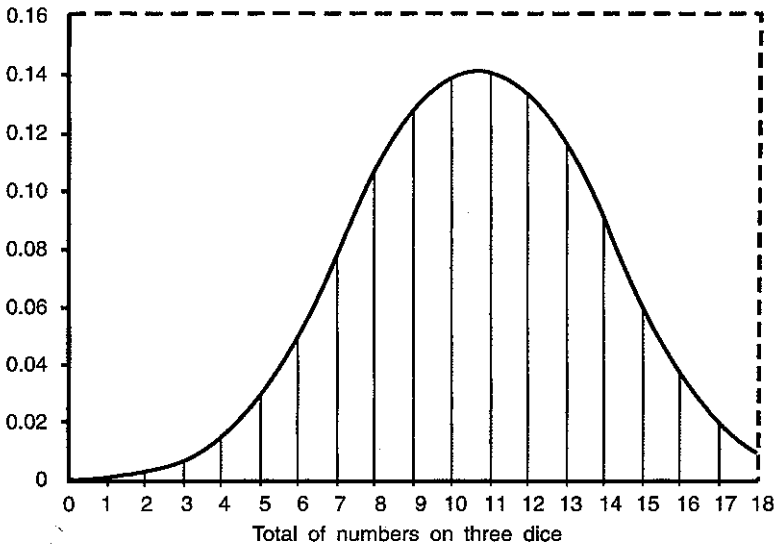


Figure A.4 Normal Curve and Three Throws

<i>B</i>	<i>A</i>				Total
	10	20	30	40	
10	20	4	1	0	25
20	10	36	9	0	55
30	0	5	10	0	15
40	0	0	0	5	5
Total	30	45	20	5	100

In other words, if *B* produces a 10% return, *A* also produces 10% during 20% of the time. But 4% of the time, *A* produces 20% when *B* produces 10%; and 1% of the time, if *B* produces 10%, *A* produces 30%.

We can work out from this data that the variance of *A*'s returns is 70 and of *B*'s returns is 60. What we want to know is: How well correlated are the two markets' returns? If they were perfectly correlated, there is nothing to choose between them. The results are probably explained by general world economic conditions. If not, there might be a significant difference between them.

For this we need the covariance, which is defined as:

$$\sigma_{A,B} = \frac{\sum_{i=1}^n (A_i - \mu_A)(B_i - \mu_B)}{n}$$

where A_i and B_i are the returns earned by *A* and *B*. We define μ_A and μ_B as the mean of the variable in question; and we have n observations. We can work out from the data that the covariance is 49. But, like the variance, the covariance units of measure are confusing. In this example, because both items are measured in percent, the covariance is measured in percent squared. This is not very useful. A better measure is the correlation, which we define as follows:

$$\rho = \frac{\sigma_{A,B}}{\sigma_A \sigma_B}$$

In other words, the correlation is the covariance scaled by the standard deviations of *A* and *B*. The advantage of this definition is that it is independent

of the units of measure. Correlation is always between -1 and $+1$ (or -100% to $+100\%$). A correlation of -1 is a perfect negative correlation. A rise in one variable is associated with a matching fall in the other. Conversely, a correlation of $+1$ implies that a rise in one is always associated with a rise in the other. A correlation of zero means that the two are independent. In our example, we have $49/(\sqrt{60}\sqrt{70})$, or 0.76 . In other words, about three-quarters of the time, the two markets are producing similar returns.

CONFIDENCE INTERVALS

Suppose that we have an estimate, \bar{x} , of the average of a given statistical population, where the true mean of the population is μ . Suppose that we believe that on average \bar{x} is an unbiased estimator of μ . In other words, we believe that on average \bar{x} is an accurate estimate; but for any given sample of data, the specific sample mean will almost always be above or below the true level. Hence if we want to be fairly confident that our inference is correct, we cannot claim that μ is precisely equal to the observed \bar{x} . Instead, we must say it falls within an interval estimate or confidence interval like this:

$$\mu = \bar{x} \pm \text{sampling error}$$

The crucial question is: How wide must this confidence interval be? The answer, of course, will depend on how much \bar{x} fluctuates. The first step is to establish how stringent we want to be. Suppose we decide that we want to be 95% confident that our estimate is accurate. Suppose, also, that we think that the elements of the population are normally distributed. In that case, we would expect that the population would be distributed along the lines portrayed Figure A.5.

