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Russel Cooper, Gary Madden, Ashley Lloyd and Michael Schipp
December 2005

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PART II: Regulation, Pricing and Evaluation by Real Options

Introduction

Russel Cooper, Gary Madden, Ashley Lloyd and Michael Schipp

This volume analyses the economics of online markets and ICT networks. The most recent version of the Web has become a platform, and building new business on this platform is no longer a multi-million dollar undertaking. Start-up companies are leveraging a decade of innovation of technology that is proven, or very nearly so. What is different is that the Web's most recent innovative wave is driven by entrepreneurs not financiers. Search has provided a fundamental business model for many Internet-enabled companies. Past lessons led to building a new service that provides a sustainable revenue base from which to refine service offerings and the definition of a viable business model. Within this context, the volume examines the micro-economics of platform structure and firm competition within and between online markets, modern theoretical treatments of regulatory intervention in online markets and the consideration of forward-looking experimental analysis of demand for yet to be provided services.

The volume is divided into three parts: innovation and competition in online markets; regulation, pricing and evaluation with real options; and empirical approaches to market analysis. The structure of the volume is guided by the basic themes considered at the International Telecommunications Society's Africa-Asia-Australasia Regional Conference 'ICT Networks—Building Blocks for Economic Development', which was held in Perth Western Australia on 28-30 August 2005. The volume contains a selection of parallel session papers presented at the conference as well as five invited papers commissioned to augment the volume. The invited papers are authored by Abraham Hollander and Thierno Diallo (Chapter 1), Ian Harper, Ric Simes and Craig Malam (Chapter 2), James Alleman and Paul Rappoport (Chapter 9), Nadine Bellamy and Jean-Michel Sahut (Chapter 11) and Aniruddah Banerjee and Harold Ware (Chapter 12).

The Conference was sponsored by: Arnold & Porter LLP, BAKOM, BT, CRA International, Curtin Business School, Commonwealth Department of Communications, Information Technology and the Arts, Edward Elgar Publishers, Elsevier Science Publishers, France Telecom, IDATE, InfoCom Research, Inc., KT, Optus, NERA Economic Consulting, NTT DoCoMo, Physica-Verlag, Telcordia Technologies, Telenor and Telus. The Conference also received endorsements from the National Office for the Information Economy and the Organisation for Economic Cooperation. The conference was attended by 200 researchers, practitioners and regulators involved in telecommunications market analysis.

Part I: Innovation and Competition in Online Markets

The volume begins with six chapters concerned with firm behavior, viz., product bundling and development, and competition within online markets. The analyses relate both to markets for information goods and the platforms that act as a conduit for service delivery and a means to conduct market transactions. In particular, in Chapter 1, 'Pricing and Bundling of Shared Information Goods: The Case of Cable Channels', Abraham Hollander and Thierno Diallo consider the pricing and bundling decisions of a firm that sells a product shared on a regular basis among household members, in particular the bundling of television channels. The analysis explores under what conditions a cable firm will let households choose among the channels they subscribe to, and under what conditions the cable firm will offer them an all-channels-or-nothing offer. This analysis postulates that a potential viewer derives the same utility from every channel. How pricing and bundling decisions are affected by the structure of the fee that cable distributors pay for content to cable networks and the heterogeneity of households are explored. Ian Harper, Ric Simes and Craig Malam (Chapter 2 'The Development of Electronic Payments Systems') argue that electronic payments systems are transforming economic processes. However, e-payments system innovation must lead economy-wide diffusion, e.g., economy-wide diffusion requires established viable institutional structures. Namely, customers must be confident that payment instruments are secure and reliable. This chapter examines the forces driving the spread of e-payments instruments, and why the use of some instruments burgeoned while others struggle. Secondly, the analysis considers whether there are valid public policy reasons for authorities to intervene in these markets and, if so, how they should intervene. In Chapter 3 ('Behavioral Frictions in Online Contracting: Evidence from Yankee Auctions'), Mira Slavova seeks to identify bidding behaviors in online Yankee auctions and clarify relationships between behavior and allocation and payment outcomes. Main study concerns are identification of persistent bidding behavior; monotonic correspondence between bidding behavior and auction outcome; and between payment outcomes and submitted bid numbers. The study establishes a structure of behavior for submitted bids and explores their economic rationalization. An observed monotonic correspondence between behavior and auction outcomes is consistent with mechanism design. Alternatively, evidence suggesting behaviors result from heuristic problem-solving or reduced payoffs for bidders submitting multiple bids favor the transaction costs framework. Sumi Cho and Sang-Ho Lee (Chapter 4 'Online Channel Competition in a Differentiated Goods Market') introduce an online transaction channel into a Hotelling linear city model where online and offline firms coexist in equilibrium. To examine the competition effect of an online channel, a symmetric case of two offline firms is considered and welfare loss to online business measured. Compared to the pure online competition case, the introduction of an online channel by a hybrid firm may reduce welfare when consumer offline channel transport cost are 'large' relative to firms' online channel delivery costs. The analysis is extended to the asymmetric case whereby two offline firms supply different quality goods via an online channel. Finally, how the different quality goods supplied by hybrid firms impacts on the welfare of online markets is examined. Chapter 5 by Gary Madden, Truong Truong and Michael Schipp (‘Competition and Growth in Virtual Markets’) attempts to provide insights into the understanding of fundamental tradeoffs faced by B&M and Virtual firms competing in Virtual marketplaces for Type-2 customers. An innovation contained in the paper is the establishment of a link between firm relative locations within the Virtual market to investment and ultimately profit. This innovation enabled the derivation of some testable predictions. Some ways to move beyond current model assumptions could be the consideration of non-uniform distributions of Virtual consumers (in particular non-symmetric distributions due to the skewed age distribution of customers making purchases online), the introduction of market power and allowing both the B&M and Virtual markets to be made open to competition. Armando Calabrese, Massimo Gastaldi and Nathan Levialdi Ghiron (Chapter 6, ‘Mobile Network Prospects: A Multi-sided Platform Analysis of Competition’) conclude Section I by analyzing telecommunication markets before and after the introduction of an OMTP standard. Operators supply the same phone as producers but sell the good combined with a SIM card. The analysis assumes that firms act as a cartel to maximize joint profit, and producer and operator coalitions are distinct only when their telephones have different technical standards. A sequential game analyses three scenarios. In Scenario 1 the market is characterized by separate coalitions—producers supply telephones only and operators sell their telephones with SIM cards. Scenario 2 considers a market whereby an operator coalition with an OMTP standard competes with producers that only sell standard telephones. In Scenario 3 producers adopt the OMTP standard and mobile phones are not differentiated. A goal of the analysis is to identify conditions for the transition from Scenario 2 to Scenario 3.

Part II: Regulation, Pricing and Evaluation by Real Options

The next five chapters analyze traditional areas of concern to firms and regulators in telecommunications markets, i.e., technology choice and project evaluation when future revenue streams are uncertain. Kris Funston (Chapter 7, ‘Real Options and Telecommunications Regulation’) argues that when real option theory is applied to telecommunications investment the impact on the regulated fair rate of return depends on the uncertainty of returns. When demand is reasonably certain there is less of a case to apply the real options approach. Also, when an asset is reversible an investor has a put option. The overall result is that the allowed NPV fair rate of return may exceed the true user cost. Additionally, the option to wait could be less important when making investments and can potentially be ignored. Further, it is questionable whether an access provider should be allowed to recover a call option when the option has zero value in a competitive framework. When new network investment is irreversible, there is substantial uncertainty associated with the technology and future demand for services then access regulation may lead to a truncation problem arising. Finally, when an investor is able to vertically integrate downstream retail functions with network investment the problem associated with regulatory truncation may be less important. In Chapter 8, 'A Discrete Real Options Approach to Access Pricing', Guillermo Lozano and José María Rodríguez demonstrate that cost-based access pricing can be assimilated into traditional NPV calculations by using a lattice modeling approach to calculate access prices. The approach assumes a finite time horizon in discrete- rather than continuous-time. From a policy perspective, discrete-time models are easier to interpret and understand. Additionally finite-horizon models are closer to real world applications than perpetual models. Conversely, such models may omit important properties such as the accessibility of the valuation method, tractability of model values and flexibility to incorporate competitive interactions. This framework is convenient as delay options are readily built into the NPV framework without any additional assumption. The extended-NPV approach can be viewed as a correction to ensure that traditional NPV assumptions are consistently applied. Some numerical examples to illustrate and interpret the behavior of the model are provided. Chapter 9 by James Alleman and Paul Rappoport ('Optimal Pricing with Sunk Cost and Uncertainty') argues that in using static models of the firm regulators make errors in determining a proper wholesale price as the opportunity cost delay is neglected. For an incumbent, the option is exercised and represents an opportunity cost. For a potential entrant delay need not be exercised should the regulator allow the purchase of access at below economic cost. Thus service-based entry is excessive and facilities-based entry is suboptimal. When a regulated paradigm is dynamic the converse holds: optimal prices are higher than for static calculations; only efficient service entry occurs as prices are set at the correct economic marginal cost; facilities-based entrants receive correct price signals; social welfare is maximal; an incumbent's valuation by financial markets is higher; and the cost of capital is lower than for a regulated paradigm. In Chapter 10 ('Efficient Spectrum Policy Using Real Options and Game Theoretic Methods'), Tae-Ho Lyoo, Jongwook Jeong, Hyun-Jung Lee and Jeong-Dong Lee treat spectrum allocations as acquiring a right to provide service and propose a model to combine real options and game theory methods applied to the valuation of converging communications services including WCDMA, HSDPA and WiBro. Namely, a service provider with a spectrum allocation can decide when to begin operations. An option concerning the type of service provided over this spectrum is also available. The real options approach explicitly incorporates the value obtained from decision making flexibility. However, in modern competitive communications markets there are often several service providers that affect the revenue and cost streams of market participants. Clearly, interactions among market participants should be considered in any valuation process via game theory. Nadine Bellamy and Jean-Michel Sahut (Chapter 11, 'A Real Options Approach to Investment Evaluation with a Network Externality') conclude this section with development of an analytical framework to understand and quantify the valuation of an investment when network externalities are present. Modeling starts from a probabilistic demand modeling stance and the inclusion of an option to terminate the project. These elements allow the more accurate valuation of the investment. Expected free cash flow values are larger on average than values estimated via the deterministic NPV procedures. However, probabilistic NPV estimates require the calculation of confidence intervals to evaluate project risk. Conversely, the integration of the project termination option (put option) increases the project's value that is linked to the termination probability and savings from the early abandonment of the project. Finally, while the proposed modeling approach appears more realistic it raises questions as to the best means to obtain values for the termination parameters for effective scenario implementation

Part III: Empirical Approaches to Market Analysis

The final five complementary chapters concern innovative empirical approaches to market analysis. Andiruddah Banerjee and Harold Ware (Chapter 12, 'Mixed Logit Analysis of Carrier Market Share with Stated-preference Data') recognize that as the dramatic transformation of the telecommunications industry continues business planning and product management must be continually informed of new service demand. Stated-preference survey techniques are a means to elicit consumer preferences in telecommunications markets. The study illustrates the use of ranked stated-preference data to obtain market share and choice elasticity estimates for local telecommunications services purchased by business customers. A key study finding is that, in the newly competitive business telecommunications markets, incumbent service providers face more elastic demand responses than previously believed. Yong Yeop Sohn and Hun-Wha Yang (Chapter 13, 'Information Technology, Corporate Performance and Firm Size') develop several models to show that firm performance improves with IT adoption and use. Data on firms are obtained from a survey of Korean manufacturing establishments. Study findings indicate that adoption and use of IT is positively related to profitability and sales. Also, large-size firms typically use IT systems relatively more, and so the impact of IT use on performance is greater. However, no such difference between small and medium size firms is apparent. Actually, there is a divide in adoption of IT by firm size. Further, Korean firms use IT mainly for reducing costs and not marketing and customer management improvements. Finally, Korean informatization is significantly affecting firm performance when pursued to increase productivity and firm value. In Chapter 14 ('Contingent Valuation of Terrestrial DMB Services') Sangkyu Byun, Hongkyun Bae and Hanjoo Kim assess the potential economic value of emerging T-DMB services. Due an absence of market data, experimental data are obtained from a survey of potential users. A quantitative CVM analysis estimates the subscription fee users are willing to pay conditional on their demographic characteristics, experience with telecommunications services and attitude toward T-DMB. The estimated virtual market for T-DMB services is based on a monthly subscription fee provided to respondents in a DBDC questionnaire. The analysis concludes that DMB has a promising business model based on a relative high (compared to terrestrial TV) subscription fee. Revenue per frequency for T-DMB is higher compared to that for terrestrial TV, but is lower relative to mobile telephony service. Consequently, T-DMB has the potential to provide a new catalyst to growth for Korean IT industry. Jae-Hyeon Ahn, Sang-Pil Han, Kyoung-Yong Jee and Moon-Koo Kim (Chapter 15, 'Consumer Preference for New Wireless Data Services') develop a hierarchical decision structure of consumer choice for emerging mobile services by breaking down the choice problem into a hierarchical decision structure for interrelated service attributes. The analytic hierarchy process allows analysis of consumer preferences for service attributes to determine the relative attractiveness of alternative new mobile data services. Results indicate that the economic costs are perceived most important. Also, the monthly charge is most important among costs, while transmission speed and service coverage are more the important among benefits. To successfully introduce PIS services transmission speed must be improved, especially considering that WLAN has an enhanced transmission speed of up to 54Mbps. Finally, as T-DMB service is the preferred mobile service there is merit in PIS providers offering bundled services, with DMB focusing on the broadcasting and PIS on mobile Internet service. The final chapter in this volume (Chapter 16, 'An International SME E-marketplace Networking Model') by Jaechon Park and Jemin Yang examines the *APEC Global B2B Interoperability Project* where a repository system using ebXML and Web Service is constructed to resolve technical interoperability issues. While the Project demonstrated the potential of e-marketplace networking, an M2M business model, in terms of technology and business is feasible although critical mass of buyers, sellers and products is not achieved. Clearly, post-incubation e-marketplaces must gain the trust of participants to attract more SMEs. Several benefits should be realized from the e-marketplace networking of agents including the lowering of SME international market entry barriers, reduction in the stagnation of information flow from excessive competition and improved competitiveness, and international trade facilitation.

1 Pricing and Bundling of Shared Information Goods: The Case of Cable Channels

Abraham Hollander and Thierno Diallo

Introduction

This chapter looks at the pricing and bundling decisions of a firm that sells a product shared on a regular basis among household members. Examples of such products are computer software, telephone service and cable television subscription. The pricing of shared goods has attracted recent attention in the case of academic journals. An academic journal is a product sold to an individual subscriber who does not share it and to libraries that make the journal available for consultation to readers. Ordover and Willig (1978) have characterized the welfare maximizing combination of personal and institutional subscription prices. Liebowitz (1985) has shown that journal publishers rely increasingly on discriminatory pricing to capture revenues from library visitors whose benefit from sharing is enhanced by improved access to photocopying. Besen and Kirby (1989) found that a seller's profit increases as the result of sharing when it is less costly for consumers to distribute a work via sharing than for producers to do so by making copies. Varian (2000) has found a condition under which readers and publishers are better off when a portion of books in circulation is made available for sharing in libraries. Further, Bakos et al. (1999) showed that small scale sharing influences profits by affecting the disparity of buyers' reservation prices. They also establish that when the disparity of reservation prices among members of a group that share is larger than the disparity of the willingness to pay across groups, a seller can set prices that leave less surplus to consumers than in the absence of sharing. In this regard, sharing within groups achieves a result that is akin to bundling.[1]

This chapter examines the bundling of television channels. The analysis explores when a cable firm will let households choose among the channels on offer, and when it will make an all-channels-or-nothing proposition. Some issues related to the bundling of channels by cable providers have been considered by Chae (1992) who examined the interplay between the costs of production of content and distribution per subscriber. Crampes and Hollander (2005) investigated the composition of channel bundles when subscribers differ in regard to their preferred content mix. Crawford (2004) showed that by bundling each of the top-15 cable networks in the US, cable distributors could increase profits by 4%.

This chapter focuses on a different set of determinants of bundling. The analysis assumes away differentiation among channels by postulating that a potential viewer derives the same utility from every channel. It examines how the pricing

[1] See, e.g., Adams and Yellen (1976) and Salinger (1995).

and bundling decisions are affected by: (a) the structure of the fee that cable distributors pay for content to cable networks; and (b) the heterogeneity of households. A priori, the relevant household characteristics include: the probability that individual household members will like particular programs; the utility that individual household members derive from watching certain programs; households' income; the number of individuals per household; and the number of television sets per household member. The latter is important because a household's willingness to pay depends on the probability of congestion. Congestion can occur when there are fewer television sets in a household than potential viewers. In such cases there is a positive probability that at least one household member is unable to watch a favourite program shown on a channel to which the household is subscribed. This means that the household's willingness to pay for cable, which aggregates the reservation prices of individual members, depends on the number of television sets in the household. With respect to the issue of congestion, the chapter is somewhat related to the literature on clubs.[2] In clubs, however, congestion arises when membership increases. In the case of cable television congestion correlates positively not with the number of subscriptions but with the number of household members per television set.

Next the chapter introduces notation, states basic assumptions and specifies the household's utility. A discussion of possible equilibria for the case where all potential viewers are identical follows. It serves to develop some intuition before examining the more general case where households are heterogeneous. The case where all viewers have the same probability of obtaining positive utility from programming but differ in the amount of utility they derive from it is then examined. That section shows that when payments to cable networks do not depend on the number of subscribers, distributor profits are highest when all channels are offered as a bundle. That is, the cost of content only determines the number of channels that the firm offers. When payment for content depends on the number of subscribers, the distributor may set prices that ensure that some households subscribe to fewer channels than the maximum number available. While such an outcome is possible, it emerges only for a small set of parameter values. The section also explores how the probability of this outcome depends on the probability distribution of the number of television sets per household, and on the probability that household members will obtain positive utility from watching television. A final section summarizes the results and discusses the relevance of this exploratory chapter to markets other than cable television.

Notation and Assumptions

A cable firm sells television channel subscription, and each channel shows a variety of programs. The firm may decide whether to supply enough programming for a single channel or for two channels. Use the index $i \in \{1, 2\}$ to identify the chan-

[2] See, e.g., Buchanan (1965) and Boadway (1980).

nels. Households that subscribe to cable television have either one or two members, indexed $j=\{a,b\}$. Household member j derives utility θ_j per unit of time from watching a program he or she likes, and a utility of zero from other programs. Let z_j^i denote the probability that household member j likes the programming shown on channel i.[3] The probability that a household member likes a program is independent of the probability that another household member likes the same program. Member j who watches a liked program for a portion z of the time on channel i receives gross utility $\theta_j z_j^i$. Equivalently, $\theta_j z_j^i$ denotes the expected utility per unit of time that member j obtains from viewing channel i. Some households have one television set while other households have two television sets. When members of a single-set household differ with respect to the program they would like to watch at a particular time, they choose the program by tossing a coin. In a two-set household, each person watches the program on a different television set. The number of sets in the household is denoted $k=\{1,2\}$.

The amount a household is willing to pay to gain access to a single channel or two channels equals the sum of expected utility that household members derive from access to the subscribed channels. Denote by p_1 and p_2 the prices at which the firm sells subscriptions for a single channel and for two channels when it adopts a policy whereby households can choose the number of channels they wish to subscribe.[4] The price under a bundling policy is p_B. The cable firm pays the cable network a fee $T_i = m_i q_i + c_i$ for the content shown on channel i, where q_i is the number of channel subscribers and m_i is the per subscriber charge. This fee does not depend on size of the household or number of television sets in the household. The proportion of subscribers with two television sets is denoted λ.

The expected utility of a household that subscribes to a single channel i is:[5]

$$(\theta_a+\theta_b)z_a^i z_b^i + \theta_a z_a^i(1-z_b^i) + \theta_b z_b^i(1-z_a^i) = \theta_a z_a^i + \theta_b z_b^i, \tag{1.1}$$

whether it has one or two television sets. The expected utility of a household that subscribes to both channels depends on the number of television sets owned. This is a result of the existence of a positive probability that one household member will like a program on one channel while another person likes a program simultaneously shown on the other channel. In the Appendix it is shown that on defining

[3] Alternatively z_j^i can be thought of as the portion of the time that channel i provides programming that member j likes.

[4] Because of the symmetry assumptions it is not sensible to make a distinction between a channel that is part of a basic service and another that is optional.

[5] The first term in Eq. 1.1 represents the contribution to gross utility from programs liked by household members a and b. The remaining terms are the contribution to utility of programs enjoyed by either a or b, but not both.

$\Theta \equiv \theta_a + \theta_b$ the expected gross utility of a two-set household from both channels is:

$$U_2^2(\Theta, z_a, z_b) = \Theta z_a z_b (4 - 2z_a - 2z_b + z_a z_b) + \theta_a z_a (1 - z_b)^2 (2 - z_a) + \theta_b z_b (1 - z_a)^2 (2 - z_b) \ . \tag{1.2}$$

The expected utility of a one-set household from both channels is:

$$U_2^1(\Theta, z_a, z_b) = \Theta z_a z_b (3 - z_a - z_b) + \theta_a z_a (1 - z_b)^2 (2 - z_a) + \theta_b z_b (1 - z_a)^2 (2 - z_b) \ . \tag{1.3}$$

Assume henceforth that the probability that a household member likes a program is the same for both channels, i.e., $z_a = z_b$. Also assume that $m_i = m$ and $c_i = c$, for $i = \{a, b\}$. To gain some intuition into the pricing and bundling decision, the special case where all consumers are the same is examined next.

Pricing and Bundling with Identical Consumers

From Eq. 1.1 through Eq. 1.3, Table 1.1 is constructed and displays household gross utility as a function of the number of channels subscribed and number of television sets. Table 1.1 shows that a household which has a single television set gains the amount $\Theta z(1-z)[1-z(1-z)]$ in gross utility when it subscribes to a second channel. A household that has two television sets adds $\Theta z(1-z)$ to utility by subscribing to a second channel. The contribution is larger for a two television set household because there is a positive probability that one household member watches a program on the first set while another watches on the second television set.[6]

Table 1.1. Gross Household Utility and Number of Channels and Television Sets

	One television	Two televisions
One channel	$U_1^1(\Theta, z) = \Theta z$	$U_1^2(\Theta, z) = \Theta z$
Two channels	$U_2^1(\Theta, z) = \Theta z[(2-z) - z(1-z)^2] = \Theta z\{1 + (1-z)[1 - z(1-z)]\}$	$U_2^2(\Theta, z) = \Theta z(2 - z)$

[6] Note that for a household with single-channel subscription, a second television set does not contribute to utility. However, an extra set contributes $\Theta z^2(1-z)^2$ to a household with two-channel subscription, viz., $\Theta z(1-z) - \Theta z(1-z)[1 - z(1-z)] = \Theta z^2 (1-z)^2 > 0$.

It is apparent from Table 1.1 that the contribution to utility from the second channel is a non-monotonic function of z. When z is very low, the second channel cannot substantially add to the probability that either one or two household members find a program they enjoy. When z is sufficiently high, subscribing to a single channel ensures a high probability that household members will be able to find a program they like. Therefore, the contribution to utility from the second channel is highest for intermediate values of z. When the firm sells a single channel, it is priced at the household's reservation price. When the firm offers two channels a la carte, and prices them uniformly, each channel is sold for a rate equal to the household's gain in gross utility from the second channel. The latter is $\Theta z(1-z)[1-z(1-z)]$ when $k=1$. This means that when the household has a single set, revenue from the sale of two channels is larger than revenue from the sale of a single channel if and only if $2(1-z)[1-z(1-z)]>1$, or $z<0.35$. For $k=2$, revenue from the sale of two channels is $2\Theta z(1-z)$. This revenue is larger than the revenue from the sale of a single channel when $z<0.5$.[7] When the firm sells both channels as a bundle, the price is set equal to the household's gross utility from two channels. Revenue is clearly higher than for the a la carte sale for all $z>0$.

Heterogeneous Subscriber Preferences

Now assume that Θ has a distribution $F(\cdot)$ with corresponding density $f(\cdot)$ on the interval $[0,\Theta^{\max}]$. Also assume that z is the same for all viewers. Some households may subscribe to one channel, others to two channels. The choice of a household depends on the number of television sets it has, and on prices. When the firm sets prices p_1 and p_2, households that subscribe to two channels have the preference parameters $\{\Theta, z, z\}$ that satisfy the conditions given by Eq. 1.4:

$$U_2^k(\Theta,z,z)-p_2\geq 0 \quad \text{and} \quad U_2^k(\Theta,z,z)-p_2\geq U_1^k(\Theta,z,z)-p_1, \tag{1.4}$$

for $k=\{1,2\}$. The parameters of households that subscribe to a single channel satisfy Eq. 1.5 conditions:

$$U_1^k(\Theta,z,z)-p_1\geq 0 \quad \text{and} \quad U_2^k(\Theta,z,z)-p_2\leq U_1^k(\Theta,z,z)-p_1, \tag{1.5}$$

[7] It is easily shown that when $k=1$ selling a second channel makes the largest contribution to profits when for $z=0.5$.When $k=2$ the contribution to profits of selling the second channel is largest when $z=0.25$. Subsequent sections assume non-linear rather than uniform pricing.

for $k = \{1, 2\}$. When the firm bundles, subscribers' parameters satisfy Eq. 1.6:

$$U_2^k(\Theta, z, z) - p_B \geq 0 \,. \tag{1.6}$$

The preference index that leaves a household indifferent between subscribing to a single channel and not subscribing is $\underline{\Theta}$. Further, the preference indexes of households indifferent between subscribing to two channels and not subscribing are denoted Θ' and Θ'', respectively for households that have one television set and households that have two sets. Finally, the preference indexes of households indifferent between subscribing to a single channel and subscribing to two channels are $\vec{\Theta}$ and $\overleftrightarrow{\Theta}$, respectively, for households that have one set and households that have two sets. These preferences indexes depend on prices as follows:

$$\underline{\Theta} \equiv \frac{p_1}{z} \,,$$

$$\overleftrightarrow{\Theta} \equiv \frac{p_2 - p_1}{z(1-z)} \,,$$

$$\vec{\Theta} \equiv \frac{p_2 - p_1}{z(1-z)[1 - z(1-z)]} \,,$$

$$\Theta'' \equiv \frac{p_2}{z(2-z)}$$

and

$$\Theta' \equiv \frac{p_2}{z[(2-z) - z(1-z)^2]} \,.$$

When the distributor offers two channels, some households may subscribe to one channel, others to both channels. Three configurations are possible a priori. One configuration is where both the households that have two television sets and the households that have one set are split into a segment that subscribes to one channel, and a segment that subscribes to both channels (Case 1). Another configuration has all households with two television sets subscribing to both channels, and households with one television set divided into a segment that subscribes to one channel and a segment that subscribes to both channels (Case 2). A final configuration has all households with two television sets subscribing to both channels, and all households with one television set subscribing to a single channel (Case 3). Clearly, an equilibrium where households that own two sets subscribe to a single channel or are segmented into subscribers to both channels and subscriber to a single channel, while all households with one set subscribe to both channels, cannot arise.

Case 1: One-set and Two-set Households Are Segmented

This type of segmentation requires that $\underline{\Theta} < \Theta'' < \Theta' < \overleftrightarrow{\Theta} < \vec{\Theta} < \Theta^{\max}$. Among two-set households, those that subscribe to both channels have $\Theta \in [\overleftrightarrow{\Theta}, \Theta^{\max}]$, while those that subscribe to a single channel have $\Theta \in [\underline{\Theta}, \overleftrightarrow{\Theta}]$.[8] Among households with a single television set, those that subscribe to both channels have $\Theta \in [\vec{\Theta}, \Theta^{\max}]$, whereas those that subscribe to a single channel have $\Theta \in [\underline{\Theta}, \vec{\Theta}]$.[9] The corresponding profit is:

$$\begin{aligned}\Pi = (p_1 - m)\Big\{[F(\overleftrightarrow{\Theta}) - F(\underline{\Theta})] + (1-\lambda)[F(\vec{\Theta}) - F(\overleftrightarrow{\Theta})]\Big\} \\ + (p_2 - 2m)\Big\{\lambda[F(\vec{\Theta}) - F(\overleftrightarrow{\Theta})] + [1 - F(\vec{\Theta})]\Big\} - 2c\ .\end{aligned}$$

First-order necessary conditions are:

$$1 - F(\underline{\Theta}) - p_1 f(\underline{\Theta}) \frac{\partial \underline{\Theta}}{\partial p_1} + m f(\underline{\Theta}) \frac{\partial \underline{\Theta}}{\partial p_1} = 0 \tag{1.7}$$

and

$$\begin{aligned}\lambda[1 - F(\overleftrightarrow{\Theta}) - \overleftrightarrow{\Theta} f(\overleftrightarrow{\Theta}) + m f(\overleftrightarrow{\Theta}) \frac{\partial \overleftrightarrow{\Theta}}{\partial p_2}] \\ + (1-\lambda)[1 - F(\vec{\Theta}) - \vec{\Theta} f(\vec{\Theta}) + m f(\vec{\Theta}) \frac{\partial \vec{\Theta}}{\partial p_2}] = 0\ .\end{aligned} \tag{1.8}$$

When $m = 0$ these conditions are satisfied for $\vec{\Theta} = \overleftrightarrow{\Theta} = \underline{\Theta}$. This means that the firm sets prices in a way that insures that all households subscribe to both channels. Specifically, it means that the profit maximizing p_2 equals the profit maximizing p_B, viz., profit maximization requires bundling. Under a uniform distribution of Θ, bundling yields a profit of $(z(2-z)/4)\Theta^{\max} - 2c$. By contrast, the profit from the sale of a single channel is $(z/4)\Theta^{\max} - c$. That is, when the fee paid by the cable distributor for content does not depend on the number of sub-

[8] The condition $z > 2 - (p_2 / p_1)$ implies $p_2 / z < p_2 / z(2-z) < (p_2 - p_1)/z(1-z)$. Also note that the condition $(p_2 - p_1)/z(1-z) < \Theta^{\max}$ cannot be met for $z \to 1$ or $z \to 0$, because the left-hand term converges to ∞. That is, subscribing to a second channel only pays off for intermediate values of z.

[9] It is straightforward to show that the condition $(1-z)[1-z(1-z)] < (p_2 - p_1)/p_1$ insures that $p_1 / z < p_2 / z[(2-z) - z(1-z)^2] < (p_2 - p_1)/z(1-z)[1-z(1-z)]$.

scribers, offering two channels generates higher profits than offering a single channel when $(z(1-z)/4)\Theta^{\max} > c$.

Now consider the case where $m > 0$. Note first that $\vec{\Theta} = \overleftrightarrow{\Theta} = \underline{\Theta}$ cannot be a solution to Eq. 1.7 and Eq. 1.8. Indeed, if this was a solution then:

$$[1 - F(\overleftrightarrow{\Theta}) - \overleftrightarrow{\Theta}\, f(\overleftrightarrow{\Theta}) + m\, f(\overleftrightarrow{\Theta}) \frac{\partial \underline{\Theta}}{\partial p_1}] = 0 < [1 - F(\overleftrightarrow{\Theta}) - \overleftrightarrow{\Theta}\, f(\overleftrightarrow{\Theta}) + m\, f(\overleftrightarrow{\Theta}) \frac{\partial \overleftrightarrow{\Theta}}{\partial p_2}]\,,$$

as $\frac{\partial \overleftrightarrow{\Theta}}{\partial p_2} > \frac{\partial \underline{\Theta}}{\partial p_1}$. This would also imply $[1 - F(\vec{\Theta}) - \vec{\Theta}\, f(\vec{\Theta}) + m\, f(\vec{\Theta}) \frac{\partial \vec{\Theta}}{\partial p_2}] > 0$, because $\frac{\partial \vec{\Theta}}{\partial p_2} > \frac{\partial \underline{\Theta}}{\partial p_1}$. But then, the condition in Eq. 1.8 could not be true. For the special case where F is uniform on $[0, \Theta^{\max}]$ conditions in Eq. 1.7 and Eq. 1.8 become, respectively:

$$\frac{1}{\Theta^{\max}}[\Theta^{\max} - 2\underline{\Theta} + \frac{m}{z}] = 0 \tag{1.9}$$

and

$$\begin{aligned} &\frac{1}{\Theta^{\max}}\{\lambda[\Theta^{\max} - 2\overleftrightarrow{\Theta} + \frac{m}{z(1-z)}] \\ &\qquad + (1-\lambda)[\Theta^{\max} - 2\vec{\Theta} + \frac{m}{z(1-z)[1-z(1-z)]}]\} = 0\,. \end{aligned} \tag{1.10}$$

Jointly Eq. 1.9 and Eq. 1.10 yields:

$$p_1 = \frac{1}{2}(z\,\Theta^{\max} + m) \tag{1.11}$$

and

$$\begin{aligned} p_2 &= \frac{z\Theta^{\max}}{2}[1 + \frac{(1-z)[1-z(1-z)]}{1-\lambda z(1-z)}] + m \\ &= p_1 + \frac{1}{2}[\frac{z(1-z)[1-z(1-z)]}{1-\lambda z(1-z)}\Theta^{\max} + m]\,. \end{aligned} \tag{1.12}$$

The prices given by Eq. 1.11 and Eq. 1.12 only constitute an equilibrium pair if: (a) the margins on the sale of the first and second channel are positive; and (b) the prices generate the ranking $\underline{\Theta} < \Theta'' < \Theta' < \overleftrightarrow{\Theta} < \vec{\Theta} < \Theta^{\max}$. The existence of a positive margin on the sale of the first and second channel requires $m < \min[p_1, p_2 - p_1] = p_2 - p_1 = \frac{1}{2}[\frac{z(1-z)[1-z(1-z)]}{1-\lambda z(1-z)}\Theta^{\max} + m]$. This condition is met by virtue of Eq. 1.11 and Eq. 1.12.[10] In regard to the ranking of the Θs, $\bar{\Theta} < \Theta^{\max}$ requires $m < z(1-z)[1-z(1-z)]\frac{1-2\lambda z(1-z)}{1-\lambda z(1-z)}\Theta^{\max} \equiv \alpha_{\max}$. Also, $\Theta'' > \underline{\Theta}$ requires $p_2 > (2-z)p_1$ or $m > \frac{(1-\lambda)z(1-z)^2}{1-\lambda z(1-z)}\Theta^{\max} \equiv \alpha_{\min}$. The remaining conditions on the ranking of the Θs are met by Eq. 1.11 and Eq. 1.12. The existence of a solution requires that $0 < \alpha_{\min} < m < \alpha_{\max}$. Note first that $\alpha_{\min}$ and $\alpha_{\max}$ are positive because $\lambda \in (0,1)$ and $z(1-z) < 1/4$. It is straightforward to show that $\operatorname{sign}[\alpha_{\max} - \alpha_{\min}] = \operatorname{sign}[z^2 - \lambda(1-z)(2z^2 - 1)]$. The latter entails that the prices given by Eq. 1.11 and Eq. 1.12 may constitute an equilibrium for some m and $\lambda \in (0,1)$ when $z < \sqrt{1/2}$, and that they cannot be in equilibrium when $z \geq \sqrt{1/2}$.

Case 2: One-set Households Are Segmented and Two-set Households Subscribe to Both Channels

Such an equilibrium requires that $\overleftrightarrow{\Theta} < \Theta'' < \underline{\Theta} < \Theta' < \vec{\Theta} < \Theta^{\max}$. Among households with a single television set, those that subscribe to a single channel have $\Theta \in [\underline{\Theta}, \vec{\Theta}]$ and those that subscribe to both channels have $\Theta \in [\vec{\Theta}, \Theta^{\max}]$. Among households with two sets those with a preference parameter $\Theta \in [\Theta'', \Theta^{\max}]$ subscribe to both channels, those with a lower value of Θ do not subscribe. Therefore, a firm that offers both channels has profit:

$$\Pi = (p_1 - m)(1-\lambda)[F(\vec{\Theta}) - F(\underline{\Theta})] + (p_2 - 2m)\left\{\lambda[F(\vec{\Theta}) - F(\Theta'')] + [1 - F(\vec{\Theta})]\right\} - 2c\,.$$

First-order necessary conditions are:

$$1 - F(\vec{\Theta}) - \vec{\Theta}\, f(\vec{\Theta}) + m\, f(\vec{\Theta})\frac{\partial\vec{\Theta}}{\partial p_1} = 1 - F(\underline{\Theta}) - \underline{\Theta}\, f(\underline{\Theta}) + m\, f(\underline{\Theta})\frac{\partial\underline{\Theta}}{\partial p_1} \qquad (1.15)$$

and

[10] When the condition is not met it is unprofitable to seek subscribers for a second channel.

$$\lambda[1-F(\Theta'')-\Theta''\, f(\Theta'')+2m\, f(\Theta'')\frac{\partial\Theta''}{\partial p_2}] \\ +(1-\lambda)[1-F(\vec{\Theta})-\vec{\Theta}\, f(\vec{\Theta})+m\, f(\vec{\Theta})\frac{\partial\vec{\Theta}}{\partial p_2}]=0\ . \tag{1.16}$$

Observe that when $m=0$, Eq. 1.15 and Eq. 1.16 are satisfied only when $\overleftrightarrow{\Theta}=\underline{\Theta}=\vec{\Theta}$. Note also that the latter cannot be a solution for $m>0$. For the special case where F is uniform on $[0,\Theta^{\max}]$ Eq. 1.15 and Eq. 1.16 yields:

$$\frac{1}{\Theta^{\max}}[\Theta^{\max}-2\vec{\Theta}+\frac{m}{z(1-z)[1-z(1-z)]}]=\frac{1}{\Theta^{\max}}[\Theta^{\max}-2\underline{\Theta}+\frac{m}{z}]=0 \tag{1.17}$$

and

$$\lambda\frac{1}{\Theta^{\max}}[\Theta^{\max}-2\Theta''+\frac{2m}{z(2-z)}] \\ +(1-\lambda)\frac{1}{\Theta^{\max}}[\Theta^{\max}-2\vec{\Theta}+\frac{m}{z(1-z)[1-z(1-z)]}]=0\ . \tag{1.18}$$

Jointly Eq. 1.17 and Eq. 1.18 yields:

$$p_1=\frac{1}{2}[\frac{z\lambda(2-z)}{2-z-\lambda z(1-z)^2}\Theta^{\max}+m] \tag{1.19}$$

and

$$p_2=\frac{z(2-z)}{2\lambda}[\frac{(2-z)[1-z(1-\lambda)]-z\lambda(1-z)^2}{2-z-z\lambda(1-z)^2}]\Theta^{\max}+m \\ =\frac{1}{\lambda}p_1+\frac{z(2-z)}{2\lambda}[\frac{(1-z)(1-z+\lambda z^2)-z(1-\lambda)}{2-z-z\lambda(1-z)^2}]\Theta^{\max}+\frac{2\lambda-1}{2\lambda}m\ . \tag{1.20}$$

From Eq. 1.19 and Eq. 1.20 $\overleftrightarrow{\Theta}<\Theta''$ requires:

$$m<\frac{2-z}{\lambda[2-z-\lambda z(1-z)^2]}\Theta^{\max}A,$$

where

$$A \equiv (2-z)\lambda^2 - (1-z)(1+z^2)\lambda - (1-z)^2 - z\,.$$

It is easily shown that $A \le 0$ for all $(\lambda, z) \in [0,1]\times[0,1]$. So, a solution corresponding to Case 2 cannot exist when $m > 0$.

Case 3: One-set Households Subscribe to One Channel and Two-set Households Subscribe to Both Channels

Such an equilibrium requires that $\overleftrightarrow{\Theta} < \Theta'' < \underline{\Theta} < \Theta^{\max} < \vec{\Theta}$. The profit function is:

$$\Pi = (p_1 - m)(1-\lambda)[1 - F(\underline{\Theta})] + (p_2 - 2m)\lambda[1 - F(\Theta'')] - 2c\,.$$

First-order necessary conditions are:

$$1 - F(\underline{\Theta}) - (p_1 - m)\, f(\underline{\Theta})\frac{1}{z} = 0 \tag{1.21}$$

and

$$1 - F(\Theta'') - (p_2 - 2m)\, f(\Theta'')\frac{1}{z(2-z)} = 0\,. \tag{1.22}$$

For a uniform F on $[0, \Theta^{\max}]$ the conditions in Eq. 1.21 and Eq. 1.22 yields:

$$p_1 = ½(z\Theta^{\max} + m) \tag{1.23}$$

and

$$p_2 = ½[z(2-z)\Theta^{\max} + 2m] = p_1 + ½[z(1-z)\Theta^{\max} + m]\,. \tag{1.24}$$

Note that Eq. 1.23 and Eq. 1.24 entail $\underline{\Theta} = \frac{1}{2}[\Theta^{\max} + \frac{m}{z}]$ and $\Theta'' = \frac{1}{2}[\Theta^{\max} + \frac{2m}{z(2-z)}$. This means that $\Theta'' < \underline{\Theta}$ can only hold when $\frac{2}{2-z} < 1$, which is impossible. Thus the prices given by Eq. 1.23 and Eq. 1.24 are not an equilibrium pair.

Final Remarks

This exploratory chapter examined the effect of household characteristics and the tariff structure of content on the pricing and bundling decisions of a cable distributor. The analysis examined these effects within a framework of a non-linear pricing model where bundling emerges as a limiting case. For reasons of tractability the chapter is limited to cable firms that offer either one or two channels. Study findings suggest that it is profitable for cable distributors to bundle channels which potential subscribers consider not to be substantially differentiated.[11]

The chapter also highlights the critical role played by the fee structure of content providers, and shows in particular that for a wide class of distribution functions for the preference parameter, bundling is dominant from the point of view of the distributor when the fixed component of the fee is relatively large compared to the variable component. This situation clearly applies to channels that contain programming produced by the distributor or on behalf of the producer. The result also applies to channels whose distribution is mandated by a regulatory body. Although bundling may be dominated by conventional non-linear pricing when the variable component of the fee is substantial, the parameters space for which this is true is small for the case where the distribution of preferences is uniform. When the variable fee is large enough the firm simply limits the number of channels on offer rather than set prices at which some households subscribe to less than all channels. The only equilibrium configuration that is consistent with some households subscribing to fewer than two channels under a uniform distribution of preferences has one-set households and two-set households segmented into subscribers to a single channel and subscribers to both channels.

Although the discussion has centered on cable television subscription, some insights are relevant to telephone service pricing and the pricing of access to software that have partially overlapping functions. In the case of telephone service the issue is how a supplier should set the price of extra lines that connect a household. The issue of congestion that arises in the context of telephone service is not unlike congestion in the case of television. The probability of congestion in the case of telephones clearly depends on the number of lines per household. Finally, it is noted that the model may also serve to draw inferences about the fees a cable distributor should charge for installation of additional outlets or cable connections.

[11] A channel may appeal to a population segment but not another segment.

Appendix

When a household subscribes to two channels, the probability that each channel will at the same time offer content liked by both a and b is:

$$F = z_a^1 z_b^1 z_a^2 z_b^2 .$$

The probability that a program on a single channel will be attractive to both a and b is:

$$G = z_a^1 z_b^1 [z_a^2 (1 - z_b^2) + z_b^2 (1 - z_a^2) + (1 - z_a^2)(1 - z_b^2)] \\ + z_a^2 z_b^2 [z_a^1 (1 - z_b^1) + z_b^1 (1 - z_a^1) + (1 - z_a^1)(1 - z_b^1)]$$

and

$$G = z_a^1 z_b^1 (1 - z_a^2 z_b^2) + z_a^2 z_b^2 (1 - z_a^1 z_b^1) .$$

The probability that a household member will like programs on both channels simultaneously is:

$$H = z_a^1 z_b^2 (1 - z_a^2)(1 - z_b^1) + z_a^2 z_b^1 (1 - z_a^1)(1 - z_b^2) .$$

The probability that of two television channels, there is a program offered that is enjoyable by only one household member is:

$$J = z_a^1 (1 - z_a^2)(1 - z_b^1)(1 - z_b^2) + z_a^2 (1 - z_a^1)(1 - z_b^1)(1 - z_b^2) \\ + z_b^1 (1 - z_a^2)(1 - z_a^1)(1 - z_b^2) + z_b^2 (1 - z_a^2)(1 - z_b^1)(1 - z_b^1) .$$

The probability that only one household member at a point in time will enjoy programs shown on both channels is:

$$M = z_a^1 z_a^2 (1 - z_b^1)(1 - z_b^2) + z_b^1 z_b^2 (1 - z_a^1)(1 - z_a^2) .$$

Assuming $z_j^1 = z_j^2 = z_j$ for $j = \{a, b\}$, denote by $U_n^k(\Theta, z_a, z_b)$ the utility of a household that has k, $k = \{1, 2\}$ sets, subscribes to $n = \{0, 1, 2\}$ channels, and has preference parameters Θ, z_a and z_b, where $\Theta = \theta_a + \theta_b$. The latter entails:

$$\begin{aligned}
F &= (z_a z_b)^2 , \\
G &= 2z_a z_b (1-z_a z_b) , \\
H &= 2z_a z_b (1-z_a)(1-z_b) , \\
J &= 2(1-z_a)(1-z_b)[z_a(1-z_b)+z_b(1-z_a)], \text{ and} \\
M &= 2[z_a(1-z_b)]^2 .
\end{aligned}$$

Therefore the gross utility of a household that has two television sets and subscribes to both channels is:

$$\begin{aligned}
U_2^2 = \Theta(F+G+M) &+ \theta_a\{2z_a(1-z_a)(1-z_b)^2 + [z_a(1-z_b)]^2\} \\
&+ \theta_b\{2z_b(1-z_b)(1-z_a)^2 + [z_b(1-z_a)]^2\} .
\end{aligned}$$

For a household that subscribes to both channels and has one television set, gross utility is $U_2^1 = U_2^2 - \dfrac{\Theta}{2} H$.

Derivations for Table 1.1

For the values $z_a = z_b = z$ then $F = z^4$; $G = 2z^2(1-z^2)$; $H = 2z^2(1-z)^2$; $J = 4z(1-z)^3$ and $M = 2z^2(1-z)^2$. Therefore:

$$\begin{aligned}
U_2^1 &= \Theta[(F+G)+(H+J+M)/2] \\
&= \Theta[z^4 + 2z^2(1-z^2) + [2z^2(1-z)^2 + 4z(1-z)^3 + 2z^2(1-z)^2]/2] \\
&= \Theta[z^2(2-z^2) + 2z(1-z)^2] \\
&= \Theta z[2-2z+2z^2-z^3] \\
&= \Theta z[(2-z)-z(1-z)^2] ,
\end{aligned}$$

and

$$\begin{aligned}
U_2^2 &= \Theta[(F+G+H)+(J+M)/2] \\
&= \Theta[z^4 + 2z^2(1-z^2) + 2z^2(1-z)^2 + [4z(1-z)^3 + 2z^2(1-z)^2]/2] \\
&= \Theta[z^4 + 2z^2(1-z^2) + 2z^2(1-z)^2 + z(1-z)^2[2(1-z)+z]] \\
&= \Theta[z^2[z^2 + 2(1-z^2) + 2(1-z)^2] + z(1-z)^2(2-z)] \\
&= \Theta[z^2(2-z)^2 + z(1-z)^2(2-z)] \\
&= \Theta z(2-z)[z(2-z)+(1-z)^2] \\
&= \Theta z(2-z) .
\end{aligned}$$

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3 Behavioral Frictions in Online Contracting: Evidence from Yankee Auctions

Mira Slavova

Introduction

Mechanism design and transaction cost economics are strains of the economics literature focusing on the formation of contractual relations. Both strains offer a perspective on auctions as instruments for the negotiation of contracts. The treatment of auctions within the literature on mechanism design adopts the frictionless abstraction of neoclassical economics. Whereas the transaction costs literature introduces costs to the contracting process which Williamson (1985) considers are 'the economic equivalent of friction in physical systems'. Both perspectives offer insights which are not prudent to ignore. The behavioral assumptions of mechanism design include strong forms of rationality and opportunism (Williamson 1985). The rationality assumption reflects the cognitive competence of both the principal and agents, and allows actions to be based on comprehensive information-impacted utility maximizing calculations. The assumption of opportunism amounts to a presumed disposition of the participants to use asymmetric private information strategically for personal gain rather than to share it honestly.

Mechanism design casts an auction as an instance of the adverse selection problem (Salanié 1997). The auctioneer, as the uninformed party, is imperfectly informed of bidder characteristics, who are the informed party. The auctioneer moves first by constructing a mechanism based on his belief about potential participants, their possible types and outcomes (Milgrom 2004). At an auction, the underlying types are revealed through the bidding process, and realized bids are matched to outcomes via allocation and payment rules. The allocation rule determines the probability a bidder is allocated a good given the submitted bid. A payment rule determines a bidder's payment as a function of the bid. The bidder's problem is to find the bid which maximizes the expected difference between his valuation for the good and the price at which it was obtained. The different components of the auction model are assembled via the pervasive assumption of monotonicity which can be held or relaxed in relation to aspects of the modeling. Monotonic bidding behavior and the allocation and payment rules translate as follows: bidders with higher valuations offer higher bids which provide a higher likelihood of winning and correspond to higher payment obligations. Usually auctions focus on only a single dimension of the awarded contract: the price offered by the highest bidder. Thus, the participants' types are commensurate with their valuations, i.e., their capacity to offer a high price. Consequently, most auction theory is devoted to analyzing situations where the overriding model fundamental is the distribution of bidder valuations with the overriding outcome measure the selling price. The Yankee auction mechanism ranks bids not only on the basis of the final price offer but also on the final quantity request and the bidder's time of entry into the auction. Thus, analysis of Yankee auctions necessitates the extension of this type structure to multiple dimensions. In particular, bidder types are considered as consisting of the fundamental characteristics: (i) valuation per unit of the good; (ii) capacity to absorb a fixed number of units; and (iii) a constraint determined by demands on a bidder's time which impacts auction participation.

The behavioral assumptions of transaction cost economics include a semi-strong form of rationality and a strong form of opportunism (Williamson 1985; Rao 2003). Agents are conceived as having limited cognitive capacity that results in a restricted ability to handle complex decision-making problems. The ensuing behaviors are bounded rational, i.e., they are intended rational but only limitedly so. Opportunism extends beyond pure self-interest to include the 'full set of ex ante and ex post efforts to lie, cheat, steal, mislead, disguise, obfuscate, feign, distort and confuse'.[1] By comparison, mechanism design is focused on aspects of opportunism which are tractable and attributable to asymmetries of information. Bounded rationality and opportunism produce ex ante contractual incompleteness and a need for ex post adaptation to the terms of the contract. At the re-contracting stage the opportunism principal is positioned to gain as the agent has incurred principal-specific sunk transaction costs that are not part of the contract domain. Williamson (1985) presents an argument focusing on the emergence of vertically integrated governance structures due to the incentive to economize on the costs related to investment in physical principal-specific assets. In this analysis of auctions, the focus is on economizing on the costs of scarce auction-specific cognitive resources. The emergence of heuristic problem-solving behavior is considered as evidence for an intended curtailment of the non-trivial cognitive costs associated with the preparation and submission of the bids in online auctions.

Within the transaction costs framework this study regards an online auction as an example of the 'hold-up' problem (Salanié 1997). Assume that prior to submitting a first bid at an online auction bidders have to make ex ante investments. These investments can be either general purpose or auction specific. General-purpose investment consists of the development of skills transferable to other Internet auctions such as computer competence and strategic thinking. Auction-specific investments can involve familiarization with the details of auction protocols at a particular Web site, registering for bidding, and developing tools and strategies for participation. Auction-specific investment generates surplus due to efficiency effects. For instance, the installation of software which allows the simultaneous monitoring of multiple auctions creates scale efficiency. Prior participation in auctions held by an auctioneer creates experience efficiency. During the auction, when the parties are negotiating the contract, the ex ante investments are already sunk. These investments are profitable as long the bidder's offer is provisionally accepted by the auctioneer but loses value when a bid is rejected. At this

[1] Complementary to opportunism is the concept of dignitarian values. In the presence of this behavioral feature individuals are willing to make altruistic and fair, rather than opportunistic, ex post amends to the contract. See Williamson (1985).

point hold-up occurs because the sunk costs have already been incurred. The implication for revised bids is that they are more aggressive, and bring smaller payoffs to bidders. The present study seeks to identify distinct bidding behavior in online Yankee auctions, and to clarify the relationship between these behaviors and subsequent allocation and payment outcomes. The main concerns are the: (i) existence and characteristics of persistent bidding behavior; (ii) monotonic correspondence between bidding behavior and auction outcome; and (iii) relationship between payment outcomes and the number of submitted bids. The study focus is on establishing a structure of behavior among the submitted bids and exploring their economic rationalization. An observed monotonic correspondence between behavior and auction outcomes is considered a sign of consistency with the paradigm of mechanism design. Alternatively, evidence suggesting that behaviors are the result of heuristic problem-solving and/or evidence pointing to reduced payoffs for bidders who submit multiple bids favor the transaction costs framework.

Data Set

The data set contains bidding information from 194 fully contested single- and multiple-item Internet auctions completed in the Desktops category of uBid.com during March 2004. The number of distinct bidders participating in these auctions is 2430. They submitted a total of 8436 bids.[2] Even though the full range of auctions at uBid.com allow for varying degrees of automation, the auctions in this data set do not provide bidders with an automatic bidding option. Also, bidders do not have an option to acquire the auctioned good via a parallel retailing mechanism. The price is calculated by dividing the offer price by the ex post average winning price. Values above unity occur when the bid price exceeds the average selling price. The bid submission time is adjusted by the ex post duration of the auction, and records the completed fraction of the auction duration at the time of submission of the bid, and so lies within $[0,1]$. The bid quantity is the exact quantity requested by bidders in a final bid. A summary of the variables is contained in Table 3.1.

Table 3.1. Bid Variable Summary Statistics

Variable	Bid / Auction	Mean	Std. Dev.	Minimum	Maximum
Adjusted price	8436	0.74	0.28	0	1.24
Adjusted time	8436	0.59	0.34	0	1
Adjusted quantity	8436	0.37	0.36	0	1
Requested quantity	8436	1.31	1.72	1	50
Lot size	194	3.42	5.92	1	50

[2] Namely, 1495 bids from single-item auctions and 6941 bids from multiple-item auctions.

During the month of data collection, the 2430 bidders contained in the sample participated repeatedly in auctions at the uBid.com Web site. Repeated participation implies that bidding behaviors are not likely to be the result of naiveté or lack of experience. 4069 separate bidding episodes or bid selections are recorded, and adopted as the unit of analysis. Bid selections are described by: (i) the time the first bid is submitted, i.e., the time of entry (TOE)[3]; (ii) the time the final bid is submitted, i.e., time of exit (TOX); (iii) the number of bids submitted (NOB); (iv) the price offered in the final bid (PRC); and (v) the quantity requested in the final bid (QTY).

The correlation matrix of bid selection characteristics is contained in Table 3.2. Table 3.2 shows the highest positive correlation is between TOX and PRC, and TOE and TOX. Due to the ascending format of the auction the later bidders submit their final bid, the higher must be their offer price. A higher exit time value is correlated with a high entry time value because the support of the exit time decreases as the entry time increases. Table 3.2 also shows a small negative correlation between the requested quantity and all other bid selection characteristics. The Table 3.2 results are complemented graphically by Fig. 3.1. The scatter plot of NOB against TOX, shows that when bidders exit the auction early they do not submit multiple bids. This finding suggests that even though a significant proportion of last bids are submitted late, they are often revisions of past bids and not evidence of opportunistic attempts by newly arrived bidders.

Table 3.2. Bid-selection Characteristic Correlation Matrix

	TOE	TOX	NOB	PRC	QTY
TOE	1.00				
TOX	0.88	1.00			
NOB	0.19	0.43	1.00		
PRC	0.71	0.81	0.33	1.00	
QTY	–0.04	–0.03	–0.01	-0.02	1.00

[3] TOE for bid selections consisting of a single bid is identical to TOX.

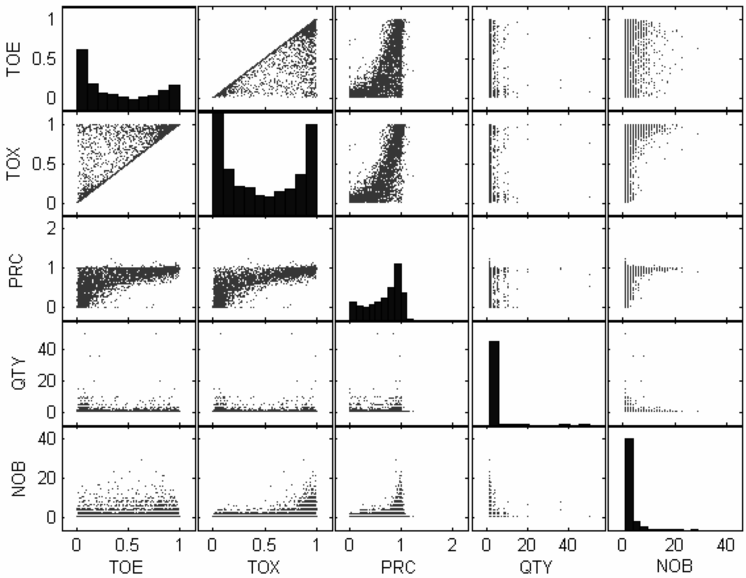


Fig. 3.1. Plots: TOE, TOX, PRC, QTY, NOB

Cluster Analysis

Clustering algorithms operate on a data set of inputs presented in an $n \times p$ matrix. The matrix consists of n objects for which p features are observed. In this section, the objects are the 4069 bid selections and features are PRC, QTY and TOE. A distance metric operates on the set of inputs to construct an intermediate $n \times n$ matrix of dissimilarity between pairs of objects. Several measures can be used to construct this matrix. The $n \times n$ matrix of similarities is used to calculate a homogeneity measure which is optimized using a partition algorithm in order to achieve a clustering. The most commonly used dissimilarity measures come from the family of Minkowski metrics, indexed by the parameter λ:

$$d_{ij} \equiv \left(\sum_{k=1}^{p} w_k^{\lambda} \left| x_{ik} - x_{jk} \right|^{\lambda}\right)^{\frac{1}{\lambda}}, \tag{3.1}$$

where $\lambda \geq 1$. Above, x_{ik} denotes the value of the kth quantitative variable for the i th object ($i = 1 \dots n$, $k = 1 \dots p$) and w is an optional weight attached to features. Metrics with parameters $\lambda = \{1, 2\}$ are used. These metrics are the ‘city block’ and ‘squared Euclidean’ distance measures. The squared Euclidean distance metric is a default metric in many clustering applications, and is usually combined with the sum of squares as a heterogeneity partitioning criterion. A classification achieved in this manner is interpreted as minimizing the sum of Euclidean distance. The city block distance measure accounts for distance in the way they are covered in a typical American city, viz., streets typically cross at right angles. Both Minkowski metrics reflect differences between actual values of variables to account for the ‘size’ of the measures. Alternative measures included focus on the relative differences, or the ‘shape’ of the objects. The similarity measures in Eq. 3.1 and Eq. 3.2 compare the directions of object characteristic vectors. The cosine distance rule is:

$$s_{ij} = \frac{\sum_{k=1}^{p} x_{ik} x_{jk}}{(\sum_{k=1}^{p} x_{ik}^2 \sum_{l=1}^{p} x_{jl}^2)^{\frac{1}{2}}}. \tag{3.2}$$

While the correlation coefficient measure is:

$$s_{ij} = \frac{\sum_{k=1}^{p} (x_{ik} - \overline{x}_i)(x_{jk} - \overline{x}_j)}{(\sum_{k=1}^{p} (x_{ik} - \overline{x}_i)^2 \sum_{l=1}^{p} (x_{jl} - \overline{x}_j)^2)^{\frac{1}{2}}}. \tag{3.3}$$

The cosine of the angle between two vectors measure the angular separation of the vectors measured from the origin, whilst the correlation coefficient compares angles between vectors measured from the mean of these data. When required similarities are transformed into dissimilarities via $d_{ij} = 1 - s_{ij}$.

The sum of dissimilarities is minimized using the k-means partitioning algorithm. The procedure randomly divides objects among the k groups and calculates the centers of the groups. Subsequently, observations are redistributed among the groups to minimize the heterogeneity criterion for a group. A disadvantage of k-means clustering is that the number of clusters in these data has to be specified ex ante. For this specification the taxonomy of bidding behavior in Yankee auctions by Bapna et al. (2004) is employed. The silhouette value proposed as a validity measure by Kaufmann and Rousseeuw (1990) is calculated for object i belonging to cluster C_r (which contains $n_r (\geq 2)$ objects) by:[4]

$$a(i) = \frac{\sum_{j \in \{C_r \setminus i\}} d_{ij}}{n_r - 1}, \tag{3.4}$$

[4] Definitions are according to Gordon (1999).

$$b(i) = \min_{s \neq r} \left\{ \frac{\sum_{j \in C_s} d_{ij}}{n_s} \right\} \tag{3.5}$$

and

$$s(i) = \frac{b(i) - a(i)}{\max\{a(i)b(i)\}} . \tag{3.6}$$

The silhouette value $s(i)$ for an object measures how similar that object is to other objects in that cluster relative to objects in other clusters. Silhouette values lie in the range $[-1,1]$. Objects with silhouette values close to unity are considered properly classified, objects with values close to zero lie between clusters, and objects with negative values are wrongly classified. Silhouette values can be computed for any cluster partition regardless of the distance metric used. Kaufman and Rousseeuw (1990) suggest comparing clustering procedures in favor of those that perform best for the silhouette coefficient diagnostic:

$$SC = \max_{k} s(\overline{k}) , \tag{3.7}$$

where $\overline{s} = (\sum_{i \in C_r} s(i)) / n_r$. A subjective assessment of silhouette coefficient values is provided in Table 3.3. Kaufman and Rousseeuw also propose a graphical display or silhouette plot in which all object values within a cluster are presented as horizontal lines and arranged vertically in descending order. Silhouette plots are an important main tool for assessing results.

Table 3.3. Silhouette Coefficient Subjective Interpretation

Value	Interpretation
$0.71-1$	Strong structure
$0.51-0.7$	Reasonable structure
$0.26-0.5$	Weak and possibly artificial structure. Try another method
≤ 0.25	No substantial structure

Bidding Behavior

In previous research on the taxonomy of bidding behavior, Bapna et al. (2004) include TOE, TOX and NOB as classification features. TOE is used as a classification variable because of the theoretical impact on participation and auction revenue (Engelbrecht-Wiggans 1987; Harstad 1990; Levin and Smith 1994; Klemperer 2000; Seidmann and Vakrat 2000). TOX is employed as the interaction with TOE provides a measure of how bidders balance incentives to bid early and late. The frequency with which bidders update their bids (NOB) contains information about bidders' involvement in the auction. Bapna et al. (2004) identify the bidder groups: (i) early evaluators (EEV) that place a bid in the early stages of an auction; (ii) middle evaluators (MEV) who place a bid in the middle of an auction; (iii) opportunists (OPP) that place a bid in the closing stages of an auction; (iv) sip-and-dippers ($S-D$) place two strategic bids—i.e., a bid is submitted in the early stages of an auction to establish time priority, and a second is submitted toward the end of an auction; and (v) participators that place multiple bids throughout an auction. Bapna et al. (2004) obtain a data set of 229 auctions with 9025 unique data points. In the Bapna et al. sample, inclusive of bidding agents, they identify five bidding behaviors. Since this sample excludes auctions with bidding automata only four behaviors are considered.

Results from clustering the standardized measures TOE, PRC, QTY and QTY are reported in Table 3.4.[5] Silhouette coefficient values for the clustering procedures show that strong and semi-strong structures are reported by the cosine and correlation algorithms. The squared Euclidean distance algorithm produced three reliable clusters and a particularly weak cluster. The city block distance procedure realized a silhouette coefficient that points to a weak or artificial structure. In terms of entry times and final price offers results that are reasonably consistent by clustering procedure. For example, a group of early evaluators place their first bid after 10% of the auction duration and offer a final price of 25% of the average selling price. They are followed by a group of middle evaluators who enter the auction after 22% of the duration and submit a final price of 64% of the average winning price. A third group, sip-and-dippers, have a similar arrival time at 24%. Eventually, sip-and-dippers offer a higher price that is 82% of the average selling price. Finally, opportunists register a first bid when 80% of the auction is complete and offer 92% of the final average price. For consistency, the labels proposed by Bapna et al. (2004) are used. Next, consider the overlaps and discrepancies between the studies. In both analyses early one-time bidders are classified as early evaluators. Middle evaluators are intermediate one-time bidders. Sip-and-dippers are bidders who place two bids with the first bid received considerably earlier than the later bid. Opportunists are late bidders who are active at the auction close to the deadline, and are quite unlike the opportunists bidders that submit many bids.

[5] Standardized measures are mean deviations divided by their standard deviation.

Table 3.4. Cluster Results

Algorithm	EEV	MEV	$S-D$	OPP	SC
Euclidean	27.9%	1.1%	34.8%	36.2%	0.427
TOE	0.079	0.372	0.255	0.803	
PRC	0.243	0.642	0.763	0.928	
QTY	1.214	12.182	1.205	1.145	
NOB	1.209	1.795	2.132	2.690	
$s(i)$	0.696	–0.284	0.518	0.779	
City Block	21.0%	25.2%	23.9%	29.9%	0.394
TOE	0.070	0.135	0.432	0.848	
PRC	0.170	0.629	0.836	0.946	
QTY	1.390	1.340	1.201	1.298	
NOB	1.178	1.644	2.425	2.784	
$s(i)$	0.507	0.243	0.293	0.533	
Cosine	36.0%	4.6%	18.1%	41.3%	0.694
TOE	0.116	0.329	0.209	0.762	
PRC	0.331	0.703	0.842	0.911	
QTY	1.097	5.850	1.084	1.067	
NOB	1.223	2.053	2.547	2.631	
$s(i)$	0.822	0.520	0.585	0.849	
Correlation	26.6%	14.4%	20.7%	38.3%	0.740
TOE	0.140	0.121	0.258	0.775	
PRC	0.259	0.589	0.859	0.900	
QTY	1.695	1.585	1.077	1.052	
NOB	1.241	1.485	2.746	2.508	
$s(i)$	0.786	0.651	0.665	0.861	
Mean $s(i) \geq 0.51$					
TOE	0.101	0.225	0.241	0.797	
PRC	0.251	0.646	0.821	0.921	
QTY	1.349	3.718	1.122	1.141	
NOB	1.213	1.769	2.475	2.653	

This finding is likely to be related to the automatic extension mechanism of Yankee auction that allows bidders to retaliate to late activity. An interesting characteristic extracted by the Euclidean and cosine procedures is that middle evaluators tend to request much larger quantities than other groups. Figure 3.2 through Fig. 3.5 shows graphically the structures for alternative clustering procedures. Figure 3.2 and Fig. 3.4 show the Euclidean and cosine distance algorithm classifications consist of three groups in the $TOE-PRC$ plane and an additional group that is vertically removed. The groups whose selections are plotted on the plane occupy three of the four quadrants. These groups are labeled as early evaluators, sip-and-dippers and opportunists. Due to the ascending nature of the mechanism no bids are observed in the lower right-hand quadrant. The vertically separated bidders are middle evaluators. Middle evaluators are shown in Fig. 3.2 and in Fig. 3.4. The middle evaluator defining characteristic is the quantity requested rather than their entry time or final offer price.

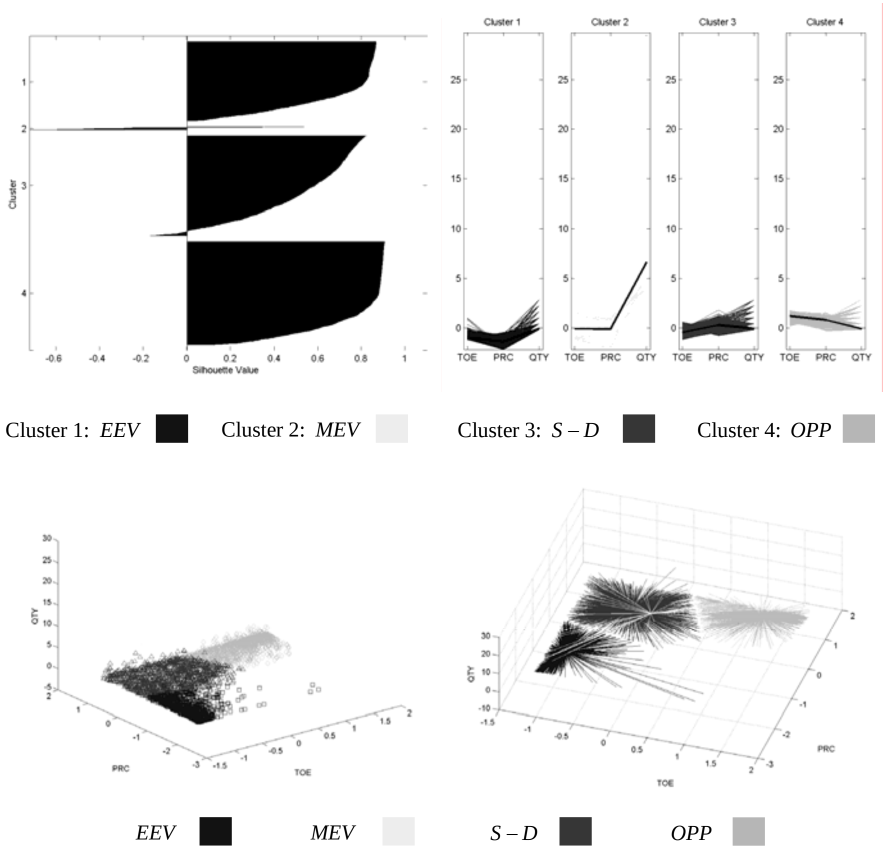
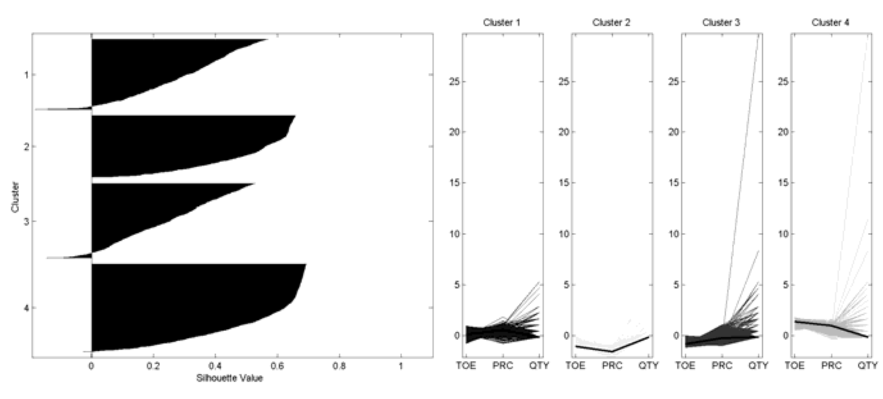
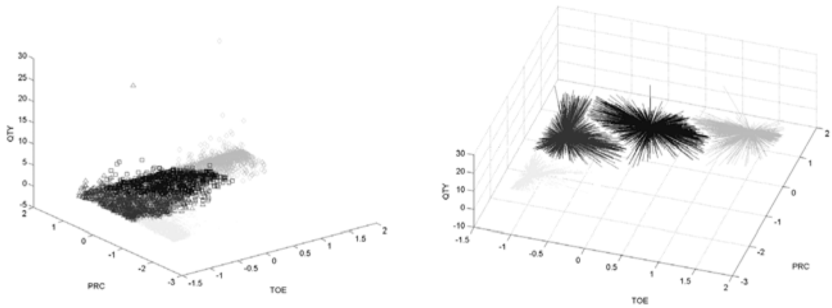


Fig. 3.2. Squared Euclidean Distance

From Fig. 3.3 it is concluded that the influence of vertical separation on the city block metric is insufficient to form a separate cluster of bid selections characterized by large quantity requests. In this case the clustering algorithm optimally partitions the sample according to the position of the observations on the horizontal plane. This clustering result makes little use of the requested quantity as a cluster feature.



Cluster 1: *S – D* Cluster 2: *EEV* Cluster 3: *MEV* Cluster 4: *OPP*



S – D *EEV* *MEV* *OPP*

Fig. 3.3. City Block Distance

Results from the correlation distance algorithm are summarized in Fig. 3.5. Similarly to the results for the Euclidean and cosine algorithms correlation are affected by bidders' requested quantity. Observations with the highest quantity component are split between early and middle evaluator groups. Consequently, at 1.695 and 1.585 the mean requested quantity for neither group is particularly large. Nonetheless, the quantities are noticeably larger than those requested by sip-and-dippers and opportunists. The reported clustering results suggest the existence of the following behaviors:

(i) Early evaluators are weak or naïve bidders who participate in the auction at opening stages. This behavior is rational within the framework of mechanism design where the private information of the early evaluators consists of a low valuation, low demand and few time constraints. Such information provides an incentive to bid aggressively in terms of entry time.

(ii) Middle evaluators are bidders with later entry times than early evaluators. Their most conspicuous characteristic is a capacity to purchase a substantially larger quantity than other bidders. Private information about this capacity encourages aggressive bidding in terms of quantity.

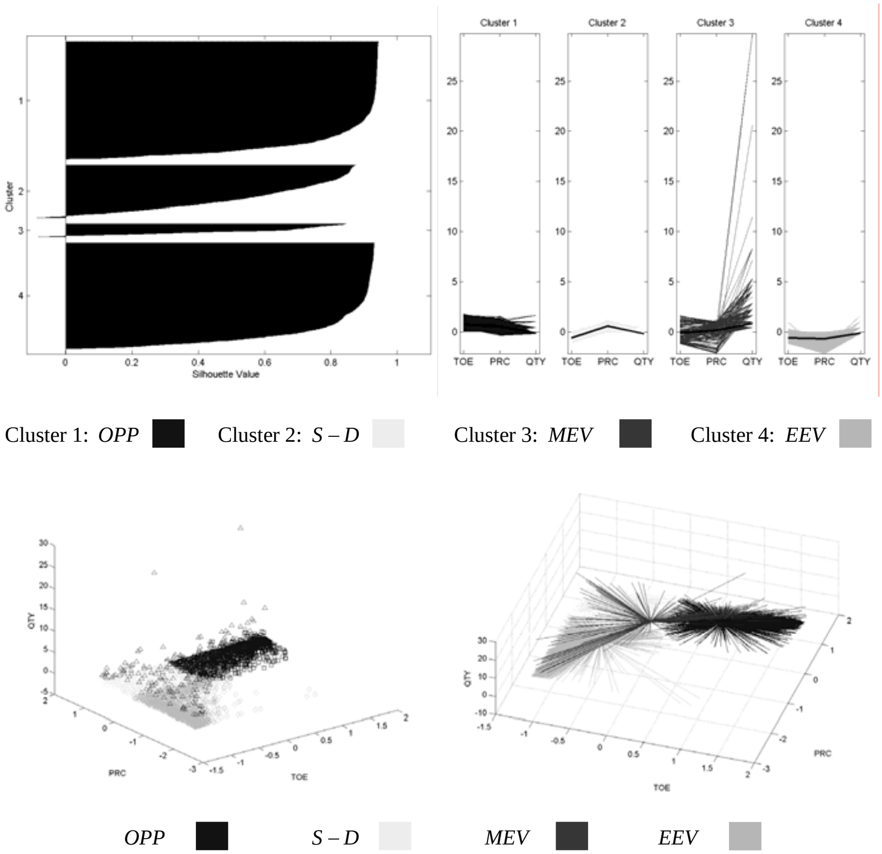


Fig. 3.4. Cosine Distance

(iii) Sip-and-dippers are bidders with potentially high valuations who begin their participation at an auction early. These participants appear alert to the possibility of competition from stronger bidders, and prefer to secure an advantage via an early entry time. This characteristic is a heuristic way to use different auction attributes to their advantage. Sip-and-dippers submit more than two bids to establish potential for a hold-up situation consistent with a transactions cost perspective on auctions.

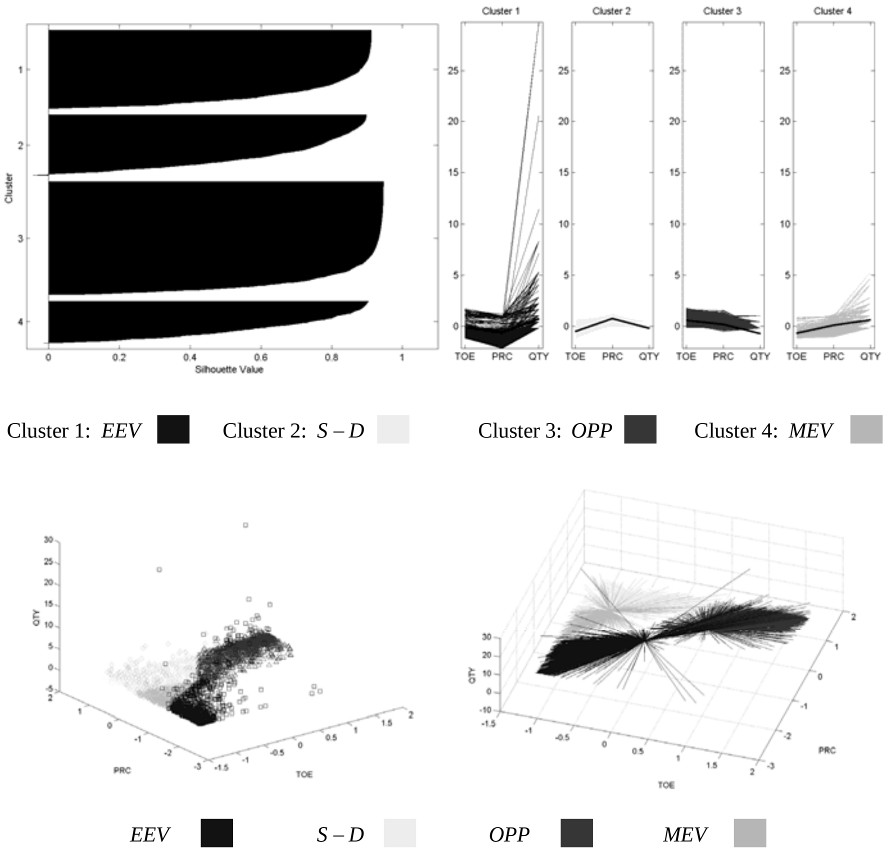


Fig. 3.5. Correlation Distance

(iv) Opportunists are bidder’s who by joining an auction close to the end of the auctions duration are committed to outbidding competitors by offering a higher price. This aggressive price behavior is likely due to opportunists’ private information about high valuations. Similarly to sip-and-dippers, opportunists submit more than a single bid. However, unlike sip-and-dippers their sunk investment is smaller as they join the auction late. This price-aggressive revision of bids can be attributed to hold-up effects.

Quantity Outcomes

Next, consider the success of bids in terms of the quantity allocated as a fraction of the requested quantity. Accordingly, the Kruskal-Wallis rank test is used to check whether allocation means are the same across bidding behaviors. This focus of the comparison is the partitions obtained from using the squared Euclidean and cosine distance measures.

Table 3.5. Mean Allocation by Bidder Classification

Distance		Frequency	Mean	Std. Dev.
Euclidean	*EEV*	1133	0.000	0.000
	MEV	44	0.083	0.236
	$S-D$	1420	0.070	0.253
	OPP	1472	0.312	0.461
Cosine	*EEV*	1491	0.000	0.000
	MEV	187	0.067	0.227
	$S-D$	737	0.110	0.311
	OPP	1654	0.284	0.449
Total		4069	0.138	0.343

Table 3.5 reports mean allocations by bidder class from the Euclidean and cosine distance algorithms. Clearly, early evaluators are the least likely to win units in Yankee auctions. In fact, the early adopter group did not win in any of the 194 auctions. The opportunist group, on average, is allocated between 28% and 31% of their final requested quantities. The middle evaluator and the sip-and-dipper classifications receive, respectively, 6.7% and 11% of the final quantities they requested. A surprising feature of the results reported in Table 3.5 is that the middle evaluator group receives a higher allocation when compared to the sip-and-dipper group by the squared Euclidean algorithm classification. This finding is undermined somewhat by a lack of significance for this difference between the means reported in Table 3.7. The Kruskal-Wallis test results contained in Table 3.6 show that statistically significant differences in the mean allocations achieved via alternative bidding behaviors. According to the pair-wise comparison tests reported in Table 3.7 the mean allocations for the early evaluator and opportunist groups are significantly different from the allocations of other groups. However, the tests are unable to distinguish between the mean allocations for middle evaluator and sip-and-dipper groups. Table 3.8 reports Jonckheere-Terpstra test values that examine whether mean allocations increase monotonically with increasing bidders' types. Monotonic allocation outcomes are confirmed by Cuzick trend test z-statistics of 21.8 and 22.7 for Euclidean and cosine classifications, respectively.

Table 3.6. Mean Allocation Rank by Bidder Classification Test

	Euclidean			Cosine		
	Frequency	Rank Sum	Rank Mean	Fre-quency	Rank Sum	Rank Mean
EEV	1133	1.98×10^6	1746	1491	2.60×10^6	1746
MEV	44	8.79×10^4	1998	187	3.62×10^4	1938
S – D	1420	2.69×10^6	1893	737	1.46×10^6	1975
OPP	1472	3.53×10^6	2395	1654	3.86×10^6	2333
$\chi^{2\ a}$	227.6			199.9		
d.f.	3			3		
p-value	0.0001			0.00010		

Note. Calculated value is not corrected for ties. Euclidean χ^2 corrected value is 621.9 with 3 d.f. $(p = 0.0001)$. Cosine χ^2 corrected for ties is 546.2 with 3 d.f. $(p = 0.0001)$

Table 3.7. Pair-wise Mean Allocation Comparison by Bidder Classification Test

	Euclidean					Cosine				
	Mean	*EEV*	*MEV*	*S – D*	*OPP*	Mean	*EEV*	*MEV*	*S – D*	*OPP*
EEV	0.000	–				0.000	–			
MEV	0.083	0.081	–			0.067	0.017	–		
S – D	0.070	0.001*	0.279	–		0.110	0.000*	0.351	–	
OPP	0.312	0.000*	0.014	0.000*	–	0.284	0.000*	0.000*	0.000*	–

Note. * indicates significant

Table 3.8. Monotone Allocation by Bidder Classification Test

	Euclidean	Cosine
$U_{EEV, MEV}$	28325	153573
$U_{EEV, S\text{-}D}$	862779	611310
$U_{EEV, OPP}$	1099576	1587915
$U_{MEV, S\text{-}D}$	29434	70057
$U_{EEV, OPP}$	39179	185730
$U_{S\text{-}D, OPP}$	1302842	716674
J	3362136	3325260
J^*	13.6	13.2

Payment Outcomes

Eq. 3.8 combines the loss of surplus measure proposed by Bapna et al. (2004) with the allocation outcome measure. Bidders receive zero loss of surplus when they pay the marginal unit price but realize a loss should they pay more, viz.

$$LOS = \frac{AsQty}{Qty} \times \frac{PRC - MPrc}{MPrc}. \tag{3.8}$$

Table 3.9. Loss of Surplus by Bidder Classification

Distance		Frequency	Mean	Std. Dev.
Euclidean	MEV	6	0.008	0.013
	OPP	469	0.014	0.027
	$S-D$	103	0.023	0.046
Cosine	MEV	19	0.009	0.018
	OPP	476	0.014	0.027
	$S-D$	83	0.024	0.050
Total		578	0.016	0.032

From the 4069 bid selections recorded only 578 receive an allocation. Table 3.9 presents the mean loss of surplus by bidder group identified by the squared Euclidean and cosine procedures. The table shows the minimum loss of surplus is achieved by the middle evaluator group. For the middle evaluator group identified by the Euclidean algorithm the mean loss is 0.79%, while for this group identified by the cosine algorithm the loss is 0.95%. The opportunist classification reports the second lowest mean loss of surplus paying, on average, 1.4% more than the minimum winning bid. The sip-and-dipper group has the largest loss of surplus and pays an average of 2.3% or 2.4% above the minimum winning bid. The results for the other classifications are similar and have an intuitive appeal. The least surplus loss by the middle evaluators can be attributed to a strategy of requesting large quantities in the expectation of receiving the residual supply at the marginal price. The opportunist group receives the second lowest loss of surplus by observing the current winning bids near the end of the auction and raising incrementally the marginal bid. The highest surplus loss accrues to bidders that end their auction participation relatively early and are not using the quantity component of their bid as a means to secure a lower price. This group is the sip-and-dippers and they pay a premium.

Table 3.10. Equality of Mean Loss of Surplus by Bidder Classification Test

	Euclidean			Cosine		
	Frequency	Rank Sum	Rank Mean	Frequency	Rank Sum	Rank Mean
MEV	6	1342.5	223.7	19	4481.5	235.8
S – D	103	32662.5	317.1	83	26376.0	317.7
OPP	469	133326.0	284.2	476	136473.5	286.7
χ^2	4.2			4.4		
d.f.	2			2		
p-value	0.122			0.106		

Note. χ^2 is not corrected for ties. Euclidean χ^2 corrected for ties is 4.42 with 2 d.f. $(p = 0.109)$. Cosine χ^2 corrected for ties is 4.705, 2 d.f. $(p = 0.095)$

Results from a Kruskal-Wallis test on the null of equal mean surplus loss by bidder behavior is reported in Table 3.10. The calculated test statistics are significant only at the 10%—12% level. This failure to reject the null is in part due to the relatively small surplus loss difference for the middle evaluator and opportunist groups. Table 3.11 reports a nonparametric umbrella (Mack-Wolfe) test that peak mean surplus loss occurs for the sip-and-dipper group. The test supports the view that the monetary gains of Yankee auction participants are non-monotonic by bidding type.

Table 3.11. Monotonic Surplus Loss by Bidder Classification Test

	Euclidean			Cosine		
	MEV	*S – D*	*OPP*	*MEV*	*S – D*	*OPP*
Ap	28224	27306	23515	26181	22890	23948
Amean	25869	24462	25869	25064	20542	25064
Avar	2472253	2360631	2472253	2356170	1982351	2356170
Astar	1.49	1.85	–1.49	0.72	1.66	0.72
p-value	0.07	0.032*	0.932	0.233	0.047*	0.766

Note. * Significant a peak in the $S - D$ group

The analysis of allocation outcomes suggests that the lexicographic ordering of the bidding behavior corresponds monotonically to an ordering of allocation outcomes. The reported difference in monetary payoffs suggests monotonicity is violated. Fig. 3.6 summarizes the differences in the outcomes associated with alternative bidding behaviors. The relatively weak bidders, identified as middle evaluators, are able to realize a greater surplus by requesting large quantities and paying the marginal price. Due to their aggressive bidding in terms of price opportunists realize larger losses than the middle evaluator group. However, these losses are less than those reported by the sip-and-dipper group who gain an advantage by joining the auction early, but do not use the quantity dimension of the auction strategically and drop out of the auction prior to the close.

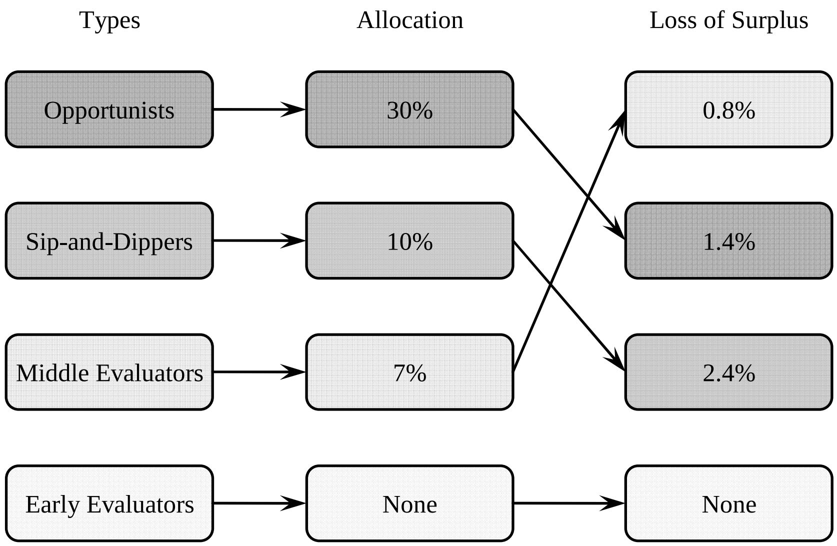


Fig. 3.6. Monotonicity

Conclusions

The application of 4-means clustering to bid selections from Internet Yankee auctions identify a stable structure of bidding behavior in keeping with previous research. Two groups identified comprise bidders with lower valuations that bid aggressively in terms of secondary attributes. These bidders are early and middle evaluators, respectively. The remaining groups have higher valuations and become active participants later in an auction. Sip-and-dippers enter the auction relatively early while opportunists only enter when the auction is 80% complete. Contrary to behavior documented at auction sites such as eBay, both late-bidder groups submit more than a single bid. The aggressive bidding behavior of early evaluators, middle evaluators and opportunists appears related to significant private information. An inference from this behavior is that, relative to their competitors, early evaluators are faced with few or no time constraints, middle evaluators have a high capacity to absorb the good while opportunists have high valuations. The ordering of bidder types according to the Yankee auction ranking rules corresponds monotonically to observed allocation outcomes. This suggests the relevance of multi-dimensional mechanism design as an analytical framework for the study of Internet Yankee auctions. Further, the analysis of payment outcomes indicates the effect of behavioral friction in Yankee auctions. Sip-and-dippers are bidders that follow the heuristic behavior of combining the primary bid component of price with a tertiary component of entry time. The presence of this behavior indicates the significance of cognitive considerations in the modeling of the decision process. Compared to opportunists, sip-and-dippers have higher sunk costs because they join the auction early. Both groups revise their bids which suggest a hold-up situation. Among the bidders in the two groups that receive an allocation ex post, sip-and-dippers have a significantly greater loss of surplus. Finally, study evidence indicates the existence of behavioral friction in the Internet contracting environment and to the relevance of frameworks such as transaction cost economics that allow semi-strong and bounded forms of rationality.

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4 Online Channel Competition in a Differentiated Goods Market

Sumi Cho and Sang-Ho Lee

Introduction

Internet-based business has drastically improved the ease with which goods are purchased online. Online channels offer increased information, lower transaction costs and wider choice. Further, new market opportunities via online channels are regularly emerging. While 'pure' online firms are appearing in electronic commerce (e-commerce) markets, there is also an increasing trend for traditionally offline firms to enter online markets, thus creating a hybrid firms. Also, competition between online and hybrid firms leads to improved efficiency of extant markets and the creation of new markets. Recent e-commerce research examines whether online market entry necessarily leads to price competition. For example, Bakos (1997), Lynch and Ariely (2000), and Harrington (2001) analyze the relation between search costs and good price in online markets using a circular city model. Bailey (1998), Liang and Huang (1998), Brynjolfsson and Smith (2000), and Chun and Kim (2005a) empirically analyze good prices for online and offline markets. Also, Zettelmeyer (2000), Cho et al. (2001) and Chun and Kim (2005b) consider the relative efficiency of transaction and delivery costs in a strategic game between online and offline firms. Finally, Goolsbee (2000), Shy (2001) and Lee (2005) investigate revenue impacts from e-commerce taxation.

This chapter introduces an online transaction channel into a Hotelling linear city model where online and offline firms coexist in equilibrium. To examine the competition effect of an online channel, a symmetric case of two offline firms is considered and welfare loss to online business is measured. Compared to the pure online competition case, the introduction of an online channel by a hybrid firm may reduce welfare when consumer offline channel transport costs are 'large' relative to firms' online channel delivery costs. The analysis is extended to the asymmetric case whereby two offline firms supply different quality goods via an online channel. Finally, how the different quality goods supplied by hybrid firms impacts on the welfare of online markets is examined. This chapter is organized as follows: the next section provides the basic model of pure online competition, using a Hotelling linear city model. Then, two mixed cases where offline firms enter the online market as a hybrid business are examined. The first case considered is for blockaded entry. The second case is a free entry model. The welfare consequences of both cases are quantified and a comparison of the social costs is made. Then the analysis is extended to an asymmetric good quality case and examines policy implications from online channel entry by differentiated good offline firms. A conclusion is provided in the final section.

Pure Online Competition

Following Hotelling (1929), consider a linear city of unit length where consumers are uniformly distributed along this interval. Consumers are indexed by their location on $x \in [0, 1]$, where x is the distance from the origin. Suppose that there are two offline firms at either end of the city. The firms sell the same good and have zero marginal costs. Denote the (offline firm) Firm A good price as p_f^A. Firm A is located at point 0. p_f^B is the price for the (offline firm) Firm B good. Firm B is located at point 1. Consumers that purchase a unit of the good from offline firms pay the firm's good price and transportation costs τ per unit distance. For example, a consumer located at x must pay transportation costs τx for purchasing from Firm A, or $\tau(1-x)$ for purchasing from Firm B. Next, define the total payment made by a consumer located at x by $p_f^A + \tau x$ when purchasing from Firm A, and $p_f^B + \tau(1-x)$ when purchasing from Firm B. Next consider a pure online firm that sells identical goods as the offline firms. The online firm good price is denoted p_n. Also assume this firm faces zero production costs.[1] Assuming that consumers at every location have Internet access, consumers may purchase goods from either offline or online firms.[2] When the consumer purchases goods from the online firm, irrespective of customer location, the consumer incurs no costs, i.e., the consumer pays the price p_n only.[3] The online firm delivers goods and incurs delivery costs d. Let x_A denote a consumer who is indifferent to purchasing a good from an offline firm, Firm A or Firm B. Then, from the equality that $p_f^A + \tau x = p_n$:

$$x_A = \frac{p_n - p_f^A}{\tau}. \tag{4.1}$$

Similarly:

$$x_B = 1 - \frac{p_n - p_f^B}{\tau}. \tag{4.2}$$

The analysis is restricted to a coexistence equilibrium where online and offline firms sell the good in equilibrium, i.e., $0 < x_A < x_B < 1$, and both firms earn non-negative profits. Next, assume the condition $\tau > d$ holds hereafter.

1 To focus on the relative magnitude of transportation and delivery costs, assume the production costs of the online channel are the same as for the offline channel. See Lynch and Ariely (2000), and Chun and Kim (2005a) for a discussion of online production costs.

2 In this analysis the focus concerns the market-covered case where consumers purchase a good either from an online firm or the offline firms.

3 For simplicity, any risk in transacting online is not considered in the model. For a discussion about e-commerce transaction costs, see Strader and Shaw (1997) and Sohn (2005).

Assumption 1: $\tau > d$

$\tau > d$ implies that the delivery costs are 'small' relative to consumer transportation costs. That is, firm transportation costs should be less than that for consumers due to economies of scale for transportation services.

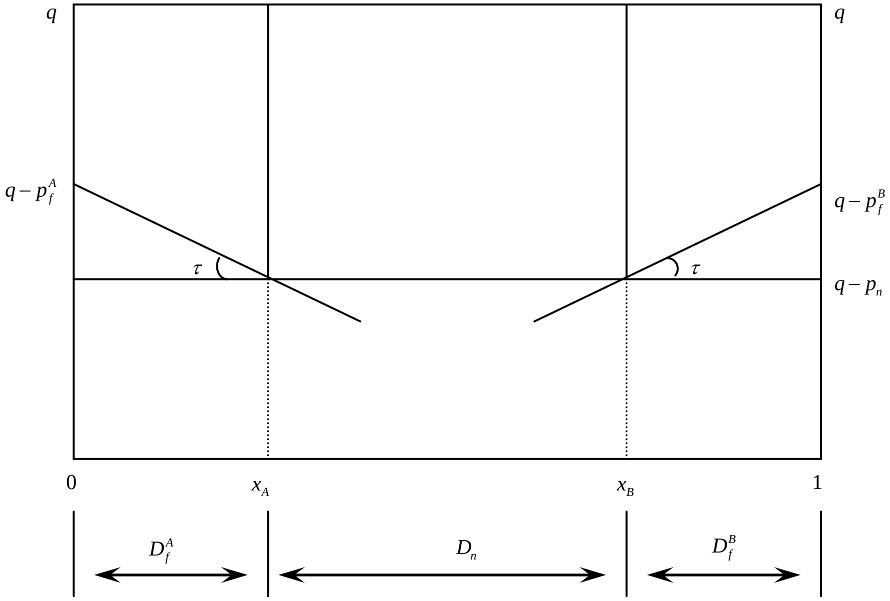

Fig. 4.1. Coexistence Equilibrium

In the coexistence equilibrium, depicted in Fig. 4.1, where q is consumers' benefit from purchasing the goods, the demand functions for each firm are:

$$D_f^A = x_A = \frac{p_n - p_f^A}{\tau}, \tag{4.3}$$

$$D_f^B = 1 - x_B = \frac{p_n - p_f^B}{\tau} \tag{4.4}$$

and

$$D_n = x_B - x_A = \frac{\tau - (2p_n - p_f^A - p_f^B)}{\tau}, \tag{4.5}$$

where $D_f^A + D_f^B + D_n = 1$. First-order necessary conditions for the offline firm profit functions, $\pi_f^i = p_f^i D_f^i$, $i = A, B$ and for online firm profits, $\pi_n = (p_n - d)D_n$ are:

$$\frac{\partial \pi_f^A}{\partial p_f^A} = \frac{p_n - 2p_f^A}{\tau} = 0\,,$$

$$\frac{\partial \pi_f^B}{\partial p_f^B} = \frac{p_n - 2p_f^B}{\tau} = 0$$

and

$$\frac{\partial \pi_n}{\partial p_n} = 1 - \frac{2p_n - p_f^A - p_f^B + 2(p_n - d)}{\tau} = 0\,.$$

In symmetric equilibrium between the two offline firms, $p_f^A = p_f^B = p_f^*$, and coexistence equilibrium between offline and online firm equilibrium prices are:

$$p_f^* = \frac{\tau + 2d}{6} \quad \text{and} \quad p_n^* = \frac{\tau + 2d}{3}\,, \tag{4.6}$$

where $p_n^* > p_f^* > 0$. Notice that the online firm sets a higher price than the offline firms in equilibrium.[4] However, the net price-cost margin for the online firm may be less than for the offline firm, i.e., $p_n^* - d < p_f^*$ if $\tau < 4d$. This outcome implies that when transportation costs are slightly higher than the firm delivery costs, online firms can set the lower prices. Market equilibrium demands are:

$$D_f^* = D_f^A = D_f^B = \frac{\tau + 2d}{6\tau} \quad \text{and} \quad D_n^* = \frac{2\tau - 2d}{3\tau}\,, \tag{4.7}$$

where $D_n^* > D_f^*$ if $\tau > 2d$. Profits for offline and online firms, respectively, are:

$$\pi_f^* = \pi_f^A = \pi_f^B = \frac{(\tau + 2d)^2}{36\tau} \tag{4.8}$$

and

$$\pi_n^* = \frac{2(\tau - d)^2}{9\tau}\,. \tag{4.9}$$

Also, total industry profit is:

$$\Pi^* = \pi_f^A + \pi_f^B + \pi_n = \frac{5\tau^2 - 4\tau d + 8d^2}{18\tau}\,. \tag{4.10}$$

[4] Studies analyzing price competition between offline and online firms yield conflicting results that depend on search costs and product characteristics. See Chun and Kim (2005a).