A well-known fact about the normal distribution is that 2.5% of the values of a normally distributed variable can be expected to fall more than 1.96 standard deviations from the mean. Clearly, therefore, 95% of the outcomes can be expected to fall within ± 1.96 standard deviations. So there is a 95% chance that the random variable \bar{x} will fall between $\mu - 1.96$ standard deviations and $\mu + 1.96$ standard deviations. This would be called a "two-sided" confidence interval. It measures the chance of a move up or down by the variable outside the limits we would normally expect.

But a case can be made that we should only use a one-sided test if we

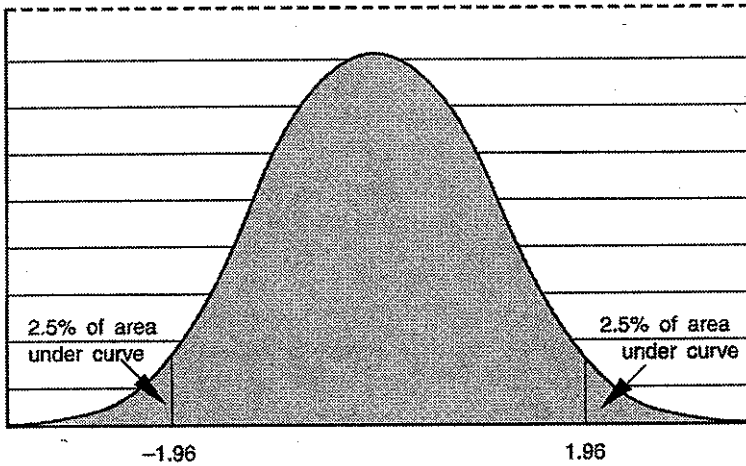


Figure A.5 Two-Sided Confidence Interval

are concerned with the risk of loss: a move upward into profit is of less concern. Another well-known fact about the normal distribution is that 5% of the values of a normally distributed variable can be expected to fall more than 1.65 standard deviations from the mean. This would be referred to as a one-sided confidence interval.

Let's take an example. Suppose we have a position in sterling. We are long of sterling at \$1.70. We think that \$1.70 is likely to be the mean of sterling's distribution. We think that the sterling exchange rate has an annual standard deviation of 17 cents (10% volatility). In that case, if we want a 95% confidence interval for sterling, we will set the interval at 1.65 times 17 cents (assuming a one-sided confidence interval); that is, an interval of 28.05 cents. In other words, we are 95% confident that sterling will remain above \$1.70 - 0.2805, or \$1.4195, during the next year.

Alternatively, if we were to set a two-sided confidence interval, we would use an interval of 1.96 times 17 cents—an interval of 33.32 cents. In this case, we would expect with 95% confidence that sterling would remain in the range \$1.3668 to \$2.0332.

Clearly, an annual standard deviation of 17 cents will translate into a smaller daily movement: in fact, to convert from annual to daily, we must divide the annual rate by $1\sqrt{250}$. (The denominator, $\sqrt{250}$, arises from the assumed number of 250 working days in the year. We use the square root

to conform with the definition of the normal distribution.) Thus the daily standard deviation is $17/15.811$, or 1.07517 cents.

Hence, on a daily basis, using a one-sided confidence interval, we would be 95% confident that sterling would not fall by more than 1.65×1.07517 , or 1.77404 cents; that is, we would be 95% confident that sterling would remain above \$1.6822. Using a two-sided confidence interval, we would be 95% confident that sterling would remain within the range $\$1.70 \pm (1.96 \times 1.07517)$, or \$1.6789 to \$1.7211.

RISK, UNCERTAINTY, AND DIVERSIFICATION

We need to be clear about the difference between uncertainty and risk. In the insurance world, the classic definition distinguishes between *uncertainty* and *risk*: “If you don’t know for sure what will happen, but you know the odds, that is risk; if you don’t even know the odds, that is uncertainty.” Uncertainty, then, is a situation in which we cannot apply “scientific” principles to risk management. All we can do is to consider what might happen to us under a worst-case scenario. Conditions of total uncertainty will not be discussed at much length in this book. But it is clear that, provided sound risk management disciplines are in place and the worst-case scenario has been assessed, an institution should be able to survive such a situation in normal circumstances.

A broader issue is the benefit or otherwise of risk diversification. Regulators and practitioners have argued about how much allowance should be made for the risk-reduction benefits of a diversified set of exposures in comparison with an undiversified set.

The point is that *risk falls as you include different types of asset, as long as their returns are not perfectly correlated. Diversification pays.* Say you hold both equities and bonds. They won’t normally both perform badly in the same year. So the weak performance of one will be offset by the other. The portfolio as a whole will be more stable than either asset individually. Diversifying reduces your risk.