Finally, the welfare loss incurred from transportation and delivery costs is calculated. The social cost (shaded area in Fig. 4.2) of pure online competition is:

$$C^* = \frac{\tau^2 + 28\tau d - 20d^2}{36\tau}. \tag{4.11}$$

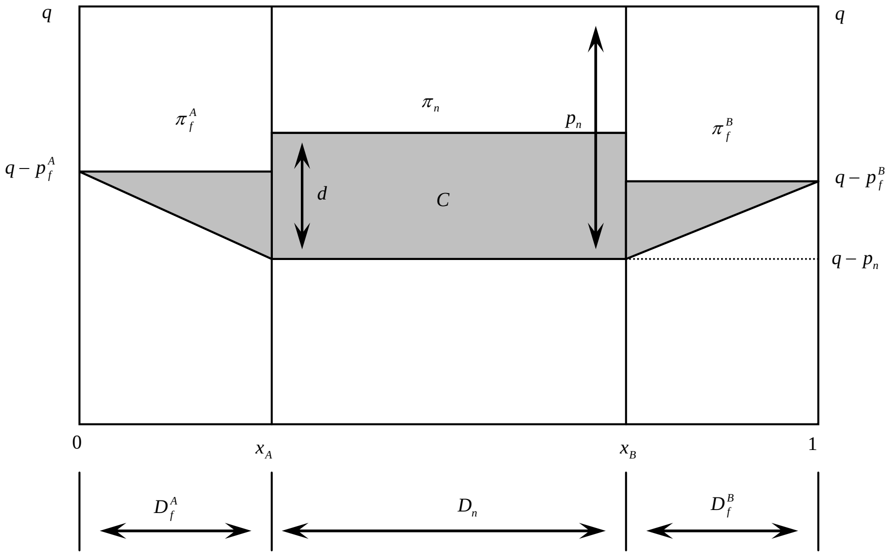

Fig. 4.2. Social Cost of Pure Online Competition

Online Channel Entry by an Offline Firm

In this section, two cases of online channel entry by an offline firm are considered. The first case concerns blockaded entry, where an offline firm enters an online market to compete with a pure offline firm that does not enter the online market. The other case considered is that of free entry, i.e., where both offline firms introduce an online channel and undertake price competition.

Hybrid Firm with Blockaded Entry

Assume that (offline firm) Firm A introduces an online channel to compete against (offline firm) Firm B. The profit function for Firm A is $\pi_A = p_f^A D_f^A + (p_n - d) D_n$, while profit function of Firm B is $\pi_B = p_f^A D_f^B$, where the demand functions are defined by Eq. 4.3 to Eq. 4.5. The corresponding first-order necessary conditions are:

$$\frac{\partial \pi_A}{\partial p_f^A} = \frac{(p_n - 2p_f^A) + (p_n - d)}{\tau} = 0\,,$$

$$\frac{\partial \pi_A}{\partial p_n} = \frac{p_f^A}{\tau} + 1 - \frac{(2p_n - p_f^A - p_f^B) + 2(p_n - d)}{\tau} = 0$$

and

$$\frac{\partial \pi_B}{\partial p_f^B} = \frac{p_n - 2p_f^B}{\tau} = 0\,.$$

In coexistence equilibrium with two firms provides the equilibrium prices:

$$p_f^{A**} = \frac{4\tau + d}{6}, \quad p_f^{B**} = \frac{\tau + d}{3} \quad \text{and} \quad p_n^{**} = \frac{2\tau + 2d}{3}, \tag{4.12}$$

where $p_n^{**} > p_f^{A**} > p_f^{B**} > 0$. Note the net price for an online good is less than for an offline good for Firm A, i.e., $p_f^{A**} > p_n^{**} - d$. Also, note that equilibrium prices after the introduction of an online channel by Firm A can be higher compared to equilibrium prices from online competition, i.e., $p_f^{A**} > p_f^*$, $p_f^{B**} > p_f^*$, $p_n^{**} > p_n^*$, for all τ, from Eq. 4.6. This finding implies a hybrid firm under blockaded entry faces reduced price competition between channels. The corresponding equilibrium market demands are:

$$D_f^{A**} = \frac{d}{2\tau}, \quad D_f^{B**} = \frac{\tau + d}{3\tau} \quad \text{and} \quad D_n^{**} = \frac{4\tau - 5d}{6\tau}, \tag{4.13}$$

where $D_f^{B**} > D_f^{A**} > 0$. Eq. 4.12 demonstrates that Firm A sets a higher offline price compared to that for Firm B—thus the market demand for the Firm A offline channel is lower compared to that for Firm B. Also, market size for the online channel in Eq. 4.13 is less than that in Eq. 4.7, i.e., $D_n^{**} < D_n^*$. This finding suggests that online market entry by Firm A reduces the size of the online market, reducing price competition. However, offline demand for Firm B goods increases simultaneously, viz., $D_f^{B**} > D_f^*$. The resulting equilibrium profits are:

$$\pi_A^{**} = \frac{16\tau^2 - 16\tau d + 13d^2}{36\tau} \tag{4.14}$$

and

$$\pi_B^{**} = \frac{(\tau + d)^2}{9\tau}, \tag{4.15}$$

where $\pi_A^{**} > \pi_B^{**} > 0$. Notice also $\pi_A^{**} > \pi_f^* + \pi_n^*$ and $\pi_B^{**} > \pi_f^*$. Thus, Firm A and Firm B both earn greater profits with the introduction of online channel by Firm A in the blockaded entry equilibrium. Total industry profit is:

$$\Pi^{**} \equiv \pi_A^{**} + \pi_B^{**} = \frac{20\tau^2 - 8\tau d + 17d^2}{36\tau}. \tag{4.16}$$

$\Pi^{**} > \Pi^*$ implies total industry profit after online channel entry by Firm A is greater when compared to the online competition outcome of Eq. 4.10.

Finally, the social cost of online channel introduction by Firm A is:

$$C^{**} = \frac{4\tau^2 + 56\tau d - 47d^2}{72\tau}. \tag{4.17}$$

Comparing Eq. 4.11, the social cost from the introduction of pure online channel by a hybrid firm to Eq 4.17, under blockaded entry, welfare is reduced only if the offline transport cost is 'large' relative to online delivery costs, i.e., $\tau > 1.87d$.

Proposition 1

When an offline firms enters an online market under blockaded entry, social welfare is reduced if the transport cost is 'large' relative to delivery costs, i.e., $C^* < C^{**}$ if $\tau > 1.87d$.

Hybrid Firm with Free Entry

This section examines the impact on social welfare when online channel entry is free. That is, both offline firms enter an online market and compete via Bertrand pricing. Profit functions for the hybrid firms are $\pi_i = p_f^i D_f^i + (p_n^i - d)D_n^i$, $i = A, B$. Bertrand competition yields $p_n^i = d$ in equilibrium. With the demand functions Eq. 4.3 and Eq. 4.4, in a symmetric equilibrium, the corresponding equilibrium prices are:

$$\hat{p}_f = \hat{p}_f^A = \hat{p}_f^B = d/2 \quad \text{and} \quad \hat{p}_n = \hat{p}_n^A = \hat{p}_n^B = d. \tag{4.18}$$

Clearly, $\hat{p}_f < p_f^*$ and $\hat{p}_n < p_n^*$, i.e., free entry equilibrium prices are less than those for the online competition case (Eq. 4.6). This means that consumer surplus must increase after online channel entry. Market equilibrium demands are $\hat{D}_f = d/2\tau$ and $\hat{D}_n = (\tau - d)/\tau$. Also note that because of price competition, $\hat{D}_f < D_f^*$ and $\hat{D}_n > D_n^*$, i.e., online market demand increases under the free entry scenario. Equilibrium profits for the hybrid firms is $d^2/4\tau$, and industry profits is

$\hat{\Pi} = d^2 / 2\tau$. With $\hat{\Pi} < \Pi^* < \Pi^{**}$, industry profit is reduced under the free entry. Finally, the social cost of online channel entry is:

$$\hat{C} = \frac{4\tau d - 3d^2}{4\tau} . \qquad (4.19)$$

Comparing Eq. 4.11 and Eq. 4.17, the following relationship holds:

$$\hat{C} < C^* \text{ if } \tau > 7d, \text{ and } \hat{C} > C^* \text{ if } \tau < 7d,$$
$$\hat{C} < C^{**} \text{ if } \tau > 3.5d, \text{ and } \hat{C} > C^{**} \text{ if } \tau < 3.5d .$$

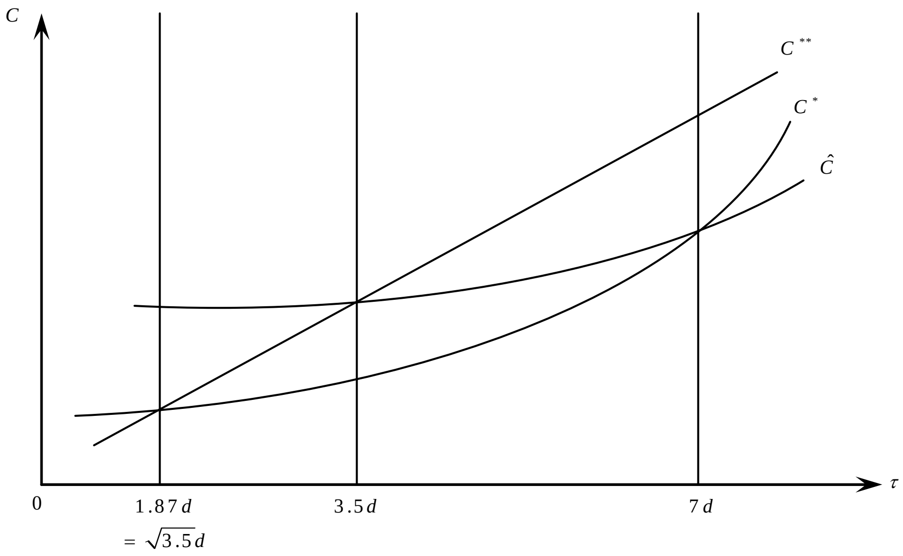

Fig. 4.3. Social Cost Comparison

Comparing the results of Proposition 1 the following relationship holds:

$$C^{**} < C^* < \hat{C} \text{ if } \tau < 1.87d ,$$

$$C^* < C^{**} < \hat{C} \text{ if } 1.87d < \tau < 3.5d ,$$

$$C^* < \hat{C} < C^{**} \text{ if } 3.5d < \tau < 7d$$

and

$$\hat{C} < C^* < C^{**} \text{ if } \tau > 7d .$$

Notice that social costs under free entry are not always least. In particular, $\tau < 3.5d$ implies social cost is largest among these market scenarios. Thus, social welfare under free entry increases only if $\tau > 7d$, i.e., transport costs are 'large' relative to delivery costs.

Proposition 2

When both offline firms introduce an online channel under free entry social welfare is reduced unless transports costs are 'large' relative to delivery costs. That is, $\hat{C} > \min\{C^*, C^{**}\}$ if $\tau < 7d$.

Furthermore, this result is strengthened when sunk set-up costs are considered. So, in an e-commerce market, the mixed competition between pure online and hybrid firms with free entry may not necessarily yield a better societal outcome.

Asymmetric Quality Goods and Competition

Below the model is extended to consider two offline firms selling goods of different quality. Let the quality of Firm i good be q_i, with $q_A \geq q_B$. Define $\Delta \equiv q_A - q_B \geq 0$. To ensure coexistence equilibrium, in addition to Assumption 1 assume:[5]

Assumption 2: $\Delta < \min\{\tau + d, (4\tau - 5d)/2\}$

Each consumer purchases a unit of Firm A high-quality good or Firm B low-quality good. A consumer at x receives a net benefit of $q_A - p_f^A - \tau x$ if the good is purchased from Firm A or $q_B - p_f^B - \tau(1-x)$ if the Firm B good is purchased.

There are two effects from entering an online channel to sell goods of different quality. First, a price effect arises from the high-quality good firm competing with a low-quality good firm with multiple channels. This price effect is strongest if the low-quality good firm sells low-quality goods via an online channel. Conversely, the effect is weakest when the high-quality good firm sells via an online channel. Second, there is a consumer quality effect from purchasing from an online channel—otherwise consumers would purchase goods from an offline channel and pay transport costs. Also this quality effect is strongest when the high-quality good firm sells via an online channel. Again, the effect is weakest when the low-quality good firm sells via online channels. That is, a trade-off exists between price and quality effects in an asymmetric quality market scenario.

[5] Assumption 2 implies $\Delta < (4\tau - 5d)/2$ if $\tau < 3.5d$ and $\Delta < \tau + d$ if $\tau > 3.5d$.

Online Channel Competition with High-quality Goods

Firm A, that sells a high-quality good enters an online channel to compete with offline Firm B. In coexistence equilibrium, the total expenditure of a consumer that purchases a high-quality good from Firm A and an online good is $p_f^A + \tau x$ and p_n^A. The benefit to purchase a good from Firm B and an online purchase from Firm A is, $q_B - p_f^B - \tau(1-x)$ and $q_A - p_n^A$. Thus:

$$x_A^H = \frac{p_n^A - p_f^A}{\tau} \quad \text{and} \quad x_B^H = 1 - \frac{p_n^A - p_f^B - \Delta}{\tau}.$$

Firm A and Firm B profit functions, respectively, are $\pi_A^H = p_f^A D_f^A + (p_n^A - d) D_n^A$ and $\pi_B^H = p_f^B D_f^B$, with corresponding demands functions $D_f^A = x_A^H$, $D_f^B = 1 - x_B^H$ and $D_n^A = x_B^H - x_A^H$. The resultant first-order necessary conditions are:

$$\frac{\partial \pi_A^H}{\partial p_f^A} = \frac{(p_n^A - 2p_f^A) + (p_n^A - d)}{\tau} = 0,$$

$$\frac{\partial \pi_A^H}{\partial p_n^A} = \frac{p_f^A}{\tau} + 1 - \frac{(2p_n^A - p_f^A - p_f^B - \Delta) + 2(p_n^A - d)}{\tau} = 0$$

and

$$\frac{\partial \pi_B^H}{\partial p_f^B} = \frac{p_n^A - 2p_f^B - \Delta}{\tau} = 0.$$

In coexistence equilibrium between two firms the equilibrium prices are:

$$p_f^{AH} = \frac{4\tau + d + 2\Delta}{6}, \quad p_f^{BH} = \frac{\tau + d - \Delta}{3} \quad \text{and} \quad p_n^{AH} = \frac{2\tau + 2d + \Delta}{3}. \tag{4.20}$$

Notice that while $p_n^{AH} > p_f^{AH} > p_f^{BH} > 0$, however, $p_f^{AH} > p_n^{AH} - d$. Further, market equilibrium demands are:

$$D_f^{AH} = \frac{d}{2\tau}, \quad D_f^{BH} = \frac{\tau + d - \Delta}{3\tau} \quad \text{and} \quad D_n^{AH} = \frac{4\tau - 5d + 2\Delta}{6\tau}, \tag{4.21}$$

where $D_f^{AH} + D_n^{AH} > D_f^{AL}$. As entry is by the high-quality good firm, price effects are relatively weak. That is, as online channel consumers benefit from high-quality goods the quality effect is more important. Firm profits are:

$$\pi_A^H = \frac{16\tau^2 + 13d^2 - 16\tau d + 4\Delta^2 + 16\tau\Delta - 8d\Delta}{36\tau} \tag{4.22}$$

and

$$\pi_B^H = \frac{(\tau + d - \Delta)^2}{9\tau}, \tag{4.23}$$

where $\pi_A^H > \pi_B^H > 0$. Finally, the social costs of introducing an online channel by a high-quality firm are:

$$C^H = \frac{4\tau^2 - 47d^2 + 56\tau d + 28\Delta d + 4\tau\Delta - 8\Delta^2}{72\tau} \tag{4.24}$$

and

$$C^{**} + \Delta \frac{28d + 4\tau - 8\Delta}{72\tau}, \tag{4.25}$$

where $28d + 4\tau - 8\Delta > 0$ if $\tau < 6d$.

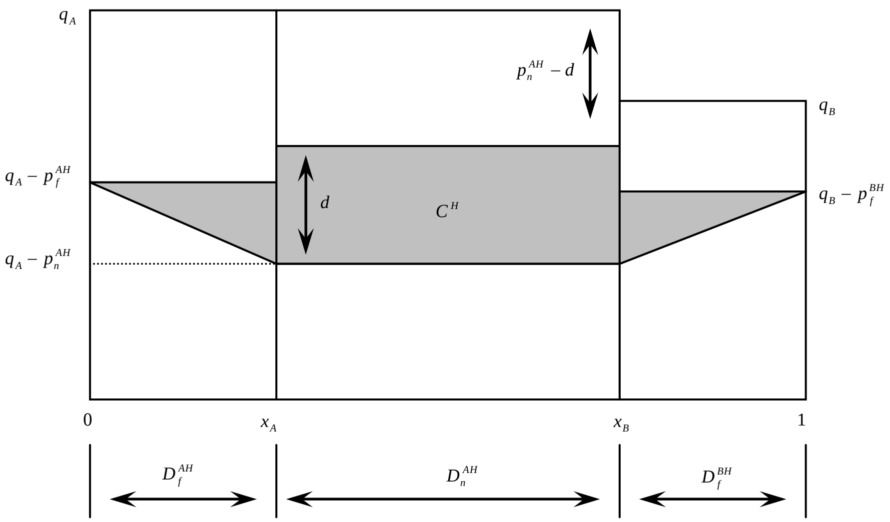

Fig. 4.4. Social Cost of Online Competition—High-quality Good Case

Online Channel Competition with Low-quality Goods

Consider next, the case where offline Firm B selling a low-quality good introduces an online channel to compete with offline Firm A. Again, in a coexistence equilibrium, if consumers purchase a low-quality good from Firm B, a comparison is made between $p_f^B + \tau(1-x)$ and p_n^B, and between $q_A - p_f^A - \tau x$ and $q_B - p_n^B$. Similarly:

$$x_A^L = \frac{p_n^B - p_f^A + \Delta}{\tau} \quad \text{and} \quad x_B^L = 1 - \frac{p_n^A - p_f^B}{\tau}.$$

Profit functions for Firm A and Firm B, respectively, are $\pi_A^L = p_f^A D_f^A$ and $\pi_B^L = p_f^B D_f^B + (p_n^B - d) D_n^B$, while the demand functions are defined by $D_f^A = x_A^L$, $D_f^B = 1 - x_B^L$ and $D_n^B = x_B^L - x_A^L$. The first-order necessary conditions are:

$$\frac{\partial \pi_A^L}{\partial p_f^A} = \frac{p_n^B - 2p_f^B + \Delta}{\tau} = 0,$$

$$\frac{\partial \pi_B^L}{\partial p_f^B} = \frac{(p_n^B - 2p_f^B) + (p_n^B - d)}{\tau} = 0$$

and

$$\frac{\partial \pi_B^L}{\partial p_n^B} = \frac{p_f^B}{\tau} + 1 - \frac{(2p_n^B - p_f^A - p_f^B + \Delta) + 2(p_n^B - d)}{\tau} = 0.$$

In coexistence equilibrium between the firms, equilibrium prices are:

$$p_f^{AL} = \frac{\tau + d + \Delta}{3}, \quad p_f^{BL} = \frac{4\tau + d - 2\Delta}{6} \quad \text{and} \quad p_n^{BL} = \frac{2\tau + 2d - \Delta}{3}, \tag{4.26}$$

where $p_f^{AL} > p_n^{BL} > p_f^{BL} > 0$ and $p_f^{BL} > p_n^{BL} - d$. Also note that $p_f^{AH} > p_f^{AL}$, $p_f^{BH} > p_f^{BL}$ and $p_n^{AH} > p_n^{BL}$. Compared to the high-quality good case the price effect is stronger. Namely, as Firm B online and offline channels compete with Firm A high-quality goods, the quality effect is weak as consumers using the online channel do not gain much benefit from low-quality goods. The market demands in equilibrium are:

$$D_f^{AL} = \frac{\tau + d + \Delta}{3\tau}, \quad D_f^{BL} = \frac{d}{2\tau} \quad \text{and} \quad D_n^{BL} = \frac{4\tau - 5d - 2\Delta}{6\tau}, \tag{4.27}$$

where $D_f^{AH} < D_f^{AL}$ and $D_n^{AH} > D_n^{BL}$. Firm profits are:

$$\pi_A^L = \frac{(\tau + d + \Delta)^2}{9\tau} \tag{4.28}$$

and

$$\pi_B^L = \frac{16\tau^2 + 13d^2 - 16\tau d + 4\Delta^2 - 16\tau\Delta + 8d\Delta}{36\tau}. \tag{4.29}$$

Finally, social costs from the low-quality good firm entering an online channel are:

$$C^L = \frac{4\tau^2 - 47d^2 + 56\tau d - 16\Delta d + 8\tau\Delta + 4\Delta^2}{72\tau} \tag{4.30}$$

and

$$= C^{**} + \Delta\frac{2\tau + \Delta - 4d}{18\tau}. \tag{4.31}$$

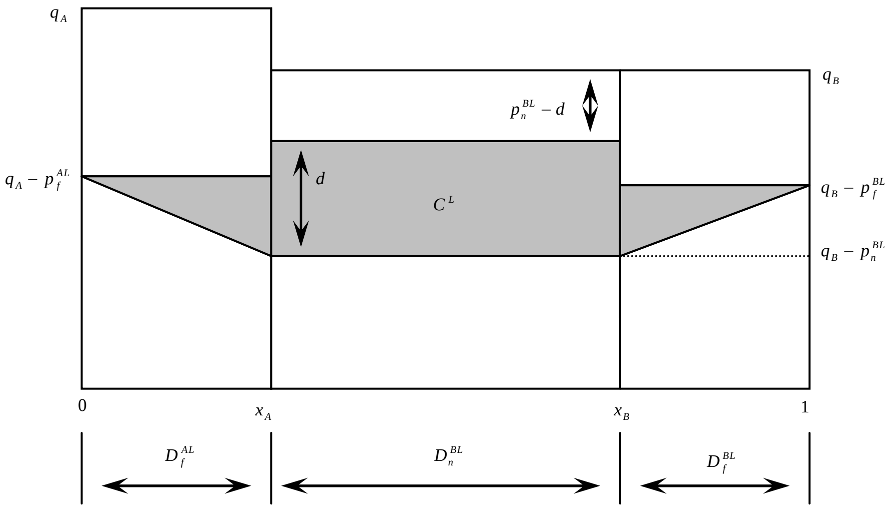

Fig. 4.5. Social Cost of Online Competition—Low-quality Good Case

Comparison

Comparing the social costs between the high-quality good case (Eq. 4.24) and the low-quality case (Eq. 4.30) suggests that:

$$C^H > C^L \quad \text{if} \quad \Delta < \frac{11d - \tau}{3} \quad \text{and} \quad C^H < C^L \quad \text{if} \quad \Delta > \frac{11d - \tau}{3}. \tag{4.32}$$

Therefore, under the coexistence equilibrium the following relationship, where $\tau > 3.5d$, holds:

$$C^L < C^H \quad \text{if} \quad 0 < \Delta < \frac{11d - \tau}{3}$$

and

$$C^H < C^L \quad \text{if} \quad \frac{11d - \tau}{3} < \Delta < \tau + d \; .$$

This result supports the premise that increased social benefit does not necessarily arise from a high-quality good offline firm adding an online channel when quality difference is small. Also the introduction of an online channel by a low-quality good offline firm may save social costs compared with the situation of a high-quality good offline firm adding an online channel.

Proposition 3

Suppose the offline firms supply different quality goods, under coexistence equilibrium, the impact on social welfare from the introduction of an online channel depends on the magnitude of quality difference. In particular, only for a 'large' quality difference is net social welfare enhanced.

Furthermore, a preemption game may be played between offline firms under blockaded entry as social welfare after channel entry depends not only on quality difference but the order of online market entry. For example, when a network effect is present then a first-mover advantage exists in a preemption model. Another example arises from high irrecoverable sunk costs. Again there is a disadvantage for the follower. Finally, when government regulations extend to online channels there may be a wasteful race to receive permission to enter. Accordingly, policy needs to be aware of the nature of price competition in a mixed online market where offline firms can enter.

Conclusion

This chapter considered a Hotelling model that incorporates competition effects arising from offline firm entry into online channels by examining equilibrium outcome when offline firms compete in online markets. Comparison is made of the welfare loss from online channel entry. First, a symmetric case of two offline firms demonstrates that, compared to the case of pure online competition, the entry into an offline channel may reduce welfare depending on the magnitude of consumer's transport costs relative to firm's offline delivery costs. The analysis is extended to an asymmetric case where two offline firms supply different quality goods. The result for this case provides useful input for policymakers dealing with online markets. Further research needs to consider dynamic issues such as the impact of network effects of online business and the lock-in effect of offline channels. Other challenging issues that require examination are the strategic incentives of hybrid firms, e.g., a storage cost saving effect from multiple channels and a complementary effect of online channels from advertising and online experience.

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5 Competition and Growth in Virtual Markets

Gary Madden, Truong P. Truong and Michael Schipp

Introduction

The introduction of the Internet that led to the establishment of online marketplaces, to enable the conduct of e-commerce via a Web site, was prophesized to usher in a New Economy.[1] However, many New Economy (Virtual or Internet) firms, like many Old Economy (Bricks-and-Mortar, B&M) firms, have not survived (Varian 2004).[2] Those Old Economy and New Economy firms that survive typically do so in Hybrid form, viz., conduct business via a store, factory or office but also through a Web site. While much has been written on the conduct of business-to-consumer and business-to-business e-commerce markets, the competitive process that transforms B&M firms and Virtual firms into Hybrid firms has not been extensively examined.[3] Alternative equilibrium states are considered. First, assume the combined (B&M and Virtual) market does not grow and that the B&M market is not contested by the Virtual entrant. That is, the B&M and Virtual markets are horizontally differentiated, and competition is modelled in a Hotelling homogeneous good framework. Firms vie for Virtual market share through price competition. Firms are able to reduce price because of the lower production costs associated with Internet technology, while this technology also enables customers to more effectively price search. Second, in a growth market setting the customer base changes as new customers are attracted to online shopping. Also, firms are more likely to introduce new products, while customers search price and quality. Accordingly, the model incorporates essential features of a no growth combined market such as homogeneous goods without quality variation. Stylized facts required in the model specification include cost functions that reflect Internet technology's lower marginal costs. Further, sunk B&M firm costs are higher than those for the Virtual firm. For the growth market, a market expansion parameter γ is needed. The value of γ is assumed to rely on firm investment differentials and Virtual market size. The following section describes alternative equilibrium states; a description of the relationship between firm investment and market share follows; next a two-period game derives equilibrium no growth market shares and profits; the following section solves this game for a growth market setting; a com-

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[1] Gordon (2000) offers a dissenting view.

[2] For the purposes of this study, e-commerce is defined as sales of goods and services, where an order is placed by a buyer or price and terms of sales are negotiated over an Internet, extranet, electronic data interchange network, e-mail or other online system. Payment may or may not be made online.

[3] Brynjolfsson and Smith (1999) is one such study.

parative-static analysis of equilibrium profits is then made; and a final section concludes.

Alternative Equilibrium States

In the no growth market a Virtual firm enters the former B&M only market. Entry segments the market. The B&M firm retains monopoly supply over the B&M segment that shrinks to $[0,\alpha]$. With no combined market growth the Virtual market segment is $[\alpha,1]$. The remaining B&M (Type-1) customers are either unable or unwilling to use the Internet to purchase goods. Both firms compete in the Virtual (Type-2) customer segment. The market shares are $[0,\alpha]+\beta[\alpha,1]$ for the Hybrid firm and $(1-\beta)[\alpha,1]$ for the Virtual firm, where $0<\alpha<1$ and $0<\beta<1$.

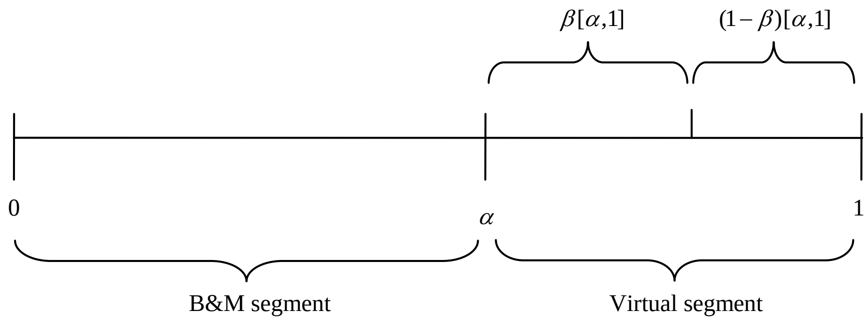

Fig. 5.1. No Growth Post-entry Market Shares

In Fig. 5.1 the size of the B&M and Virtual market shares are determined by α. The magnitude of α reflects both consumer Internet connectivity and online shopping preference. β's size reflects the strength of competition between the (formerly B&M) Hybrid firm and the Virtual firm for Type-2 customers. Competition in the Virtual market is assumed to depend primarily on firm's investment and cost structure.

Figure 5.2 depicts the growth market with the combined market expanding by γ to $[0,1+\gamma]$. Also, assume that this growth occurs only in the Virtual market. Namely, competition in the $[1,1+\gamma]$ segment is the same as on $[\alpha,1]$. The problem then reduces to one of competition between the Hybrid firm and a Virtual firm for share of the Virtual segment $[\alpha,1+\gamma]$. The Hybrid firm's combined market share is comprised of the B&M market, former B&M customers that shop online and a Virtual market growth component. The Virtual firm's market share comprises former B&M customers that shop online and a Virtual market growth component.

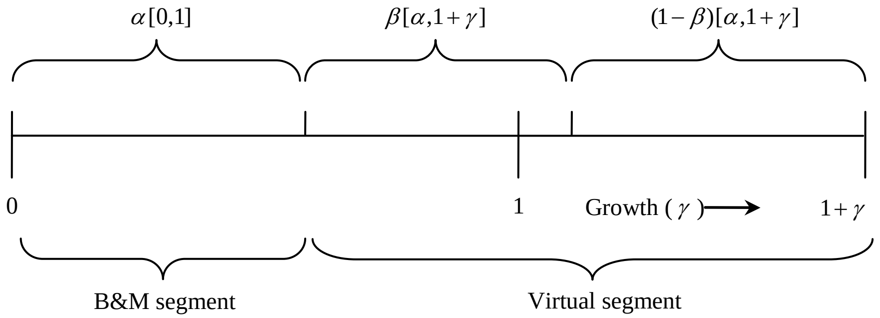

Fig. 5.2. Growth Post-entry Market Shares

Should the Hybrid firm gain, retain or lose customer base depends on whether $[0,\alpha]+\beta[\alpha,1+\gamma]\geq 1$ or <1. That is, the size of the Hybrid firm's customer base depends on consumer online shopping preference (α), Virtual market growth (γ) and strength of competition (β). A smaller α (Type-1 customer base) and larger γ (Type-2 customer growth) provides an incentive for the B&M firm to invest and compete in the Virtual market as a Hybrid firm (increasing β).

Firm Investment and Market Share

In Fig. 5.3 the Hybrid firm and a Virtual firm compete for Type-2 customers residing on a Hotelling main street to the right of point $[\alpha]$. The further to the right of $[\alpha]$ a Type-2 customer resides the stronger is her preference for shopping online. As Type-2 customers are distributed uniformly along $[\alpha,1]$ when the firm's price identically they gain equal market shares. Customers residing the left of the midpoint $[x]$ purchase goods from the Hybrid firm while those residing to the right of $[x]$ purchase from the Virtual firm.

Through investment firms can strategically position themselves on the $[\alpha,1]$ segment at points such as $[a]$ and $[b]$ with a view to gaining market share. For instance, to acquire Virtual firm characteristics a B&M firm moves away from $[\alpha]$ to point $[a]$. Online characteristics that provide Type-2 consumers utility include an ability to view product information or make online payments securely. To provide these services and reduce distance to the Type-2 customers located to the right of $[x]$ requires the B&M firm invest, e.g., to establish a Web site that has online payment security. Similarly, a Virtual firm might acquire B&M firm characteristics by purchasing a showroom or distribution centre to appeal more to customers who gain utility from being able to physically inspect or return goods. That is, the Virtual firm moves toward $[\alpha]$, away from $[1]$, to point $[b]$.

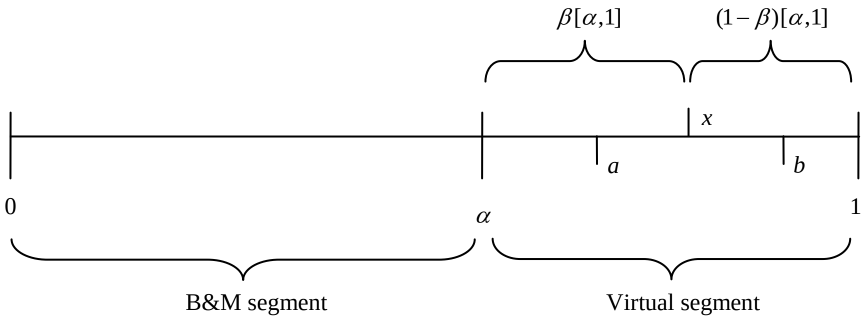

Fig. 5.3. Hotelling Main Street

To reach point $[1]$ from $[\alpha]$, the B&M firm must invest I_V (Virtual firm sunk cost). However, because of likely retaliation the B&M firm invests $F_a < I_V$ and establishes an intermediate position at $[a]$ to the right of $[\alpha]$ but left of $[1]$. Similarly, to reach point $[\alpha]$ from $[1]$, the Virtual firm must invest $I_{B\&M}$ (B&M firm sunk cost). Nonetheless, the entrant invests $F_b < I_{B\&M}$ to establish a position at $[b]$ to the left of $[1]$ but right of $[\alpha]$.

No Market Growth Game

Consider next strategic decisions faced by the firms described by a two-stage game. In Stage 1 the firms decide their optimal investment to acquire B&M and Virtual characteristics, i.e., the Hybrid firm selects position $[a]$ and the Virtual firm chooses position $[b]$. In Stage 2 the firms determine price to maximize own profit given the customer distribution and their relative positions on $[\alpha,1]$.

A customer positioned at point $[x]$ can purchase the good for P_a from the Hybrid firm at $[a]$ or for P_b from the Virtual firm at $[b]$. The customer's indirect utility from purchase is:

$$U_{xa} = A - t(x-a)^2 - P_a \tag{5.1a}$$

$$U_{xb} = B - t(x-b)^2 - P_b \tag{5.1b}$$

respectively.[4] When a customer is indifferent to purchase mode:

$$A - t(x-a)^2 - P_a = B - t(x-b)^2 - P_b \,. \tag{5.2}$$

When $A = B$, i.e., the product is homogenous or equivalent quality, then:

$$x^* = \frac{(a+b)}{2} + \frac{(P_b - P_a)}{2t(b-a)} \,, \tag{5.3}$$

where x^* is the market share of the Hybrid firm at $[a]$ and $(1-\alpha-x^*)$ is the market share of the Virtual firm at $[b]$. Consumers to the left of x^* only purchase from the Hybrid firm as $U_{xa} > U_{xb}$. Whereas, consumers to the right of x^* only purchase from the Virtual firm as $U_{xa} < U_{xb}$.

A special case occurs when $a \neq b$ and $P_b = P_a$, so that $x^* = (a+b)/2$. For example, when the Virtual firm does not invest in a B&M facility, i.e., $[b]$ remains at $[1]$ so that $b = 1-\alpha$. Any Hybrid firm investment in an online facility is a rightward move that increases a and x^*. Maximum x^* $(\to 1-\alpha)$ occurs as $a \to b$.[5] In practice, the Hybrid firm cannot reach $[b]$ as fixed investment costs erode profit. Also the Virtual firm reacts to the Hybrid firm's action by a leftward move from investing in a B&M facility. The Virtual firm's response partially offsets the Hybrid firm's initial profit gain.

Equivalently, should the Virtual firm make the initial move, when the Hybrid firm remains at $a = 0$, at point $[\alpha]$, $x^* \to 0$. The Virtual firm does not achieve $x^* = 0$ as the Hybrid firm will react by investing in an online facility. Equilibrium is determined via a process of competition where both firms maximize own profit subject to competitor location.

So far it has been implicitly assumed that $a, b \geq 0$. $a > 0$ implies, the Hybrid firm cannot disinvest, viz., dispose of assets and concede some B&M customer base. However, while *a* cannot be negative, *b* can move further to the left of point *a*. Depending on the required fixed investment it could be more profitable for a Virtual firm to invest in a B&M facility than for a Hybrid firm to invest in an online facility.[6] This does not mean the Virtual firm is competing for the B&M

[4] The model describes horizontal product differentiation. See, e.g., Shy (1995, Chap. 12).

[5] The equilibrium value of x^* is indeterminate when $a = b$. In practice, firms do not attempt to become identical and it is reasonable to maintain that $a \neq b$. Besides, if $a = b$, and $P_b = P_a$, is more like a situation of collusion rather than competition.

[6] This includes the costs of advertising and establishing a brand name for the online shop. Consider, e.g., a B&M bookshop investing in an online facility to establish a 'good name' to compete with Amazon.com.

market share but simply establishing B&M facilities to better serve Type-2 customers that wish to visit shop fronts to inspect, collect or return goods. This means $[b]$ can move further to the left of $[\alpha]$ before the Hybrid firm responds. That is, the minimum $x^* = 0$ occurs when $b = -a$.[7] Profits are:

$$\pi_a = (P_a - MC_a)x^* - F_a \tag{5.4a}$$

$$\pi_{\mathrm{b}} = (P_b - MC_b)(1 - \alpha - x^*) - F_b , \tag{5.4b}$$

where F_i is fixed investment and MC_i is the corresponding Firm i marginal cost. F_i is assumed related to firm location. Specifically:

$$F_a = a^{\theta_a} \quad \text{and} \quad F_b = (1 - \alpha - b)^{\theta_b} , \tag{5.5}$$

where θ_a, $\theta_{\mathrm{b}} \geq 0$. Substituting Eq. 5.3 and Eq. 5.5 into Eq. 5.4, provides:

$$\pi_a = (P_a - MC_a)\left(\frac{(a+b)}{2} + \frac{(P_b - P_a)}{2t(b-a)}\right) - a^{\theta_a} \tag{5.6a}$$

$$\pi_b = (P_b - MC_b)\left(1 - \alpha - \frac{(a+b)}{2} - \frac{(P_b - P_a)}{2t(b-a)}\right) - (1 - \alpha - b)^{\theta_b} . \tag{5.6b}$$

Maximizing π_a, π_b with respect to P_a, P_b respectively, gives:

$$2P_a - MC_a = P_b + t(b-a)(b+a) \tag{5.7a}$$

[7] Any further move by the Virtual firm to the left of $b = -a$ will not increase profit as x^* cannot be negative. This is due to the assumption that the Virtual market $[\alpha,1]$ consists only of Type-2 customers. The size of the Type-2 market segment is partly determined by factors not in the control of firms. This assumption is relaxed below so that only new customers shop with the Virtual firm. When the Virtual firm acquires B&M facilities and captures some Type-1 customers then the value of α can be determined endogenously, by the level of entrant B&M facility investment as well as the online facility investment by the Hybrid firm, i.e., an equilibrium x^* that can be negative.

$$2P_b - MC_b = P_a - t(b-a)(b+a-2+2\alpha) \tag{5.7b}$$

or

$$P_a = \tfrac{1}{3}((2MC_a + MC_b) + t(b-a)((b+a)+2(1-\alpha))) \tag{5.8a}$$

$$P_b = \tfrac{1}{3}((MC_a + 2MC_b) - t(b-a)((b+a)-4(1-\alpha))) \ , \tag{5.8b}$$

from which the resulting price differential is related to firm's MC and location, and α :

$$P_b - P_a = \tfrac{1}{3}((MC_b - MC_a) - 2t(b-a)((b+a)-(1-\alpha))) \ . \tag{5.9}$$

In the special case, where $MC_a = MC_b = MC$:

$$P_a - MC = \tfrac{1}{3}t(b-a)((b+a)+2(1-\alpha)) \tag{5.10a}$$

$$P_b - MC = -\tfrac{1}{3}t(b-a)((b+a)-4(1-\alpha)) \tag{5.10b}$$

$$P_b - P_a = -\tfrac{2}{3}t(b-a)((b+a)-(1-\alpha)) \tag{5.10c}$$

$$x^* = \frac{(b+a)}{6} + \frac{(1-\alpha)}{3} \ . \tag{5.10d}$$

For both firms to invest defensively and maintain their initial equal market share requires that $(a+b) = (1-\alpha)$. That is, point $[a]$ shifts to the right of $[\alpha]$ the same distance that $[b]$ shifts to the left of $[1]$, so that:

$$P_a = P_b = MC + t(1-\alpha)(b-a) \tag{5.11a}$$

$$x^* = \frac{(1-\alpha)}{2} \ . \tag{5.11b}$$

A particular case occurs when neither firm invests aggressively to capture market share. The Virtual firm does not invest in B&M facilities, and so the B&M firm does not invest in Virtual facilities, maintaining its position at α, viz., $a=0$ and $b=1-\alpha$:

$$P_a = P_b = MC + t(1-\alpha)^2 . \tag{5.12}$$

The maximum investment firms make to defend market share occurs at $[x]$. At $[x]$, $(b-a)=0$ and price equals minimum MC. Further investment results only in lost profit. Of course, zero profit may be reached before either firm reaches $[x]$, viz., when fixed investment costs are not considered.[8]

Substituting Eq. 5.8 into Eq. 5.6, with $MC_a = MC_b = MC$, provides firm Stage 2 profit:

$$\pi_a = \tfrac{1}{18} t(b-a)((a+b)+2(1-\alpha))^2 - a^{\theta_a} \tag{5.13a}$$

$$\pi_b = \tfrac{1}{18} t(b-a)((a+b)-4(1-\alpha))^2 - (1-\alpha-b)^{\theta_b} . \tag{5.13b}$$

When firms invest defensively profits are:

$$\pi_a = \tfrac{1}{2} t(b-a)(1-\alpha)^2 - a^{\theta_a} \tag{5.14a}$$

$$\pi_b = \tfrac{1}{2} t(b-a)(1-\alpha)^2 - (1-\alpha-b)^{\theta_b} . \tag{5.14b}$$

From Eq. 5.14, so long as $\theta_a, \theta_b \geq 0$, $\partial\pi_a / \partial a < 0$, $\partial\pi_b / \partial b > 0$ and $\partial\pi_a / \partial b < 0$, $\partial\pi_b / \partial a > 0$, maximum profit for both firms occurs at $a=0$ and $b=1-\alpha$. This result is intuitively appealing as with no combined market growth the only motivation to invest is defensive. Further investment only increases costs and with no customer base expansion profits fall. This result occurs only if there is tacit collusion.[9]

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[8] $[x]$, however, is a theoretical maximum position for both firms so it is reasonable to assume $b-a \geq 0$.

[9] Firms may not initially compete via price. However, defensive investment and position to customers may cause price falls where (b–a) decreases from maximum $(1-\alpha)$ and cause price to fall. Such action reduces profit and firms earn zero profit as in a Bertrand-type competition.

Market Growth Game

So far, both firms are assumed to vie for shares of a fixed Virtual market, i.e., investment has no effect on the combined market size. Next, assume firm investment results in combined market growth, however, assume this growth occurs only in the Virtual segment whose size increases to $[\alpha, 1+\gamma]$.[10] With the B&M market size fixed and the Virtual market augmented the relative size of α is $\alpha' = \alpha/(1+\gamma)$ while the relative size of the Virtual market becomes $[\alpha/(1+\gamma), 1]$. The locations of the firms also change to $a' = a/(1+\gamma)$ and $b' = (b+\gamma)/(1+\gamma)$.[11] Substituting for a, b and α with a', b' and α' does not otherwise affect prior equations. For example, after substitution (5.14) becomes:

$$\begin{aligned}\pi_a &= \tfrac{1}{2}t(b'-a')(1-\alpha')^2 - F_a(a') \\ &= \tfrac{1}{2}t(b-a+\gamma)(1-\alpha+\gamma)^2/(1+\gamma)^3 - (a/(1+\gamma))^{\theta_a}\end{aligned} \tag{5.15a}$$

$$\begin{aligned}\pi_b &= \tfrac{1}{2}t(b'-a')(1-\alpha')^2 - F_b(b') \\ &= \tfrac{1}{2}t(b-a+\gamma)(1-\alpha+\gamma)^2/(1+\gamma)^3 - (1-\alpha'+\gamma-b')^{\theta_b} \\ &= \tfrac{1}{2}t(b-a+\gamma)(1-\alpha+\gamma)^2/(1+\gamma)^3 - (1-\alpha/(1+\gamma)+\gamma-(b+\gamma)/(1+\gamma))^{\theta_b}.\end{aligned} \tag{5.15b}$$

Virtual market growth from firms' investment impacts both on profit and the distance between firms located in the Virtual segment—measured by $g' = (b'-a')$. That is, with market growth both customer base and sales increase. Growth also increases g' (that leads to higher prices) by overriding the defensive investment impact. However, the net effect on profits is unclear. Optimum profit occurs when $a' > 0$ and $b' < 1-\alpha'$.

In particular, assume that the relation between firm investment—measured by narrowing of distance $g' = (b'-a')$—and market expansion γ is:

$$\frac{g'}{1-\alpha'} = \frac{(b'-a')}{(1-\alpha')} = \frac{(b-a+\gamma)}{(1-\alpha+\gamma)} = \frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)}. \tag{5.16}$$

In rearranged form:

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[10] This assumption is prima facie reasonable as private firm investment is unlikely to stimulate Type-1 customer's connectivity which is more likely to depend on public infrastructure and education programs.

[11] The location of the Virtual firm is measured relative to end point $[1]$. With increased market size, this point shifts to $[1+\gamma]$ and the position of the virtual firm is $(b+\gamma)/(1+\gamma)$ rather than $b/(1+\gamma)$.

$$g' = \frac{(b-a+\gamma)}{(1+\gamma)} = \frac{1}{(1+\gamma)} \; \frac{\gamma_{\max}-\gamma}{\gamma_{\max}} \; \frac{(1+\gamma-\alpha)}{1+\gamma} . \tag{5.17}$$

Equation 5.17 implies increasing investment, narrowing g', corresponds with $\gamma \to \gamma_{\max}$. In the form Eq. 5.17, distance g' relates to the product of a 'discount rate' (that declines with market growth), the potential market growth rate and a relative Virtual market size term.

Substituting Eq. 5.17 into Eq. 5.15, provides:

$$\begin{aligned} \pi_a &= \tfrac{1}{2} t \left(\frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)} \right) \left(\frac{(1-\alpha+\gamma)}{1+\gamma} \right)^3 - F_a(\gamma) \\ &= \tfrac{1}{2} t \left(\frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)} \right) \left(\frac{(1-\alpha+\gamma)}{1+\gamma} \right)^3 - \left(\frac{a}{1+\gamma} \right)^{\theta_a} \end{aligned} \tag{5.18a}$$

$$\begin{aligned} \pi_b &= \tfrac{1}{2} t \left(\frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)} \right) \left(\frac{(1-\alpha+\gamma)}{1+\gamma} \right)^3 - F_b(\gamma) \\ &= \tfrac{1}{2} t \left(\frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)} \right) \left(\frac{(1-\alpha+\gamma)}{1+\gamma} \right)^3 - \left(1 - \frac{\alpha}{1+\gamma} + \gamma - \frac{b+\gamma}{1+\gamma} \right)^{\theta_b} , \end{aligned} \tag{5.18b}$$

where $F_a(\gamma)$ and $F_b(\gamma)$ are the firms' investment as a function of γ. Assume $F_a(\gamma) = F_b(\gamma) = F(\gamma)$.[12] Further, define α_0 as B&M market size prior to market growth and $\alpha = \alpha_0 /(1+\gamma)$ the B&M post-growth market size. Substituting α into Eq. 5.18 gives:

$$\pi = t \left(\frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)} \right) \left(\frac{1-\alpha_0+\gamma}{1+\gamma} \right)^3 - F(\gamma) . \tag{5.19}$$

To determine optimal investment and hence market growth requires the solution of the necessary condition for γ:

[12] Conditions for $F(\gamma) = F_a(\gamma) = F_b(\gamma)$ are demonstrated. $F_a(\gamma) = a'^{\theta_a} = \gamma^{\theta_a}$ requires Hybrid firm location at $[a']$ equal the market growth. Additionally, $F_b(\gamma) = [1-\alpha/(1+\gamma) + \gamma - (b+\gamma)/(1+\gamma)]^{\theta_b} = [((1+\gamma) - \alpha + \gamma(1+\gamma) - b - \gamma)(1+\gamma)^{-1}]^{\theta_b}$ $= [((1-\alpha) + \gamma(1+\gamma) - b)(1+\gamma)^{-1}]^{\theta_b} = [(\gamma(1+\gamma)(1+\gamma)^{-1}]^{\theta_b} = \gamma^{\theta_b}$ Finally, $\theta_a = \theta_b$. This condition is more likely to hold as g' closes.

$$\begin{aligned}\frac{\partial\pi}{\partial\gamma} &= t\left(\frac{-(1+\gamma_{\max})}{\gamma_{\max}(1+\gamma)^2}\right)\left(\frac{1-\alpha_0+\gamma}{1+\gamma}\right)^3 + 3t\left(\frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)}\right)\left(\frac{1-\alpha_0+\gamma}{1+\gamma}\right)^2\left(\frac{\alpha_0}{(1+\gamma)^2}\right) - F'(\gamma)\\ &= t\left(\frac{1-\alpha_0+\gamma}{1+\gamma}\right)^2\left(\left(\frac{-(1+\gamma_{\max})}{\gamma_{\max}(1+\gamma)^2}\right)\left(\frac{1-\alpha_0+\gamma}{1+\gamma}\right)+3\left(\frac{\gamma_{\max}-\gamma}{\gamma_{\max}(1+\gamma)}\right)\left(\frac{\alpha_0}{(1+\gamma)^2}\right)\right) - F'(\gamma) \quad (5.20)\\ &= t\left(\frac{1-\alpha_0+\gamma}{1+\gamma}\right)^2\left(\frac{-(1+\gamma_{\max})(1-\alpha_0+\gamma)+3(\gamma_{\max}-\gamma)(\alpha_0)}{\gamma_{\max}(1+\gamma)^3}\right) - F'(\gamma) = 0.\end{aligned}$$

When $\theta_b = 0$ (which is reasonable for 'small' g') the marginal investment cost is zero, γ that maximizes combined firm profit is:

$$-(1+\gamma_{\max})(1-\alpha_0+\gamma)+3(\gamma_{\max}-\gamma)(\alpha_0)=0 \quad (5.21)$$

or

$$\gamma^* = \frac{\gamma_{\max}(4\alpha_0-1)-(1-\alpha_0)}{1+\gamma_{\max}+3\alpha_0}. \quad (5.22)$$

From Eq. 5.22, the smaller the Type-2 customer segment $(1-\alpha_0)$, and the larger the potential market expansion ($\gamma_{\max}$), the greater is the optimal value of γ that maximizes combined firm profit. This result is sensible as the only source of potential gain from investment is from growth and this is inversely related to the initial Virtual market size and the potential Virtual customer reach.[13]

Comparative-static Analysis

In the no growth market game with equal marginal costs the firm's optimal profits depend on relative firm investment and Virtual segment position, and Virtual market size for both the general case and when investment is defensive. Table 5.1 and Table 5.2 report equilibrium profit own- and cross-derivatives for firm investment, both for the general and defensive investment case, respectively. Not surprisingly investment by either firm unambiguously diminishes own and other firm profit. This result holds even when the B&M firm concedes the Virtual market and does not invest, viz., $a+b=0$. For both the general and defensive investment cases the rate of investment generated profit decline slows with t and a, but increases with α.

[13] Note that the value for γ^* may become negative if the values of α_0 and $\gamma_{\max}$ fall below certain levels. In this case, it is assumed that the firm stays at the initial position, i.e., at $a=0$ and $b=1-\alpha$.

Table 5.1. Equilibrium Derivatives, No Growth and $MC_i = MC$

$$\frac{\partial \pi_a}{\partial a} = \tfrac{1}{18} t[(a+b)+2(1-\alpha)] \times [2(b-a)-(a+b)-2(1-\alpha)] - \theta_a a^{\theta_a - 1}$$

$$\frac{\partial \pi_b}{\partial a} = \tfrac{1}{18} t[(a+b)-4(1-\alpha)] \times [2(b-a)-(a+b)+4(1-\alpha)]$$

$$\frac{\partial \pi_a}{\partial b} = \tfrac{1}{18} t[(a+b)+2(1-\alpha)] \times [(a+b)+2(1-\alpha)+2(b-a)]$$

$$\frac{\partial \pi_b}{\partial b} = \tfrac{1}{18} t[(a+b)-4(1-\alpha)] \times [(a+b)-4(1-\alpha)+2(b-a)] + \theta_b (1-\alpha-b)^{\theta_b - 1}$$

Table 5.2. Equilibrium Derivatives, No Growth and $MC_i = MC$ and $a+b=1-\alpha$

$$\frac{\partial \pi_a}{\partial a} = -\tfrac{1}{2} t(1-\alpha)^2 - \theta_a a^{\theta_a - 1}$$

$$\frac{\partial \pi_b}{\partial a} = -\tfrac{1}{2} t(1-\alpha)^2$$

$$\frac{\partial \pi_a}{\partial b} = \tfrac{1}{2} t(1-\alpha)^2$$

$$\frac{\partial \pi_b}{\partial b} = \tfrac{1}{2} t(1-\alpha)^2 + \theta_b (1-\alpha-b)^{\theta_b - 1}$$

The more interesting case concerns that of Virtual market growth. Table 5.3 reports equilibrium profit derivatives for own and competitor investment for the defensive case with equal marginal costs assumed. Investment by either firm does not unambiguously increase own profit. For the B&M firm $\partial \pi_a / \partial a$ increases with $\gamma_{\max}$. As the Virtual market matures ($\gamma \to \gamma_{\max}$) the contribution of potential growth lessens, however, this is offset by the $(1+\gamma)^2$ term. These effects are scaled up by the $[(1-\alpha+\gamma)/(1+\gamma)]^2$ term, i.e., weighted by relative Virtual market size. While the first term is positive the overall effect could be negative if the scaled 'investment' term $(\theta_a a^{\theta_a - 1})/(1+\gamma)^{\theta_a}$ is sufficiently large. The net outcome is an empirical issue. An analogous result holds for Virtual firm equilibrium profit.

Table 5.3. Equilibrium Derivatives, Growth Equilibrium with $MC_i = MC$

Firm decision variables	
$\frac{\partial \pi_a}{\partial a} = \frac{1}{2} t \left(\frac{1-\alpha+\gamma}{1+\gamma} \right)^2 \times \left(\frac{3\alpha(\gamma_{\max}-\gamma)+\gamma_{\max}(1+\gamma_{\max})(1+\gamma)^2}{\gamma_{\max}^2 (1+\gamma)^3} \right) - \frac{\theta_a a^{\theta_a -1}}{(1+\gamma)^{\theta_a}}$	-
-	$\frac{\partial \pi_b}{\partial b} = \frac{1}{2} t \left(\frac{1-\alpha+\gamma}{1+\gamma} \right)^2 \times \left(\frac{3\alpha(\gamma_{\max}-\gamma)-\gamma_{\max}(1+\gamma_{\max})(1+\gamma)^2}{\gamma_{\max}^2 (1+\gamma)^3} \right) + \frac{\theta_b}{1+\gamma} \left(\gamma + \frac{1-\alpha-b}{1+\gamma} \right)^{\theta_b -1}$
Realised and potential growth variables	
$\frac{\partial \pi_a}{\partial \gamma} = \frac{1}{2} t \left(\frac{1-\alpha+\gamma}{1+\gamma} \right)^2 \times \left(\frac{3\alpha(\gamma_{\max}-\gamma)-(1+\gamma_{\max})(1-\alpha+\gamma)}{\gamma_{\max}(1+\gamma)^3} \right) + \frac{\theta_a a^{\theta_a}}{(1+\gamma)^{\theta_a +1}}$	$\frac{\partial \pi_b}{\partial \gamma} = \frac{1}{2} t \left(\frac{1-\alpha+\gamma}{1+\gamma} \right)^2 \times \left(\frac{3\alpha(\gamma_{\max}-\gamma)-(1+\gamma_{\max})(1-\alpha+\gamma)}{\gamma_{\max}(1+\gamma)^3} \right) - \theta_b \left(1 - \frac{1-\alpha-b}{(1+\gamma)^2} \right) \left(\gamma + \frac{1-\alpha-b}{1+\gamma} \right)^{\theta_b -1}$
$\frac{\partial \pi_a}{\partial \gamma_{\max}} = \frac{1}{2} t \left(\frac{\gamma}{\gamma_{\max}^2 (1+\gamma)} \right) \left(\frac{1-\alpha+\gamma}{1+\gamma} \right)^3$	$\frac{\partial \pi_b}{\partial \gamma_{\max}} = \frac{1}{2} t \left(\frac{\gamma}{\gamma_{\max}^2 (1+\gamma)} \right) \left(\frac{1-\alpha+\gamma}{1+\gamma} \right)^3$

The rate of investment driven profit growth increases with γ. Next, consider the direct impact of increases in potential ($\gamma_{\max}$) and realized (γ) Virtual market growth on equilibrium profits. First, an increase in $\gamma_{\max}$ implies increased profit. This rate of profit increase is attenuated by a larger α (larger Type-1 consumer base). Second, increased γ does not necessarily raise profit. This ambiguity arises, e.g., for the Hybrid firm because the derivative is comprised of components with different signs. The positively signed $\frac{1}{2}t[(1-\alpha+\gamma)/(1+\gamma)]^2$ term is the weighted relative Virtual market size, viz., the larger Virtual market the larger the impact of γ on profit. The positive $(\theta_a a^{\theta_a})/(1+\gamma)^{\theta_a+1}$ term implies the larger is the B&M firm Virtual facility investment the greater is realized Virtual market growth on profit. Intuitively, this can be thought of as marginal Virtual facility investment discounted by weighted Virtual market growth. Further, the $[3\alpha(\gamma_{\max}-\gamma)-(1+\gamma_{\max})(1-\alpha+\gamma)]/\gamma_{\max}(1+\gamma)^3$ term cannot be unambiguously signed, but on balance it is probably small and negative. To see this, note that as the Virtual market matures ($\gamma \to \gamma_{\max}$) this term is clearly negative. As to magnitude, note that a relatively large Virtual-to-B&M market size (small α) implies this term is small, i.e., approximately equal to $1/\gamma(1+\gamma)$. This means that the derivative is probably positive, and that it appears reasonable to presume that realized Virtual market growth has a positive impact on the Hybrid firm's Virtual market equilibrium profit. An analogous result holds for Virtual firm equilibrium profit.

Conclusions

This chapter attempts to provide some useful insights into the understanding of fundamental tradeoffs faced by B&M and Virtual firms competing in Virtual marketplaces for Type-2 customers. An innovation contained in the paper is the establishment of a link between firm relative locations within the Virtual market to investment and ultimately profits. This innovation enabled the derivation of some testable predictions. Some ways to move beyond current model assumptions could be the consideration of non-uniform distributions of Virtual consumers (in particular non-symmetric distributions due to the skewed age distribution of customers making purchases online), the introduction of market power and allowing both the B&M and Virtual markets to be made open to competition.

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6 Mobile Network Prospects: A Multi-sided Platform Analysis of Competition

Armando Calabrese, Massimo Gastaldi and Nathan Levialdi Ghiron

Introduction

This chapter analyzes telecommunication markets before and after the introduction of an open mobile terminal platform (OMTP) standard. OMTP is an organization comprised of mobile operators attempting to reach an OMTP standard. Calabrese et al. (2004) show strategic choices for two market players, operators and hardware producers under alternative competition scenarios. This study integrates network economics and a multi-sided platform industry in the modeling. Producer and operator firms are considered. Operators supply the same telephone as producers but sell the good combined with a SIM card. The analysis assumes that firms act as a cartel to maximize joint profit. Moreover, producer and operator coalitions are assumed distinct only when their telephones have different technical standards. A sequential game similar to Economides and Flyer (1997) is introduced to study this behavior. The game analyses three scenarios. In Scenario 1 the market is characterized by separate coalitions—producers supply telephones only and operators sell their telephones with SIM cards. Scenario 2 considers a market whereby an operator coalition with an OMTP standard competes with producers that only sell standard telephones. In Scenario 3 producers adopt the OMTP standard and mobile phones are not differentiated. A goal of the analysis is to identify conditions for the transition from Scenario 2 to Scenario 3. Assuming that the standard is not subject to ownership rights the decision by a coalition to adopt depends on potential profit. This case describes a non-cooperative equilibrium (Economides and Flyer). When a standard is subject to ownership rights, for a coalition to adopt the standard requires consent from the right's owner. This case results in a consensual equilibrium (Economides and Flyer). The next section defines the market. A description of an incompatible (differentiated) goods market in Cournot competition is then described. The compatible (undifferentiated) goods case is described next. Scenario 1 is then proposed. Then a multi-sided platform industry and the OMTP standard are described. Analyses of Scenario 2 and Scenario 3 follow. Finally, study arguments are summarized and conclusions made.

Market Demand

Coalitions i are comprised of producers (p) and operators (o), and have a combined production that when normalized indicate their market shares, viz.

$0 \le n_p + n_o \le 1$. All consumers are identified by a parameter ω. A consumer's propensity to purchase a unit of coalition i good is $u(\omega, n_i) = \omega h(n_i)$. Customers are distributed uniformly along the interval $[0,1]$. A linear network externality function $h(n_i)$ indicates customer utility is proportional to network size:

$$h(n_i) = K + A_i n_i , \tag{6.1}$$

where K represents an intrinsic benefit received from consumption of the good, viz., when $K = 0$ the good has a pure network effect. The corresponding normalized function is:

$$h(n_i) = k_i + n_i , \tag{6.2}$$

where $k_i = K / A_i$ and the pure network effect of the good occurs for $k = 0$.

Incompatible Goods and Cournot Competition

Coalitions are denoted C_1 and C_2, with C_i market share n_i. Assume the coalition index inversely relates to sales, i.e., $n_1 > n_2$. Let ω_1 denote a marginal consumer indifferent to purchasing from either coalition. Indifference implies:

$$\omega_1 h(n_2) - p_2 = \omega_1 h(n_1) - p_1 \quad \Leftrightarrow \quad \omega_1 = \frac{p_1 - p_2}{(k_1 + n_1) - (k_2 + n_2)} . \tag{6.3}$$

Consumers $\omega > \omega_1$ receive greater utility from purchasing Good 1. Conversely, consumers $\omega < \omega_1$ prefer Good 2 (Cricelli et al. 1999). Consumers purchase Good 2 until $u(\omega, n_2) \ge 0$ or $\omega_{LIM} = p_2 / (k_2 + n_2)$. So consumers ω purchase a good that belongs to the coalition with greater sales. The good sold by the coalition with greater market share has a price $p_1 > p_2$.

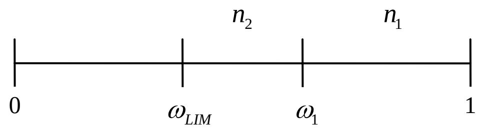

Fig. 6.1. Market Division for the Incompatible Goods Case

Coalition sales are:

$$n_1 = 1 - \omega_1 = 1 - \frac{p_1 - p_2}{(k_1 + n_1) - (k_2 + n_2)} \tag{6.4a}$$

and

$$n_2 = \omega_1 - \omega_{LIM} = \frac{p_1 - p_2}{(k_1 + n_1) - (k_2 + n_2)} - \frac{p_2}{(k_2 + n_2)} \ . \tag{6.4b}$$

The corresponding inverse demand functions are respectively:

$$p_1 = (k_1 + n_1)(1 - n_1) - (k_2 + n_2)n_2 \tag{6.5a}$$

and

$$p_2 = (k_2 + n_2)(1 - n_1 - n_2) \ . \tag{6.5b}$$

Assuming zero costs coalition profit is:

$$\Pi_i = n_i p_i \ . \tag{6.6}$$

Coalitions choose their production level simultaneously in Cournot competition and profit is maximized when:

$$\frac{\partial \Pi_1}{\partial n_1} = p_1 + n_1 \frac{\partial p_1}{\partial n_1} = (k_1 + n_1)(1 - n_1) - (k_2 + n_2)n_2 + n_1((1 - n_1) - (k_1 + n_1)) = 0 \tag{6.7a}$$

and

$$\frac{\partial \Pi_2}{\partial n_2} = p_2 + n_2 \frac{\partial p_2}{\partial n_2} = (k_2 + n_2)(1 - n_1 - n_2) + n_2((1 - n_1 - n_2) - (k_2 + n_2)) = 0 \ . \tag{6.7b}$$

Solution of Eq. 6.7a and Eq. 6.7b provides equilibrium market shares. Replacing the solutions n_1^* and n_2^* in Eq. 6.5 and Eq. 6.6 provides optimum price and profit for technically incompatible goods case.

Compatible Goods Case

When the coalitions of producer and operator have the market shares $n_s = n_p + n_o$, where n_p is the number of producers and n_o is the number of operators, then there is a standard good that provides a network externality:

$$h(n_s) = k_s + n_s \,. \tag{6.8}$$

The propensity of consumer ω to purchase the good is $\omega(k_s + n_s)$, equilibrium price is p_s and the marginal customer of the compatible good is defined by:

$$\omega_{LIM}(k_s + n_s) - p_s \geq 0 \quad \Leftrightarrow \quad \omega_{LIM} = \frac{p_s}{k_s + n_s} \,. \tag{6.9}$$

Since consumers at least ω_{LIM} purchase the good, market demand at p_s is:

$$n_s = 1 - \omega_{LIM} = 1 - \frac{p_s}{k_s + n_s} \,. \tag{6.10}$$

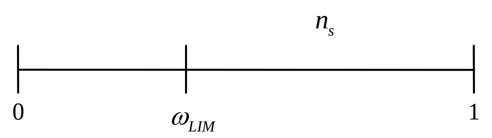

Fig. 6.2. Market Share for the Compatible Goods Case

The corresponding inverse demand function is:

$$p_s = (1 - n_s)(k_s + n_s) = (1 - (n_p + n_o))(k_s + (n_p + n_o)) \,. \tag{6.11}$$

Again, with costs assumed zero profits for producer and operator coalitions, respectively, are:

$$\Pi_p = n_p p_p \tag{6.12a}$$

and

$$\Pi_o = n_o p_o \,. \tag{6.12b}$$

Maximization of Eq. 6.12a and Eq. 6.12b implies the first-order necessary conditions:

$$\begin{aligned}\frac{\partial \Pi_p}{\partial n_p} &= p_s + n_p \frac{\partial p_s}{\partial n_p} \\ &= (1-(n_p+n_o))(k_s+(n_p+n_o)) + n_p((1-(n_p+n_o)) - (k_s+(n_p+n_o))) = 0\end{aligned} \tag{6.13a}$$

and

$$\begin{aligned}\frac{\partial \Pi_p}{\partial n_o} &= p_s + n_o \frac{\partial p_s}{\partial n_o} \\ &= (1-(n_p+n_o))(k_s+(n_p+n_o)) + n_p((1-(n_p+n_o)) - (k_s+(n_p+n_o))) = 0.\end{aligned} \tag{6.13b}$$

Eq. 6.13a and Eq. 6.13b result in the coalition optimum quantities:

$$n_p^* = n_o^* = \frac{3(1-k_s) + (9k_s^2 + 14k_s + 9)^{\frac{1}{2}}}{16}, \tag{6.14}$$

with the corresponding equilibrium price:

$$p_s^* = \frac{(5+3k_s - (9k_s^2+14k_s+9)^{\frac{1}{2}})(5k_s+3+(9k_s^2+14k_s+9)^{\frac{1}{2}})}{64}. \tag{6.15}$$

The combined coalition equilibrium profit is:

$$\Pi_s^* = \frac{(-3+3k_s-(9k_s^2+14k_s+9)^{\frac{1}{2}})(5+3k_s-(9k_s^2+14k_s+9)^{\frac{1}{2}})(5k_s+3+(9k_s^2+14k_s+9)^{\frac{1}{2}})}{512} \tag{6.16}$$

Since the quantity produced by both coalitions is identical, the alliance profit is divided equally, viz.

$$\Pi_p^* = \Pi_o^* = \frac{\Pi_s^*}{2}. \tag{6.17}$$

Scenario 1

Scenario 1 analyzes the current market situation with identical telephones supplied by both coalitions, viz., sold as a stand alone telephone by producers and as a SIM-locked telephone by operators. Telephones supplied by the coalitions have an identical network value and utility, i.e., $k_p = k_0$. The incompatibility of a SIM-locked mobile phone with other operator networks is an intended restriction. Producer telephone sales exceed sales by operators that combine SIM cards, i.e., $C_1 \to C_p$ and $C_2 \to C_o$. This assumption is consistent with the price hypothesis that the coalition with the greater market share has the higher priced mobile phones, i.e., a stand alone telephone sells at a higher price than a SIM-locked telephone. In Table 6.1 equilibrium market share, price and profit are calculated for alternative network parameter k values.

Table 6.1. Equilibrium Values for the Incompatible Goods Case (Scenario 1)

k	Producer Share	Operator Share	Producer Price	Operator Price	Producer Profit	Operator Profit
0.0	0.636	0.243	0.173	0.030	0.110	0.007
0.2	0.581	0.255	0.211	0.074	0.123	0.019
0.4	0.536	0.271	0.252	0.130	0.135	0.035
0.6	0.499	0.285	0.298	0.191	0.149	0.055
0.8	0.470	0.297	0.348	0.256	0.164	0.076
1.1	0.439	0.308	0.429	0.356	0.189	0.110
1.4	0.418	0.316	0.517	0.457	0.216	0.144
1.7	0.404	0.320	0.608	0.558	0.245	0.179
2.1	0.390	0.324	0.733	0.693	0.286	0.225
2.5	0.381	0.327	0.861	0.827	0.328	0.270
2.9	0.374	0.328	0.990	0.962	0.370	0.316

Incumbent producers maximize profit by acting independently. To see this Table 6.2 reports equilibrium market share, price and profit when producers and operators unite and supply a compatible good with network value k_s. Figure 6.3 shows coalition profit for the compatible and incompatible good cases. Examination of Fig. 6.3 shows that for any network value $k > 1.1$ the coalitions prefer to stay allies in a non-cooperative equilibrium. However, when the network value grows, viz., $k < 1.1$, the profits in the compatible good case are included with incompatible good profit. That is, producers prefer incompatibility while operators prefer compatibility. When producers are dominant, i.e., have the greater profits, then the stand alone status quo of incompatibility is maintained. Therefore, operators must act alone even though they would prefer an alliance. Since this outcome represents the current situation it is reasonable to conclude that next-generation mobile telephony possesses a network value $0 \le k_p = k_o \le 1.1$.

Table 6.2. Equilibrium Values for the Compatible Goods Case (Scenario 2)

k	Single coalition market share	Price	Single coalition profit
0.0	0.375	0.188	0.070
0.2	0.368	0.247	0.091
0.4	0.363	0.309	0.112
0.6	0.359	0.372	0.134
0.8	0.356	0.436	0.155
1.1	0.353	0.532	0.188
1.4	0.350	0.630	0.221
1.7	0.348	0.728	0.253
2.1	0.346	0.860	0.298
2.5	0.345	0.992	0.342
2.9	0.343	1.124	0.386

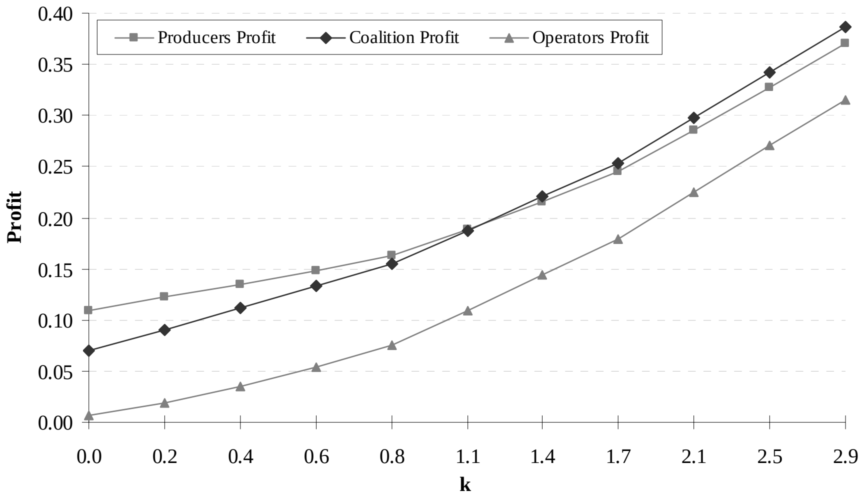

Fig. 6.3. Profit Comparison. Note. Coalition profit is for compatible goods; producer and operator profits are for incompatible goods

Multi-sided Service Markets and the OMTP Standard

Next, consider the impact of introducing an OMTP standard to the market. OMTP mobile phones have a high network value as they enable new services. That is, OMTP telephones are incompatible with current mobile phones as they have additional functions. Besides, operator profit would not only rely to the supply of the telephone but also on sales of new services made possible by the OMTP standard. To undertake an analysis of this market scenario requires an understanding of multi-sided service modeling (Rochet and Tirole 2002, 2003, 2004; Evans 2003; Wright 2003a, 2003b). To begin, let an operator coalition of cellular telephony networks provide the only platform that can interconnect users, advertisers and suppliers of a service. Further, the marginal cost of a transaction is $c \geq 0$. The potential numbers of service subscribers B equals the numbers of OMTP cellular telephone owners or $B = n_o$. Advertisers provide the service through the platform only when the benefit from their transaction is greater than the price required by operators, $b^S \geq p^S$. The benefit is assumed uniformly distributed among advertisers using the platform and is denoted $S \in [0,1]$. With all subscriber-advertiser pairs identifying a potential transaction and with their probability of meeting assumed independent of any benefit implies the platform transaction volume is defined by $V = B \cdot S$. The corresponding operator coalition profit derived when acting as a monopolist is:

$$\Pi = (p^B + p^S - c)(B \cdot S) . \tag{6.18}$$

In a multi-sided market both the equilibrium price and the decomposition among agents (p^B and p^S) is important. With B and S assumed logarithmic-concave the Π is also logarithmic-concave. The maximum is characterized by first-order necessary conditions:

$$\frac{\partial \log \Pi}{\partial p^B} = \frac{1}{p^B + p^S - c} + \frac{B'}{B} = 0 . \tag{6.19a}$$

and

$$\frac{\partial \log \Pi}{\partial p^S} = \frac{1}{p^B + p^S - c} + \frac{S'}{S} = 0 . \tag{6.19b}$$

Eq. 6.19a and Eq. 6.19b characterize the values of p^B and p^S that maximize service volume and imply the total price p. The demand elasticity for consumers is:

$$\eta^B = -\frac{p^B B'}{B} \text{ and } \eta^S = -\frac{p^S S'}{S} . \tag{6.20}$$

Further, monopoly prices are provided by the rule:

$$p^B + p^S - c = \frac{p^B}{\eta^B} = \frac{p^B}{\eta^B}\ . \tag{6.21}$$

That is, $p^* = p^B + p^S$ is chosen by the monopolist via the Lerner formula:

$$\frac{p-c}{p} = \frac{1}{\eta} \quad \text{or} \quad p^* = \frac{\eta}{\eta - 1}c\ , \tag{6.22}$$

where $\eta = \eta^B + \eta^S$ is the total sales elasticity. Accordingly, the allocation of price among the coalitions is:

$$p^{*B} = \frac{\eta^B}{\eta}p = \frac{\eta^B}{\eta - 1}c \quad \text{and} \quad p^{*S} = \frac{\eta^S}{\eta}p = \frac{\eta^S}{\eta - 1}c\ . \tag{6.23}$$

Because the distribution of advertiser demand is unknown, then neither are the elasticity values S are η^S known. Accordingly, assume all OMTP telephone owners n_o are potential service subscribers so that the telephone elasticity demand is used instead of the service elasticity. To conclude, the expression for optimum operator coalition profit is:

$$\Pi^*_{\text{multi-sided}} = \frac{1}{\eta - 1}\cdot c \cdot B \cdot S = \frac{1}{\eta - 1}\cdot c \cdot n_o \cdot S\ . \tag{6.24}$$

Scenario 2

Assume that the operator coalition introduces an OMTP standard telephone and only operator's telephones support the standard. From Scenario 1 producers sell a phone with net value $k_p \le 1.1$. When operators launch a telephone based on a new standard their strategic choice concerns the network value of the good, i.e., they must ensure that the OMTP telephone provide consumers with a greater network effect, i.e., $k_o^{OMTP} < k_p \le 1.1$. In this case, the added value obtained from an OMTP telephone is due to the provision of multi-sided services. In this situation the operator coalition is the market leader—relegating producers to be followers—and $C_1 \to C_o$ and $C_2 \to C_p$. The consequence of choosing a network value of k_o while the standard telephone network benefit is fixed at k_p is examined next. The coalition equilibrium market share, price and profit for the incompatible good case (Scenario 1) are provided in Table 6.3.

Table 6.3. Equilibrium Values for the Incompatible Goods Case (Scenario 2)

k_p	k_o	Producer Share	Operator Share	Producer Price	Operator Price	Producer Profit	Operator Profit
1.1	1.1	0.308	0.439	0.429	0.356	0.110	0.189
1.0	1.0	0.305	0.448	0.402	0.322	0.098	0.180
0.9	0.9	0.301	0.458	0.374	0.289	0.088	0.172
0.8	0.8	0.297	0.470	0.348	0.256	0.076	0.164
0.7	0.7	0.291	0.484	0.323	0.223	0.065	0.156
0.6	0.6	0.285	0.499	0.298	0.191	0.055	0.149
0.5	0.5	0.279	0.516	0.275	0.160	0.045	0.142
0.5	0.4	0.277	0.519	0.227	0.159	0.044	0.118
0.5	0.3	0.275	0.522	0.180	0.157	0.044	0.093
0.4	0.4	0.271	0.536	0.252	0.130	0.035	0.135
0.4	0.3	0.268	0.541	0.207	0.128	0.034	0.112
0.4	0.2	0.263	0.549	0.164	0.125	0.033	0.090
0.4	0.1	0.256	0.559	0.122	0.121	0.031	0.068
0.3	0.3	0.263	0.557	0.231	0.101	0.027	0.129
0.3	0.2	0.257	0.567	0.189	0.098	0.025	0.107
0.3	0.1	0.250	0.579	0.149	0.094	0.024	0.086
0.3	0.0	0.240	0.594	0.112	0.090	0.022	0.066
0.2	0.2	0.255	0.581	0.211	0.074	0.019	0.123
0.2	0.1	0.247	0.594	0.171	0.071	0.018	0.102
0.2	0.0	0.236	0.610	0.135	0.067	0.016	0.082
0.1	0.1	0.248	0.608	0.192	0.050	0.013	0.116
0.1	0.0	0.237	0.624	0.155	0.047	0.111	0.097
0.0	0.0	0.243	0.636	0.173	0.030	0.007	0.110

Table 6.3 indicates when a telephone's network value is $0.5 < k_p \leq 1.1$ operators cannot increase network value as this reduces market share and profit. When extant telephones have high network value ($k_p < 0.5$) this increases market share and profit from multi-sided services, while profits decrease due to a price fall. This network value variation is appraised according to the service market impact. Behavior is explained by movement in network value obtained from the network externality function $h(n_i) = k_i + n_i$. When k_p is sufficiently high a move from k_o generates too high a utility loss to be compensated by an increase in market share. Alternatively, should k_p remain fixed, the impact of market share on utility is greater and the operator coalition can increase both utility and market share—even with negative impacts on equilibrium price and profit.

Operator Profit from Multi-sided Services

Operators base their prices on the conditions:

$$p^{*B} = \frac{\eta^B}{\eta} p = \frac{\eta^B}{\eta - 1} c \quad \text{and} \quad p^{*S} = \frac{\eta^S}{\eta} p = \frac{\eta^S}{\eta - 1} c \, . \tag{6.26}$$

First, assume that the service elasticity for consumers B is the same as for cellular telephony. Values for k_p and k_o are listed in Table 6.4.

Table 6.4. Customer Elasticity (Scenario 2)

k_p	k_o	η^B
1.1	1.1	0.878
1.0	1.0	0.823
0.9	0.9	0.770
0.8	0.8	0.719
0.7	0.7	0.670
0.6	0.6	0.629
0.5	0.5	0.589
0.5	0.4	0.441
0.5	0.3	0.320
0.4	0.4	0.553
0.4	0.3	0.413
0.4	0.2	0.300
0.4	0.1	0.208
0.3	0.3	0.520
0.3	0.2	0.389
0.3	0.1	0.284
0.3	0.0	0.200
0.2	0.2	0.487
0.2	0.1	0.366
0.2	0.0	0.270
0.1	0.1	0.447
0.1	0.0	0.341
0.0	0.0	0.388

Notice that demand elasticity for both the telephone and OMTP services decline with network value growth. That is, as the telephone's intrinsic value increases without interconnection consumers are less sensitive to price variation. With consumer elasticity known operators are able to set OMTP service price to maximize profit.

Table 6.5. Multi-sided Services Market Profit (Scenario 2)

k_p	k_o	p^B	p^s	Profit
1.1	1.1	$0.878c/(-0.122+\eta^s)$	$\eta^s c/(-0.122+\eta^s)$	$0.439cS/(-0.122+\eta^s)$
1.0	1.0	$0.823c/(-0.178+\eta^s)$	$\eta^s c/(-0.178+\eta^s)$	$0.448cS/(-0.178+\eta^s)$
0.9	0.9	$0.769c/(-0.231+\eta^s)$	$\eta^s c/(-0.231+\eta^s)$	$0.458cS/(-0.231+\eta^s)$
0.8	0.8	$0.719c/(-0.281+\eta^s)$	$\eta^s c/(-0.281+\eta^s)$	$0.470cS/(-0.281+\eta^s)$
0.7	0.7	$0.672c/(-0.328+\eta^s)$	$\eta^s c/(-0.328+\eta^s)$	$0.484cS/(-0.328+\eta^s)$
0.6	0.6	$0.629c/(-0.371+\eta^s)$	$\eta^s c/(-0.371+\eta^s)$	$0.499cS/(-0.371+\eta^s)$
0.5	0.5	$0.589c/(-0.411+\eta^s)$	$\eta^s c/(-0.411+\eta^s)$	$0.516cS/(-0.411+\eta^s)$
0.5	0.4	$0.441c/(-0.559+\eta^s)$	$\eta^s c/(-0.559+\eta^s)$	$0.519cS/(-0.559+\eta^s)$
0.5	0.3	$0.320c/(-0.681+\eta^s)$	$\eta^s c/(-0.681+\eta^s)$	$0.522cS/(-0.681+\eta^s)$
0.4	0.4	$0.553c/(-0.447+\eta^s)$	$\eta^s c/(-0.447+\eta^s)$	$0.536cS/(-0.447+\eta^s)$
0.4	0.3	$0.413c/(-0.587+\eta^s)$	$\eta^s c/(-0.587+\eta^s)$	$0.541cS/(-0.587+\eta^s)$
0.4	0.2	$0.300c/(-0.700+\eta^s)$	$\eta^s c/(-0.700+\eta^s)$	$0.549cS/(-0.700+\eta^s)$
0.4	0.1	$0.208c/(-0.792+\eta^s)$	$\eta^s c/(-0.792+\eta^s)$	$0.559cS/(-0.792+\eta^s)$
0.3	0.3	$0.520c/(-0.480+\eta^s)$	$\eta^s c/(-0.480+\eta^s)$	$0.557cS/(-0.480+\eta^s)$
0.3	0.2	$0.389c/(-0.611+\eta^s)$	$\eta^s c/(-0.611+\eta^s)$	$0.567cS/(-0.611+\eta^s)$
0.3	0.1	$0.284c/(-0.716+\eta^s)$	$\eta^s c/(-0.716+\eta^s)$	$0.579cS/(-0.716+\eta^s)$
0.3	0.0	$0.200c/(-0.800+\eta^s)$	$\eta^s c/(-0.800+\eta^s)$	$0.594cS/(-0.800+\eta^s)$
0.2	0.2	$0.487c/(-0.513+\eta^s)$	$\eta^s c/(-0.513+\eta^s)$	$0.581cS/(-0.513+\eta^s)$
0.2	0.1	$0.366c/(-0.634+\eta^s)$	$\eta^s c/(-0.634+\eta^s)$	$0.594cS/(-0.634+\eta^s)$
0.2	0.0	$0.270c/(-0.730+\eta^s)$	$\eta^s c/(-0.730+\eta^s)$	$0.610cS/(-0.730+\eta^s)$
0.1	0.1	$0.447c/(-0.553+\eta^s)$	$\eta^s c/(-0.553+\eta^s)$	$0.608cS/(-0.553+\eta^s)$
0.1	0.0	$0.341c/(-0.659+\eta^s)$	$\eta^s c/(-0.659+\eta^s)$	$0.624cS/(-0.659+\eta^s)$
0.0	0.0	$0.388c/(-0.612+\eta^s)$	$\eta^s c/(-0.612+\eta^s)$	$0.636cS/(-0.612+\eta^s)$

Scenario 3

Operators by introducing the OMTP standard (Scenario 2) generate a fundamental change in the market when compared to the standard telephone case—OMTP telephony and services enable the operator coalition to become market leaders. Therefore producers must adopt the market standard and supply a compatible cellular telephone. Compatibility equates coalition equilibrium market share and profit. This outcome is advantageous to producers as their profit increases compared to Scenario 2. However, operators are an obstacle to new standard diffusion. Namely, as market leaders they resist making OMPT the standard as their profit may fall. However, while the introduction of OMPT telephony will reduce telephone profit, more consumers adopt multi-sided services that increase profit (see Table 6.6).

Table 6.6. Customer Market Share (Scenario 3)

	OMTP Telephone Penetration	
k	Scenario 2	Scenario 3
1.1	0.439	0.705
1.0	0.448	0.707
0.9	0.458	0.709
0.8	0.470	0.712
0.7	0.484	0.715
0.6	0.499	0.718
0.5	0.516	0.722
0.4	0.536	0.726
0.3	0.557	0.730
0.2	0.581	0.736
0.1	0.608	0.742
0.0	0.636	0.750

The impact that access to the standard has on the producer coalition is now examined. In Scenario 2 operators had to launch OMTP telephony and determine service characteristics (intrinsic value), viz., decide whether to maintain the value of the producers telephone ($k_o^{OMTP} = k_p$) or increase the intrinsic value ($k_o^{OMTP} < k_p$). This latter action is sensible only if $k_p < 0.5$. In Scenario 2, the producers simply continue to supply the same telephone with the same net value in conformity with the OMTPs standard. That is, only if the operators had chosen not to modify the telephone in Scenario 2 (where $k_p^{OMTP} = k_o^{OMTP}$) or to align themselves to the new good launched by the operators that conforms to the OMTP standard, i.e., $k_p^{OMTP} \to k_o^{OMTP}$. In this case there is a unique compatible good with the net value $k_s = k_p^{OMTP} = k_o^{OMTP}$. For the Cournot competitive model for the case of a compatible good the equilibrium quantity, price and profit for the alliance is reported in Table 6.7. The operator profit declines and producer profit increases are contained therein.

Table 6.7. Equilibrium Profit Comparisons, Scenario 2 and Scenario 3

k_p	k_o	Producer Profit Scenario 2	Operator Profit Scenario 2	Coalition Profit Scenario 3	Producer Profit Difference	Operator Profit Difference
1.1	1.1	0.110	0.189	0.188	0.078	–0.001
1.0	1.0	0.098	0.180	0.177	0.079	–0.003
0.9	0.9	0.088	0.172	0.166	0.078	–0.006
0.8	0.8	0.076	0.164	0.155	0.079	–0.009
0.7	0.7	0.065	0.156	0.144	0.079	–0.012
0.6	0.6	0.055	0.149	0.134	0.079	–0.015
0.5	0.5	0.045	0.142	0.123	0.078	–0.019
0.5	0.4	0.044	0.118	0.112	0.068	–0.006
0.5	0.3	0.044	0.093	0.102	0.057	0.008
0.4	0.4	0.035	0.135	0.112	0.077	–0.023
0.4	0.3	0.034	0.112	0.102	0.067	–0.011
0.4	0.2	0.033	0.090	0.091	0.058	0.001
0.4	0.1	0.03	0.068	0.081	0.050	0.012
0.3	0.3	0.027	0.129	0.102	0.075	–0.027
0.3	0.2	0.025	0.107	0.091	0.066	–0.016
0.3	0.1	0.024	0.086	0.081	0.057	–0.005
0.3	0.0	0.022	0.066	0.070	0.049	0.004
0.2	0.2	0.019	0.123	0.091	0.072	–0.032
0.2	0.1	0.018	0.102	0.081	0.063	–0.021
0.2	0.0	0.016	0.082	0.070	0.055	–0.012
0.1	0.1	0.013	0.116	0.081	0.068	–0.036
0.1	0.0	0.11	0.097	0.070	–0.041	–0.026
0.0	0.0	0.007	0.110	0.070	0.063	–0.039

Next consider multi-sided service operator profit. The potential OMPT service subscriber base is higher than for Scenario 2 as all OMTP telephone owners must be considered—and not only consumers that directly purchased OMTP telephones from operators. An important consequence of the general diffusion of this standard is that the demand elasticity is constant (variations are in the order of 10^{-5}) and equal to 0.5. Unlike Scenario 2 (see Fig. 6.4) a higher or lower network value does not impact on consumers' propensity to purchase the good. Rather with standard diffusion the elasticity is lower than when the standard is not shared. When the standard is not shared and the good has an elasticity smaller than for Scenario 3 that requires the good has a high network value, i.e., $k_o < 0.3$.

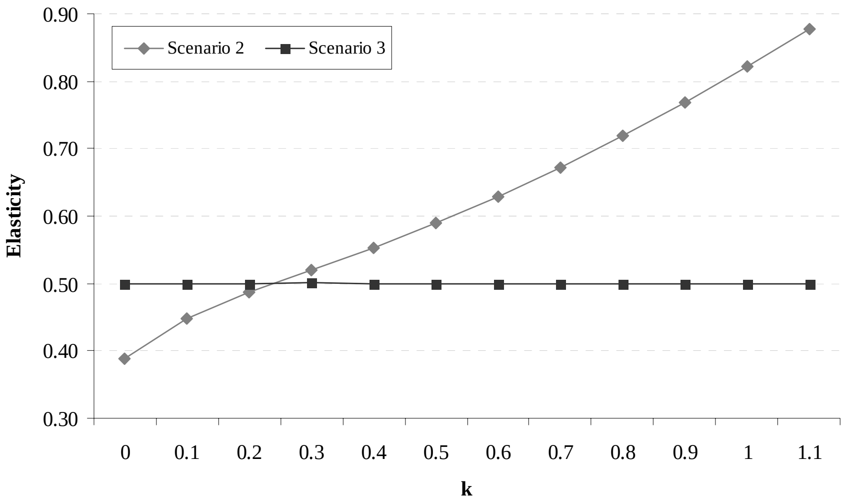

Fig. 6.4. Elasticity Magnitudes

An explanation of this result is that when there is no market standard nor is the good differentiated then consumers are not influenced by alternative network values. What matters to consumers is that a standard assures compatibility, and hence possible interaction. In Scenario 2, when operators offer a good according to a standard not shared by competing agents the intrinsic characteristics of the good have the decisive role in consumer choice. When the good's intrinsic characteristics are inferior (superior) this makes demand more (less) own price elastic. With market share and consumers elasticity values unknown, as in Scenario 2, operator multi-sided service profit is calculated. Increases in elasticity magnitude and market share should increase profit and offset profit reduction due to reduced sales. Further, it can be reasonably assumed, compared to the preceding case, that the advertiser elasticity is relatively small because of the increased potential service demand. Accordingly, advertisers should be less sensitive to operator price variation. Now, consider the limiting cases where $k_o < 1.1$ and $k_o = 0$, and also an intermediary case where $k_o = 0.4$. Also set the marginal cost of service at 0.1. To analyze this situation parameters for market share and advertiser elasticity are varied in response to operator profit and in seeking to broaden the standards diffusion to encompass the producer coalition. For $k = 1.1$, coalitions are indifferent between choosing to maintain incompatibility or broadening the alliance. In Scenario 2 operators earn profit 0.1885, with diffusion of the standard profit for the allied coalition is 0.1877, a loss of 0.0008. Multi-sided service profit varies from Scenario 2 ($\frac{0.439 \cdot c \cdot S}{\eta^S - 0.122}$) to Scenario 3 ($\frac{0.705 \cdot c \cdot S}{\eta^S - 0.500}$). Varying the advertiser elasticity and market share—with the elasticity $\eta^S \geq 0.5$ to ensure non-negative profit in Scenario 3—provides the profit surfaces contained in Fig. 6.5.

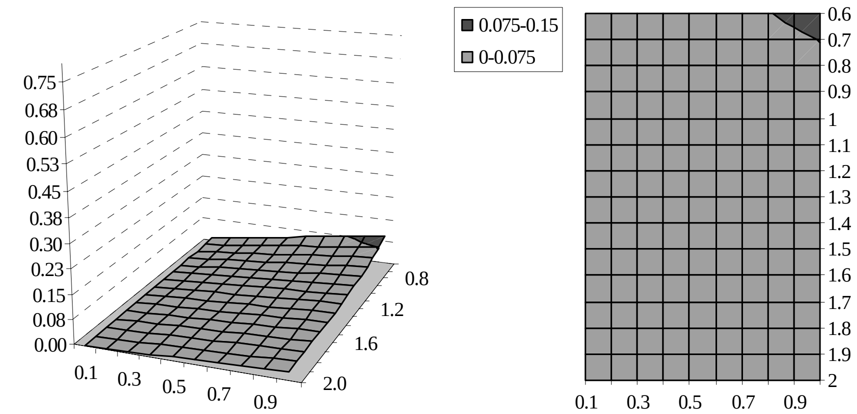

Fig. 6.5. Profit Surface for Scenario 2 with $k = 1.1$

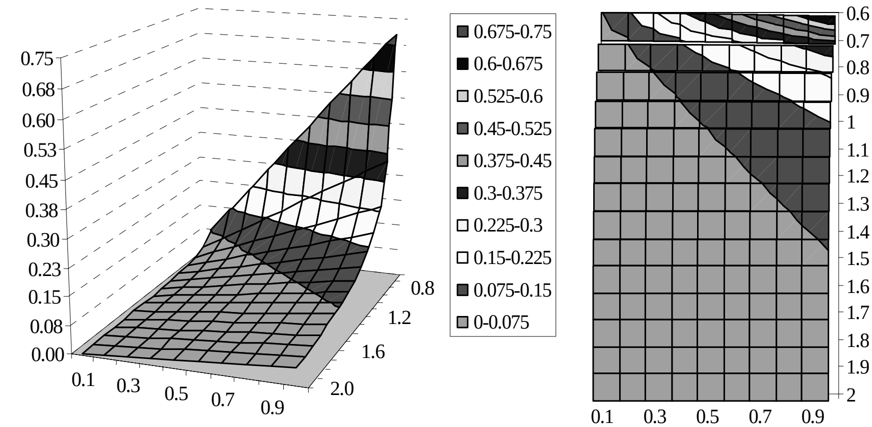

Fig. 6.6. Profit Surface for Scenario 3 with $k = 1.1$

In the case where profit is least, viz., when advertisers have a small market share of 0.1 and demand is highly elastic ($\eta^B = 2$), profit increases from 0.002338 (Scenario 2) to 0.0047 (Scenario 3)—an increase of 0.002362. This profit increase compensates for the 0.0008 loss related to the telephone sales decline. Obviously, profit increases are greater with more favorable market conditions, viz., high market share and inelastic demand. Clearly, it is in operator's best interest to extend standards adoption to producers. For $k = 0.4$, assume the good has a high network value. In this instance the loss of operator profit due to declining telephone sales is –0.0231, which is greater than for the low network value case. However, multi-sided service profits are higher.

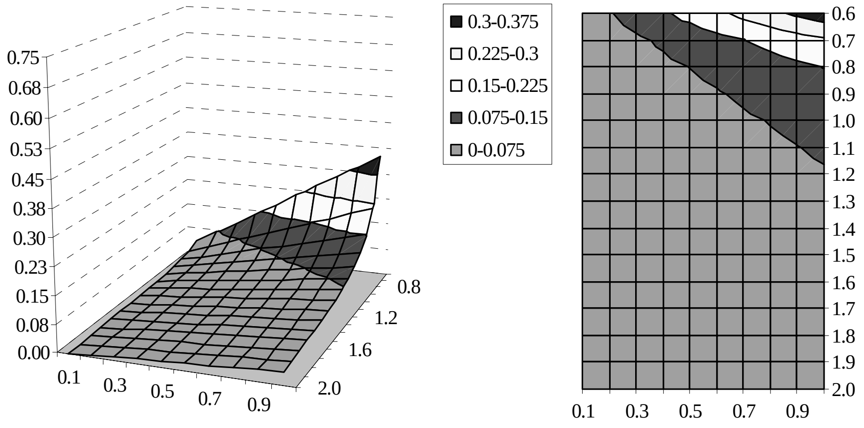

Fig. 6.7. Profit Surface for Scenario 2 with $k = 0.4$

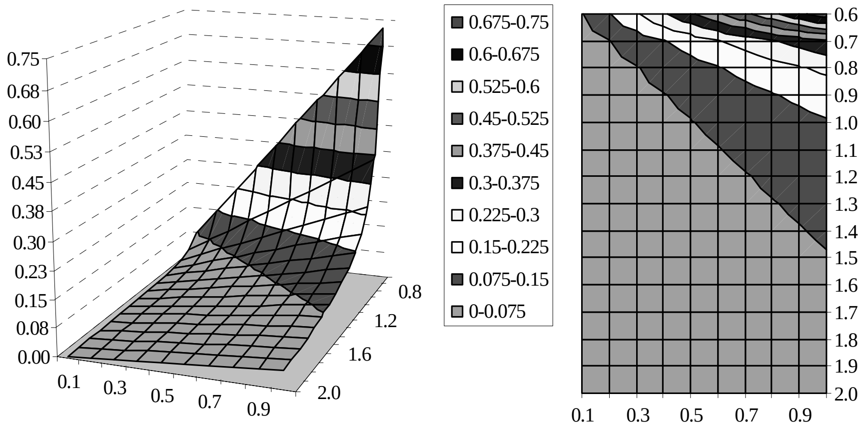

Fig. 6.8. profit Surface for Scenario 3 with $k = 0.4$

Nevertheless, profit growth is the greater for Scenario 2. Unlike the preceding case, whatever the configuration of market share elasticities the combined telephone and OMTP service profit is greater for Scenario 3. Table 6.8 reports the difference between the Scenario 3 and Scenario 2 profit.