Let’s look at a practical example. Suppose you think, after studying history and making your forecasts, that the following asset classes will produce a certain pattern of risks (defined as *standard deviation of return*) and returns. Let’s say, over the next five years, you expect:

	U.S. Bonds	Non-U.S. Bonds
Return	8%	9.5%
Risk (standard deviation)	9%	12%

And let's suppose you think the returns will have a correlation of 0.4—U.S. bond returns will vary in line with non-U.S. returns 40% of the time.

To work out the risk of the combined portfolio we need the covariance between the two assets: this is the reverse of the calculation earlier, where we derived the correlation from the covariance. So we take the standard deviation of each asset multiplied together and weighted by the correlation between the assets. So the covariance is $0.09 \times 0.12 \times 0.4$, or 0.00432. We'll also need the variances of the two assets, which are the squares of the standard deviations (0.0081 and 0.0144, respectively).

Before getting into the example, we will work through how to find the risk of a portfolio. The formula for the variance of a portfolio is a weighted average of the variance correlation between the positions:

$$\sigma_p^2 = w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + 2\rho_{12}w_1w_2\sigma_1\sigma_2$$

Here we are looking at a portfolio with two assets in it. The share of asset 1 in the portfolio is w_1 (as a decimal, e.g., 0.45) and the share of asset two is w_2 . We can see at once that if the correlation between the two assets is zero, so that the last term disappears, and both assets have the same volatility σ , then the portfolio risk is:

$$\sigma_p^2 = w_1^2\sigma_1^2 + w_2^2\sigma_2^2$$

Clearly, the overall volatility must be less than the volatility of the individual assets (because the weights are less than 1). So we have reduced our risk by diversifying.

Conversely, if both assets have the same volatility, σ , and the correlation is exactly 1, then we have:

$$\sigma_p^2 = w_1^2\sigma^2 + w_2^2\sigma^2 + w_1w_2\sigma^2$$

which is the same as:

$$\sigma_p^2 = (w_1 + w_2)^2 \sigma^2 = \sigma^2$$

because $(w_1 + w_2) = 1$. In other words, there is no benefit from diversifying into perfectly correlated assets. The portfolio risk is the same as that of the individual assets.

What about the cases in between? Suppose both assets have the same volatility, and we have half the portfolio in each asset ($w_1 = w_2 = 0.5$). Suppose the correlation coefficient is quite high: say, 0.90. Then we have

$$\sigma_p^2 = 0.25\sigma^2 + 0.25\sigma^2 + 2 \times 0.9 \times 0.5 \times 0.5\sigma^2 = (0.25 + 0.25 + 0.45)\sigma^2$$

In other words, provided the correlation is less than 1, the portfolio variance is always less than that of the components, given we assumed each asset had the same volatility.

COMBINING ASSETS

Now we can find the risk and return of a portfolio combining these elements. Suppose we start by holding everything in U.S. bonds. Then we gradually push up the share of non-U.S. bonds to 100%. Finding the return is an easy calculation: a weighted average. The risk is a little more tricky. We have to apply again the formula given earlier for the standard deviation of a portfolio.

Let's take the risk when we have 30% in non-U.S. bonds. The calculation is $(0.0081 \times 0.49) + (0.0144 \times 0.09) + (2 \times 0.7 \times 0.3 \times 0.00432) = 0.0070794$.

In words: (U.S. bonds variance \times Square of 70% weight) + (Non-U.S. bonds' variance \times Square of 30% weight) + 2 \times (70% U.S. weight \times 30% non-U.S. weight \times Covariance).

That is the variance of the combined portfolio: to find the standard deviation, we take the square root, which comes out at 0.084139, or 8.41%. So now we do the sums for all the different weights and we get:

Combined Portfolio

U.S. Fixed	Non-U.S.	Risk	Return
100%	0%	9.00	8.0
90	10	8.65	8.1
80	20	8.45	8.2
70	30	8.41	8.3
60	40	8.54	8.4
50	50	8.82	8.5

and so on.

As you push up the share of non-U.S. bonds, the risk of the combined portfolio falls from 9.00% to 8.41% when you have 30% in non-U.S. bonds. *While the risk is falling, though, the return is rising.* You can get 30 basis points more return for less risk if you push the share of non-U.S. bonds from 0% to 30%.

It must be said that in the worst case, many financial assets do show a high degree of correlation. The classic example is the Crash of 1987. Equity markets around the world showed much more correlation than normal. This point is discussed further in Chapter 19, under correlation risk. In practice, though, a diversified portfolio of risks will almost always be less risky than one that is not diversified. But we still have the problem of accurately estimating the correlation between our different exposures.