Table 6.8. Scenario 3 and Scenario 2 Profit Difference

Elasticity	Advertiser market share									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
2.0	0.021	-0.020	-0.019	-0.018	-0.016	-0.015	-0.013	-0.012	-0.011	-0.009
1.9	-0.022	-0.020	-0.019	-0.017	-0.016	-0.014	-0.013	-0.011	-0.010	-0.008
1.8	-0.022	-0.020	-0.018	-0.017	-0.015	-0.013	-0.012	-0.010	-0.009	-0.007
1.7	-0.021	-0.020	-0.018	-0.016	-0.014	-0.013	-0.011	-0.009	-0.007	-0.005
1.6	-0.021	-0.019	-0.017	-0.015	-0.013	-0.011	-0.009	-0.008	-0.006	-0.004
1.5	-0.021	-0.019	-0.017	-0.014	-0.012	-0.010	-0.008	-0.006	-0.004	-0.001
1.4	-0.021	-0.018	-0.016	-0.013	-0.011	-0.008	-0.006	-0.004	-0.001	0.001
1.3	-0.020	-0.018	-0.015	-0.012	-0.009	-0.006	-0.004	-0.001	0.002	0.005
1.2	-0.020	-0.017	-0.013	-0.010	-0.007	-0.004	-0.000	0.003	0.006	0.001
1.1	-0.019	-0.015	-0.011	-0.008	-0.004	0.000	0.004	0.008	0.012	0.016
1.0	-0.018	-0.013	-0.009	-0.004	0.001	0.006	0.011	0.016	0.020	0.025
0.9	-0.017	-0.011	-0.004	0.002	0.009	0.015	0.021	0.028	0.034	0.040
0.8	-0.014	-0.005	0.004	0.013	0.022	0.031	0.040	0.049	0.058	0.067
0.7	-0.008	0.007	0.022	0.037	0.053	0.068	0.083	0.098	0.113	0.128
0.6	0.015	0.052	0.090	0.127	0.165	0.203	0.240	0.278	0.316	0.353

For $k = 0$, the operator profit decline of –0.0631 is greater in magnitude than in the preceding cases. Telephone service profits are, with costs fixing at 0.1, and allowing advertiser market share and elasticity ($\eta^S \in (0.7, 2)$) parameters to vary to avoid negative profit in Scenario 2.

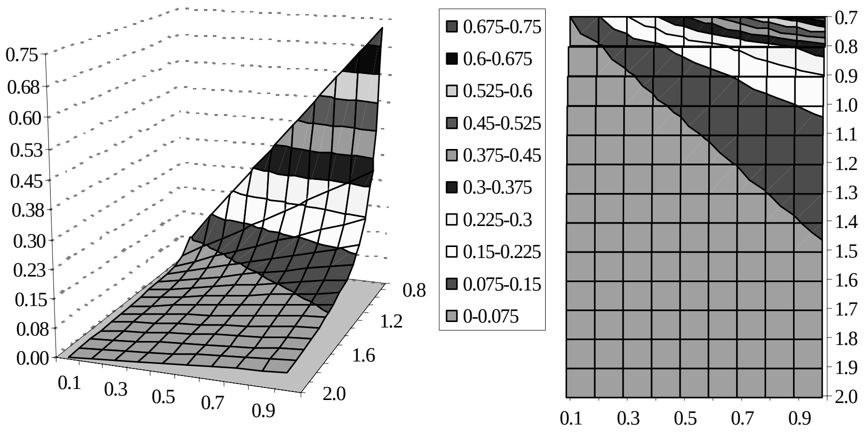

Fig. 6.9. Profit Surface for Scenario 2 with $k = 0$

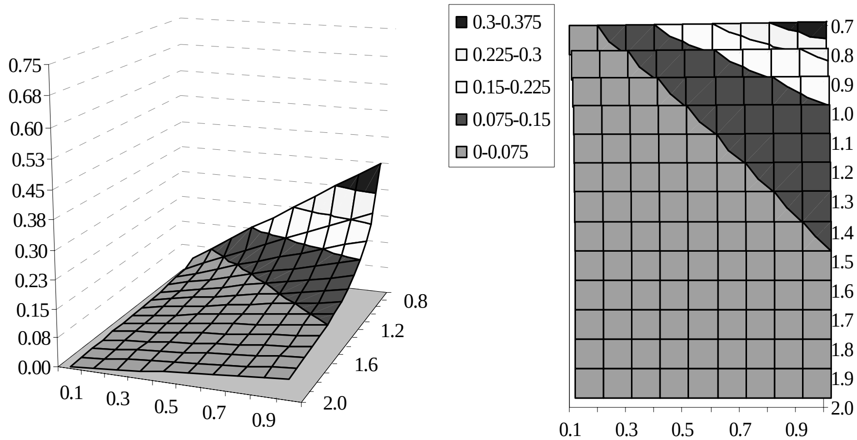

Fig. 6.10. Profit Surface for Scenario 3 with $k = 0$

In this case, Scenario 2 profits are always greater than for Scenario 3. Operators must accept that the standard's diffusion diminishes the goods network value. Moreover OMTP profits are greater than those from telephone sales, even for a low k_o. This means that the standard should be diffused more widely whatever the network value. However, correct cost parameters are required to draw precise conclusions.

Conclusions

In Scenario 1 of the study a theoretical model of current market conditions is constructed, viz., incumbent producers and operators that sell SIM-locked or operator-locked telephones compete to supply the telephony market. Scenario 2 considers the introduction of OMTP standard cellular telephones by operators. Producers are assumed to continue to supply standard telephones. Ultimately, the OMTP standard telephone dominates so that the operator coalition is market leader. Finally, a situation whereby OMTP telephones do not dominate the entire market is considered. The operator coalition wishes to preserve incompatibility to prevent producers adopting the new standard. This situation is analyzed by employing the theory of the multi-sided markets. That is, operator profit from supplying both cellular telephones and OMTP services. Therefore operators should share the standard with producers and allow the diminution of telephone profits to be offset OMTP service profit. The greater is OMTP cellular telephone diffusion then more compatibility is desirable. However, rather than consider Scenario 2 results in isolation it is more informative to make a comparison of Scenario 2 and Scenario 3 results. This approach hypothesizes that standard diffusion occurs and that operator and producer telephones are perfectly compatible. In this way analysis, based on assumptions about the magnitude of elasticity and advertiser parameters, examines the ease with which operators pass from Scenario 2 (incompatibility) to Scenario 3 (compatibility), and determines the likelihood of OMTP becoming the dominant standard. Whether OMTP becomes the standard depends on the network value and on costs of multi-sided services. The higher is network value the greater the reduction in operator profit and more customer service revenue is required.

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7 Real Options and Telecommunications Regulation

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Introduction

The capital-intensive nature of regulated telecommunications investments means that the allowed fair rate of return on capital set by the regulator is a crucial determinant of the cost-based access price. When the allowed fair rate is set too low, the regulated access price under-compensates the access provider for the investment, and deters further upgrade of an extant facility. Should the allowed fair rate be set too high then the regulated access price may lead to consumer welfare loss in downstream retail markets. Telecommunications regulators in several countries use an approximation of the long-run marginal cost on the total service to determine an appropriate cost-based price to be paid by parties seeking network interconnection.[1] The approach uses neoclassical investment theory or net present value rule (NPV), which allows an access provider to earn a fair rate of return on the investment, and is comprised of a commensurate rate of return on an asset of equivalent risk and a rate of return of the asset. A criticism of the approach is that neoclassical investment theory sets the allowed fair rate below the user cost of capital, and so under-compensates the access provider as it fails to deal with the interaction between sunk costs and uncertainty—both are key features of telecommunication network investment. Hausman (1999) argues that to appropriately compensate an access provider, real option theory should be used. The real option theory of investment is a method of valuing the options that exist when new investments are made in real assets that are subject to irreversibility and uncertainty. Advocates of adopting a real options approach in telecommunications access regulation claim that, when faced with uncertainty, the ability of an access provider to defer an irreversible investment in a network is an option that has a value, which should be taken into account through a real option surcharge.[2] Hausman was the

[1] For example, the Australian Competition and Consumer Commission (ACCC) adopted total service long-run incremental cost to price access, while US Federal Communications Commission (FCC) employed the total element long-run incremental cost (TELRIC) method. For further detail about this type of cost-based access pricing see Gans and King (2004) and AAPT (2005).

[2] See Hausman (1997, 1999) and Alleman (1999, 2002) and Alleman and Rappoport (2002).

first to raise real option arguments in his written submission to the FCC in 1996.[3] Since then a debate as to whether the real options approach should be adopted for pricing telecommunications access has emerged (see Alleman and Noam 1999).

Although the use of real option theory was initially rejected by the FCC, other regulators are considering incorporating a real options approach. For example, in New Zealand, the Commerce Commission (2002: 79) states that, "…the obligation to provide interconnection services removes the option for access providers to delay investment in their fixed PSTNs. If this option has a value, the costs of foregoing the option are a cost that should be reflected in interconnection prices". Further, in the UK, Ofcom (2005: Sect. 6.45) outlined an initial view that it should consider ways to estimate the value of a real option to delay investment—or what it refers to as a 'wait and see option'—for British Telecom's (BT's) next generation networks (NGNs). This chapter critically examines whether real option theory should be used to regulate access to telecommunications networks. The chapter also considers a suggestion by Small and Ergas (1999) that real option theory should be used to calculate an appropriate premium for what the Productivity Commission (2001a, 2001b, 2004) has labelled the 'truncation problem'.

The structure of the chapter is as follows. The following section contrasts the neoclassical theory of investment with the real options approach. Next, the real option to delay investment is discussed. Arguments are assessed for whether or not the regulator should compensate an access provider for its call option to delay an investment. In assessing these arguments, the following should be considered: the applicability of real option theory to telecommunications investments; the increased growth opportunities (put option) which can arise after a telecommunications investment is made; the first-mover advantage and the incentive to pre-empt investment; and the potential for the real option to delay surcharge to compensate the access provider for lost market power that results from regulation. Additionally, the truncation problem arising from access regulation and the potential for the use of real option theory is analysed. A final section concludes the discussion.

Neoclassical and Real Options Investment Theory

Neoclassical investment theory states that a firm makes an investment when the present value of future expected net revenue streams—usually discounted by a risk-adjusted discount rate—is greater than or equal to the direct cost of investment, or alternatively, the net present value is greater than or equal to zero (i.e., $\mathrm{NPV} \geq 0$). Although the NPV rule is commonly used to evaluate projects, Dixit and Pindyck (1994) point out that the rule implicitly assumes the investment is reversible and that the investment involves a 'now or never' decision. That is, the

[3] See, Reply Affidavit of Jerry Hausman, In the Matter of Implementation of Local Competition Provision in the Telecommunications Act of 1996, CC-Docket No.96-98, 30 May 1996. The arguments put forward in his testimony were later formally presented in (Hausman 1997, 1999).

rule does not account for the sunk costs that arise from an investment in industry specific productive capital and assumes that there is a binary investment decision, where if the investment is not immediately undertaken, it is foregone forever. These assumptions neglect an important role that managerial flexibility plays in determining the timing and scale of a new investment that is subject to uncertainty and irreversibility. Consequently, Dixit and Pindyck (1994: 136) assert that, "the simple NPV rule is not just wrong; it is often very wrong" and the NPV rule is one reason "why neoclassical investment theory has failed to provide a good empirical model of investment behaviour" (Pindyck 1991: 1112).

By using the Black and Scholes (1973) technique for valuing financial options, a technique was established for valuing options that exist when a firm considers making an uncertain and irreversible investment in a real asset. The real option theory of investment recognizes the importance of managerial flexibility to adapt future actions in response to altered and uncertain market conditions. While Trigeorgis (1993) and Lander and Pinches (1998) review different types of real options, economists have tended to focus on the real option to wait or delay the investment.[4] As arguments for compensating the access provider for a lost option to wait have also typically arisen in the context of challenges to telecommunications access regulation, the following section examines the option to delay investment.[5]

A Call Option from Investment Delay

Real option theory contends that the ability of an investor to defer an irreversible and uncertain investment has a value. This option allows an investor to receive new information that assists in resolving some of the uncertainty surrounding the investment. The ability to defer an irreversible investment provides the investor with something similar to a financial option or American call option. That is, the firm has the opportunity but not the obligation to invest at a future time. Given that the investor holds this valuable option, when the investment does occur and the firm exercises the option to invest, it foregoes an opportunity to defer the investment and wait to receive further information. As there is an additional opportunity cost associated with undertaking an investment this cost should be added to the direct costs in order for the appropriate investment decision to be made. Taking this call option to invest into account, the NPV rule must be modified so that under real option theory, the firm only undertakes an investment in any period when the present value of the future expected revenues generated by the investment minus the direct investment costs are greater than or equal to the value of the

[4] Alleman and Rappoport (2002: 391) outline this and cite for their examples, McDonald and Siegel (1986) and Dixit and Pindyck (1994).

[5] For example, Ofcom (2005: Sect. 6.33) states, "BT's recent submission to Ofcom focused on the value of wait and see options, focusing on the incentives that, absent regulatory intervention, give an incumbent incentives to delay investment".

option to invest, i.e., $\text{NPV} \geq \text{option to invest}$. Using reasonable parameter values, McDonald and Siegel (1986: 708) show that the value of an option to wait is substantial and leads to the sunk investment only being undertaken if, "the present value of the benefits from a project is double the investment cost". To illustrate the value of an option to wait, a numerical example is provided in the Appendix. The Appendix compares the results from the NPV approach and real option theory of investment. The example is similar to those employed by Dixit and Pindyck (1994: 26–30). It highlights how the value of an option to invest is derived from an ability to asymmetrically alter the payoffs under uncertainty, and how the real option to delay represents an additional opportunity cost of undertaking the investment.

Real Option Theory and Telecommunications Regulation

Advocates of applying real option theory in telecommunications access regulation claim that regulators fail to compensate access providers for a real option to wait. The argument states that by mandating the provision of access and not recognising the additional opportunity cost the real option to wait imposes on investment, the regulator removes the ability of an access provider to defer investment. This action also provides a free option to those seeking access. Hence, to adequately compensate an access provider for the lost call option to wait and maintain incentives for efficient network investment, the allowed fair rate of return must be increased. Hausman, in a submission prepared on behalf of the incumbent local exchange carrier Pacific Bell to the FCC in 1996, calculated the mark-up that was required to compensate for a lost call option to delay the investment. By employing the theoretical framework of McDonald and Siegel (1986) and parameter values from Dixit and Pindyck (1994), Hausman estimated that a 3.2–3.4 scale increase in the access price of the investment component of unbundled network elements (UNEs) of the Pacific Bell local exchange (considered sunk) was necessary. As the proportion of sunk costs estimated on links was 0.59 and on ports 0.10, Hausman concluded a 135% mark-up was required on the cost-based charge for use of links and a 23% mark-up was required on the cost-based charge for the use of ports.[6]

Hubbard and Lehr (1996: 10) critique Hausman's analysis and argue that, "Hausman offers no justification for his application of the basic McDonald-Siegel problem to the telecommunications case under consideration". In particular, they question the appropriateness of employing the McDonald and Siegel framework to telecommunications as it assumes the investment can be indefinitely deferred, something that is unrealistic when competitive entry is possible. By augmenting the Hausman analysis with a Poisson jump, to allow for competitive entry, Hub-

[6] Similarly, Alleman (1999: 173) outlines that by not taking real options into account the cost model used by regulators underestimates the access price by up to 60%.

bard and Lehr show the proposed mark-up for the real option to delay an irreversible investment fell substantially. Further, Holm (2000: 83) indicates that the Dixit and Pindyck data employed by Hausman are "based on reasonable not necessarily representative parameters", and that these "chosen parameters have nothing to do with the telecom industry". The Hausman arguments were ultimately rejected by the California Public Utilities Commission (CPUC), which determined that the appropriate access price for UNEs should be based on a TELRIC model with a 19% mark-up to recover shared and common costs.[7] While no regulator has permitted any access provider to recover a call option to delay the investment in the allowed fair rate of return, regulators in New Zealand and the UK have considered real option arguments. To guide regulators in determining whether it is appropriate to compensate an access provider for a real option to wait, the following factors should be considered, viz., (a) the uncertainty and irreversibility of new telecommunications network investments; (b) whether the focus on a call option to delay the investment is too narrow; (c) any first-mover advantage that may motivate an access provider to invest earlier rather than delay investment; and (d) whether compensating for the call option to delay the investment provides the investor with a return for market power that is lost due to regulation.

Uncertainty and Irreversibility of New Telecommunications Network Investment

It is generally maintained that telecommunications investment is subject to substantial irreversibility and uncertainty as: (a) a considerable portion of new network investment has little if any resale value; and (b) rapid technological progress, and constantly changing demand means that the profitability of additional network investment is very uncertain. However, Hubbard and Lehr (1996) and Economides (1999) question the degree of irreversibility and uncertainty of new investment by an incumbent in the local exchange in the US.[8] Hubbard and Lehr (1996: 13) state that, "…much of the switch and switching centre investment is clearly not irreversible. Switches can be moved to new locations and the end-office real estate can be sold. Rights of way, conduit, and even excess wire-line facilities which may face reduced demand for ordinary telephone lines, may be sold for other uses (such as delivery of video to the home via technologies such as ADSL)". Further, Economides (1999: 211) considers that new investment in the local exchange that is sunk—such as new investment in the local loop—is unlikely to experience much demand uncertainty, while local exchange new investment that is likely to be subject to significant technological and demand uncertainty—such as electronic

[7] See CPUC (1999: 21–7) for a summary of the Hausman argument and proposed access price mark-up.

[8] Similarly, Gans and King (2003: 163–4) note, in assessing high-risk infrastructure investment, that augmentations to fixed line telephony often carry little risk.

equipment—"can be moved or resold at almost full value, or can be used for other functions".

Although this analysis specifically evaluates new investment in the US local exchange, it does highlight that both the level of irreversibility and uncertainty—and hence, instances where real option theory may apply—vary substantially depending on technological characteristics of the investment and demand for the service that the investment provides. For example, investment in a well-established technology for which there is an existing customer base with a consistent pattern of demand is unlikely to experience the level of uncertainty for real option theory to apply. In contrast, investment in non-standard technology which relies on the introduction of new service applications is likely to be subject to substantial technological and demand uncertainty, and may warrant a real options approach. This argument implies that neoclassical investment theory is more appropriate for commercially assessing new investment in the local loop, while real option theory is more appropriate for evaluating the investment in NGNs, such as fibre-to-the-premises or home or third-generation (3G) mobile networks.[9]

In the context of regulating telecommunications access, the analysis suggests that regulators only need consider compensating for a lost real option to wait when regulating a new network investment subject to high technological and demand uncertainty. Therefore, as Ofcom (2005: 46) notes, a real options approach should not be used to compensate BT for access to its copper network. Further, Ofcom (p.38, Sect. 6.4) draws a distinction between investment that delivers extant voice and data service using new technology—i.e., next generation core network (NGCN) investment—and investment that delivers the high-bandwidth service that it is speculated will use new technology in the future—i.e., next-generation access network (NGAN) investment. As there is likely to be technological and demand uncertainty associated with NGAN investment, but possibly only technological uncertainty with NGCN investment, Ofcom (p.48, Sect. 6.45) concludes that it should consider methods to estimate an option to wait on NGAN investment that is regulated, and to a lesser extent, the real option to wait on NGCN investments subject to regulation. It appears that regulators do appreciate some of the risks associated with investment in new technology and do not choose to regulate services provided by new technologies that experience uncertain demand. An example is the decision by the ACCC on the mobile termination access service. The Australian Competition and Consumer Commission (ACCC 2004) decided to regulate the mobile termination access service for voice on 3G infrastructure, but importantly did not regulate data services where there is still a degree of uncer-

[9] In outlining Sprint's view on commercial use of real options in telecommunications, Nevshemal and Akason (2002) argue the theory can be used to consider the 3G build out. Real option theory appears suitable for analyzing such decisions, as the investment in infrastructure is sunk, and voice service aside, 3G faces uncertainty on the level of demand for the multimedia high-bandwidth wireless services. For a recent paper that uses real option theory to analyze migration to 3G investment, see Tanguturi and Harmantzis (2005).

tainty over the level of future demand for multimedia high-bandwidth wireless services.[10]

Accounting for Call and Put Options in Telecommunications

The real options literature emphasizes the irreversibility of uncertain investment, and the resulting call option to delay. Abel et al. (1996) extend the analysis by developing a two-period model to examine an investment under uncertainty where there is an arbitrary degree of reversibility. The reversibility assumption allows consideration of both the call option associated with deferring an investment and a put option that arises from an ability to resell installed capital. In assessing these options Abel et al. show that when the put option is more important, the user cost of capital to the investor is potentially less than the neoclassical user cost of capital. Hubbard and Lehr (2000) indicate that real option theory has implications for pricing telecommunications investment. They argue the original debate focused too narrowly on the call option value to delay the new investment, and by doing so, established the result that the allowed the fair rate set by neoclassical investment theory underestimated the true cost of capital to the access provider. Hubbard and Lehr suggest that the emergence of the Internet and technology such as xDSL on copper, increased the value of embedded telecommunications investment in the local exchange, leading to a more general framework being required to assess the appropriate user cost of capital. They therefore adopt the Abel et al. model that incorporates the notion that while current investment extinguishes an option to defer, it also provides the investor with a growth opportunity and the strategic flexibility to adjust capital in the future. That is, contrary to Hausman (1997, 1999), the original investment may actually increase opportunities available to the firm.

Hubbard and Lehr (2000) examine the effect that the Internet has had on call and put options, and the user cost of capital. For instance, the authors argue that as the Internet is based on open standards, interoperability and flexible interconnection between heterogenous equipment—this lowers the cost of constructing and maintaining extant networks, and increases the value of the call option to delay. Also, as Internet networks are more flexible than circuit-switched networks, new technology can be readily integrated and new services are more easily supported. These features enhance the reversibility of the network—increasing the put option—and decreasing network expansion costs—augmenting the call option. And, Internet protocols increase the number of potential applications that can be supported on extant physical infrastructure which increases the put option value. To sum, whether the allowed fair rate of return determined using NPV theory is higher or lower than the true user cost of capital for regulated investment depends on the more important option. If the put option is more important the allowed fair

[10] The ACCC (2004: xvii) are not convinced that data services provided on 2.5G or 3G networks are sufficiently mature to warrant regulation.

rate of return using neoclassical investment theory over-compensates the access provider for its investment. The Hubbard-Lehr framework has important implications for access providers who argue that regulators should apply real option theory for incremental new investment to extant network infrastructure such as the local access network. Further, appropriate application of real options to such investment should account for both call and put options.

Strategic Pre-emption and First-mover Advantage

Within an oligopoly framework, Weeds (2002: 729) notes that, “the option to invest cannot be held independently of strategic considerations”. The literature combining real option theory and game theory suggests that the first-mover advantage and incentive to strategically pre-empt the investment can decrease or eliminate an option to wait that arises from uncertainty and irreversibility.[11] Weeds also notes for a market with few firms and a first-mover advantage, the ability to delay investment is undermined by fear of pre-emption, and the NPV rule is appropriate for appraising investments. Further, Mason and Weeds (2005) examine real options in a duopoly framework when there is an advantage from investment and a positive network effect between investors. The model demonstrates that increased uncertainty, rather than leading to further delay, provides an incentive to invest earlier. Arguments about strategic pre-emption lead Economides (1999: 211–2) to claim in relation to the US local telephony market, that in the current oligopolistic environment with anticipation of competition, firms invest looking forward to competition and cannot afford to wait. He concludes, “the value to an ILEC of waiting to invest may well be negative”.

They show that while it may be possible to defer investment, delay can lead an access provider to miss an industry bandwagon or first-mover advantage. Further, they conclude that a first-mover advantage decreases call option values and increases put option values. The joint effect reduces any mark-up required in the allowed fair rate of return. An implication of the results outlined in this section is that in a duopoly or oligopoly setting the regulator need not necessarily compensate an access provider for a lost option because the incentives of an access provider to derive a first-mover advantage and pre-empt investment may have extinguished the real option to wait. Finally, Clarke (1999: 223) notes in telecommunications, “…gains typically do not flow to those who wait, but rather are reaped by those who can become ‘first movers’”.

[11] Gans and Williams (1999) highlight the impact strategic pre-emption has on investment in infrastructure in a framework with certainty.

The Real Option to Wait—Compensation for Lost Market Power?

Early analysis of an irreversible investment under uncertainty considered the monopoly investor case. While Leahy (1993) and Dixit and Pindyck (1994) show that a single firm in a competitive market requires the same price threshold above cost as a monopoly investor to make an irreversible investment under uncertainty it is established that the value of the real option to wait or remain uncommitted is competed away to zero. This result invokes the question of whether it is appropriate for a regulator to compensate a firm for the value of a lost option to wait. When a regulator has a statutory duty to simulate the effects of a perfectly competitive market then the result suggests that the regulator should set the value of the lost option at zero. Further, by claiming compensation for a loss of the real option to wait, access providers could be viewed as requesting compensation for the loss of market power associated with regulation forcing them to provide access and increase investment. When this is the case, the real option surcharge argued for by access providers may suffer from the sort of problems that Tye (1994) identifies with the Efficient Component Pricing Rule (ECPR). That is, the access provider is able to claim or reclassify lost economic rents as an opportunity cost of supplying access services. Jamison (1999) formally shows a link between the ECPR and real options approach by demonstrating that both identify an additional opportunity cost of production.

The Truncation Problem and Real Option Theory

In Australia, Inquiry Reports by the Production Commission into *Telecommunications Competition Regulation* (Productivity Commission 2001a) and the *National Access Regime* (Productivity Commission 2001b) emphasised the importance of access regulation encouraging investment in essential infrastructure. Significantly, a concern raised in both reports is that for sunk investment subject to a high degree of risk, access regulation could potentially lead to what is described as a truncation problem.[12] The truncation problem is also highlighted in detail by Gans and King (2003, 2004).[13] The truncation problem resulting from ex post access regulation of an asset can be understood as follows: assume that there is an irreversible investment in essential infrastructure subject to a high degree of risk, which in the absence of regulation is considered viable because it yields a positive expected net

[12] See Productivity Commission (2001a, Chap. 9) and Productivity Commission (2001b, Chap. 11).

[13] Kolbe et al. (1993) and Kolbe and Tye (1995) identify a similar type of problem when dealing with stranded costs in the US electricity industry. They refer to it as a problem of ‘regulatory risk’. While Hausman and Myers (2002) note that the cost-based access pricing regulation used by the US Surface Transportation Board for rail, creates what they refer to as ‘asymmetric risk’.

present value.[14] After the firm commits to the irreversible investment possible scenarios are the project may be unsuccessful, moderately successful, or very successful. Where the project is unsuccessful or moderately successful, competitors do not seek access to the essential infrastructure and enter the market. However, when the investment is very successful there is strong incentive for competitor entry. If the regulator ex post allows competitors access to the essential infrastructure in the successful state the high return that can be earned from the investment is reduced. The prospect of ex post regulation truncates potential upside returns from investment, but still exposes the investor to the downside returns. An investor, recognising the potential for ex post access regulation, derives a lower ex ante expected rate of return from the investment and has a lower incentive to invest. It may be that the prospect of ex post regulation leads an investor to derive a negative expected net present value, and prevent socially-beneficial essential infrastructure from being provided.

The Productivity Commission suggests overcoming the truncation problem on such regulated investments, by allowing the access provider a mark-up or what they refer to as a ‘truncation premium’ on the allowed fair rate of return. This allowed fair rate that is set ex post by the regulator removes the problem of truncation by covering all the relevant ex ante risk that is faced by the investor. To calculate the premium the regulator could use an arbitrary method, such as allowing for an increased beta on the allowed return on equity. It is evident that the use of real option theory is ideally suited for calculating or estimating the size of such a premium as it explicitly deals with such irreversible and uncertain investments.[15] Adopting this approach, the estimate for the real option to wait would now be equal to the required premium on the allowed fair rate.

Gans and King (2003), however, outline problems associated with the regulator being able to ex ante commit to a higher fair rate of return if ex post access regulation occurs. For example, Gans and King (2003, 166) suggest that regulators do not have the necessary discretion over access prices to allow for such mark-ups, and that estimating the size of the premium is difficult, as an access provider has an incentive to overstate the ex ante risk to increase its allowed fair rate of return. Consequently, Gans and King propose the use of an ‘access holiday’ arrangement, which acts like a patent creating the incentive to invest by allowing the investor a period where it faces no access regulation. Further, it is not clear that it is appropriate to provide a truncation premium (or access holiday) where the access provider vertically integrates a new investment into a downstream market. In such instances it may not be necessary to provide a truncation premium—when the investor is able to dominate the downstream market there are fewer adverse consequences associated with setting a fair rate or return or access price that is too low. For example, the Productivity Commission (2001a: 396) observes that in relation to the public switched telecommunications network (PSTN), even if Tel-

[14] Gans and King (2003: 164–6) provide a discussion and numerical example highlighting the truncation problem.

[15] See Small and Ergas (1999).

stra's cost-based access price was set too low, the impact of this is more than offset by the rents that accrued at that time from its dominant downstream market position. So, even if the access price is set too low, an investor that vertically integrates the investment into its downstream retail market operations is still able to gain a competitive advantage over its rivals by increasing the effective cost faced by access seekers through discrimination on non-price terms and conditions. Beard et al. (2001) refer to this behaviour as sabotage. The problem of a vertically-integrated supplier engaging in sabotage has been recognised in recent statements by the Chairman of the ACCC.[16]

Conclusion

This chapter shows that if a regulator applies real option theory to assess telecommunications investment, the impact on the allowed fair rate of return will depend upon each of the following factors. First, whether or not real option theory can be applied by regulators to assess telecommunications investment will depend on the uncertainty of the returns derived from the new investment. When the demand for service supplied by the new technology is reasonably certain there is less of a case for the regulator to apply a real options approach to the new investment. As highlighted by Hubbard and Lehr (1996), the assumption about the type of uncertainty can impact on the level of any required mark-up. Second, when the asset is reversible, i.e., has a high resale value, then an investor has a put option on the asset. As Hubbard and Lehr (2000) outline, technological convergence created by the Internet is likely to reduce the value of any call option while increasing the value of any put option. The overall result is that the allowed fair rate of return set using the NPV approach may exceed the true user cost of capital. Third, strategic pre-emption and first-mover advantages may influence the private investment decision. That is, the real option to wait could be less important when making investments and can potentially be ignored by a regulator. Fourth, it is questionable whether a regulated access provider should be allowed to recover a real option to wait when the option has zero value in a competitive framework. When the new investment in the telecommunications network is irreversible and there is substantial uncertainty associated with the new technology and future demand for services then access regulation may lead to a truncation problem arising. For such investments the real call option to wait can be used to calculate the size of the truncation premium that the investor requires. Gans and King (2003) outline though, that due to the incentives of access providers to overstate the ex ante risk on investment and the problem of regulators committing to such mark-ups, an access holiday—i.e. a period where the asset is not subject to any access regulation—is likely to

[16] See Graeme Samuel, 'Current State of Telecommunications Regulation', Address to the Australian Telecommunications User Group (ATUG), Sydney, 10 March 2005, available at: http://www.accc.gov.au/content/item.phtml?itemId=591603&nodeId=file422f9e9581125&fn=20050310%20ATUG.pdf.

provide a simpler solution. Finally, when an investor is able to vertically integrate downstream retail functions with new network investment the problem associated with regulatory truncation may be of less importance.

Appendix

To capture the essence of real option theory for an irreversible investment under uncertainty it is assumed here for simplicity that the uncertainty being modelled in this example is: only over the net cash flows π; resolved after a year i.e., at time $t=1$; and binomially distributed. In addition to these properties of the uncertainty it is assumed that: the investor is risk neutral; once the irreversible investment of $I=\$6,000$ is made the project is instantaneously operational immediately generating a net cash flow to the investor; the net cash flow π at time $t=0$ (i.e., π_0) is certain and equal to \$300, but at time $t=1$ the net cash flow may increase with probability $p=0.5$ to $\pi^{+}=\$350$ or decrease with probability $(1-p)=0.5$ to $\pi^{-}=\$250$. The net cash flow will remain at the resulting level from time $t=1$ onwards (i.e., $t=1,2,\ldots\infty$); and the risk over future net cash flows is fully diversifiable so the firm can discount cash flows using the risk-free interest rate $R_f=0.05$ or 5%.

Using these assumptions the NPV approach yields:

$$\text{NPV}=-\$6000+\$300+\sum_{t=1}^{\infty}\frac{0.5\times\$350+0.5\times\$250}{(1+0.05)^{t}}=\$300. \tag{7.A1}$$

As the $\text{NPV}>0$ under neoclassical theory investment in the project is undertaken. However, if the firm has the necessary managerial flexibility to delay the investment this would be a mistake. That is, immediate investment ignores the opportunity cost associated with foregoing the opportunity to invest in the instance when the net cash flow increases in period 1. This is highlighted by calculating the NPV of holding the option to invest in the following period when the net cash flow rises to \$350:

$$\begin{aligned}\text{Option to invest}&=\$0+0.5\Big(-\frac{\$6000}{(1+0.05)}+\sum_{t=1}^{\infty}\frac{\$350}{(1+0.05)^{t}}\Big)+0.5\times\$0\\&=0.5(-\$5714.29+\$7000)\\&=\$642.86.\end{aligned} \tag{7.A2}$$

Note, when the net cash flow decreases the firm chooses not to invest. Part of the attraction of the option to invest is that management—by accounting for the asymmetry of the outcomes—is able to skew the distribution of possible outcomes upside. Hence, an investor with flexibility postpones the irreversible investment until the following year as the option to invest of \$642.86 exceeds the NPV from investing at time 0. By investing at $t = 0$ the firm foregoes \$342.86, which is the additional opportunity cost of investing now and the real option to delay the investment. That is:

$$\text{Option to delay or wait} = \text{Option to invest} - \text{NPV} = \$342.86\,. \tag{7.A3}$$

Alternatively, the \$342.86 can be thought of as representing the price that an investor is willing to pay to acquire the managerial flexibility necessary to defer the investment for one period. Following Holm (2000: 62), the value of the option to delay the investment is comprised of: (a) the lost net cash flow from not investing at time $t = 0$ (i.e., $-\pi_0$)—equals –\$300; (b) the cost saving from deferring the investment until time $t = 1$ (i.e., $I - I/(1+R_f)$)—equals \$285.71; and (c) the expected value from avoiding the bad outcome (i.e., $(1-p)(I/(1+R_f) - \sum_{t=1}^{\infty} \pi^- /(1+R_f)^t)$)—equals \$357.14. It is evident from this example that the value of the option to delay the investment is driven by the magnitude and likelihood of the bad outcome. This is consistent with Bernanke (1983), who notes that the willingness to undertake an investment depends only on the severity of the bad news and the potential good news does not matter. Bernanke (1983: 91) refers to this outcome as the, “bad news principle of irreversible investments”. Dixit and Pindyck (1994: 40) outline a similar result by stating that it is “the ability to avoid the consequence of ‘bad news’ that leads the investor to wait”. In the example presented here, all other things equal, an increase in the probability of the bad outcome to 0.75 increases the value of the option to delay to \$521.43. Meanwhile, if the overall expected net cash flow was to remain unchanged, but the net cash flow in the bad state decreases to \$200 (i.e., a mean-preserving spread), then the value of the option to delay will increase to \$842.86.

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8 A Discrete Real Options Approach to Access Pricing

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Introduction

Traditional cost-based access pricing can be assimilated to net present value (NPV) calculations. Regulated access prices are set so as to allow carriers to recover network asset costs over their economic life plus compensation for the opportunity cost of capital.[1] However, NPV calculations do not capture managerial flexibility, viz., the ability to delay, expand or abandon a project. In particular contexts this flexibility is valuable. For instance, when an investment project implies sunk assets and uncertain returns, delaying the investment until more information on profitability is revealed can increase the value of the investment opportunity. Therefore if mandatory unbundling is regulated according to traditional cost-based access prices when capital costs are sunk, returns are uncertain and a network carrier has the opportunity to delay investment, both incumbent and access-seeker decisions are distorted leading, ceteris paribus, to under investment.[2] The theoretical underpinnings of this claim are understood by academics and regulators.[3] Nonetheless, full acceptance of the approach in regulatory proceedings has not occurred, mainly due to reservations regarding the validity of underlying assumptions (such as uncertainty, sunk nature of assets and ability to wait) and perceived implementation challenges. The underlying assumptions of the real options approach adequately represent investment opportunities for new telecommunication services, especially markets for broadband and next generation networks (NGN). Therefore, the focus of this chapter is to provide a feasible solution to the access pricing problem based on the real options approach.[4] An early attempt to apply real options analysis to access problems in regulated industries is undertaken by Hausman (1997, 1999) in the context of TELRIC pricing within the telecommunications industry. Hausman and Myers (2002) also apply the approach to rail regulation, while Pindyck (2005) analyzes vertical services in the telecommunications industry.[5]

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[1] See, for example, Pindyck (2004).

[2] Either investment is delayed until the uncertainty is resolved or is cancelled.

[3] See Hausman (1999), Monopolies and Mergers Commission (1998), Oftel (2001), New Zealand Commerce Commission (2002), Pindyck (2004) and Ofcom (2005).

[4] This chapter only considers wait and see options. Other types of real options can arise in telecommunications markets, see Ofcom (2005).

[5] These authors applied the real options approach to assess the impact of an obligation to serve imposed on a European telecommunications carrier.

In this chapter a lattice modeling approach is employed to calculate access prices. While the approach resembles Pindyck by assuming a finite time horizon, the study differs from Hausman (1997, 1999), Hausman and Myers (2002), Dobbs (2004) and Pindyck (2005) by working in a discrete- rather than continuous-time setting. From a policy perspective, discrete-time models are easier to interpret and understand as their mathematical derivation requires only simple algebra. Thus, the black-box effect is avoided and the resultant simplicity provides a more effective decision support tool. Additionally, finite-horizon models are closer to real world applications than perpetual models, which are often specified for analytical convenience. Also, it should be noted that for this kind of application, continuous-time model specifications do not substantially improve the accuracy of valuation results. Conversely, such models may omit important properties of the discrete-time approach, such as the accessibility of the valuation methodology, tractability of the values in the model and the flexibility to add features necessary to incorporate competitive interactions. Following an established convention in the real options literature, this study employs an extension of the NPV framework. This framework is convenient as delay options are readily built into the NPV framework without any additional assumption.[6] The extended-NPV approach is simply viewed as a correction to ensure that traditional NPV assumptions are consistently applied. The balance of the paper proceeds as follows. The next section develops an access pricing real option based model within a discrete space and time framework. Some numerical examples to illustrate and interpret the behavior of the proposed model follow. A final section concludes.

The Model

Consider the problem of calculating fair access prices. Let a_t denote the access price applicable at time t. The next ingredient required is a probabilistic description of how demand changes through the time horizon of interest. Demand at current time $t = 0$ for a new telecommunication service is assumed known and denoted D. At any future time t demand for the service is uncertain, and denoted by D_t. Assume D_t follows a stationary multiplicative binomial process over successive periods. That is, demand D at the current time may increase next period by a multiplicative factor u with probability p to uD or decrease with complementary probability $(1-p)$ to dD. More generally demand t-periods later than current time can take the values:

[6] Other than a technical point regarding the consistency between the volatility of the underlying and risk behavior assumed to derive the risk-adjusted discount rate used in the NPV calculations.

$$D_t = Du^j d^{t-j}\,, \tag{8.1}$$

where $j = 0,...,t$. Each demand value has the corresponding probability:

$$\Pr(D_t) = \frac{t!}{j!(t-j)!} p^j (1-p)^{t-j}\,, \tag{8.2}$$

where $j = 0,...,t$. To provide the new service, specific equipment with a finite economic life and no alternative use must be deployed. Thus this service requires irreversible investment. Let I denote the amount invested to acquire and deploy this equipment and let T be the economic life of the asset. This economic life is expressed in absolute terms, i.e., the equipment does not generate cash flows during T years after deployment. Rather it provides inflows during T years starting from the current period, so if, e.g., the equipment is installed in T years, by then it will generate no inflows.[7] The economic life of the equipment T sets the limit of the time horizon, as it is over this T-length period that the investor expects to benefit for making the sunk investment I .

The estimated cost of capital and the risk-free rate are denoted k and r , respectively. Operating expenditure is reasonably assumed negligible. Assume further the equipment is in place and has an economic life that lasts until T . Let V_t denote the present value of future cash flows to be received from t until T . As future demand D_t , the corresponding present value is uncertain and evolves through time. Cash flow present value t periods hence is given by:

$$V_t = D_t \sum_{i=t}^{T} \frac{a_i}{(1+k)^{i-t}} \sum_{j=0}^{i-t} \frac{i!}{j!(i-j)!} p^j (1-p)^{i-t-j} u^j d^{i-t-j}\,. \tag{8.3}$$

All of the values have the same associated probability as D_t , i.e.,

$$\Pr(V_t) = \frac{t!}{j!(t-j)!} p^j (1-p)^{t-j}\,, \tag{8.4}$$

where $j = 0,...,t$. Traditional analysis calculates the a_t so that the NPV of the investment is set to zero. Formally, the following condition is imposed at $t = 0$:

[7] A substantial portion of telecommunications equipment has rapid obsolescence as a feature due to, e.g., emergence of an alternative technology. Clearly, in this context this assumption seems reasonable.

$$I = V_0 \tag{8.5}$$

or

$$I = D\sum_{i=0}^{T}\frac{a_i}{(1+k)^i}\sum_{j=0}^{i}\frac{i!}{j!(i-j)!}p^j(1-p)^{i-j}u^j d^{i-j} \tag{8.6}$$

with D denoting known demand D_t at time $t = 0$.

When a constant access price is considered a valid solution the access price is calculated by the rule:

$$a = \frac{I}{D\sum_{i=0}^{T}\frac{1}{(1+k)^i}\sum_{j=0}^{i}\frac{i!}{j!(i-j)!}p^j(1-p)^{i-j}u^j d^{i-j}}. \tag{8.7}$$

A more general solution might set the access price so that the price evolves over the T horizon along a preset path.[8] Following traditional analysis, the regulator sets the access price such that the NPV of the investment is zero. That is, the access price is just enough for the firm to invest immediately and break even. Given this price, though, the correct decision of the firm may be to not invest now but wait. Delay value drivers are: investment when made is delayed which means that interest costs are saved; delay carries an implicit insurance, viz., by waiting the investor is protected from the possibility that cash flows fall below levels that justify the investment; and delay prevents an investor from collecting early cash flows generated from the investment.

The extended value W_t of an investment opportunity is the value that is realized when the optimal investment timing is executed. To calculate this value the risk-neutral probability is introduced. The risk-neutral probability q is obtained by applying the rule:

$$q = \frac{(pu + (1-p)d)(1+r) - (1+k)d}{(u-d)(1+k)}. \tag{8.8}$$

The extended value is calculated by backward induction. At $t = T$ this value is:

$$W_T = \max(V_T - I, 0). \tag{8.9}$$

The extended value at times $t < T$ is:

[8] See, for example, Hausman and Myers (2002).

$$W_t = \max\left(\frac{qW_{t+1}^u + (1-q)W_{t+1}^d}{1+r}, V_t - I\right). \tag{8.10}$$

Whenever:

$$\frac{qW_{t+1}^u + (1-q)W_{t+1}^d}{1+r} > V_t - I, \tag{8.11}$$

waiting generates more value than investing, viz., a delay value exists. That is, when access prices are set using the traditional approach typically delay value arises. So contrary to what the regulator might expect investment does not occur immediately. Should the immediate deployment of infrastructure required for the new telecommunication service be a regulatory goal, the access price should be set so that no delay value arises. This outcome is accomplished by determining access prices according to the expression:

$$\begin{aligned} a_t = \frac{I}{u^t D} - \frac{qu + (1-q)d}{1+r} \sum_{i=t+1}^{T} \frac{a_i}{(1+k)^{i-t-1}} \\ \times \sum_{j=0}^{i-t-1} \frac{i!}{j!(i-j)!} p^j (1-p)^{i-t-1-j} u^j d^{i-t-1-j}. \end{aligned} \tag{8.12}$$

At $t = T$, Eq. 8.12 collapses to:

$$a_T = \frac{I}{u^T D}. \tag{8.13}$$

By substituting a_T obtained in Eq. 8.13 into Eq. 8.12, access prices a_T are calculated moving backwards, i.e., starting from $t = T$ and moving back until $t = 0$. Summing, to ensure immediate investment, access prices are set so that the extended value is equal to the NPV. The access prices calculated impose this equality and force both values to zero. Other equalities at positive non-zero values lead to immediate investment but at the cost of access-seekers providing extraordinary profits to infrastructure owners. Thus, the access prices derived above are the minimum access prices that ensure immediate new service deployment.

Some implementation issues are worthy of note. First, the binomial valuation approach provides greater insight and an acceptable degree of accuracy with relatively few tree steps.[9] In the above model specification, it appears reasonable to associate with the period between consecutive t values a particular length of calendar time, however, there is no reason to do so. The horizon between $t = 0$ and

[9] Further, accuracy is gained only at the expense of computation time.

$t = T$ can be divided into more periods generating a more realistic tree. For instance, provided an adequate parameterization is in place, as the time interval shortens and the number of steps increases the limiting case is a geometric Brownian motion.[10] The geometric Brownian motion is a continuous-time stochastic process that represents the evolution of an uncertain variable:

$$dD = \mu D dt + \sigma D dz \,, \tag{8.14}$$

where t is time, D is the random variable that evolves over time, μ is a constant parameter representing a drift rate per unit time and σ^2 is the variance rate of the proportional change in D. σ is usually referred to as volatility.

There are several ways to construct a binomial tree that approximates a geometric Brownian motion. An acceptable tree must generate an appropriate distribution as the length of the tree step approaches zero. Alternative methods of constructing the binomial tree result in different u and d demand D_t movements. Cox et al. (1979) construct a binomial tree by applying the expressions:

$$u = e^{\sigma\sqrt{h}} \tag{8.15a}$$

and

$$d = e^{-\sigma\sqrt{h}} \tag{8.15b}$$

where h is the time step between the discrete-time points considered. The lattice model described above is based on a recombining tree. A binomial tree is recombining when for any tree node all paths that lead to the node contain the same number of ‘upward moves’ and ‘downward moves’. If an upward move followed by a downward move leads to a different price than a downward move followed by an upward move, a non-recombining tree results. This analysis assumes the trees are recombining as they are more tractable because there are a smaller number of nodes in the backward recursive procedure to be examined.

An Illustration

Table 8.1a to Table 8.1c report real options access pricing model simulations with alternative assumptions about underlying demand volatility. In particular, values are assumed for inputs demand volatility, cost of capital, investment required, ini-

[10] The geometric Brownian motion is probably the most common stochastic process used to represent uncertainty in option pricing literature, with the most eminent example of its use the Black-Scholes option pricing model.

tial demand and risk-free rate. Volatility and discount rates are specified on a per annum basis. Also displayed are calculated values for the 'up' and 'down' jump size, and the risk-neutral probability. The time horizon under consideration is 8 years, with a lower bound of $t = 0$ and end point $t = T = 8$. The time-step between nodes of the binomial tree is a year. The annual compounding discount factor and expected demand are simulated for each time step. Expected demand per period is computed via:

$$ED = D\sum_{j=0}^{i} \frac{i!}{j!(i-j)!} p^j (1-p)^{i-j} u^j d^{i-j} \ . \tag{8.16}$$

Expected demand is used to derive access prices by applying a discounted cash flow model. The access price obtained from application of the standard model is traditional access price *a*. Access prices a_t, calculated for all periods, are real option based access prices or 'non-delay access' prices. Non-delay access prices are computed by applying the recursive procedure described above. Finally, the model simulation provides five relative measures of non-delay access prices. These ratios have the traditional access price as denominator. Numerators for the ratios are maximum, minimum, average, discount factor weighted average and initial value non-delay access prices, respectively.

Table 8.1a. Access Price Simulation—Constant Investment Cost, Demand Volatility=0.15

Assumed input value		Calculated value	
Demand volatility σ	0.15	Up jump probability p	0.5
Cost of capital k	10%	Time step h	1
Investment I	1000	Up jump size u	1.1618
Initial demand D	6000	Down jump size d	0.8607
Risk free rate r	4%	Risk-neutral probability q	0.3168

Simulated variable	Time path 0	1	2	3	4	5	6	7	8
Discount factor f	1	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47
Expected demand ED	6000	6068	6136	6205	6275	6346	6417	6490	6563
Non-delay access price a_t	0.035	0.030	0.026	0.022	0.019	0.016	0.014	0.012	0.050
Traditional access price a	0.025								

Relative non-delay access price metric	
Maximum a_t / a	1.9823
Minimum a_t / a	0.4807
Average a_t / a	0.9860
f-weighted average a_t / a	1.0027
a_0 / a	1.3737

Table 8.1b. Access Price Simulation—Constant Investment Cost, Demand Volatility=0.25

Assumed input value		Calculated value	
Demand volatility σ	0.25	Up jump probability p	0.5
Cost of capital k	10%	Time step h	1
Investment I	1000	Up jump size u	1.2840
Initial demand D	6000	Down jump size d	0.7788
Risk free rate r	4%	Risk-neutral probability q	0.3886

Simulated variable	Time path								
	0	1	2	3	4	5	6	7	8
Discount factor f	1	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47
Expected demand ED	6000	6188	6383	6583	6790	7003	7223	7450	7684
Non-delay access price a_t	0.045	0.035	0.027	0.021	0.017	0.013	0.010	0.008	0.023
Traditional access price a	0.024								

Relative non-delay access price metric	
Maximum a_t / a	1.9027
Minimum a_t / a	0.3306
Average a_t / a	0.9324
f-weighted average a_t / a	1.0339
a_0 / a	1.9027

The non-delay access price path shares a common pattern across volatility assumptions contained in Table 8.1a through Table 8.1c. Initially, non-delay access prices are above the traditional access price a by scale factors that vary from 1.37 to 3.77. Subsequent access prices decline from between 11% and 48% of the traditional access price. Also, note that the only non-delay access price at time $t = 8$ that is higher than a is for a demand volatility of 0.15. A pattern of non-delay access prices that are initially greater than the traditional access price and decrease afterwards suggests a 'price frontloading' effect. This effect increases with volatility and reveals a delay value is embedded in the non-delay access prices.[11]. Recall, the solution is found by imposing a zero delay value condition. The absence of any delay value is imposed by improving near term prices and 'softening' future prices. Thus, incentives to wait are removed as current revenues are too attractive to forego, while future revenues do not by themselves justify making the investment later. The discount-factor weighted average ratio is more revealing than the non-weighted average ratio as the former factors in the time value of money. The weighted ratios computed in Table 8.1a to Table 8.1c are greater than one in value, meaning that the weighted average of non-delay access prices for all as-

[11] This frontloading effect is the widening of the gap between the non-weighted average ratio and the discount-factor weighted average ratio.

sumed volatilities assumed are higher than the traditional access price. The impact is small for low volatility. For instance, increasing volatility from 0.15 to 0.25 only increases the weighted average ratio by 3%, whereas doubling volatility from 0.25 to 0.5 adds almost 30 % to the ratio.

Table 8.1c. Access Price Simulation—Constant Investment Cost, Demand Volatility=0.50

Assumed input value		Calculated value	
Demand volatility σ	0.50	Up jump probability p	0.5
Cost of capital k	10%	Time step h	1
Investment I	1000	Up jump size u	1.6487
Initial demand D	6000	Down jump size d	0.6065
Risk free rate r	4%	Risk-neutral probability q	0.4410

Simulated variable	Time path 0	1	2	3	4	5	6	7	8
Discount factor f	1	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47
Expected demand ED	6000	6766	7629	8603	9701	10939	12335	13909	15685
Non-delay access price a_t	0.063	0.038	0.023	0.014	0.009	0.005	0.003	0.002	0.003
Traditional access price a	0.017								

Relative non-delay access price metric	
Maximum a_t / a	3.7669
Minimum a_t / a	0.1138
Average a_t / a	1.0645
f-weighted average a_t / a	1.3276
a_0 / a	3.7669

A discrete setting provides the flexibility to enable model assumptions to be altered. For example, in Table 8.2a through Table 8.2c results obtained by modifying the investment cost invariance assumption are reported. In this scenario the investment cost I_t evolves through time via the rule:

$$I_t = \frac{I_0}{(1+\alpha)^t} \tag{8.16}$$

where α is a decay parameter that captures declining investment cost due, for instance, to technological obsolescence. Table 8.2a through Table 8.2c also presents alternative non-delay access price estimates for declining investment costs. The results are based on the same volatility assumptions employed in the simulations reported in Table 8.1a through Table 8.1c. The reported value of the traditional access price a is independent of the decay factor values α. The results reveal that declining investment costs reinforce the frontloading effect reported for the invariant investment cost model. Across volatility assumptions, higher decay factors lead to increased weighted average ratios. Again, the incremental effect is more important for high volatility scenarios.

Table 8.2a. Access Price Simulation—Declining Investment Cost, Demand Volatility=0.15

Assumed input value		Calculated value		
Demand volatility σ	0.15	Up jump probability p		0.5
Cost of capital k	10%	Time step h		1
Investment I	1000	Time horizon T		8
Initial demand D	6000			
Risk free rate r	4%			
Simulated variable		Decay α		
	0%	10%	30%	50%
Final investment I_8	1000	467	123	39
Initial access price a_0	0.0348	0.0468	0.0652	0.0787
Final access price a_8	0.0502	0.0234	0.0062	0.0020
Relative non-delay access price metric		Decay α		
	0%	10%	30%	50%
Maximum a_t / a	1.9823	1.8472	2.5755	3.1097
Minimum a_t / a	0.4807	0.3317	0.1436	0.0637
Average a_t / a	0.9860	0.9137	0.8426	0.8098
f-weighted average a_t / a	1.0027	1.0120	1.0215	1.0262
a_0 / a	1.3737	1.8472	2.5755	3.1097
Traditional access price a	0.0253			

Note that the results are also based on imposing a condition that NPV is equal to zero. This assumption ensures that the frontloaded pricing scheme is just sufficient to guarantee full-cost recovery. A solution with positive NPV is not appealing as: (a) access prices that lead to positive NPV deliver extraordinary profits to investors—a circumstance that probably makes a regulator uncomfortable; and (b) a positive NPV solution can be viewed as a non-equilibrium solution as the availability of extraordinary profits triggers renewed entry.

Table 8.2b. Access Price Simulation—Declining Investment Cost, Demand Volatility=0.25

Assumed input value		Calculated value		
Demand volatility σ	0.25	Up jump probability p		0.5
Cost of capital k	10%	Time step h		1
Investment I	1000	Time horizon T		8
Initial demand D	6000			
Risk free rate r	4%			
Simulated variable		Decay α		
	0%	10%	30%	50%
Final investment I_8	1000	467	123	39
Initial access price a_0	0.0450	0.0560	0.0730	0.0855
Final access price a_8	0.0226	0.0105	0.0028	0.0009
Relative non-delay access price metric		Decay α		
	0%	10%	30%	50%
Maximum a_t / a	1.9027	2.3709	3.0912	3.6195
Minimum a_t / a	0.3306	0.2114	0.0856	0.0368
Average a_t / a	0.9324	0.8947	0.8555	0.8362
f-weighted average a_t / a	1.0339	1.0521	1.0719	1.0822
a_0 / a	1.9027	2.3709	3.0912	3.6195
Traditional access price a	0.0236			

Concluding Remarks

The regulation of access prices raises a question of dynamic versus static efficiency. The traditional approach toward cost-based access pricing ignores that under certain circumstances the ability to manage the timing of an investment increases the value of the project. By ignoring this option value the regulation of access prices distorts investment incentives and is biased towards service- rather than infrastructure-based competition. This chapter contributes to the literature concerned with the practical implementation of the real option approach to access pricing. The proposed pricing method is easy to interpret and understand, able to cope with real-world conditions and can be generalized to account for alternative uncertainty representations and include more sophisticated industry features such as competitive interactions. The proposed method is illustrated with numerical examples. Non-delay access prices—which embed the delay option value and eliminate extraordinary profits—can initially be substantially greater than the traditional access price. Although the values change through time, on average non-delay access prices are typically higher than traditional values. Furthermore, the difference between non-delay and traditional access price increases with uncertainty.

Table 8.2c. Access Price Simulation—Declining Investment Cost, Demand Volatility=0.50

Assumed input value		Calculated value	
Demand volatility σ	0.50	Up jump probability p	0.5
Cost of capital k	10%	Time step h	1
Investment I	1000	Time horizon T	8
Initial demand D	6000		
Risk free rate r	4%		

Simulated variable	Decay α			
	0%	10%	30%	50%
Final investment I_8	1000	467	123	39
Initial access price a_0	0.0630	0.0725	0.0870	0.0976
Final access price a_8	0.0031	0.0014	0.0004	0.0001

Relative non-delay access price metric	Decay α			
	0%	10%	30%	50%
Maximum a_t / a	3.7669	4.3298	5.1959	5.8310
Minimum a_t / a	0.1138	0.0671	0.0224	0.0071
Average a_t / a	1.0645	1.0727	1.0823	1.0877
f-weighted average a_t / a	1.3276	1.3712	1.4245	1.4555
a_0 / a	3.7669	4.3298	5.1959	5.8310
Traditional access price a	0.0167			

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9 Optimal Pricing with Sunk Cost and Uncertainty

James Alleman and Paul Rappoport

Introduction

Marginal-cost pricing results are often employed to justify the imposition of regulatory policy that determines optimal prices. In a more sophisticated form Ramsey pricing is also recommended as a pricing tool (Willig 1979). While the methods are static they are commonly applied to network industries such as telecommunications. Implicitly these methods assume future events are certain and so stochastic cash flow changes are not explicitly modeled. This modeling limitation is important as uncertainty can impact substantially on otherwise optimal prices. Moreover, substantial sunk (irreversible) costs are routinely incurred by incumbent firms in telecommunications network industries. When an investment is sunk the firm has exercised a delay option, i.e., the delay option is no longer available. This opportunity cost is not typically acknowledged by regulators in their pricing decisions. Additionally, in neglecting opportunity costs regulators impact on an incumbent firm's cost of capital. This chapter develops a model with sunk costs that is solved to determine optimal prices in the spirit of traditional marginal-cost pricing. The modeling demonstrates the impact sunk costs have on the opportunity cost of immediate investment. Real options methods assist in analyzing cash flows that impact on an investments value. The social welfare maximum—the maximal discounted sum of producer and consumer surplus—is obtained.[1] Without regulatory constraint, the modeling shows that 'uncertainty prices' differ substantially from traditional marginal-cost and Ramsey prices. Policy implications for the telecommunications industry are important, in particular, total element long run incremental cost (TELRIC) rates are incorrect. Further, should the rates derived from this static theoretical construct be exactly as TELRIC requires they would be erroneous. The chapter is structured as follows. The next section provides a literature review, description of background issues and proposes a framework to address these concerns. The review aims to develop reader intuition toward the real options approach to sunk costs. Next, a model is formalized while a demonstration shows how real option modeling is helpful in understanding the role of irreversible investments as an opportunity cost and that insight on the role of regulation on investment incentives can be gained. A final section concludes and suggests areas for further research.

[1] Models that assume depreciation is exogenously determined fail to include any interaction between demand and economic depreciation, and so provide poor policy direction.

Literature Review

The literature considers in order: the impact of regulation on investment—either rate-of-return or incentive regulation—usually in a static context though occasionally with dynamic models of investment behavior; generic real options analysis; interconnection, wholesale or access pricing; and real options applied to telecommunications and increasingly to access pricing. A review of static and dynamic aspects of investment under alternative regulation and optimal (Ramsey) pricing is provided by Biglaiser and Riordan (2000). Most of this literature assumes an Averch and Johnson (1962) type static framework applies. The models show that rate-of-return regulation does not provide any incentive for firms' to minimize costs or optimize capital investments. Firm growth is considered via exponential models that have time as an explanatory variable. Economic depreciation is treated as exogenous. The dynamic models are deterministic complete information growth models. The financial real options literature is reviewed and integrated in Trigeorgis (1996). Dixit and Pindyck (1994, 1995) provide an economists perspective on this literature. Dixit and Pindyck focus on the delay option. Conversely, Luenberger (1998) and Hull (2000), in analyzing the received financial real options literature, provide a more extensive coverage of options available to investors. Network interconnection access pricing is another area that has been debated extensively. During the 1990s an important debate considered the correct method to price interconnection. Typically, the debate concerned variants of the efficient component pricing rule (ECPR or Baumol-Willig rule) first proposed by Willig (1979). The rule is based on the contestability theory of Baumol et al. (1984) and the more traditional approach of Laffont et al. (1998a, 1998b), and is summarized by Laffont and Tirole (2000). Criticism of the pricing methods is provided in Alleman (1998a, 1998b). Noam (2001) also extensively reviews interconnection issues. Finally, Vogelsang (2003) provides a critique of access pricing methods and issues. These analyses are based on static or comparative-static models.

Ergas and Small (2000) apply real options techniques to examine the sunk network costs and regulator impact on the distribution of returns. They attempt to establish a link between regulation, the value of the option to delay and economic depreciation. Small (1998) studied investment with uncertain future demand and costs by real options methods. More recently, d'Halluin et al. (2004a) apply real options methods to an ex post analysis of long-distance data service capacity. d'Halluin et al. (2004b) also applies these methods to wireless service issues. Other application of real options techniques to telecommunications markets include Pak and Keppo's (2004) analysis of network optimization and Kulatilaka and Lin's (2004) study of strategic investment in technology standards. Finally, several papers address the principal issue concerning this chapter. In particular, Hausman (1999, 2003) uses a real options approach to examine sunk cost of assets and the delay option in the context of unbundled network elements. Similarly, Hausman and Myers (2002) estimate the magnitude of mistakes by the failure of regulators to account for sunk costs in the railroad industry. Hori and Mizuno (2004) employ real options methods to access charges in the telecommunications industry. Lozano and Rodríguez (2005) use a lattice approach—for its intuitive appeal—to show that access price is higher than that calculated by a traditional net present value approach. Clark and Easaw (2003) address access pricing in a competitive market to show that when uncertainty is considered prices should be higher than under certainty. That is, entrants should pay a premium to enter a market to reward an incumbent for bearing the risk of uncertain revenue streams. Pindyck (2004) demonstrates that failure to account for sunk costs leads to distorted investment incentives and in unbundled network elements—a variant of access pricing. Similarly, Pindyck (2005a) shows that sharing infrastructure at rates determined by regulators subsidizes entrants and discourages investment when sunk costs are not properly considered in the determining prices. Pindyck suggests how prices should be adjusted to allow for sunk costs. Pindyck (2005b) also demonstrates how sunk costs are an entry barrier and impact on market structure.

Regulation and Pricing

Since the introduction of telegraph interconnection has remained important in ensuring the connectivity of industry networks. In 1865, the predecessor of the International Telecommunication Union formed to ensure interconnection of telegraph service internationally. Currently, issues of network access are more critical as interconnection is required for multiple communications technologies, viz., the Internet, mobile telephony, WiFi (80211.x) wireless networks, wide and local area networks, satellite systems and cable broadband. Not only must arrangements for the interconnection of this technology be established on geographic and technical bases, but also an economic foundation is required. Because interconnection is an inter-firm matter, access issues do not have the visibility of retail telecommunications markets. Recent policy has aimed to replace regulation with competition as the preferred policy instrument. As many networks can potentially enter another market, interconnection is a means by which the competition objective can be achieved. From the incumbent's point of view the pricing of intermediate services is an extremely important issue. Interconnection or intermediate pricing represents the price of the intermediate good or service needed by a firm to provide a service. Within the telecommunications industry this access price is charged by a service provider for connection to their network so that another provider can complete the service for its own end-user customers. For example, in the United States the access price represents the price that long-distance carriers must pay to exchange carriers to complete calls on the PSTN. Pricing is more complex when the company charging the interconnection price also competes with the company to which it supplies the intermediate service. The company charging for interconnection has an incentive to overcharge the competing company—not only to enhance own revenue but to increase competing company costs, and perhaps price. From an economic perspective, what should be the goals of interconnection? Alleman (1998a) suggests that appropriate goals are set to avoid incentives that lead to inefficient bypass; prices should be equivalent for comparable facilities and that prices should be transparent. Interconnection on this basis means that companies have no incentive to invest in uneconomical assets. Further, an access charge should be applicable to all services, viz., wire and wireless, telephony and cable, the Internet and voice services. When interconnection is not priced correctly room is left to arbitrage the uneconomical prices. Equivalent access prices may ensure that inefficient bypass is avoided. Transparency is a criterion that assures prices are comparable. Market power should not be a factor in negotiations to determine an interconnection price. But the critical question remains as to what are the correct costs to measure and so meet these goals. This is where most analyses fail to account for the nature of sunk costs.

Sunk Costs

Sunk costs comprise a substantial component of investment costs in telecommunications networks and play a critical role in the determination of market structure (Pindyck 2005b). The US Federal Communications Commission (FCC) and Canadian Radio and Television Commission, and United Kingdom (UK) Office of Communications (Ofcom) have to varying degrees implicitly recognized this situation. For instance, the FCC attempted to promote competition by requiring that incumbents make their network available to competitors at incremental cost. Canada has a similar policy but of limited duration, whereas the UK regulator is explicitly asking for comments on a real options approach to determining wholesale prices (Ofcom 2005). But what are sunk costs and how do these costs impact on pricing issues, entry conditions and market structure? Sunk costs are distinct from fixed costs. Sunk costs are costs not recoverable once incurred, whereas fixed costs end when a firm ceases production. Sunk costs generally are industry and firm specific which implies they are not fungible. In particular, when an economy enters a 'down cycle' firms' plant and equipment cannot be sold to competitors because they are of no value. Thus, a factor that distinguishes fixed from sunk costs is that sunk costs are incurred at the initiation of a project prior to the profitability of the project being 'known' (Pindyck 2005b). For an incumbent firm this means that the delay option is exercised. However, because of this expenditure by the incumbent, a potential competitor has to value the direct cost of investing and the value to delay.

Regulatory Distortion

The nominal purpose of regulation is to optimize social welfare and ensure that monopoly rents are eliminated from monopolistic firms' prices. Generally benefit is measured by consumer surplus while economic costs are estimated incorrectly, by firms' historical accounting costs. Economic costs are a preferred measure as they recognize all appropriate costs. In particular, without considering firm investment dynamics significant costs are not recognized. The interaction of regulation and valuation bears on welfare estimation in several respects. First, when a regulator does not recognize certain costs then prices set on that basis are not correct. Second, should the financial sector recognize that the regulator is not accounting for all costs then raising debt becomes more costly, and equity capital increases cost, thereby leading to consumers facing increased prices. Among costs that typically are not adequately identified (or quantified) is the obligation to serve. Under the current practice whenever a customer demands service incumbent carriers are obliged to provide the service. This requirement is part of mandated common carrier obligations. The US Congress is considering legislation requiring telephone companies to provide mandatory broadband service. This legislation would remove an incumbent's ability to assess market conditions on a commercial basis and decide when and where to enter this market. Namely, under this legislation an incumbent loses the option to delay entry. Moreover, even when servicing a customer is unprofitable the carrier must continue to provide service to that customer. Thus, the carrier also loses the option to abandon the service to that particular customer.[2] Another 'commercial viability' option is the ability to shutdown and restart operations. This, option is also precluded under the most regulatory regimes. Finally, a time-to-build option, which includes an ability to default in the midst of a project, is not available in the current regulatory context. This lack of options is not considered in cost models that are utilized by regulators for policy purposes. Clearly, restricting the availability of options imposes opportunity costs on the firm and society.[3]

Real Options Pricing

Real options pricing methods utilize financial option principles to value real assets under uncertainty. This section evaluates regulatory actions ex post to determine the impact of regulatory constraint on investment decision-making. To illustrate the real options approach a stylized binomial model is employed. The model is intended to provide an intuitive understanding that regulation bears costs, thus showing that regulation restricts the flexibility of a firm through the imposition of price constraints or by imposing costs associated with delay, abandonment or shutdown and restart options. Since cost models used by public policy decision makers do not account for the time-to-build options available to the firm, and these regulatory impacts are left unaccounted, there are substantial costs imposed on the firm and society. A clear example of the telecommunications regulatory failure to apply dynamic analysis is in the use of cost models and a type of long run incremental cost methodology to determine prices and obligations-to-serve subsidies (Alleman 1999).

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[2] The argument that network provides an external benefit beyond the value of an additional subscriber may offset this cost however this argument is not compelling in areas that have substantial telephony penetration.

[3] This is not to imply that these public policies be abandoned, but in order to weigh the policy alternatives, their costs must be understood.

Model Specification

Assume cash flows shift each period based on a discrete probability—a cash flow is either high with probability q or low with probability $(1-q)$. This cash flow is modeled for two periods with the intertemporal demand cross-elasticity assumed zero. These simplifying assumptions enable capture of the effects of time and uncertainty and serves as a foundation for more complex analysis. To explore uncertain cash flows first note that the traditional engineering economics methodology quantifies an expected value of the discounted present value of the profit function. This procedure requires, inter alia, the specification of a 'correct' discount rate. To account for uncertainty this rate is adjusted for risk using the capital asset pricing model. In the regulatory context, this rate is equivalent to the determination of the rate-of-return for the firm. In the rate base, rate-of-return regulation context, a historical year is chosen and the rate-of-return determined. Prospective costs and revenues are assumed estimated with the past and historical year representing the mean of that past. Before competition emerged in the telecommunications industry discounted present value techniques were a useful analytical technique to apply. That is, industry had stable and predictable revenue and cost streams (and hence, cash flows), however more recently, industry norms have become less reliable (Noam 2002, Alleman 2003). This analysis differs from the traditional present value approach in that investment and their prospective cash flows are modeled with investment having either a 'good' or 'bad' outcome. Accordingly, a binomial real option model is employed to analyze the investment.[4] Viewed in this fashion, the fundamental question is: what is the value of an investment to the firm with the management flexibility option removed? Analogously, how is the value of this option determined? Black and Scholes (1973) are the first to provide a method to price financial options. This method is much revised since, e.g., see Nembhard et al. (2000) for a review. Next, consider a stock-option example. Factors that influence stock option prices include the current and exercise price spread, length of time during which the option can be exercised and the volatility of stock returns. Both the current price of the asset and the exercise price (the price at which the stock can be purchased at a specified future time) are known. The greater is the current and exercise price spread the lower is the option price, i.e., only a substantial current price rise will increase the stocks value above the exercise price. Naturally, large price shifts are less likely to occur than smaller changes. The option expiry date is also important in determining an options value. The longer the duration of the option the greater is the probability of a stock price rise (be 'in the money') beyond the exercise price. Finally, the more volatile is a stock's price the higher the option price. An important aspect of real options is the treatment of uncertainty. Discounted cash flow analyses treat higher risk by increasing the discount rate which reduces the value of later period cash flows. Thus, uncertainty must reduce the value of a project. Conversely, the real options approach leads to

[4] Two-period models are readily extended to analyze n-period cash flows. For example, Cox et al. (1979) solve n-period models and demonstrate that in the limit these results converge to a Black-Scholes option pricing model result.

an increase in the value of the project as management has an option to delay or expand the project—the greater is uncertainty greater is the project's value, just the reverse of the discounted cash flow approach.

Delay Distortion, Obligation to Serve

In Fig. 9.1 a two-period investment has two possible outcomes: a good result V^+ and a bad result V^- with probabilities q and $(1-q)$, respectively. Traditional practice would evaluate the investments by calculating the expected value of the discounted cash flow outcomes. Alternatively, the investment can be evaluated by options pricing techniques. Intuitively delay has a value as it allows a firm to have the state-of-nature revealed.

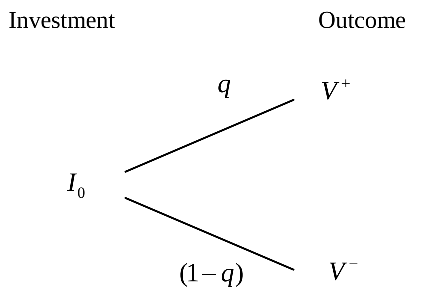

Fig. 9.1. Two-period Binomial Model Outcomes

Consider in Fig. 9.2, the good state realizes a net return of \$ 80 (prior to discounting) whether the firm defers the project or not. As the firm can defer investment should the bad state occur, it does not invest. However, if the firm is not able to defer it loses \$ 40. Clearly, deferral is of value to the firm.

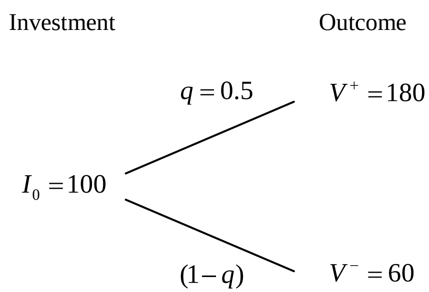

Fig. 9.2. Two-period Binomial Model Numerical Example

When the discounted cash flow (DCF) is calculated using Eq. 9.1 with a risk-adjusted interest rate of 20% the project has a zero value.

$$DCF = -I_0 + (qV^+ + (1-q)V^-)/(1+r)\ . \tag{9.1}$$

Table 9.1. Post-commitment Outcomes

State	Investment	Outcome	Net Return	Option Value
V^+	100	180	80	Max (80, 0) = 80
V^-	100	60	– 40	Max (– 40, 0) = 0

Several methods can value an option. The twin security (relative pricing) approach identifies a security with a similar outcome pattern. A replicating portfolio that matches the project's outcome is then sought. The replicating portfolio value is the value to defer, and equal to the difference between the traditional present value measure of the project and this flexibility value.

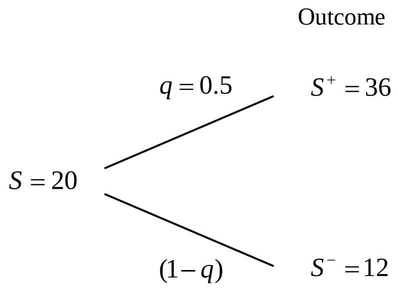

Fig. 9.3. Twin Security Outcomes

For an assumed risk-free interest rate of 5%, the twin portfolio that replicates the outcome of project deferral is found by solving the simultaneous equations,

$$mS^+ - (1-r_f)B = \$\,80 \text{ and } mS^- - (1-r_f)B = \$\,0\ . \tag{9.2}$$

Let B represent borrowing at the risk free rate and m be the twin security share holding. For the assumed parameter values: $S^+ = \$\,36$, $S^- = \$\,12$ and $r_f = 5\%$, Eq. 9.2 is solved for $\bar{B} = \$\,42.11$ and $\bar{m} = 3.33$. The corresponding delay option value is $\overline{m}S - \overline{B} = \$\,24.56$. The project's delay option value equals the twin portfolio value net of the DCF value, viz., $\$\,24.56 - \$\,0 = \$\,24.56$.[5] In the regulatory context a firm does not have a delay option available, i.e., the firm must supply basic service as mandated.[6] The cost of such mandated inflexibility is the delay option value or opportunity cost of immediate investment as the firm has no opportunity to wait to determine whether the market will improve or worsen. Additionally, an entrant must incur network investment direct costs and must also consider opportunity costs.

Long-run Marginal and Sunk Costs

Next, consider the characterization of long-run marginal cost (LRMC) for a firm that enters a market with no option to wait. Assume that a zero short-run marginal cost, a single unit of output produced per period, no technical change and an initial investment serves the market indefinitely. For this case, with amortization of direct investment costs (I) and opportunity cost (OC), the LRMC is equal to $(I + OC)/r_f$.[7] Clearly, this measure is greater than for the LRMC in a certain environment, i.e., I/r_f. This LRMC value is determined by the volatility of the revenue stream—the greater is volatility the greater the opportunity cost. In the context of TELRIC pricing, engineering process models only use the equivalent of amortized investment costs that systematically underestimate correct prices. This simple model reveals that to set prices equal to LRMC in a dynamic world requires higher prices than in a static world. In the static case prices are set too low because the opportunity cost is not considered by the regulator for either the incumbent or potential entrant. Moreover, inefficient entry occurs as prices are not set at the correct marginal cost. However, a potential entrant has an option to delay that presents a barrier to facilities-based entry. Therefore, a potential entrant not only considers the discounted present value of investment but on entry forgoes an option to delay. Thus, the real option impacts on both incumbent and potential entrant's investment decisions. Moreover, to the extent financial markets recognize that incumbent firm's prices will be too low due to regulation, the market's valuation of the firm is less.

Optimal Prices in a Dynamic Context

Consider next a binomial model for a profit-maximizing monopolist facing two alternative states of nature, viz., strong and weak demand states. Also, assume the

[5] Adding additional periods increases the value of a delay option, e.g., Dixit and Pindyck (1994) and Pindyck (2004, 2005a, 2005b) specify an infinite horizon model to demonstrate the delay option.

[6] An exception is discretionary services such as DSL.

[7] This approach is similar to average incremental cost employed by Baumol and Sidak (1994a, 1994b).

monopolist is able to adjust immediately to any state of nature. In either state, the firm sets price where marginal cost equals marginal revenue to determine maximum profit. With this information, the option value of the profit is determined as in Fig. 9.4. Thus, the value of this opportunity cost can be determined a priori as the solution to the binomial option value. The solution is the incremental value of the firm at that point.

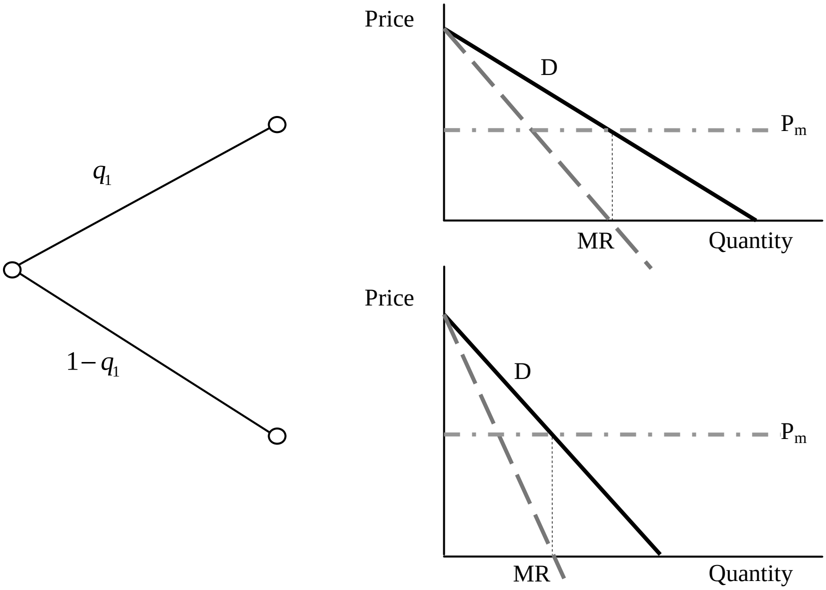

Fig. 9.4. Two-period Monopolistic Binomial Outcome

Figure 9.4 can also be used to contrast this outcome with that of a fully informed and perfectly-regulated monopolist. In this case, the price is set at zero (as marginal cost is assumed zero). The delay option value in this regulated state-of-nature is less than that for an unregulated monopoly since no monopoly profits arise for either outcome. How do financial markets treat regulated versus unregulated markets? The case of a regulated monopolist is displayed in Fig. 9.5. The firm has declining unit operating costs and the firm's incremental value depends on the option value determined by the state of nature in the next (and final) period. However, the Ramsey price depends on the next period outcome as the average unit operating cost relies on the realized state. The instantaneous Ramsey price occurs at the intersection of the demand and average unit operating cost curves, plus the average option value (curved dashed line).[8] This result maximizes consumer surplus in both cases. While the optional price depends on the second-

[8] The unit cost of the option value behaves like a fixed cost in traditional models declines rapidly and asymptotes to the average unit operating cost curve.

period state the value is higher than the average unit operating cost which an omnipotent regulator sets without considering the opportunity cost.

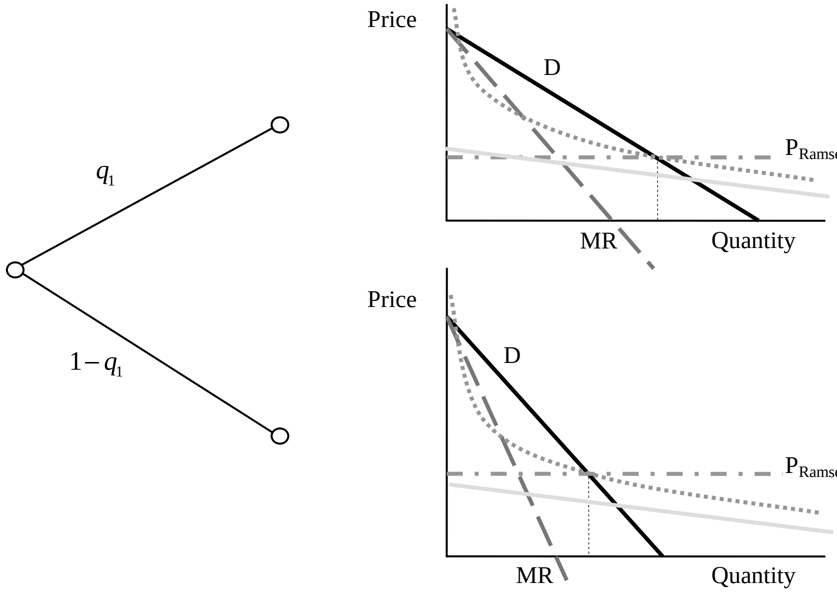

Fig. 9.5. Two-period Ramsey Pricing Model

Conclusion

When static models of the firm are considered regulators make serious errors in the determination of the proper wholesale price as the opportunity cost of the delay option is neglected. For an incumbent, the option is exercised and represents an opportunity cost. For a potential entrant the delay option need not be exercised should the regulator allow the purchase access at below economic cost, i.e., operating cost plus the delay options cost. Thus service-based entry is excessive and facilities-based entry remains suboptimal. To summarize, in a static-regulated paradigm: wholesale prices are below their economic cost; inefficient service entry occurs as prices are not set at the correct marginal cost while an entrant is not required to exercise a delay option; social welfare is suboptimal; incumbent firm's valuation by the financial markets is less; and the cost of capital for incumbent firms is higher. When a regulated paradigm is dynamic the converse holds: optimal prices are higher than for static calculations; only efficient service entry occurs as prices are set at the correct economic marginal cost; facilities-based entrants receive correct price signals; social welfare is maximal; an incumbent's valuation by financial markets is higher; and the cost of capital is lower than for a regulated paradigm. This chapter has demonstrated the profound implications for regulatory practices. In particular, dynamics and uncertainty matter for the realization of optimal regulatory pricing outcomes. However, much work remains to develop and quantify precise models to fit the telecommunications context.

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10 Efficient Spectrum Policy Using Real Options and Game Theoretic Methods

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Background

Policy is becoming increasingly important to the optimal allocation of spectrum. When innovative wireless communication technology is introduced spectrum policy must allow providers of new service to acquire any unused spectrum and encourage the more efficient use of bandwidth by current service providers. Clearly, new services and their technology pose a unique challenge to policymakers in determining the design and implementation of appropriate regulatory and competition policy for the communication services industry. Issues related to spectrum policy include the bandwidth of allocated spectrum, structure of license fees, license period and number of operators. Further, as technology evolves policymakers need to decide whether to recoup previously allocated spectrum for redistribution to providers of new services. In a perfectly competitive and efficient second market for spectrum these issues are resolved by market transactions. However, as spectrum is scarce, market access is limited. Thus, spectrum is often considered a public good whose positive externality influences dynamic industry and national competitiveness. As perfect second markets for spectrum do not exist public intervention is required to achieve desirable social outcomes. Accordingly, obtaining an accurate spectrum valuation is a primary objective of spectrum policy. Several methods are commonly used to obtain spectrum valuations and the value of services that utilize spectrum. The cost approach employs the cost of service provision as the basis for spectrum valuations. An alternative is the income method that calculates the present value of future service streams based on cash flows (Mun 2002). Both approaches are based on assumptions that future service cash flows can be forecast reliably and there is limited flexibility to change business strategy at an arbitrary future time. However, these assumptions are questionable with the business environment that generates communication service demand often volatile, with decisions responding to developments in current business conditions. For example, services demands are often terminated or scaled down when business conditions become unfavorable.

Spectrum allocation can be considered as acquiring a right to provide service, i.e., an option to make decisions contingent on the market's state of evolution. Namely, a service provider with a spectrum allocation can decide when to begin operations. An option concerning the type of service provided over this spectrum is also available. Importantly, these decisions are not required to be made at the time of spectrum acquisition. Commencement and service provision decisions can be delayed until after further market information is revealed in stepwise manner.

Clearly, obtaining a spectrum allocation grants a provider with service abandonment and delay options, an option to switch the service provided and an option to expand geographic service coverage. However, the commonly adopted discounted cash flow valuation method does not readily accommodate such strategic flexibility. The real options approach explicitly incorporates the value obtained from decision making flexibility. However, in modern competitive communications markets there are often several service providers that affect the revenue and cost streams of market participants. Clearly, interactions among market participants should be considered in any valuation process via game theory methods. Research that combines real option and game theory in strategic decision making includes the work of Smit (2001) that analyzed a symmetric duopoly with uncertainty (later extended by Huisman and Kort 1999). Smit and Ankum (1993) illustrate a two-person prisoners' dilemma game within a real options framework. Additionally, Huisman and Kort (2004) and Joaquin and Buttler (2000) investigate a duopoly model that concerns competition for new technology adoption. Also, Dixit and Pindyck (1994), Grenadier and Weiss (1997) and Nielsen (2002) suggest models to determine optimal investment timing under competition with real options theory. Finally, Smit (2003) proposes an integrated real options and game theory framework to analyze a strategic R&D investment game. The present study proposes a model to combine real options and game theory methods applied to the valuation of converging communications services. Services included in this modeling include wide code division multiple access (WCDMA), high-speed downlink packet access (HSDPA) and wireless broadband Internet (WiBro) that are at the center of discussions concerning next-generation mobile services. This chapter is organized as follows. The next section presents real option and game theory methods. Next, the characteristics of WCDMA, HSDPA and WiBro services are explained in the context of Korean markets. A numerical simulation is then analyzed. A final section contains policy implications and an agenda for future research.

Theoretical Framework

The value of the spectrum depends on the value of services provided. For the purpose of modeling communications service markets assume an asymmetric duopoly structure as elaborated by Joaquin and Buttler (2000) applies. This structure is considered appropriate as the number of competing communications firms is typically small, and the positioning of players in most communication markets is asymmetric. Firms are assumed heterogeneous in terms of their operating cost. For simplicity assume there are low-cost and high-cost firms. The exponential inverse demand function $p = D(Q)$ is assumed to describe sufficiently well market demand conditions. Another assumption is the risk neutrality of the firms, with constant discount factor r and constant sunk cost of adopting new technology equal to I. Under these assumptions the profit flow of firm i is represented by Eq. 10.1:

$$\pi = D(Q)Y \, , \tag{10.1}$$

where Y is a variable indicating demand uncertainty. $Y(t)$ is assumed to follow the geometric Brownian motion (GBM) process:[1]

$$dY(t) = aY(t)dt + \sigma Y(t)dw(t) \, , \tag{10.2}$$

and

$$Y(0) = y \, , \tag{10.3}$$

where $Y > 0$, $0 < a < r$ and $\sigma > 0$. a is a drift parameter, σ a variance parameter and $dw(t)$ is independently and identically distributed according to a normal distribution with mean zero and variance dt. The exponential structure of the demand function is specifically defined as:

$$p = ae^{-\varepsilon(Q)} \, , \tag{10.4}$$

where the optimal quantity for the low-cost (Q_l) and high-cost firms (Q_h) are obtained from profit maximization, viz., the maximization of:

$$\pi_l(Q_l) = Q_l(ae^{-\varepsilon(Q_h+Q_l)} - c_l) \tag{10.5}$$

and

$$\pi_h(Q_h) = Q_h(ae^{-\varepsilon(Q_h+Q_l)} - c_h) \, . \tag{10.6}$$

The corresponding first-order necessary conditions are:

$$\frac{\partial \pi_l}{\partial Q_l} = (a - \varepsilon a Q_l)e^{-\varepsilon(Q_h+Q_l)} - c_l = 0 \tag{10.7}$$

and

$$\frac{\partial \pi_h}{\partial Q_h} = (a - \varepsilon a Q_h)e^{-\varepsilon(Q_h+Q_l)} - c_h = 0 \, . \tag{10.8}$$

[1] For the illustrative example $Y(0) = 0.01$.

where c_l and c_h are low- and high-operating firm costs, respectively. Q_l^M is calculated by solving the necessary condition Eq. 10.9:[2]

$$\frac{\partial}{\partial Q_l^M}[Q_l^M(ae^{-\varepsilon(Q_l^M)}-c_l)]=0\,. \tag{10.9}$$

A natural conjecture is that the low-cost firm leads and the high-cost firm follows, so linking their decisions with the leader's action. The follower's investment threshold (Y_h^{F*}) is given by:

$$Y_h^{F*}=\frac{\beta_1}{\beta_1-1}\cdot\frac{\delta I}{\pi_h}\,, \tag{10.10}$$

where δ is a dividend yield and β_1 is the positive root obtained from solving Eq. 10.11:

$$½\sigma^2\beta(\beta-1)+(r-\delta)\beta-r=0\,. \tag{10.11}$$

The follower's valuation of the business for the high-cost firm is calculated from Eq. 10.12:

$$½\sigma^2Y^2F_{YY}+(r-\delta)YF_Y-rF=0\,. \tag{10.12}$$

Therefore, the follower's value is represented by:

$$F_h(Y)=\begin{cases}\left(\pi_h\dfrac{Y_h^{F*}}{\delta}-I\right)\left(\dfrac{Y}{Y_h^{F*}}\right) & \text{if } Y<Y_h^{F*}\\[2ex] \pi_h\dfrac{Y}{\delta}-I & \text{if } Y\geq Y_h^{F*}\,,\end{cases} \tag{10.13}$$

and the follower's strategy is to invest at the time:

$$T^F=\inf\,(t\,|\,Y(t)\geq Y_h^{F*})\,. \tag{10.14}$$

The leader's business valuation for the high-cost firm is obtained from Eq. 10.14:

[2] Only a low-operating cost firm exists when the market is monopolistic. Superscript M indicates a monopoly firm while subscript l indicates a low-operating cost firm.

$$½\sigma^2 Y^2 L_{YY} + (r-\delta)YL_Y - rL + (\pi_l^M)^2 Y = 0\,. \tag{10.15}$$

Using Eq. 10.15, the leader's business valuation for the low-cost firm is obtained from:

$$L_l = \begin{cases} \pi_l^M \dfrac{Y}{\delta} + (\pi_l - \pi_l^M)\left(\dfrac{Y_h^{F*}}{\delta}\right)\left(\dfrac{Y}{Y_h^{F*}}\right)^{\beta_1} - I & \text{if } Y < Y_h^{F*} \\ \pi_l^M \dfrac{Y}{\delta} - I & \text{if } Y \geq Y_h^{F*} \end{cases} \tag{10.16}$$

under the condition:

$$\pi_l^M (Q_l^M) = Q_l^M \,(a e^{-\varepsilon(Q_l^M)} - c_l)\,. \tag{10.17}$$

For the region $Y \geq Y_h^{F*}$, L_h is equal to the firm's simultaneous investment value. The leader's threshold is represented by:

$$\min(Y_h^{L*}, Y_l^{M*})\,, \tag{10.18}$$

where Y_h^{L*} is the investment threshold of Y making the follower's business valuation $L_h = F_h$. In Eq. 10.18, Y_l^{M*} is the investment threshold for a monopolistic market (Joaquin and Buttler 2000).

Next Generation Convergence Services

Third-generation (3G) systems were developed to provide multimedia services. 3G systems render comparatively high-quality image services and high-data transfer rates. However, 3G service has unsatisfactory quality, speed and price characteristics. 4G services, based on orthogonal frequency division multiplexing, are expected to be commercialized after 2010 thus requiring the introduction of interim services between 3G and 4G. HSDPA and WiBro are current alternatives to 3.5G technology. HSDPA is an upgraded version of WCDMA based on the 3rd Generation Partnership Project's Release 5 and universal mobile telecommunications system (UMTS). HSDPA service is a mobile communication focusing on download speed—a critical factor in enabling user's mobile multimedia data service. Conversely, WiBro is an upgraded wireless local area network (LAN) service and provides mobile LAN service. When the communication environment evolves to an IP-based service WiBro has an advantage in that it provides IP-based triple play service. These competing services provide access to multimedia service anytime and anywhere (mobile Internet service) while subscribers are in motion. While the services are substitutes their characteristics differ. Table 10.1 lists HSDPA and WiBro characteristics.

Table 10.1. HSDPA and WiBro Service Characteristics

Characteristic	HSDPA	WiBro
Spectrum	1.9-2.2 GHz	2.3GHz
Bandwidth	5MHz	10MHz
Services	Voice + data	Data
Downlink maximum speed	2Mbps	5.1Mbps
Uplink maximum speed	1.213Mbps	7.6Mbps
Quality of service	Guaranteed	Not guaranteed
Mobility	250km/hr	60km/hr

Source: ETRI (2005)

WCDMA is the only available solution to mobile Internet service provision at present. Alternative HSDPA and WiBro technology is not to be introduced until late-2005 or early-2006. However, even when technically feasible, service launch should consider strategic considerations—especially when alternative services focus on consumer need that leads to investment duplication. Clearly, policy should focus on the service provided and sequencing of service introduction. HSDPA and WiBro are interim 3.5G services that will probably evolve into 4G services. Thus, several communication technology platforms are allowable. Currently, in Korea, HSDPA is supported by the dominant mobile service provider while WiBro is promoted by a fixed-line asymmetric digital subscriber line provider. Both players announced investment plans and proposed service launch timetables. Some experts claim that should both services be simultaneously introduced WiBro would be at a disadvantage since the dominant mobile service provider would transfer that market power to mobile Internet markets. In anticipation of weak competition in the newly opened market policymakers may intervene to ensure a competitive environment. In particular, policy intervention may dictate the time of service introduction so as to ensure effective competition.

Numerical Simulation

To assist empirical simulation, assume that HSDPA and WiBro services compete in a market. Also allow the regulator an option to delay the introduction of

HSDPA service to preclude ineffective market competition from transfer of market power from the provider of an existing service. According to operating cost, WiBro is viewed as leader and HSDPA as follower. Currently, there exist no forecasts for mobile Internet service markets. However, it is reasonable to expect that HSDPA and WiBro will focus on similar markets in the medium term. Thus, recent WiBro forecasts, presented in Table 10.2, are used to proxy overall mobile Internet service market demand.

Table 10.2. WiBro Service Subscription Forecasts, 2005-2011 (‘000)

	2005	2006	2007	2008	2009	2010	2011
Optimistic	2,114	4,509	7,295	9,444	10,636	11,178	11,403
Pessimistic	1,226	2,511	4,045	5,356	6,192	6,631	6,837

Source: ETRI (2003)

To specify GBM process parameters a performance indicator that reasonably simulates mobile Internet market evolution is sought. For this purpose consider the mobile multimedia service NATE—a wired and wireless integrated Internet multimedia service that embraces personal computer, cellular, PDA and vehicle-mounted terminals. Data are from 2000.1 to 2005.7. GBM parameters are estimated by generalized method of moments using a Hansen-Heaton-Ogaki Gauss program (Ogaki 1993). Also, assume WiBro and HSDPA service subscription follows the GBM process characterized by the specified parameters. Initial investment is assumed identical by service at 1,200 billion Korean won. All parameters, except operating cost, identical across services are summarized in Table 10.3.

Table 10.3. Case Study Parameters

Parameter	WiBro	HSDPA
Risk free discount rate (r)	0.0423	0.0423
Risk adjusted discount rate (μ)	0.4000	0.4000
Dividend yield (δ)	0.0502	0.0502
Operating cost (c)[a]	0.0121	0.0152
Drift parameter (α)	0.3498	0.3498
Variance parameter (σ)	0.1050	0.1050

Note. *a* per-month subscriber

The risk free discount rate r is a 3-year Korean Treasury bond rate. The dividend yield δ equals $\mu - \alpha$, where μ is a risk-adjusted discount rate calculated by the risk-adjusted discounted rate suggested by Razgaitis (1999) and the difference between the US Treasury and Korean bond rate. Operating cost is computed by company monthly trunk module maintenance cost per subscriber. Parameters for the exponential demand function are $a = 32173.55$ and $\varepsilon = 0.00003$. The main results, summarized in Fig. 10.1, show that the investment threshold indicating the timing for later service commencement has an average of 3.0854. To reach this investment threshold takes approximately 2.7 years, i.e., HSDPA service needs to be delayed by 2.7 years. That is, by delaying the introduction of HSDPA the spectrum's value is maximized given that the nature of 3.5G service market competition is uncertain.

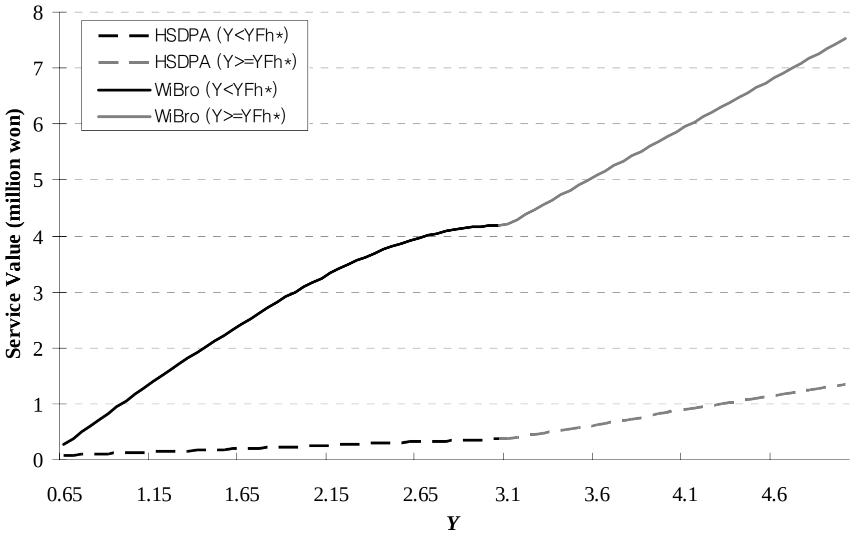

Fig. 10.1. WiBro and HSDPA Service Value (million won)[3]

In delaying the entry of HSDPA service substantial economic value is provided to WiBro and related industry. This benefit arises from WiBro service providers being able to develop voice service technology combined with WiBro data service. Therefore, WiBro service providers can overcome any disadvantage from not being able to provide voice service compared to HSDPA service thus making the mobile Internet market more competitive. Also, WiBro service providers can upgrade their mobile technology networks during this period. Additionally, WiBro-related industry has a first-mover advantage in global markets as core technologi-

[3] Y is the value derived from the GBM process described by Eq. 10.2.

cal features are developed by Korean players. In this sense the expected value from waiting is substantial.

Concluding Remarks

It is important to efficiently allocate spectrum for next-generation services as they are linked to future national competitiveness. In particular, this chapter focuses on next-generation services using HSDPA and WiBro. Joaquin and Buttler's (2000) model is modified to enable determination of the introduction of these services so as to maximize the spectrum's value in a competitive market. The results suggest that policymakers can achieve optimal spectrum use by delaying the HSDPA service introduction by approximately 2.7 years. In doing so lower priced and higher quality 3.5G mobile service are provided to consumers. A reason for this outcome is that WiBro service network and related industry investment enable a more competitive mobile communication market by embracing both wire and wireless service providers. This scenario is particularly important in an era of converging information and communication technology. Accordingly, asymmetric regulation should be reconsidered. The optimal timing of service introduction drawn from the numerical simulation is sensitive to the assumptions employed in the modeling. However, the principal study focus is on providing a consolidated framework for real option and game theory approaches to analyze spectrum policy. That is, the intention of the analysis is to provide an indication of how dynamic spectrum policy should be approached and what are the advantages gained from that policy. However, important issues not considered in this study include the optimal number of service providers, spectrum redeployment, pricing of spectrum and unlicensed spectrum policy. Clearly, study findings can be strengthened by considering these policy questions in a unified analytic framework. This framework would allow estimation of more accurate service market values by considering future market environments that incorporate more real options. Sensitivity analysis would also increase the reliability of the optimal timing estimates.