JP Morgan, for example, in its RiskMetrics model, calculates exponentially weighted averages of daily correlations. Others argue for different estimation methods. This is an area of continuing debate. However, it is quite clear that under normal circumstances, a widely diversified trading book will always be less risky than one concentrated in one or two instruments. (This assumes that there is sufficient management skill and understanding in each of the markets traded. A bank that trades short-date interest rates and then diversifies into aluminum trading may not be reducing its overall risk if the management do not understand the aluminum market.)

Appendix B

Islamic Value Dates

There are a number of complications in value dates for Islamic currencies. These complications are caused by the different working week and also by Ramadan: Friday is a holiday in Islam, whereas Saturday and Sunday are normal working days. A dealing room in a Moslem country dealing a currency such as the Saudi riyal deals the following dates:

Dealing Date	Spot Value
Monday	Wednesday
Tuesday	Thursday
Wednesday	Dollars Friday/Riyals Saturday
Thursday	Monday
Saturday	Wednesday
Sunday	Wednesday

Wednesday deals have split value dates because no Gulf payments can be made on a Friday. The Thursday value date moves to a Monday to enable people to deal against the dollar without making weekend adjustments. Saturday and Sunday deals move the value date to Wednesday to be in line with the rest of world markets when they open on Monday. For money market deals, people try to avoid having maturities on a Sunday or a Tuesday as spot deals are not usually done for these value dates.

Ramadan is another factor. Ramadan is the traditional month of fasting in Moslem countries. As a general rule, economic activity slows somewhat during this period. The problem for dealers is that the holiday at the end

of Ramadan (Eid) is determined by the sighting of the moon at the start of Ramadan. Hence, it is difficult to determine in advance. Also, the official holiday is three days, but some banks may close for up to 10 days. The accepted market practice with deals maturing during a holiday is to extend the deal at the existing rate until the first accepted clearing day after the holiday.

Some general remarks may be of help in understanding the Arab calendar. The Arab calendar is a lunar calendar, rather than the solar or Gregorian calendar used in the West. It starts from July 15 or 16 of A.D. 622, the year of the Hijra (Mohammed's flight to Medina). It is a 354-day year with 12 months. The odd months have 30 days, and the even months have 29 days. To keep the calculated lunar calendar in line with the new moon, leap years have to be included. There are 11 leap years in every 30 years: the 2nd, 5th, 7th, 10th, 13th, 16th, 18th, 21st, 24th, 26th, and 29th. So, to find out if a particular year is a leap year, one has to divide it by 30, take the remainder, and see whether it matches one of these years. For instance, A.D. 1982 is equivalent to A.H. 1403. We divide $1403/30 = 46.76$; $46 \times 30 = 1380$, so the remainder is 23, which is not one of the leap years in the cycle. So, 1403 is not a leap year, although 1404 will be because 24 is one of the cyclical leap years.

To convert a Hijra year (A.H.) into its A.D. equivalent, we proceed as follows:

1. Find out how far the Hijra calendar is ahead of our calendar by dividing the Hijra year number by 33 (33 Hijra years are equivalent to 32 years in our calendar).
2. Subtract the quotient (ignoring the remainder) from the Hijra year number. The answer will give the number of solar years since the Hijra.
3. Add 621 to the answer (621 is the number of whole years between the base dates of the two calendars). For example, take the Hijra year 1399: $1399/33 = 42$ remainder 13; so in 1399 lunar years, the Hijra calendar gained 42 years on ours. We subtract 42 from 1399 to find that 1357 solar years have elapsed from the Hijra. Then we add 621 to find that A.H. 1399 = A.D. 1978.

The conversion formulas to get from Hijra years (H) to Gregorian years (G) and vice versa are:

$$G = H - \frac{H}{33} + 621$$

$$H = G - 621 + \frac{G - 621}{32}$$

Bear in mind that 33 Hijra years equal 32 Gregorian years. These formulas give the Gregorian year in which the Hijra year begins. If we want the year in which it ends, we adjust by 622 rather than 621.

Because the two years do not match, Ramadan is continually starting earlier in the Gregorian year.

There may be slight variations from country to country. In particular, the Iranian calendar is different. And there may be a difference of a day or two between eastern and western Islamic countries as the visible new moon differs from the astronomic new moon calculations based on Mecca. There is an interesting general discussion in V. V. Tsybulsky, *Calendars of Middle East Countries* (Moscow: U.S.S.R. Academy of Sciences Institute of Oriental Studies, 1979).

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