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11 A Real Options Approach to Investment Evaluation with a Network Externality

Nadine Bellamy and Jean-Michel Sahut

Introduction

Information and communications technology (ICT) industries are characterized by the important role that network effects (network externalities) play in their evolution. Network externalities occur when members of a network offer by their presence a public good to other network members. When a network good or service provides a collective advantage shared by all network members then a positive network externality exists. Accordingly, network effects influence individual and firm network good consumption choices. Network effects are attributable to: (a) the importance of direct connection between members in that arrival of additional members increases extant members' utility, e.g., online discussion in real time with ICQ; (b) another indirect effect is due to demand economies of scale. Namely, members benefit indirectly from network size, e.g., as the number of holders of a credit card increases then more merchants are willing to offer this payment service; and (c) membership contagion effects increase member growth. A famous example is the development of e-commerce. When a product or service which includes such effects is successfully launched market penetration is characterized by an S-shaped diffusion curve that describes different stages of the adoption process (Goolsbee 2005). The ultimate success of a product launch depends on how quickly the inflection point, viz., maximum speed of adoption, is reached and the magnitude of market saturation.

Accordingly, the financial evaluation of investment projects subject to network effects is particularly difficult with traditional techniques such as the net present value (NPV) method because future demand is uncertain, especially for 'new' goods. However, when a firm exploits network effects effectively—perhaps through saturation advertising at the time of launch to a particular demographic segment of the market—the subscriber base can grow exponentially. When this is not the case the project will tend to fail, viz., not reach the critical mass required to ensure market viability. That is, network externalities introduce an additional source of risk into investment projects that make such investment more risky. However should a project fail, firms can abandon their investment during the term of the project to avoid incurring any additional loss. That is, an option is available to the firm other than the initial decision to invest, viz., the firm has a choice of whether to continue or terminate the project. Thus abandonment is a put option that when exercised makes possible the cancellation of costs associated with maintaining the investment. This research proposes a technique to evaluate investment projects. The modeling recognizes both the probabilistic modeling of demand and also allows for the possibility of abandonment.

Model Specification

Consider an investment project subject to network effects—like the launch of universal mobile telecommunications system (UMTS) services in period $\tau \in [0,T]$. Naturally, project cash flows depend on subscriber base with the project profitable only when a critical mass of customers is realized at end date T. Only with this critical mass of subscribers are capital (CAPEX) and operating expenses (OPEX) covered. However, as network subscription is characterized by an s-shaped curve it is not necessary to wait until T to know whether this critical level is attainable. At some time τ (with $0 < \tau < T$) the subscriber base is so small that project continuance will only lead to further loss and it is rational for the firm to abandon the project. With τ fixed the problem becomes one of choosing a threshold subscriber level $l > 0$, such that should subscriber numbers be lower than l at τ then the project is terminated. Clearly, this additional source of randomness must be considered when calculating free cash flows. The value of the project is the sum of the discounted expected free cash flow and the abandonment option value. Denote $V(T,\tau,l)$ the value of an option that includes the possibility of terminating the project when the subscriber base is lower than threshold l at τ. That is, F_t^c is the value at t of the accumulated free cash flows. When $F_\tau^c > F_T^c$ the project is abandoned and losses at τ are 'accepted' to avoid incurring further loss from project continuance. The value of the benefit is $(F_\tau^c - F_T^c)\cdot 1_{S_\tau \le l}$. Since the problem is set within an uncertain world a possible state is $F_\tau^c < F_T^c$ so that $(F_\tau^c - F_T^c)\cdot 1_{S_\tau \le l}$ measures the loss associated with imprudent abandonment. Consequently, the specification of $V(T,\tau,l)$ is:

$$V(T,\tau,l) = E[(F_\tau^c - F_T^c)\cdot 1_{S_\tau \le l}] .$$

This formula includes both profit that results from abandoning the project justifiably and any penalty from incorrectly terminating the project. Therefore, the total project value at $t = 0$ is:

$$C(T,\tau,l) = E(F_T^c \cdot 1_{S_\tau > l}) + V(T,\tau,l) ,$$

so that:

$$C(T,\tau,l) = E(F_T^c \cdot 1_{S_\tau > l}) + E[(F_\tau^c - F_T^c) \cdot 1_{S_\tau \le l}]. \tag{11.1}$$

Modeling is in discrete time. An initial concern is the specification of a dynamic process to describe discounted free cash flows. Denote the free risk rate r and let ρ be the weighted average cost of capital (WACC). Next, assume $\rho > r > 0$. The network subscriber base is then described by the process S_t for $t \ge 1$:

$$S_t = \beta(N_t + f(t)), \tag{11.2}$$

with $0 \le t \le T$ and $S_0 = 0$, β is a constant, f is a strictly positive random function that is strictly increasing in the interval $[1,T]$ and $(N_t)_{t\ge0}$ is a Poisson process defined on the probability filter $(\Omega, F, (F_t)_{t\ge0}, \mathrm{P})$. The function f is specified such that surplus subscribers at t, i.e., the positive difference between new subscribers and customers canceling subscription, equals $\beta(N_t + f(t))$. f also includes the network effect from infra-marginal subscribers joining the network. Further, firm revenues are generated directly (flat rate, pay per view or pay per unit) and indirectly by subscribers, e.g., advertising revenue generated by a Web site. So, project revenue is assumed proportional to the subscriber base, viz.:

$$REVENUE(t) = aS_t.$$

Total firm expenditure is split into CAPEX and OPEX components. CAPEX contributes to firms' tangible and intangible assets and are depreciable through time. CAPEX are incurred both: (a) prior to commercial launch of the project, e.g., to build a minimum size network prior to selling UMTS services—the UMTS license cost is part of the initial investment and is assumed fixed; and (b) during the project network capacity must increase to accommodate additional subscribers. Accordingly, second phase investment is assumed to depend on subscriber numbers while initial investment is fixed. That is, the CAPEX value at $t = 0$ is:

$$CAPEX(0) = I_0.$$

For $t \ge 1$ assume:

$$CAPEX(t) = d\ln(S_t - S_{t-1}) - e.$$

OPEX does not augment network infrastructure but represents network maintenance and other firm operational costs, e.g., variable technical and commercial operation costs that depend on the subscriber base. In this model, OPEX are assumed proportional to subscriber numbers. Denote as K_0 the OPEX value at the project commencement date:

$$OPEX(0) = K_0 .$$

For $t \geq 1$ let:

$$OPEX(t) = b \ln S_t - c .$$

Accordingly, the discounted free cash flows at t are defined by:

$$FCF_{act}(t) = \frac{1}{(1+\rho)^t}[REVENUE(t) - OPEX(t)] - \frac{1}{(1+r)^t} CAPEX(t) .$$

The discounted rate for the cash flows is the WACC for the firm that includes project risk. When project investment has different characteristics to other economic risks facing the firm, the WACC is calculated by adjusting the cost of capital. That is, the cost of capital is determined using a sector-specific β, i.e., the sector where investment occurs. Alternatively, the discounted CAPEX rate is the risk-free rate as the investment value is precisely forecast. Typically, a real options model uses a single discount rate for all cash flows—the risk-free rate. In this modeling, cash flows are discounted by the WACC as the option cannot capture project uncertainty which is the sum of both the cumulative discounted free cash flow and the option value. So, for $t > 1$:

$$FCF_{act}(t) = \frac{1}{(1+\rho)^t}(aS_t - b \ln S_t + c) - \frac{1}{(1+r)^t}(d \ln(S_t - S_{t-1}) - e)$$

and

$$FCF_{act}(0) = aS_0 - K_0 - I_0 .$$

With there being assumed no network subscribers at project commencement, then:

$$FCF_{act}(0) = -K_0 - I_0 .$$

Note the values of parameters I_0, K_0, b, c, d, e and β must ensure that the inequalities $OPEX(t) > 0$ and $CAPEX(t) > 0$ are satisfied for any t. Finally, under the above assumptions the following relations hold:

$$F_t^c = \sum_{s=1}^{s=t} \frac{1}{(1+\rho)^s}[aS_s - b\ln S_s + c] - \sum_{s=1}^{s=t} \frac{1}{(1+r)^s}(d\ln(S_s - S_{s-1}) - e) - K_0 - I_0 \ .$$

From Eq. 11.2 F_t^c is written:

$$F_t^c = \sum_{s=1}^{s=t} [A(s, N_s) - B(s, N_s, N_{s-1})] - K_0 - I_0 \ , \tag{11.3}$$

with

$$\tilde{a} = a\beta \ , \quad \tilde{c} = c - b\ln\beta \quad \text{and} \quad \tilde{e} = e - d\ln\beta$$

where

$$A(s, N_s) = \frac{1}{(1+\rho)^s}[\tilde{a}N_s + \tilde{a}f(s) - b\ln(N_s + f(s)) + \tilde{c}], \qquad \text{for } s > 0$$

$$B(s, N_s, N_{s-1}) = \frac{1}{(1+r)^s}[d\ln(N_s - N_{s-1} + f(s) - f(s-1)) - \tilde{e}] \qquad \text{for } s > 1$$

and

$$B(1, N_1, N_0) = \frac{1}{(1+r)}[d\ln(N_1 + f(1)) - \tilde{e}] \ .$$

In subsequent notation, for any real number x, $[x]$ denotes the integer part.

Project Valuation

Next explicit formulae for project characteristics, viz., trigger value and project termination probability is provided. Assume τ that must be reached to reconsider the project is determined a priori. Thus, the firm's strategy is set by the trigger value l. Opting for a 'too high' value leads to incorrectly terminating profitable projects. While a 'too low' value results in the maintenance of projects that incur further loss. Assuming a target value l, the project termination probability at τ is:

$$P(S_\tau \le l) = P\left(N_\tau \le \beta^{-1} - f(t)\right) .$$

When the function f is deterministic, the probability is:

$$P(S_\tau \le l) = \sum_{n=0}^{[\beta^{-1} - f(\tau)]} e^{-\lambda\tau} \frac{(\lambda\tau)^n}{n!} \,. \tag{11.4}$$

Further, the option value is determined by:

$$V(T,\tau,l) = E\left[\left(\sum_{s=\tau+1}^{s=T} [A(s,N_s) - B(s,N_s,N_{s-1})]\right)\cdot 1_{S_\tau \le l}\right],$$

While the value of the investment project at $t = 0$ is of the form:

$$C(T,\tau,l) = V(T,\tau,l) + E(F_T^c \cdot 1_{S_\tau > l}) \,,$$

where $E(F_T^c \cdot 1_{S_\tau > l})$ is the expected value of terminal profit. The value of the expectation is specified in Proposition 1 below.

Proposition 1

When f is deterministic expected terminal profit is:

$$\begin{aligned} E(F_T^c \cdot 1_{S_\tau > l}) = \sum_{s=1}^{s=T} e^{-\lambda s}&\left[\sum_{n\ge 0} A(s,n)\frac{(\lambda s)^n}{n!} - \sum_{k\ge 0}\sum_{n\ge 0} \lambda^{n+k} B(s,n+k,n)\frac{(s-1)^n}{k!n!}\right] \\ &+ \sum_{s=1}^{s=T} [E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau \le l}) - E(A(s,N_s)\cdot 1_{S_\tau \le l})] \\ &+ (K_0 + I_0)(P(S_\tau \le l) - 1) \end{aligned}$$

where $E(A(s,N_s)\cdot 1_{S_\tau \le l})$ and $E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau \le l})$ values are from Lemma 2 in the Appendix and $P(S_\tau \le 1)$ is from Eq. 11.4. A proof of Proposition 1 is also contained in the Appendix.

Numerical Illustration

To provide an illustration consider a UMTS investment project, Simobiz, undertaken with the International Telecommunication Union and INT in 2003–2004. The parameters values in Table 11.1 are assumed to hold.

Table 11.1. Specified Parameter Values

$\tilde{a} = 52.8$	$b = 162$	$\tilde{c} = -356.1$	$d = 160$	$\beta = 10^5$
$\tilde{e} = -342.07$	$r = 0.04$	$\rho = 0.09$	$K_0 + I_0 = 800$	$\tau = 5$

Next, consider the scenarios:

(a) Scenario u (full-term profitable) provides a favorable outcome from project investment. In this scenario expected cumulative discounted free cash flows (ECF) are positive at the project end date $t = 15$;

(b) Scenario m (full-term unprofitable) is an unprofitable project outcome, however even thought the project commenced on the basis of an inaccurate initial demand forecast, the project continues beyond $t = 5$ as accrued losses to $t = 15$ are lower than those incurred to $t = 5$; and

(c) Scenario d (early termination unprofitable) considers a case where the discounted cash flows are never positive and increasingly negative. For this trajectory the project is not launched (ECF is negative at $t = 15$). However, at $t = 0$ another trajectory Scenario u is forecast and the project commences. Post-commencement the true project trajectory becomes apparent and the project is terminated at $t = 5$.

Under these scenarios new subscription is specified by Eq. 11.2:

$$f(t) = k\Phi(t)$$

where Φ follows the Gaussian law, viz., $N(m,\sigma)$. The set of model parameters for the scenarios are listed in Table 11.2.

Table 11.2. Profitable and Unprofitable Scenario Parameter Values

Scenario	λ	k	m	σ
u	1.35	60	5.7	2.1
m	1.25	60	9.2	3.0
d	1.20	29	9.3	4.0

Denote S^u, S^m and S^d, respectively, as new subscriber numbers associated with scenarios u, m and d. Figure 11.1 presents variations with respect to time of expected new subscriber numbers for the scenarios. Figure 11.2 shows how variation in the expected discounted free cash flow for the non-termination strategy for all scenarios.

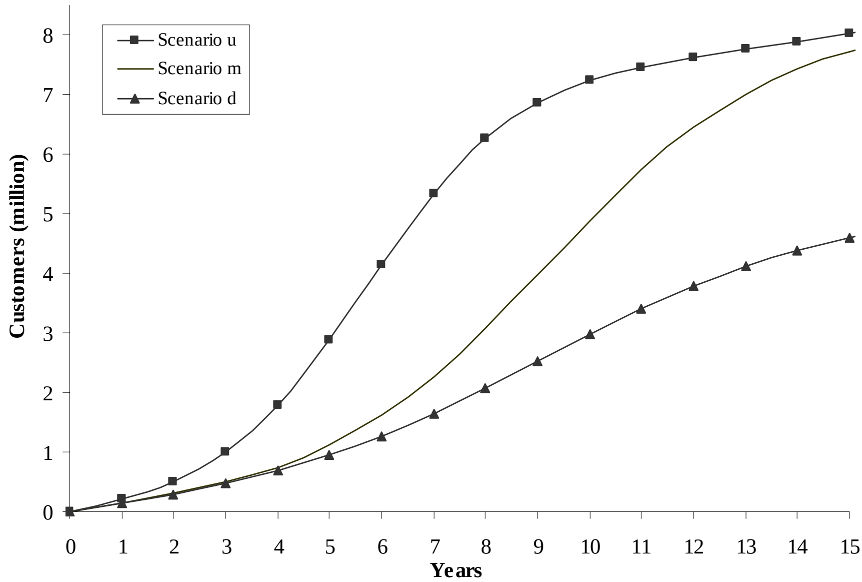

Fig. 11.1. Expected New Subscribers by Scenario

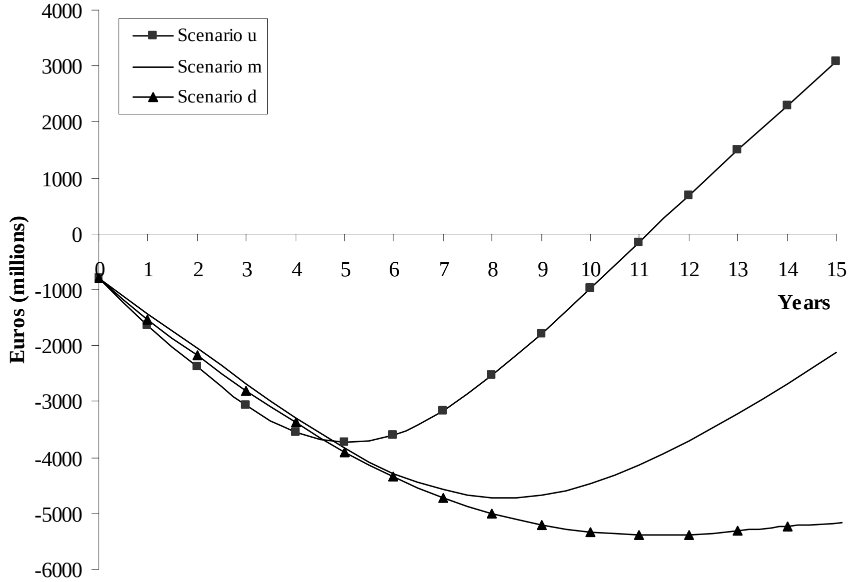

Fig. 11.2. Expected Discounted Free Cash Flow by Scenario

Table 11.3 demonstrates the impact of trigger value l on the project termination probability. Investor strategy for Scenario m or Scenario d are clearly influenced by l. Conversely, investor decisions for Scenario u are unaffected by l.

Table 11.3. Termination Probability at $\tau = 5$ by Scenario

	Scenario		
	u	m	d
$l = 8.5 \times 10^5$	0	0.130	0.446
$l = 10.0 \times 10^5$	0	0.406	0.606
$l = 11.5 \times 10^5$	0	0.566	0.847
$l = 13.0 \times 10^5$	0	0.820	0.916

The examples considered so far rely on the realization of a particular scenario only. Next, consider the derivation of expected project outcomes generated by the probabilistic weighting of scenarios. In particular, post-project subscriber base:

$$S_t = \begin{cases} S^u & \text{with probability } p^u \\ S^m & \text{with probability } p^m \\ S^d & \text{with probability } p^d \end{cases} . \tag{11.5}$$

So that the corresponding project termination probability is given by:

$$P(S_\tau \le l) = p^u \sum_{n=0}^{[\beta^{-1} - f^u(\tau)]} e^{-\lambda\tau} \frac{(\lambda\tau)^n}{n!} + p^m \sum_{n=0}^{[\beta^{-1} - f^u(\tau)]} e^{-\lambda\tau} \frac{(\lambda\tau)^n}{n!} + p^d \sum_{n=0}^{[\beta^{-1} - f^u(\tau)]} e^{-\lambda\tau} \frac{(\lambda\tau)^n}{n!} .$$

The most general case are mixed scenarios generated by the linear combinations:

$$S_t = \begin{cases} \alpha^u S_t^u + \alpha^m S_t^m + \alpha^d S_t^d & \text{with probability } p^u \\ \beta^u S_t^u + \beta^m S_t^m + \beta^d S_t^d & \text{with probability } p^m \\ \gamma^u S_t^u + \gamma^m S_t^m + \gamma^d S_t^d & \text{with probability } p^d \end{cases}$$

where $\alpha = (\alpha^u, \alpha^m, \alpha^d)$, $\beta = (\beta^u, \beta^m, \beta^d)$ and $\gamma = (\gamma^u, \gamma^m, \gamma^d)$ are in the following set Δ:

$$\Delta = \left\{ (\alpha, \beta, \gamma) \middle| \alpha \geq 0,\ \beta \geq 0,\ \gamma \geq 0 \text{ and } \alpha + \beta + \gamma = 1 \right\}.$$

Figure 11.3 presents mixed-scenario simulations specified by a linear combination of Scenario m and Scenario d. The mixed scenarios provide a more realistic forecast of the expected cumulative discounted free cash flow. For better project evaluations it is important to account for the risk of failure. This approach allocates a probability to profitable and unprofitable scenarios and allows development of a more 'global' evaluation that integrates all possible states of nature—even when some states realistically have a small probability of occurrence.

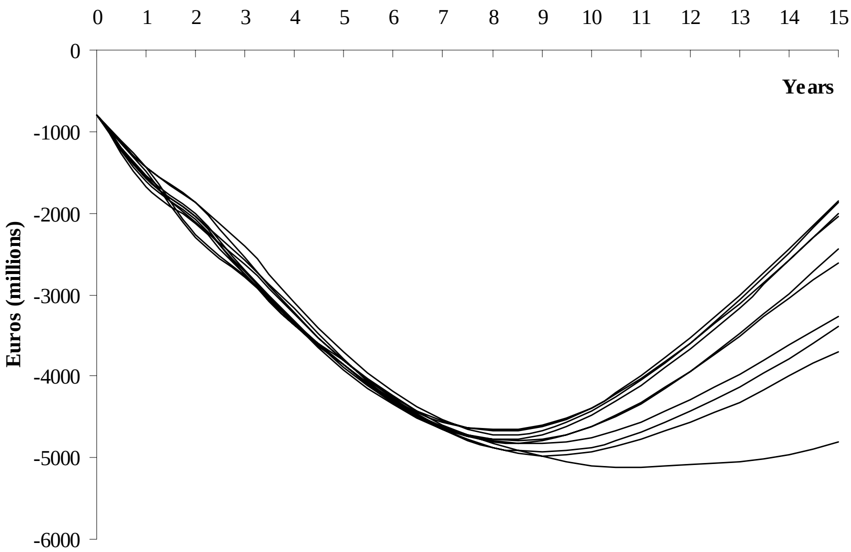

Fig. 11.3. Mixed-scenario Simulated Discounted Free Cash Flows

Analyzing Mixed Scenarios

The mixed-scenario modeling illustration is intended to shed some light on the importance of individual parameters on simulated project NPV values. The scenario parameter values listed in Table 11.4 allow comparison of deterministic and probabilistic NPV values by scenario. Deterministic NPV cash flows are calculated based on expected new subscriber numbers, whereas probabilistic NPV values are based on the expected discounted and accrued free cash flows $E(F_T^c)$. The scenarios do not consider possible early termination of the project at τ. Simulation results are recorded in Table 11.5.

Table 11.4. Scenario Parameter Values

Scenario	λ	k	m	σ
1	1.25	60	9.20	3.0
2	1.30	58	8.00	2.2
3	1.30	58	7.45	2.2

Note. The reference frontier is set at $l = 10^6$

NPV calculations reported in Table 11.5 demonstrate that when investors consider probabilistic aspects of the project and base their decisions on a deterministic process the average value of the project is underestimated. As a consequence, decision making based on a deterministic process leads to abandonment of profitable projects at τ. Moreover, the deterministic approach can also induce investors to not commence such projects. However, uncertainty generates risk and confidence interval for the probabilistic NPV values must be calculated to allow evaluation of the project's risk. The source of uncertainty is S_t, the number of new subscribers at t, viz., this value must not fall below a predetermined threshold value. Therefore, the expected value $E(S_t) = m(t)$ is compared with $\underline{m}(t)$ defined by $P(S_t < \underline{m}(t)) = \alpha$ where α is the risk level.

Table 11.5. Probabilistic and Deterministic Scenario NPV Estimates (€ million)

Scenario	Probabilistic NPV	Deterministic NPV
1	–2,128.12	–2,359.81
2	–459.90	–897.49
3	154.75	–192.70

Table 11.6 shows how the ratio $[m(t) - \underline{m}(t)]/m(t)$ varies with α and t. Calculations are made for the $\alpha = 16\%$, $\alpha = 5\%$ and $\alpha = 1\%$ risk levels, respectively, for the set of parameter values $\lambda = 4.6$, $k = 17$, $m = 4$ and $\sigma = 1.1$. First, notice that the ratio increases with the confidence level (as α falls). Also, the standard deviation of the ratios falls for all risk levels through time as forecasts improve. Finally, while the probabilistic NPV estimates reported in Table 11.5 are larger than the corresponding deterministic NPV estimates, a larger confidence interval is obtained for lower risk levels.

Table 11.6. $[m(t) - \underline{m}(t)] / m(t)$ by t

t	$\alpha = 16\%$	$\alpha = 5\%$	$\alpha = 1\%$
1	0.344	0.559	0.773
2	0.633	0.735	0.838
3	0.639	0.699	0.758
4	0.572	0.610	0.647
5	0.542	0.569	0.596
6	0.559	0.582	0.604
7	0.594	0.614	0.635
8	0.628	0.647	0.665
9	0.658	0.675	0.692
10	0.683	0.698	0.714
11	0.704	0.719	0.734
12	0.723	0.737	0.751
13	0.740	0.753	0.766
14	0.754	0.767	0.779
15	0.767	0.779	0.791

Note. $\lambda = 4.6$, k=17 , $m = 4$ and $\sigma = 1.1$

Finally, the impact of early project termination is integrated into the modeling. To further analyze the scenarios contained in Table 11.4 requires calculation of the option value $V(T,\tau,l)$ from terminating the project, the project value $C(T,\tau,l)$ and the expected discounted and accrued free cash flows $E(F_T^c \cdot 1_{S_\tau > l})$. For the purpose of calculating these values assume that $l = 10^6$, $T = 5$ and $\tau = 5$. The results are summarized in Table 11.7.

Table 11.7. Termination Probability and Value

Scenario	$P(S_\tau \leq l)$	$V(T,\tau,l)$	$E(F_T^c \cdot 1_{S_\tau > l})$	$C(T,\tau,l)$
1	0.406	502.35	–1,812.40	–1,310.05
2	0.369	898.08	–726.77	171.32
3	0.043	152.23	109.36	234.59

Note. Values are € millions. $l = 10^6$ and $T = \tau = 5$

From Table 11.7 it is apparent that the option value V is not zero—even when the expected free cash flow value is negative. Moreover, the option makes a substantial contribution to the project value. For instance, in Scenario 2 from Table 11.7

the project's value is positive even though expected free cash flows are negative. Also, the option value $V(T,\tau,l)$ in Scenario 1 is less that for Scenario 2 due to a lower profit probability when the project is terminated prematurely. Indeed, Scenario 1 corresponds to an unprofitable project that should not have commenced. Similarly, the option value for Scenario 3 is less that for Scenario 2 due to a relatively low termination probability, viz., the project is apparently very profitable. However, for this scenario the option contributes 50% of the project's value.

Conclusion

This chapter has developed an analytical framework to understand and quantify the valuation of an investment when network externalities are present. Modeling starts from a probabilistic demand modeling stance and the inclusion of an option to terminate the project. These elements allow the more accurate valuation of the investment. Expected free cash flow values are larger on average than values estimated via the deterministic NPV procedures. However, probabilistic NPV estimates require the calculation of confidence intervals to evaluate project risk. Conversely, the integration of the project termination option (put option) increases the project's value that is linked to the termination probability and savings from the early abandonment of the project. Finally, while the proposed modeling approach appears more realistic it raises questions as to the best means to obtain values for the termination parameters for effective scenario implementation.

Appendix

Lemma 2

Let $A(s,n)$ and $B(s,n,m)$ be deterministic functions.

1(a). For $s<\tau$:

$$E(A(s,N_s)\cdot 1_{S_\tau\le l})=e^{-\lambda\tau}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\le p}\lambda^p A(s,n)\frac{s^n(\tau-s)^{p-n}}{n!(p-n)!}$$

1(b). For $s>\tau$:

$$E(A(s,N_s)\cdot 1_{S_\tau\le l})=e^{-\lambda s}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\ge p}\lambda^n A(s,n)\frac{\tau^p(s-\tau)^{n-p}}{p!(n-p)!}$$

1(c). For $s=\tau$:

$$E(A(\tau,N_\tau)\cdot 1_{S_\tau\le l})=e^{-\lambda\tau}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\lambda^p A(\tau,p)\frac{\tau^p}{p!}$$

2(a). For $s<\tau$:

$$E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau\le l})=e^{-\lambda\tau}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n+k\le p}\lambda^p B(s,n+k,n)\frac{(\tau-s)^{p-n-k}(s-1)^n}{(p-n-k)!n!k!}$$

2(b). For $s-1>\tau$:

$$E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau\le l})=e^{-\lambda s}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\ge p}\sum_{k\ge 0}\lambda^{k+n}B(s,n+k,n)\frac{\tau^p(s-1-\tau)^{n-p}}{p!k!(n-p)!}$$

2(c). For $s=\tau$:

$$E(B(\tau,N_\tau,N_{\tau-1})\cdot 1_{S_\tau\le l})=e^{-\lambda\tau}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\le p}\lambda^p B(\tau,p,n)\frac{(\tau-1)^n}{(p-n)!n!}$$

2(d). For $s-1=\tau$:

$$E(B(\tau+1,N_{\tau+1},N_\tau)\cdot 1_{S_\tau\le l})=e^{-\lambda(\tau+1)}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\ge p}\lambda^n B(\tau+1,n,p)\frac{(\tau)^p}{(n-p)!p!}$$

Proof

1(a). For $s<\tau$:

$$\begin{aligned}E(A(s,N_s)\cdot 1_{S_\tau\le l})&=\sum_{n,p}E(A(s,N_s)\cdot 1_{S_\tau\le l}/N_s=n,N_\tau=p)\cdot P(N_s=n,N_\tau=p)\\&=\sum_{n\le p}E(A(s,N_s)\cdot 1_{S_\tau\le l}/N_s=n,N_\tau=p)\cdot P(N_\tau-N_s=p-n,N_s=n)\\&=\sum_{n\le p}A(s,n)E(1_{S_\tau\le l}/N_s=n,N_\tau=p)\cdot P(N_s=n)P(N_{\tau-s}=p-n)\\&=e^{-\lambda\tau}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\le p}\lambda^p A(s,n)\frac{s^n(\tau-s)^{p-n}}{n!(p-n)!}\end{aligned}$$

1(b). For $s>\tau$:

$$\begin{aligned}E(A(s,N_s)\cdot 1_{S_\tau\le l})&=\sum_{n,p}E(A(s,N_s)\cdot 1_{S_\tau\le l}/N_s=n,N_\tau=p)\cdot P(N_s=n,N_\tau=p)\\&=\sum_{n,p}E(A(s,N_s)\cdot 1_{S_\tau\le l}/N_s=n,N_\tau=p)\cdot P(N_s-N_\tau=n-p,N_\tau=p)\\&=\sum_{n\ge p}A(s,n)E(1_{S_\tau\le l}/N_s=n,N_\tau=p)\cdot P(N_\tau=p)P(N_{s-\tau}=n-p)\\&=e^{-\lambda s}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\ge p}\lambda^n A(s,n)\frac{\tau^p(s-\tau)^{n-p}}{p!(n-p)!}\end{aligned}$$

1(c). For $s=\tau$:

$$\begin{aligned}
E(A(\tau,N_\tau)\cdot 1_{S_\tau\le l}) &= \sum_p E(A(\tau,N_\tau)\cdot 1_{S_\tau\le l} / N_\tau = p)\cdot P(N_\tau = p)\\
&= \sum_p A(\tau,p)E(1_{S_\tau\le l} / N_\tau = p)\cdot P(N_\tau = p)\\
&= e^{-\lambda\tau}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\lambda^p A(\tau,p)\frac{\tau^p}{p!}
\end{aligned}$$

2(a). For $s<\tau$:

$$\begin{aligned}
E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau\le l}) &= \sum\nolimits_{n,p,k} E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau\le l} / N_s = n+k, N_{s-1}=n, N_\tau = p)\\
&\qquad \times P(N_s = n+k, N_{s-1}=n, N_\tau = p)\\
&= \sum\nolimits_{n,p,k} B(s,n+k,n)E(1_{S_\tau\le l} / N_s = n+k, N_{s-1}=n, N_\tau = p)\\
&\qquad \times P(N_s - N_{s-1} = k, N_\tau - N_s = p-k-n, N_{s-1}=n)\\
&= e^{-\lambda\tau}\sum\nolimits_{p=0}^{[\beta^{-1}-f(\tau)]}\sum\nolimits_{n+k\le p}\lambda^p B(s,n+k,n)\frac{(\tau-s)^{p-n-k}(s-1)^n}{(p-n-k)!n!k!}
\end{aligned}$$

2(b). For $s-1>\tau$:

$$\begin{aligned}
E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau\le l}) &= \sum\nolimits_{n,p,k} E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau\le l} / N_s = n+k, N_{s-1}=n, N_\tau = p)\\
&\qquad \times P(N_s = n+k, N_{s-1}=n, N_\tau = p)\\
&= \sum\nolimits_{n,p,k} B(s,n+k,n)E(1_{S_\tau\le l} / N_s = n+k, N_{s-1}=n, N_\tau = p)\\
&\qquad \times P(N_s - N_{s-1} = k, N_{s-1} - N_\tau = n-p, N_\tau = p)\\
&= \sum\nolimits_{p=0}^{[\beta^{-1}-f(\tau)]}\sum\nolimits_{n\ge p}\sum\nolimits_{k\ge 0} B(s,n+k,n)\\
&\qquad \times P(N_s - N_{s-1} = k, N_{s-1} - N_\tau = n-p, N_\tau = p)\\
&= e^{-\lambda s}\sum\nolimits_{p=0}^{[\beta^{-1}-f(\tau)]}\sum\nolimits_{n\ge p}\sum\nolimits_{k\ge 0}\lambda^{k+n}B(s,n+k,n)\frac{\tau^p(s-1-\tau)^{n-p}}{p!k!(n-p)!}
\end{aligned}$$

2(c). For $s=\tau$:

$$\begin{aligned}
E(B(\tau,N_\tau,N_{\tau-1})\cdot 1_{S_\tau\le l}) &= \sum\nolimits_{n,p} E(B(\tau,N_\tau,N_{\tau-1})\cdot 1_{S_\tau\le l} / N_{\tau-1}=n, N_\tau = p)\\
&\qquad \times P(N_{\tau-1}=n, N_\tau = p)\\
&= \sum\nolimits_{n,p} B(\tau,p,n)E(1_{S_\tau\le l} / N_{\tau-1}=n, N_\tau = p)\\
&\qquad \times P(N_\tau - N_{\tau-1} = p-n, N_{\tau-1}=n)\\
&= e^{-\lambda\tau}\sum\nolimits_{p=0}^{[\beta^{-1}-f(\tau)]}\sum\nolimits_{n\le p}\lambda^p B(\tau,p,n)\frac{(\tau-1)^n}{(p-n)!n!}
\end{aligned}$$

2(d). For $s-1=\tau$:

$$E(B(\tau+1,N_{\tau+1},N_{\tau})\cdot 1_{S_\tau\le l})=\sum_{n,p}E(B(\tau+1,N_{\tau+1},N_{\tau})\cdot 1_{S_\tau\le l}/N_{\tau+1}=n,N_{\tau}=p)$$
$$\times P(N_{\tau+1}=n,N_{\tau}=p)$$
$$=\sum_{n,p}B(\tau+1,n,p)E(1_{S_\tau\le l}/N_{\tau+1}=n,N_{\tau}=p)$$
$$\times P(N_{\tau+1}-N_{\tau}=n-p,N_{\tau}=p)$$
$$=e^{-\lambda(\tau+1)}\sum_{p=0}^{[\beta^{-1}-f(\tau)]}\sum_{n\le p}\lambda^n B(\tau+1,n,p)\frac{(\tau)^p}{(n-p)!\,p!}$$

Proof of Proposition 1

$$E(F_T^c\cdot 1_{S_\tau>l}) = \sum_{s=1}^{s=T}[E(A(s,N_s))-E(B(s,N_s,N_{s-1}))]$$
$$+\sum_{s=1}^{s=T}[E(B(s,N_s,N_{s-1})\cdot 1_{S_\tau\le l})-E(A(s,N_s)\cdot 1_{S_\tau\le l})]$$
$$-(K_0+I_0)(1-P(S_\tau\le l))$$

The proof follows from the equalities

$$E(A(s,N_s)) = e^{-\lambda s}\sum_{n\ge 0}A(s,n)\frac{(\lambda s)^n}{n!}$$

and

$$E(B(s,N_s,N_{s-1}))=\sum_{k\ge 0}\sum_{n\ge 0}B(s,n+k,n)\cdot P(N_s=n+k,N_{s-1}=n)$$
$$=\sum_{k\ge 0}\sum_{n\ge 0}B(s,n+k,n)\cdot P(N_s=N_{s-1}=k,N_{s-1}=n)$$
$$=e^{-\lambda s}\sum_{k\ge 0}\sum_{n\ge 0}\lambda^{n+k}B(s,n+k,n)\frac{(s-1)^n}{k!\,n!}\ .$$

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12 Mixed Logit Analysis of Carrier Market Share with Stated-preference Data

Aniruddha Banerjee and Harold Ware

Introduction

Telecommunications demand analysis follows the industry's evolution. From offering standard voice services the industry has witnessed a proliferation of new communications technology (fixed and mobile voice, data and video) in increasingly competitive environments marked by product differentiation. Consequently, the needs and complexity of demand analysis has changed dramatically. Formerly, with prices of regulated services stable obtaining price elasticity estimates required long time-series of data (Taylor 1994). However, with competitive pressures driving telecommunications service providers to differentiate services or offer new services, established products no longer provide a sure basis to predict sales or market share. In many instances, new services of interest have either an insufficient time-series to allow the calculation of elasticity estimates or more problematically are not yet launched. Yet, to be effective business planning and product management requires more knowledge about the demand for new services than for more established services. Recent developments in demand analysis techniques offer researchers alternatives to using systems of equations with long time-series to provide strategic market parameter estimates. Most prominent among these new methods are stated-preference, as opposed, to revealed-preference (or historical) data. These data enable the calculation of demand parameters and market shares for new services.[1] Although stated-preference techniques are widely used, this chapter shows that when stated-preference data are analyzed with flexible discrete choice techniques—such as the mixed logit model—new insights can be obtained into the nature of demand even for traditional telecommunications services.[2] The chapter is organized as follows. The next section examines differences between revealed-preference and stated-preference data. Of particular interest is that stated-preference data based on rankings of multifaceted alternatives can reliably and economically overcome many limitations associated with revealed-preference data. The following section summarizes the mathematical underpinnings of the econometric—standard and mixed logit—models that are used to estimate customer choice probabilities on ranked stated-preference data. The next section illustrates the use of ranked stated-preference data to obtain market share and choice elasticity estimates for local telecommunications services purchased by

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[1] See Train (2003, Sect. 7.2) for a discussion of revealed- and stated-preference data.

[2] For a review of how stated-preference data can be analyzed with discrete choice models, see Louviere et al. (2000).

business customers. A key finding is that, in the newly competitive business telecommunications markets incumbent service providers face more elastic demand responses than previously believed. Concluding remarks are then presented.

Revealed- versus Stated-preference

Making choices or expressing preferences amounts to arranging available alternatives in some order. At their most elementary level, alternatives can be simply different items that yield value (or utility), such as products or services. However, in more enriched choice situations, alternatives can be defined at a more granular level, e.g., consisting of a bundle of primary characteristics (or attributes) of a product or service. Also, attributes (such as brand identity, price, durability, color, flavor, speed, horsepower and capacity) can have multiple levels that are either ordinal (e.g., high price, moderate price and low price), nominal (e.g., red, blue, green and yellow) or binary (yes/no and absent/present). Therefore, in their most detailed form, alternatives can be different bundles of attributes set to different levels. Consumers routinely make choices among different products or among different brands of the same product or among different qualities (or differently-priced versions) of the same product. These choices imply the existence of preference orderings based on objective and subjective criteria that consumers employ to form preferences. It is commonly assumed that preference orderings reflect rankings of the utilities that consumers associate with available alternatives. Although in most real-world situations only the most preferred alternatives yielding the highest utility are observed. It is assumed that consumers are still able to rank the remaining alternatives, i.e., those not chosen according to the utilities associated with them.

Historical purchase information are referred to as revealed-preference data because they provide information about actual choices made by consumers and with proper analysis reveal information about how consumer choices are affected by price and other observable influences (Train 2003: Sect. 7.2). Such data are most useful for understanding the past, i.e., trends, and for identifying factors that have actually influenced consumer choices. When using revealed-preference data to forecast the future, an analyst can only make projections based on the influential factors identified from these data. Most importantly, revealed-preference data are only about choices actually made, and they tell us nothing about alternatives that consumers could have, but did not, pick or how consumers would have ranked those alternatives in order of preference. In other words, revealed-preference data are about individual consumers' top choices. In contrast, stated preferences are elicited from experiments or surveys and pertain to expressions by potential consumers of choices they would make in hypothetical situations, conditional on information provided to them about the products or services of interest and their suppliers. Stated preferences (elicited from properly designed choice or ranking exercises) are more nuanced than revealed preferences in that potential consumers can be induced to indicate not merely which of several alternative products they would choose but also how they would rank those products on different attributes. Thus, a stated-preference exercise can be useful for tracking changes in consumers' preferences as the alternatives they face are varied and simulating prospective market conditions, such as regarding the growth prospects or market share of alternative products. [3]

Modeling Behavior with Stated-preference Data

It is becoming increasingly appreciated that stated-preference surveys can generate data that lead to valid inferences about actual market behavior (Louviere 1998; Louviere et al. 2000: Ch. 13). There are several circumstances in which stated-preference data yields more reliable insights than revealed-preference data into behavior. Circumstances in which revealed-preference data performs poorly are (Louviere et al. 2000: Sect. 2.2):

1. Revealed-preference data may be a poor indicator of likely choice in new situations (e.g. demand for new products) when those situations are not analogous to existing or past situations. In the telecommunications industry this is occurring as new technology, delivery systems and convergence are allowing the introduction of unfamiliar services to the market, e.g., Google's new Voice over Internet Protocol offering;
2. Also, revealed-preference data are not suitable for understanding the role of influencing factors when there is little variation in those factors. In the telecommunications industry, prices of traditional services often stay unchanged for long periods of time (because of regulatory controls) and across service providers (because of matching or follower behavior). Although long time series of prices may be available, price elasticities are hard to estimate reliably in the absence of sufficient price variation;
3. High collinearity among marketplace variables is common. Telecommunications demand studies employing demand equation systems frequently have prices of related services among the explanatory variables. Co-movement in such prices induced by regulatory dictates rather than by competitive forces can make substitute services appear complements.[4] As a related matter, strong common trends in dependent demand (or market share) and independent variables such as prices can substantially diminish the explanatory power of the estimated econometric demand model (Granger and Newbold 1974).

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[3] A stated-preference exercise can be designed to build in the desired level of variation in influential attributes. Unlike a revealed-preference situation where data once observed are fixed an experiment affords an opportunity to generate consumer response to a diverse set of circumstances.

[4] Regulators occasionally mandate the simultaneous reduction of prices of products that offer alternative functionalities. Although those products should be regarded as substitutes, sustained price reduction for both can stimulate demand for both to the degree that they appear as gross complements (in the sense that the reduction in one's price appears to increase the demand for both products). See Henderson and Quandt (1980).

4. As products are modified or evolve through time (via the introduction or elimination of attributes), consumers too modify how they make choices. In telecommunications markets the evolution of plain old telephone service into bundles of local and long-distance message services, calling features (e.g., call waiting) and Internet access over the same telephone line has changed the consumer choice process. Consumers choose among purchasing services from a single provider or splitting purchases among providers;
5. Revealed-preference data frequently suffer from errors in observation, incomplete or missing data and variation in definition and method of measurement that can bias the results of consumer choice studies. Also, they may be expensive to collect and maintain, or not amenable to answer particular questions. For example, to determine the cross-price elasticity between wire-line and wireless services requires consistent price data that individual consumers face for those services or prices that prevailed when those consumers decided to substitute a service.[5]

In these instances, stated-preference data can compensate for the limitations of revealed-preference data. Accordingly, stated-preference surveys are a widely accepted procedure for predicting new product demand (including telecommunications services) or understanding the impacts of public policy (e.g., with respect to travel, recreation or the environment). Another desirable feature of stated-preference data is that they are relatively inexpensive to collect via carefully designed surveys. For example, stated-preference surveys can create study samples of the desired size more economically than traditional surveys by requesting multiple responses per respondent. Furthermore, because a survey can be conducted at any time, stated-preference data effectively track changes in consumer choices through time as the environment (attributes and alternatives) change. However, there are limits to the usefulness of stated-preference data, e.g., such data are of little value when real-world respondent choices vary from those encountered in stated-preference surveys. Also, it is possible that respondents ‘do not do as they say or say what they do,’ i.e., choices actually make in real situations differ from those expressed in surveys. Ideally, stated- and revealed-preference data should be combined to study consumer choice (Louviere et al. 2000, Sects. 8.2 and 13.5; Train 2003: Sect. 7.2). Combining data allows the analyst to take advantage of stated-preference data’s ability to provide attribute variation across respondents while revealed-preference data provides a reliability check on market share predictions.

[5] In the US, wireless services are offered through local, regional and national plans that may vary in price level and structure. This situation presents problems for constructing historical and cross-section varying (e.g., state specific) wireless service prices. Regulated or tariffed wireline prices, however, are easier to collect and more likely (than wireless service prices) to be specific to locations or markets. However, with consumers increasingly favoring wire-line service bundles it is difficult to determine the exact price a consumer paid for a particular service for a specific location or time.

Ranked Choice and Stated-preference Surveys

Questionnaires that only seek respondent information about past choices are called revealed-preference surveys. Alternatively, stated-preference surveys require respondents to react to hypothetical situations to elicit prospective or potential choices. For example, product demand studies require stated-preference surveys present respondents with alternatives (choice sets) and ask that they be ranked in order of preference. Ranking reveals respondent trade-offs among attributes (and their levels) embedded within alternatives. For example, for telecommunications services alternatives may be designed with non-recurring (one-time) charge, recurring (usage-based) charge, brand name (identity of service provider), speed and reliability attributes. Clearly, this mode of data gathering is useful for studying new service demand or understanding markets characterized by changing competitive conditions. In particular, when actual data on prices charged by competing service providers are difficult to source or vary little through time stated-preference ranking can yield data to reliably estimate price elasticity, market share and service provider choice (importance of brand names). Choice experiment data can be augmented by respondent demographic information. Thus, stated choices can be made functions of service attributes and respondent characteristics.[6] Additionally, to ensure respondents must trade-off attributes in making a choice no alternative is allowed to be dominant (i.e., every attribute of an alternative within a set is ‘most desirable’) or dominated (i.e., every attribute is ‘least desirable’). The technique also solves problems that hamper other forecasting methods. First, by design ranking enables an analyst to determine the relative value respondents place on embedded attributes (and their levels). From these relative values, or utilities, it is possible to predict how market shares and revenues are likely affected by differences in brand or service reliability. Second, the technique also enables estimation of the effect on choice by respondents’ characteristics. Finally, building into the experiment a suitable degree of variation in attributes averts many problems with using historical data to predict demand for existing and new products.

Historical Data and Survey Limitations

While revealed-preference data can be useful for predicting how consumers may behave they can produce misleading inferences. For example, suppose historical data show that in spite a substantial price increase customer counts and purchases for a telecommunications service from a particular provider have remained unchanged. However, it would be misleading to infer customers are insensitive to price changes as customer incomes and prices charged by other service providers for competing services could have grown by the same magnitude during the period. Moreover, purchase data obtained from customer accounts over an extended period may be difficult to interpret when consumption changes are driven by non-price demand determinants. Finally, historical data are unlikely to assist in under-

[6] Business purchaser characteristics may include revenue and employment.

standing why customers sporadically change service providers. Typically, historical data provide no information about the options that customers face during the period—especially at the time they change service providers. Traditional surveys of the attributes consumers consider important for making choices and how they respond to hypothetical changes in those attributes may appear to overcome some of the limitations of historical data. However, such surveys are not capable of probing how simultaneous conflicting attribute changes modify consumer choice. For example, surveys of telecommunications service users that, e.g., seek how important an attribute is in determining choice of service provider, cannot identify the effect of conflicting attributes. First, answers given by respondents are likely 'colored' by the use to which the respondents assume the survey will be put. Second, it is impossible to judge the trade-offs among the attributes from the responses given. When an alternative is worse on two attributes considered 'significant' but better on another attribute considered 'critically important', what choices are respondents likely to make? What if an alternative is only slightly worse on a critically important attribute but much better on a significantly important attribute, or even better on an attribute considered neither significantly nor critically important? Because traditional surveys cannot be used to estimate tradeoffs among price variables and product characteristics they cannot be informative about the impact of price changes on consumer choice when the choice environment changes. In general, survey techniques that ask customers more directly about how they would respond to price changes are susceptible to response bias and are likely to produce inaccurate inferences.

Stated-preference Data Analysis with Mixed Logit Models

Experience has confirmed the value of logit and probit models in analyzing consumer choice data. Discrete choice methods emerged from the premise that consumers maximize utility. A formulation of behavior under this assumption—the random utility model (RUM)—leads to alternative logit and probit specifications.[7] Suppose a utility-maximizing consumer n has a choice among J alternatives (Train 2003: Sect. 2.3). Also, suppose the utility received by that consumer from alternative j is represented by U_{nj}, where $j = 1, 2, ..., J$. Thus, the consumer chooses alternative i over j, if and only if, $U_{ni} > U_{nj}$. The probability of that choice is $P_{ni} = \Pr(U_{ni} > U_{nj})$ for all $j \neq i$. While U_{ni} or U_{nj} are directly observable, the analyst can observe the attributes x_{nj} of an alternative and consumer characteristics s_n that are related systematically to representative utility V_{nj} for that consumer. The unobservable (to the analyst) utility is related to representative utility by $U_{nj} = V_{nj} + \varepsilon_{nj}$, where V_{nj} depends parametrically on x_{nj} and s_n, and ε_{nj}

[7] The earliest conceptualization of the RUM is by Marschak (1960).

is a randomly distributed difference between U_{nj} and V_{nj}. Under this formulation, it is simple to show that the probability of choosing alternative i over every other alternative j is $P_{ni} = \Pr(\varepsilon_{nj} - \varepsilon_{ni} < \mathrm{V}_{ni} - \mathrm{V}_{nj})$ for all $j \neq i$. This cumulative probability is calculated as $P_{ni} = \int_{\varepsilon} I(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj}) f(\varepsilon_n) d\varepsilon_n$ for all $j \neq i$.[8] The form of probability distribution $f(\varepsilon_n)$ determines the form of discrete choice model. The standard (fixed coefficient) logit, nested logit and probit formulations arise from selecting the independently and identically distributed (iid) Extreme Value, Generalized Extreme Value and multivariate normal distributions, respectively, for $f(\varepsilon_n)$. The standard logit model emerges from the fact that the difference between two iid Extreme Value variables (such as $\varepsilon_{nj} - \varepsilon_{ni}$) is logistically distributed. With alternatives i and j, the iid assumption implies that the unobserved portions of the utilities U_{ni} and U_{nj} are independent. The logit choice probability for alternative i is $P_{ni} = e^{V_{ni}} / (e^{V_{ni}} + e^{V_{nj}})$ and in the case of multiple alternatives is $P_{ni} = e^{V_{ni}} / \sum_j e^{V_{nj}}$ (McFadden 1974). Assuming $V_{nj} = \beta' x_{nj}$ (including alternative-specific constants), the standard logit choice probability is $P_{ni} = e^{\beta' x_{ni}} / \sum_j e^{\beta' x_{nj}}$. This probability lies within the unit interval and sums to unity over all alternatives. Also, the standard logit model displays three important properties (Train 2003: Sect. 3.3). First, systematic variations in taste (linked to observed decision maker characteristics) are captured by a logit model. However, random variations in taste that are unrelated to those observed characteristics cannot be modeled. Second, the independence from irrelevant alternatives (IIA) property causes the choice probability ratio for any pair of alternatives, i.e., relative odds of choosing an alternative over another, depends only on those alternatives. This property implies a pattern of proportional substitution among alternatives that may not represent real-world situations. Third, logit models can be constructed for panel data (i.e., data on repeated choices) in the same manner as for cross-section data, and dynamics such as state-dependence can also be captured (as long as unobserved factors associated with different alternatives are independent of one another). These properties represent both advantages and limitations of the standard logit model. When only systematic variation in taste is of interest, substitution among alternatives occurs in a manner consistent with the IIA property and unobserved factors associated with alternatives are mutually independent in repeated choices the standard logit model is suitable. A more flexible logit model is required to accommodate random variation in taste, a violation of the IIA property, and correlation among unobserved factors in repeated choices.[9]

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[8] The indicator function $I(\cdot)$ is unity if the term in parentheses is true and zero otherwise.

[9] Of course, the probit model can capture random variation in taste and correlation among unobserved factors in repeated choices, while the nested logit model can accommodate violation of the IIA property. The mixed logit model can allow for all these situations.

The mixed logit model is shown to adequately and flexibly approximate any RUM (McFadden and Train 2000).[10] The model can be specified to capture whatever choice features are considered important. For example, to capture randomness in taste variation the response coefficients β are no longer fixed across decision makers. Thus, the utility that consumer n obtains from alternative j is $U_{nj} = \beta_n' x_{nj} + \varepsilon_{nj}$ where the mixing distribution for the model parameters β_n is chosen from the normal, log normal, uniform, triangular and gamma distributions.[11] The mixed logit model with a random-coefficients specification is well suited to capturing random taste variation across decision makers. The standard logit model is the default of this model when the distributions of the coefficients are degenerate, i.e., a fixed-coefficient specification is sufficient. The mixed logit model does not exhibit the IIA property or proportional form of substitution. That is, the relative odds of a pair of alternatives depend on all alternatives, viz., choice probability cross-elasticities differ across alternatives. The mixed logit model is also well suited for repeated choice.[12] For example, in a stated-preference experiment all decision maker choices through time are observed. In this situation, model specification allows coefficients to vary by decision maker but not time. Also, the utility of alternative j at time t to consumer n is $U_{njt} = \beta_n' x_{njt} + \varepsilon_{njt}$, where ε_{njt} is iid Extreme Value across consumers, alternatives and time. A more elaborate specification allows the coefficients to vary by decision makers and time.[13] Finally, mixed logit choice probabilities are a weighted average of standard logit probabilities. That is, if standard logit probabilities are estimated for all draws of model coefficients from their distributions and averaged (with weights given by their density functions) then the mixed logit choice probabilities result. Mixed logit probabilities reduce to standard logit choice probabilities when the distributions for the coefficients are degenerate.

Logit models are often use ranked data (rank-ordered logit models) to estimate characteristics of consumer choice from stated-preference experiments.[14] An early application concerned potential demand for electric cars. Other applications in travel, transport, telecommunications and environmental fields demonstrated the

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[10] This discussion is based on Train (2003: Chap. 6). For an application see Train (1999).

[11] The expected range of the sign of a coefficient across decision makers provides a basis for selecting among distributions.

[12] For an application of the mixed logit model with repeated choices (panel data) see Revelt and Train (1998).

[13] Mixed logit models are estimated by simulation. Given the mixing distributions for the random coefficients, coefficient values are repeatedly drawn from their distribution and a logit probability is calculated for every draw. Logit probabilities are averaged to the find simulated probabilities. Simulated probabilities are inserted into a simulated log-likelihood function which is maximized to yield the parameters of the distribution for each model coefficient. For a detailed description of the estimation-by-simulation procedure see Train (2003: Sect. 6.6 and Chaps. 8–10).

[14] See Beggs et al. (1981), Chapman and Staelin (1982), Hausman and Ruud (1987) and Louviere et al. (2000: Chap. 13).

usefulness of combining stated-preference data with the rank-ordered logit model.[15] Stated-preference surveys create a choice experiment in which respondents are given alternatives to rank in order of preference. It is implicitly assumed that the preference ordering produced by a respondent reflects, in descending order, the utility attached to an alternative. Suppose alternatives are labeled A, B, C, D, and E. Also, assume respondent ranks the alternatives in D, A, E, C and B order. Assuming the utility from every alternative is distributed iid Extreme Value, the probability of this ranking is:

$$\Pr(\text{rank D,A,E,C,B}) = \frac{e^{\beta' x_{nD}}}{\sum_{j=A,B,C,D,E} e^{\beta' x_{nj}}} \cdot \frac{e^{\beta' x_{nA}}}{\sum_{j=A,B,C,E} e^{\beta' x_{nj}}} \cdot \frac{e^{\beta' x_{nE}}}{\sum_{j=B,C,E} e^{\beta' x_{nj}}} \cdot \frac{e^{\beta' x_{nC}}}{\sum_{j=B,C} e^{\beta' x_{nj}}}$$

where the right-hand side is the product of $n-1$ logit probabilities, viz., the probability of choosing D with all alternatives available, A when only A, B, C and E are available, E when only B, C and E remain, and C when only B and C are in the choice set. Clearly, the ranking of five alternatives produces four pseudo-observations. In general, for J alternatives $J-1$ pseudo-observations are created. This feature provides the name exploded logit. When the stated-preference survey involves a ranking exercise a respondent generates multiple pseudo-observations. Thus, for 100 respondents and five alternatives 400 observations are available for estimation. Traditional surveys typically generate a single observation per respondent. A dependent variable is created by stacking by respondent the $J-1$ rankings of alternatives in descending order of preference. Explanatory variables include attributes from the choice experiment and their levels. An attribute's level set to unity when that level corresponds to the pseudo-observation, and zero otherwise. Also, socio-demographic and respondent characteristics variables are repeated for $J-1$ pseudo-observations by respondent, an important consideration is the selection of logit model to be estimated. When $J-1$ pseudo-observations are considered independent choices then the standard logit model with fixed coefficients is estimated. Alternatively, when pseudo-observations are correlated the mixed logit model with random coefficients is s-pecified.[16]

Telecommunications Demand Case Study

This section presents results from a study that uses stated-preference data with standard and mixed logit models. The study considered how competition in the provision of basic business telecommunications services (ordinary business lines, Centrex access lines and PBX trunks) affect customer choice of service provider

[15] See, Tardiff (1995), Calfee et al. (2001) and Hanley et al. (2001).

[16] Non-zero correlation among pseudo-observations implies that a respondent has a dedicated set of coefficients that affect the entire ranking.

(or carrier)—including an incumbent carrier—and their response to hypothetical changes in service prices for the market share elasticity of the incumbent carrier. Specifically, business customers generally decide on telecommunications purchases based on total cost—including installation and recurring charges. This assertion is supported by literature concerning the demand for bundled services (‘one-stop shopping’) and discussions with business product managers at telecommunications carriers. To measure market share elasticity from data pertaining to businesses of all sizes, i.e., from single line to multi-line business customers that use Centrex or PBX, the study focused on a bundle of core services, viz., local access, usage and ancillary services.

Stated-preference Survey Design

The stated-preference survey is designed to capture the effect on carrier choice and implied market share of service price changes allowing for demand-affecting attributes such as carrier identity and service quality. A competitive environment is modeled such as that created by the US Telecommunications Act of 1996. In that environment the incumbent carrier (ILEC) does not exclusively offer local telecommunications access and usage services, whether business or residential. For the purpose of the experiment four other carriers are introduced—two of which (IXC1 and IXC2) formerly operated as incumbent providers exclusively of long-distance services but are now permitted to offer local service. Two more carriers are relatively new entrants (CLEC1 and CLEC2) in the local services market. The survey required respondents rank alternatives defined by the attributes: service provider identity; monthly recurring service price; one-time (non-recurring) connection charge; and repair time (service quality indicator). Table 12.1 lists the attributes and their levels

Table 12.1. Stated-preference Survey Attributes

Service provider	Connection charge
ILEC	Waived
IXC1	US$ 30
IXC2	US$ 45
CLEC1	US$ 60
CLEC2	
Recurring monthly price	**Repair time**
Up 20%	2 hours
Up 10%	4 hours
No change	8 hours
Down 10%	12 hours
Down 20%	16 hours

Attributes are chosen to make ranking manageable while capturing primary influences on carrier choice and demand. Respondents are told to assume other factors that may influence demand, e.g., available ancillary services and one-stop shopping capability are the same across all alternatives. Additionally, for the monthly recurring price attribute the levels are expressed as a fixed percentage departure from the current price being charged by the ILEC. Experience with such surveys and economic theory suggest that respondents react better to departures from a reference level than a price range. When competitive options are available customers pay attention to how much they would pay for service by switching carrier, i.e. relative rather than absolute price.[17] Further, as respondents differ in terms of lines in service, service type, service mix and usage measuring recurrent monthly price through (positive or negative) discounts to current price is appropriate. The non-recurring connection charge rises from zero in steps. Table 12.2 contains a sample of alternatives provided to respondents. A respondent is sent two sets of four alternatives and asked to rank alternatives within a set in order of preference (i.e., from the most to least desirable). That is, respondents are asked to carry out the ranking in a repeated choice context. Moreover, a choice set contains only four alternatives in light of findings that ranking tends to become noisy beyond the fourth-ranked alternative.

Table 12.2. Sample of Alternatives Provided for Ranking

Alternative A		Alternative B	
Service provider	ILEC	Service provider	IXC1
Connection charge	US$ 30	Connection charge	US$ 60
Recurring monthly price	Up 10%	Recurring monthly price	No change
Repair time	4 hours	Repair time	8 hours
Alternative C		**Alternative D**	
Service provider	CLEC1	Service provider	IXC2
Connection charge	US$ 30	Connection charge	Waived
Recurring monthly price	Down 20%	Recurring monthly price	Down 10%
Repair time	12 hours	Repair time	12 hours

The five levels for the three attributes and four levels for the remaining attribute imply $5^3 \times 4 = 500$ unique attribute combinations (alternatives) are identifiable. Thus, dominant alternatives formed by combining best price and repair time levels (20% below current recurring monthly price, zero non-recurring charge and 2 hours repair time) are eliminated. Similarly, dominated alternatives (20% above current recurring monthly price, US$ 90 non-recurring charge and 16 hours repair time) are removed. To choice set consisting of 900 sets of four alternatives is gen-

[17] Survey respondents are asked about their (or business) average monthly charges for local services and reminded of these charges before commencing their ranking exercises.

erated by randomly selecting from the alternatives.[18] Further, alternatives contained in a choice set must satisfy that: no alternative dominates other alternatives in a choice set; an identical attribute level does not appear in three (or more) alternatives; no service provider appears more than once; and the ILEC appears as a service provider in every set.

A survey research firm developed a sample of small and mid-sized business customers that are users of ordinary business lines, Centrex services or PBX/Key Systems in the ILEC's service area within a state in the US mid-Atlantic region.[19] An employee size stratified random sample is constructed and customers included are asked to provide information on: number of telephone lines or stations deployed at that location; type of local service taken; service provider; and monthly charges for local service at that location—including line charges and charges for features and local usage. The sample of respondents included 129 customers for ordinary business lines and 61 customers for Centrex, PBX and Key services. The firm used a telephone-fax-telephone process to conduct the survey. Respondents are contacted to identify decision makers to be invited to participate and provide background information. Respondents are sent two sets of alternatives by fax and given instructions for ranking. Ranking and other survey responses are recorded by telephone and a database containing 1,140 pseudo-observations (i.e., six pseudo-observations per 190 respondents) is created.

Estimation

Based on respondent rankings of alternatives, a rank-ordered logit fixed-coefficient (standard logit) and random coefficient (mixed logit) models are estimated. Both Models treat the utility from an alternative as a linear function of attributes and customer characteristics. The mixed logit model allows for the estimation of additional parameters. The mixing distribution for coefficients is Gaussian.[20] Both models are estimated using a maximum simulated likelihood estimation routine that restricts coefficients to be fixed for the standard logit version but permitting a Gaussian mixing distribution for the mixed logit version.[21] Preliminary estimation indicated that customer characteristics did not significantly contribute to respondent utility. Hence, models are re-estimated with only the at-

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[18] 900 sets of options are generated to ensure there are enough respondents given that some potential respondents do not participate.

[19] Business customers are drawn from a Dunn & Bradstreet database. Over sampling of larger customers increased the likelihood of obtaining Centrex or PBX/Key systems users in suitable numbers. Strata considered are: 1–9 employees, 10–49 employees, 50–99 employees and 100–249 employees. Employees are those working at the location listed by Dunn & Bradstreet. Locations with more than 249 employees are not considered.

[20] Lognormal and triangular distributions are tried with no significant change to estimates.

[21] Maximum simulated likelihood estimation is described in Train (2003: Sect. 6.6 and Chaps. 8–10). A mixed logit estimation routine designed for repeated choices (panel data) and written in GAUSS by Kenneth Train, David Revelt and Paul Ruud is used.

tributes. The models are estimated for: the full sample of 190 respondents (1,140 pseudo-observations), a sample of 129 customers that purchase only ordinary business lines (774 pseudo-observations) and a sample of 61 customers that purchase Centrex/PBX/Key services (366 pseudo-observations).

Coefficient estimates reported in Table 12.3 are plausible. First, the carrier coefficients are positive signifying that respondents expect to receive positive utility from their carriers.[22] Moreover, the coefficients for ILEC and IXC1 (the more established of the IXCs turned local service providers) are approximately of equal size and large relative to coefficient magnitudes for other carriers. This finding underscores the value of incumbency. Second, the coefficient for the non-recurring connection charge is negative but relatively small. Similarly, the recurring monthly price (discount from the prevailing price) is positive, viz., larger discounts yield greater utility. Third, the negative coefficient implies that longer repair time corresponds to declining utility values. Finally, there is substantial variation in the coefficient values obtained from the sample of customers that purchase ordinary business lines and those who purchase Centrex/PBX/Key services. This variation is evident for the ILEC, IXC1 and IXC2 coefficients. Apparently, respondents representing the larger of the business customers had a preference for incumbents over entrants than respondents representing smaller business customers who did not require specialized equipment. This finding suggests further examination is warranted through mixed logit model estimation.

Coefficient estimates for the random coefficient version of the rank-ordered logit model are reported in Table 12.4 for all samples.[23] Only the sign of the coefficient for the mean of CLEC1 does not have the expected sign. Generally, the effects on respondent utility of the attributes are significant in the full sample and the business lines customer sample. However, this outcome does not hold for Centrex/PBX/Key customer sample. Coefficients for ILEC and IXC2 appear to have non-degenerate distributions. The CLEC1 mean coefficient is statistically indistinguishable from zero, however, a non-zero standard deviation suggests the distribution is non-degenerate and centered at zero. The monthly price discount coefficient is variable, although with the standard deviation expressed relative to the mean (coefficient of variation) variability is not beyond the range experienced by the coefficients for other attributes. Connection charge appears to have a mild effect on respondent utility and has a distribution that is degenerate. Repair time has a mild negative effect that varies by respondent.

[22] The CLEC1 coefficient is insignificant, i.e., CLEC1 does not yield incremental utility to respondents above that gained from CLEC2. The result is plausible as entrants are unlikely to provide more value to business than established carriers based on brand name.

[23] In Table 12.4 attribute coefficients are assumed to follow a two-parameter Gaussian distribution. Hence, both mean and standard distribution parameters are reported.

Table 12.3. Rank-order Standard Logit Model Coefficient Estimates

Attribute	Full sample (n=190)	Business lines sample (n=129)	Centrex/PBX/Key sample (n=61)
ILEC	0.6076 (0.1286)	0.5032 (0.1530)	0.8237 (0.2487)
IXC1	0.5729 (0.1360)	0.5094 (0.1551)	0.8176 (0.2631)
IXC2	0.3044 (0.1340)	0.1105* (0.1643)	0.6875 (0.2323)
CLEC1	0.1685* (0.1209)	0.1402* (0.1506)	0.2274* (0.2228)
Price discount	3.9978 (0.4402)	4.4233 (0.5141)	3.1645 (0.8209)
Connection charge	-0.0088 (0.0014)	-0.0102 (0.0017)	-0.0072 (0.0023)
Repair time	-0.0686 (0.0111)	-0.0612 (0.0136)	-0.0871 (0.0193)

Note: Standard errors in parentheses. * significant at 10% but not 5%. ** not significant at 10% level. Number of respondents is n. Number of pseudo-observations is $n \times 6$.

Implications for Carrier Choice, Market Share and Choice Elasticity

A mode to compare standard and mixed logit model results considers the implied market shares of the carriers. The stated-preference survey enables the prediction of whether consumers accustomed to a single supplier will choose to move to other suppliers when competitive options are available. In particular, the principal dimensions to that choice are assumed to be service provider identity (brand name) and price discounts offered by competing providers. Market share is calculated as the odds of a carrier being selected. This reduces to a calculation of the probability of selection for a carrier from the group. That probability is the ratio $e^{V_i} / \sum_i e^{V_i}$ where V_i is indirect utility associated with a carrier.

Table 12.4. Rank-order Mixed Logit Model Coefficient Estimates

Attribute/Level		Full sample (n=190)	Business lines sample (n=129)	Centrex/PBX/Key sample (n=61)
ILEC	Mean	1.0907 (0.2320)	0.7591 (0.2763)	2.4255 (1.1210)
	S.D.	1.1120 (0.3674)	1.1059 (0.4225)	3.4450* (1.8496)
IXC1	Mean	1.1506 (0.2210)	0.8837 (0.2917)	3.1873* (1.7600)
	S.D.	0.7112** (0.5113)	1.1383 (0.5717)	1.7826** (1.2518)
IXC2	Mean	0.5252 (0.2363)	0.2508** (0.3373)	2.0424* (1.0448)
	S.D.	1.2575 (0.3552)	1.5477* (0.8388)	0.5676* (0.3307)
CLEC1	Mean	0.3035** (0.2057)	0.0800** (0.2388)	–0.5655** (0.9301)
	S.D.	0.9615 (0.2627)	1.0601* (0.5638)	2.3651** (1.5567)
Price discount	Mean	8.6349 (1.1532)	9.5894 (1.4064)	12.8797 (6.2933)
	S.D.	8.7433 (1.1435)	7.9582 (1.4520)	24.5249* (12.4254)
Connection charge	Mean	–0.0176 (0.0032)	–0.0216 (0.0046)	–0.0265 (0.0107)
	S.D.	0.0136 (0.0056)	0.0141 (0.0059)	0.0298** (0.0211)
Repair time	Mean	–0.1566 (0.0352)	–0.1681 (0.0532)	–0.4247* (0.2215)
	S.D.	0.2221 (0.0409)	0.2113 (0.0409)	0.5296* (0.2772)

Note. Standard errors in parentheses. * significant at 10% but not 5%. ** not significant at 10%. Number of respondents is n . Number of pseudo-observations is $n \times 6$.

Table 12.5 shows for both models that carrier market shares at baseline, viz., when utility is associated only with carrier attributes. Also, the table provides estimates of market share change when the ILEC alone raises service price by 10%. As expected, the ILEC market share fell, most notably for the Centrex/PBX/Key services sample. The beneficiary IXC1 appears to gain relatively more market share, particularly in the Centrex/PBK/Key services sample. Judging from the pattern of market share shifts the mixed logit structure better describes the disproportionate substitution pattern. Implied market share elasticity estimates are reported in Table 12.6. Market share elasticity estimates are considerably larger in the mixed logit model than those from the standard logit model. The estimates are derived from underlying market share shift as an ILEC's price is increased. Respondent utility estimates are uniformly larger in the mixed logit specification.[24] This finding means that the incumbent service provider market share elasticity for local business telecommunications service is more elastic than previously believed. Further, the market share elasticity is larger under the mixed logit specification reflecting that business customers are highly price sensitive and more inclined to shift to another incumbent than to an entrant as an alternative source of supply.

Table 12.5. Change in Market Share as the ILEC Recurring Monthly Price Rises by 10%

Service provider	Standard Logit Model		Mixed Logit Model	
Full sample (n=190)	Baseline	Price up 10%	Baseline	Price up 10%
ILEC	26.36	19.35	30.29	15.48
IXC1	25.46	27.88	32.16	38.98
IXC2	19.47	21.32	17.20	20.86
CLEC1	14.36	15.72	10.18	12.34
CLEC2	14.36	15.72	10.18	12.34
Business lines sample (n=129)				
ILEC	26.18	18.56	28.27	13.13
IXC1	26.34	29.06	32.02	38.79
IXC2	15.83	17.46	13.23	16.03
CLEC1	15.83	17.46	13.23	16.03
CLEC2	15.83	17.46	13.23	16.03
Centrex/PBX/Key sample (n=61)				
ILEC	26.71	20.98	24.99	8.42
IXC1	26.55	28.62	53.54	65.38
IXC2	23.31	25.13	17.04	20.81
CLEC1	11.72	12.63	2.21	2.70
CLEC2	11.72	12.63	2.21	2.70

Note. Number of respondents is n . Number of pseudo-observations is $n \times 6$.

[24] This reflects that mixed logit decomposes unobserved parts of utility into a part that determines the variance in the parameters while the remaining error has an extreme value structure. Thus, the standard logit error term variance is larger than for the extreme value component of the mixed logit model error term. As the coefficients in these models are normalized to ensure that the extreme value error term has an appropriate variance, the normalization makes the mixed logit coefficients relatively large compared to those for standard logit. For a detailed explanation, see Revelt and Train (1998).

Table 12.6. ILEC Implied Market Share Own Price Elasticity Estimates

Sample	Standard Logit Model	Mixed Logit Model
Full sample (n=190)	–2.66	–4.89
Business lines sample (n=129)	–2.91	–5.36
Centrex/PBX/Key sample (n=61)	–2.14	–6.63

Note. Number of respondents n. Number of pseudo-observations is $n \times 6$.

Conclusions

Stated-preference survey techniques have become established as a means to elicit consumer preferences, particularly when a product is new or only recently exposed to competitive pressure. This development has proved particularly helpful for studying consumer behavior, both actual and potential, in telecommunications markets newly open to competition. The approach is well suited to econometric modeling via discrete choice methods—particularly when data reflect consumer ranking of alternatives in order of preference. The rank-ordered logit model has become a standard tool, particularly the mixed logit form for rank-ordered data. The mixed logit model accommodates variation in consumer response to product attributes and correlation among unobserved factors in consumer choice, e.g., when consumers make repeated choices. Mixed logit models are flexible and permit the estimation of random coefficients, and reduce to a standard logit model should empirical tests show that estimated coefficients possess degenerate distributions. This feature helps to provide insights into certain aspects of consumer behavior that hitherto have only been analyzed by standard logit models. In Particular, the mixed logit model implied much larger market share elasticity estimates for incumbent service providers. Therefore, the combination of ranked stated-preference data and mixed logit models can be a valuable tool for market analysis as the dramatic transformation of the telecommunications industry continues.

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13 Information Technology, Corporate Performance and Firm Size

Yong Yeop Sohn and Hun-Wha Yang

Introduction

IBM's *Global CEO Study* (2004) report indicated that in 2002 corporate information technology (IT) strategy was primarily focused on cost saving, however, by 2004 83% of CEOs are more concerned with the contribution of IT to sales increase through the exploitation of new markets. This increased contribution of IT to sales is the result of a strategic switch in adopting and using IT systems as a tool to enhance firms' market value, e.g., systems that have proven effective in increasing sales are enterprise resource planning, product data management, supply chain management, customer relationship management, decision-making support systems, data warehousing, B2B and Groupware. Korean Information Management Institute for Small and Medium Enterprises (KIMI 2004) calculated the informatization index by firm size. Table 13.1 indicates that while informatization has improved, the gap has widened between small and medium enterprises (SMEs) and large firms.

Table 13.1. Informatization Index by firm Size

Year	SMEs	Large firms	Relative position
2002	48.6	66.0	73.6
2003	49.2	70.4	69.9

Note. Small and medium firms employ 5–299 persons; large firms employ at least 300 persons. Source: KIMI (2004)

From 2001 to 2003, the Korean government pursued an ambitious policy to increase IT use by 30,000 SMEs. The policy induced SMEs to adopt IT systems through government provided financial and technical support. The government's intention is to enhance the competitiveness of SMEs by replacing traditional production processes and management activities with newly developed, specifically designed software for small business. When an SME adopted the recommended software or IT system the government provided approximately 50% of the cost as financial support. The Korean government also provided professional supporting services. Of the 30,932 SMEs that received program support, the manufacturing sector is represented by 58.2% of the firms entering the scheme. That is 18% of all SMEs that employ at least 5 persons.

Table 13.2. SME Informatization System Adoption

Informatization system	Frequency	Expenditure (million won)
Consultation	240	330
Basic information software	27,750	27,000
Enterprise resource planning	2,592	42,300
Product process IT	39	670
Collaborative IT	311	3,600
Total	30,932	73,900

Source: MOCIE (2004)

Separate evaluation of the SME program has resulted in conflicting assessments as to the success of the project. A 2004 survey conducted by the Korean Institute for Industrial Economics and Trade—a research institute under the Ministry of Commerce, Industry and Energy—showed that SMEs have greatly improved in terms of their information process efficiency after implementation of the policy. However, other researchers argue that the project has only been successful in terms of IT adoption, viz., 80% installed IT systems are either underutilized or unused. Clearly, it is too early to unambiguously judge the effectiveness of the program as it is only eighteen months since project completion. However, there does exist an opportunity to isolate factors worthy of further scrutiny in evaluating the ultimate success of the project. The intention of the analysis is to specify an empirical model, based on received literature on the interrelationship between firm performance (e.g., labor productivity, profitability and sales) and dimensions of IT use (e.g., supply chain management, customer relationship management, enterprise resource planning and Groupware). Model parameters are estimated on data obtained from a survey of Korean manufacturing firms, and is used to compare IT use by SMEs and large enterprises. The study is to inform SMEs of potential sources of gain from IT use. The chapter is structured as follows: a review of the literature is provided in the following section. The next section derives a theoretical model and discusses data sources. Results of the analysis are then provided. In the following section, some comparative analysis is undertaken. A final section concludes.

Literature Review

Several studies attempt to explain an observed positive relationship between IT system investment and cost savings by firms. However, relatively few studies examine the positive influence of IT investment on firm productivity and profitability. The empirical examination issues other than cost saving have arisen within a broader consideration of the goals pursued by firms. Brynjolfsson and Hitt (2003) estimate multi-factor productivity (MFP) as the key performance metric by using data on 527 large enterprises in the United States (US) for the period 1987–1994 and find that computerization made a contribution to both MFP and output growth in the short-run. Further, Brynjolfsson and Hitt find these contributions are almost 5 times greater for long periods. Hong (2004a) also finds a similar result in a case study of leading Korean e-business companies. Additionally, CEO leadership and centralized organizational culture are other factors important in explaining the positive relation between the computerization and output growth of Korean firms. That IT use effects firm performance greater when organizational change accompanies changes in IT use has been clear since Brynjolfsson and Hitt (2000). Brynjolfsson and Hitt empirically evaluate whether firms' market value is properly represented by income flows from intangible assets and IT capital by tracking 829 non-financial firms for 8 years. They find that the market value of a typical firm increased by US$5–US$20 per US$1 increase in IT expenditure, and that the market value effect of IT capital is greater when a firm implemented a corresponding change in organizational culture. Brynjofsson and Hitt (2000) and Bresnahan et al. (2002) show that the effect of IT use on firm productivity is even greater when the organizational structure of the firm is decentralized. Firms with decentralized structures tend to invest 10% more on IT than more centralized firms. Further, the effect of IT investment is 13% higher than the average impact, in a decentralized firm. Hong (2004a, 2004b) also investigates the effect of IT capital investment on the labor productivity for 583 Korean firms. This analysis shows that innovative management and training of human resources, evaluation of employees and implementation of incentive schemes are positively correlated with IT investment, and that organization decentralization supported the positive effect of IT on productivity growth. Further, this study identifies the factors affecting the efficiency of IT use and the subsequent productivity effect are the utilizing rate of e-business applications, the portion of online buying and selling, the ratio of computer use to total employees and the per capita capital stock. The analysis also suggests that Korean firms tend to adopt IT systems and make complementary investment to change organizational structure.

The US Department of Commerce (2003) investigated whether the productivity growth of economic agents is attributable to IT investment economy-wide by comparing the US and other OECD Member Countries. That study finds IT investment generates a productivity premium—the US on average has the greatest premium. The report explains the difference in the productivity premium arises from US government policy and systems that force firms to trial alternative IT uses. Recently, analysis of firm performance has started to consider the economic spillover effects of e-commerce transactions. In particular, Zhu and Kraemer (2002) calculate an e-commerce capability index by surveying 260 US manufacturing firms on their proportion of e-commerce transactions and the incidence of corporate Web sites. The impact of these e-commerce factors on firm performance is then examined. Their cost regressions show that firms with advanced IT systems are more efficient. Inventory turnover is also higher for firms with a larger e-commerce capability index. Hong (2004a) applies an analogous test to Korean data and finds similar results to Zhu and Kraemer (2002). Further, Konings and Roodhooft (2002) divide 464 Belgian e-commerce active firms into purchasing and selling groups, and compare the effect of e-commerce on productivity between groups within a Cobb-Douglas production function approach. The study shows that the productivity of large e-commerce firms is higher by 20%, and that e-sellers also have higher productivity. They also study productivity by firm size and find that e-commerce brings a sizable impact on the productivity of large enterprises. Baldwin and Sabourin (2001) find for Canadian establishments during the period 1988–1997 that communication technology played a unique role in labor productivity and market share growth. Advanced technology has brought about a soft-manufacturing revolution by being effectively combined with human cognitive capability. Most of the above literature relies on data for stock exchange listed firms. Typically, such data relates to relatively large and well-organized firms, especially in terms of their accounting and management sophistication. However, SMEs comprise 98% of Korean enterprises, most not listed on any stock exchange. Further, few SMEs (the focus of this study) have sound financial data. Hence, additional effort is needed to collect accurate and confidential data from SMEs. These data are used to test for the effects of IT use on SME performance. The analysis relies on SME survey data. These data suggest that firm size does matter in terms of the ratio of firms adopting IT, and on their performance.

Research Method

To analyze the effect of IT use on firm performance, SMEs are classified into groups according to their utilization of IT systems in production and management processes. In particular, the information systems considered relevant for the analysis are *ERP* (enterprise resource planning), *SCM* (supply chain management), *CRM* (customer relationship management) and *GW* (Groupware). Firm performance is measured by labor productivity and sales. This conceptual model is depicted in Fig. 13.1.

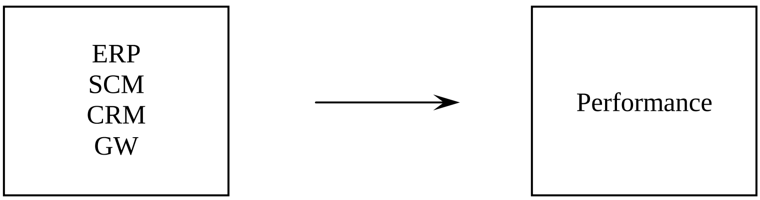

Fig. 13.1. Conceptual Model

To identify firms' IT use intensity requires an appreciation of the extent of IT integration into corporate operating systems. The extent of information systems integration is from no IT adoption through to complete integration. Sampled firms are classified by their IT systems integration. Consider, e.g., *ERP* systems. That is, when there is no established *ERP* system for employee use, e.g., non-integrated EXCEL or Microsoft Works software only. A more advanced system sees the use of piecemeal software by employees. More integration is again evident when ERP is employed for simple accounting, marketing and human resource management functions. More advanced still is ERP system utilization that has integrated accounting, finance, marketing, human resource management and inventory functions. Truly advanced systems achieve an ERP system which is thoroughly integrated, e.g., SCM and CRM systems. Similarly, classifications for the extent of SCM, CRM, and GW systems integration are specified. To investigate effects of IT use on firm performance a hedonic linear equation (Eq. 13.1) is specified, whereby firm performance depends on the level of firm informatization (extent of systems integration) by ERP, SCM, CRM and GW functions, viz.,

$$PERFORM = f(ERP, SCM, CRM, GW)\,. \tag{13.1}$$

Eq. 13.1 is a novel feature of the analysis, i.e., most studies that analyze the impact of IT and computerization on firm labor productivity and profitability performance specify econometric models with labor and IT capital input as independent variables (e.g., Baldwin and Sabourin 2001; Atrostic and Nguyen 2002). IT capital is often intended to proxy firms' intensity of IT use. However, an IT capital proxy variable does not provide any indication of the particular systems that are in operation, viz., particular systems may have differential performance impacts. To enable consideration of possible differential impacts on firm performance, alternative information system polychotomous categorical variables are included as independent variables in Eq. 13.1. The variables proxy the degree of particular IT systems utilization in production or management processes. To identify the variables 1,200 Korean manufacturing firms are surveyed during a 2-week period in metropolitan areas of Korea from April to May in 2004 by means of face-to-face interview, e-mail or facsimile transmission.[1] Among the surveyed firms: 1,100 firms employed between 50–299 persons. To gain reliable opinions, where possible, interviews are with either IT officers or chief executive officers. From the interview process, 347 completed questionnaires are harvested. Eleven percent of the completed questionnaires are from large enterprises and the remaining 89% questionnaires are from SMEs (see Table 13.3). Table 13.4 shows the distribution of surveyed firms by region.

Table 13.3. Firms by Employed Persons

Size	Frequency	%
Small (50–100)	195	56.2
Medium (101–299)	115	33.1
Large (300+)	37	10.7
Total	347	100

[1] Ulsan, a showcase of Korean industrialization, is not considered separately, but included as part of the Busan area.

Table 13.4. Firms by Region

Region	Frequency	%
Incheon	91	26.2
Seoul	72	20.7
Busan	56	16.1
Daegu	62	17.9
Gwangju	38	11.0
Daejeon	28	8.1
Total	347	100.0

The distribution of sampled firms by manufacturing classification is contained in Table 13.5. The distribution is similar to the actual distribution of firms by manufacturing industry.

Table 13.5. Firms by Industrial Classification

Industry classification	Frequency	%
Machinery and equipment	62	17.9
Metal products	20	5.8
Textile	98	28.2
Chemical and chemical products	33	9.5
Electrical machinery and electronic component	62	17.9
Medical, precision and optical instruments	11	3.2
Food products and beverages	13	3.7
Wood and wood products; publishing and printing	13	3.7
Other manufacture	18	5.2
Service related manufacture	17	4.9
Total	347	100.0

Table 13.6 indicates that more than 60% of firms employ ERP systems. The next most frequently used IT systems, in order of importance, are GW, POP/MES (point of product/manufacturing execution system) and $B2B$—each of which is employed in production and managerial processes by more than 30% of firms. Conversely, SCM, CRM, DW and DSS are infrequently adopted—especially by SMEs. The very high adoption of ERP systems is probably attributable to Korean government policy that promotes the adoption of IT systems by SMEs, in particular ERP. A casual review of the data contained in Table 13.6 suggests that IT adoption rates by large enterprise are substantially above those for SME. The finding is especially apparent in comparative adoption rates for GW, POP/MES and DW. However, differences in the adoption rates for ERP and $B2B$ are relatively close across firm size—still the difference is more than 30 percentage points.

Table 13.6. IT Adoption by Firm Size

IT system	SME		Large Firm		Sample	
	Frequency	%	Frequency	%	Frequency	%
GW	105	33.9	32	86.5	137	39.5
B2B	77	24.8	22	59.5	99	28.5
ERP	179	57.7	30	81.1	209	60.2
POP / MES	68	21.9	33	89.2	101	29.1
PDM	57	18.4	23	62.2	80	23.1
SCM	27	8.7	21	56.8	48	13.8
CRM	25	8.1	17	45.9	42	12.1
DW	33	10.6	28	75.7	61	17.6
DSS	32	10.3	15	40.5	47	13.5
Total	310		37		347	

Note. SMEs have 5–299 employees; large firms have at least 300 employees. More than one system can be adopted.

Estimation Results

The regression results that examine the effect of IT utilization on firm performance are reported in Table 13.7. The equation is statistically significant with an $F = 26.455$. The coefficient estimates have expected signs and are significant at 1% level, except *CRM*. The Beta coefficients suggest the differential impacts of alternative IT systems, with firm performance more sensitive to the level of *GW* and *SCM* utilization.

Table 13.7. Firm Performance and IT Utilization Model Results

Variable	Coefficient	Std error	Beta	t-value	P-value
ERP	0.189	0.027	0.216	3.265	0.000
SCM	0.254	0.059	0.250	2.592	0.010
CRM	0.143	0.087	0.127	0.499	0.618
GW	0.339	0.052	0.292	4.560	0.000
Intercept	5.687	0.131	-	43.354	0.000
F-statistic	26.455				
R^2	0.337				
$\bar{R}^2$	0.328				

Analysis by Firm Size

Next, to examine whether the overall results reported in Table 13.7 apply to all firms irrespective of their size, a one-way analysis of variance on IT utilization level is conducted for firm size and IT system. Firms are grouped by number of employees. Large-size enterprises employ 300 or more persons, medium-size enterprises employ 101–299 persons, and small-size firms employ 5–100 persons. Table 13.8 shows that large-size enterprise and SME groups are significantly different in ERP, SCM and GW at the 1% level. However, the difference between small and medium-size enterprise groups is less important, and it is therefore reasonable to combine the groups within an SME category.

Table 13.8. One-way Analysis of Variance by Firm Size

System	Mean	F-value	P-value
ERP	2.11	4.644	0.007
SCM	2.23	6.756	0.002
CRM	1.68	2.976	0.079
GW	2.46	11.962	0.000

Accordingly, Eq. 13.1 is estimated separately by the firm size. The estimated equations are:

$$PERFORM_{Large} = 0.154ERP^{**} + 0.282SCM^{*} + 0.482GW^{**}, \tag{13.2}$$

$$PERFORM_{Medium} = 0.105ERP^{**} + 0.413CRM^{*} + 0.230GW^{**} \tag{13.3}$$

and

$$PERFORM_{Small} = 0.138ERP^{**} + 0.152SCM^{*} + 0.188GW^{*} \tag{13.4}$$

where $*$ and $**$ indicate that the independent variable is significant at the 10% and 5% level, respectively. ERP and GW are statistically significant at 5% for all groups, except for 10% significance of GW in the small-size group. CRM is insignificant for large and small-size enterprises, but it is significant at 10% level only for medium-size enterprises. SCM is significant only for large- and small-size enterprises. Further, the estimated coefficients for ERP and GW are greatest for the large-size group, with estimated coefficients for GW increasing with firm size. This result may suggest that better internal communication is more valuable to larger enterprises.

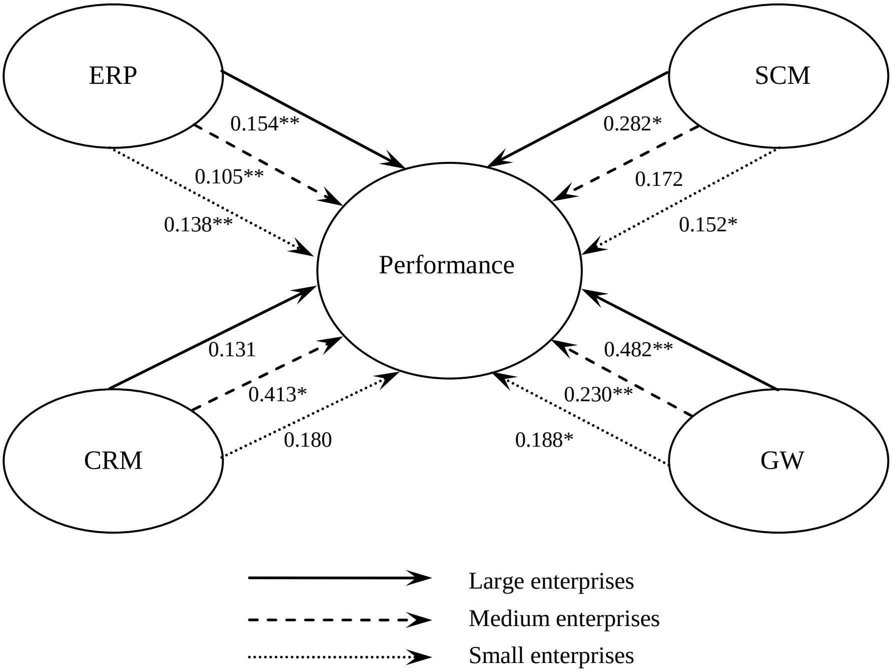

Fig. 13.2. Performance and IT Systems. Note. * significant at 10%; ** significant at 5%.

Additionally, firm performance with regard to IT system may depend on the goal of the firms. That is, the IT system adopted depends on the optimization program in place. When investment in IT systems is made, firm goals that might be pursued include cost reduction (*COSTS*), increased productivity (*PROD*) and enhancing the market value of the firm (*VALUE*). Accordingly, sample firms are classified by corporate IT use goals. The following goals are identified empirically as the most important: cost saving (144 firms), productivity improving (153 firms) and value (sales and market expansion) creating (18 firms) groups. The remaining 33 firms are otherwise classified.[2] Next, separate regressions for corporate output and sales, respectively, are estimated on the corporate IT goals of *COSTS*, *PROD* and *VALUE*. The results for the estimated output equation are provided in Table 13.9. Both estimated coefficients of *PROD* and *VALUE* have a positive effect on the performance of the firm. This result is distinctly different from that of US Department of Commerce (2003) which finds a strong IT cost saving effect for US firms. However, this conflict may arise from the fact that these cost savings have not necessarily translated into profitability improvement.

[2] The detailed classification IT use goals is suggested in Yang (2004)

Table 13.9. Firm Output Performance and IT Utilization Goal Model Results

Variable	Coefficient	Std error	Beta	t-value	P-value
COSTS	0.273	0.158	0.144	1.555	0.121
PROD	0.693	0.176	0.367	3.971	0.000
VALUE [a]	0.697	0.174	0.166	2.620	0.000
Intercept	5.030	0.266	-	31.835	0.000
F-statistic	8.510				
R^2	0.070				
$\bar{R}^2$	0.062				

Note. *a* sales in new market

Finally, Table 13.10 and Fig. 13.3 show how firm goals of IT use affect sales. As expected, the goal of new value creation increases sales.

Table 13.10. Firm Sales Performance and IT Utilization Goal Model Results

Variable	Coefficient	Std error	Beta	t-value	P-value
COSTS	0.155	0.100	0.141	1.558	0.120
PROD	0.455	0.099	0.415	4.589	0.000
VALUE [a]	0.601	0.151	0.247	3.976	0.000
Intercept	2.212	0.090	-	23.621	0.000
F-statistic	13.999				
R^2	0.332				
$\bar{R}^2$	0.110				

Note. *a* sales in new market

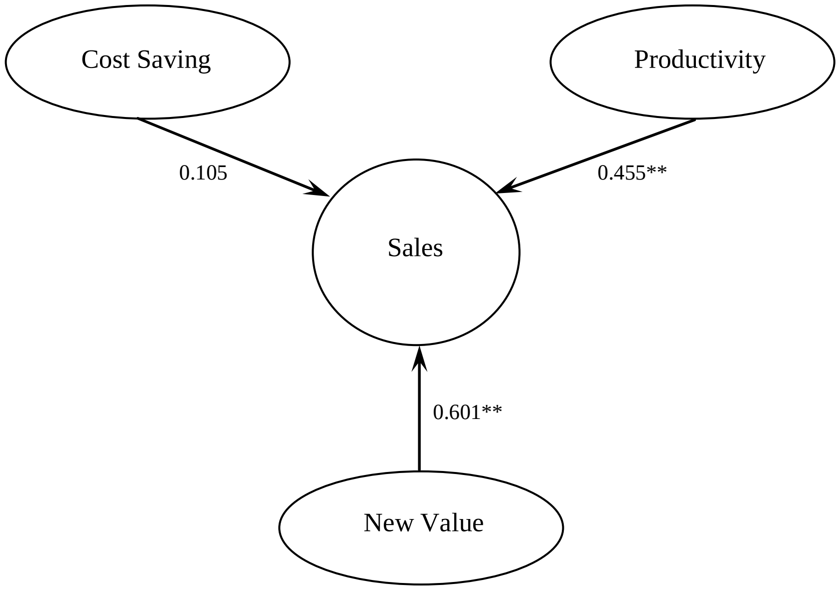

Fig. 13.3. Sales and IT Goal. Note. * significant at 10%; ** significant at 5%.

Conclusions

This chapter developed several models to show that firm performance improves with IT adoption and use. Data are collected on 347 firms are from a survey of Korean manufacturing establishments. The results from the analysis of these data are summarized below. First, adoption and use of IT is positively related to profitability and sales. In particular, *GW* and *ERP* systems are most likely to provide improved firm performance. Basic management activity, such as accounting, marketing, human resource management are mostly *GW* , *ERP* , *SCM* procedures. That is, *GW* facilitates communication, production and inventory coordination, and hence has direct affect on the performance of the large-size firm group. Second, large-size firms typically use IT systems relatively more, and so the impact of IT use on performance is greater. However, no such difference between small- and medium-size firms is apparent. Actually, there is a divide in adoption of IT by firm size. Third, *SCM* does not affect profit. This finding suggests that Korean firms use IT mainly for production efficiency and not marketing and customer management improvement. Fourth, Korean informatization is significantly affecting firm performance when pursued to increase productivity and firm value.

With the hypothesis that IT use improves SME output and sales supported in this study, the Korean government 'IT systems to 30,000 SMEs' program can be regarded as an effective policy tool. The program also assists in narrowing the digital divide between large enterprises and SMEs by encouraging informatization. Despite the impact of IT on profit, most Korean SME manufacturers remain in the early stages of IT use since more weight is placed on production management than on exploiting new markets and improving customer management. Therefore, Korean manufacturing firms must establish business-orientated information systems. Finally, to improve the analysis further requires the more careful measurement of firm performance variables. Better data would also enable the examination of dynamic aspects of informatization such as whether IT systems investment patterns matter for the maximization of firm profitability increases.

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14 A Contingent Valuation of Terrestrial DMB Services

Sangkyu Byun, Hongkyun Bae and Hanjoo Kim

Introduction

A substantial personal computer (PC) and Internet connection installed base has provided the foundation for the diffusion of digital broadcasting, mobile communications and mobile data communications (wireless LAN and mobile Internet) services. Related service industries are considered as catalysts for growth of an emerging knowledge-based economy through the 21st century. However, broadcasting institutions have been subject to waves of innovation, e.g., the evolution from monochrome to color transmission, and later still the evolutionary phase from analog to digital technology. This latter phase allowed the introduction of high-quality multi-channel and multi-functional broadcasting services. Digital technology also led to innovation in mobile broadcasting services. In particular, terrestrial digital multi-media broadcasting (T-DMB) and DVB-H enable television (TV) viewing while traveling at speeds of 150km/h. Korea, which adopted ATSC for the fixed DTV standard, is now preparing to launch mobile TV service through T-DMB technology. T-DMB can provide CD quality audio and data service, as well as mobile TV service, on a maximum size 7 inch (18 centimeter) screen. When T-DMB functions are integrated into a mobile phone handset, this combined technology has the potential to lead the fusion of broadcasting and telecommunication services. In March 2005 the Korean government selected six multiplexers (devices that can interleave two or more activities) to provide T-DMB service. Commercial operations are expected to commence by late-2005. As T-DMB services are to be provided free, their launch reinforces universal service goals. Furthermore, the diffusion of the service promotes linked industry, e.g., terminal manufacturers and digital content providers. On this basis, effective policy for successful T-DMB service diffusion is required, especially policy based on the ‘true’ economic value of the service. Accordingly, this chapter attempts to evaluate the commercial viability of T-DMB service. In particular, a survey is conducted with a view to determining the potential value of the service to customer segments based on contingent valuation method (CVM) techniques. In the next section, the sources of potential economic value from T-DMB service introduction are assessed by examining features of the services and their uses. The following section explains CVM procedures and why they are employed to assess this virtual market. Next, output from the quantitative analysis is reported. Also, implications for commercial viability of the service and spectrum efficiency are provided. A final section summarizes key implications arising from the analysis and outlines the limitations of the study.

Background

Digital radio services are provided globally by digital audio broadcasting (DAB), in-band on channel (IBOC) and by DRM services. DAB service, via terrestrial radio, is widely diffused throughout the European Union, whereas in the United States (US) IBOC service—also called HD radio—is provided via satellite technology. However, full-motion video T-DMB service is yet to be launched. With the amendment of broadcasting regulations in 2004, Korea is expected to be among the early adopters of T-DMB service. In March 2005, the spectrum for T-DMB was allocated to six multiplexers by the Minister of Information and Communication for the Seoul metropolitan area. Each multiplexer is able to provide a video motion channel, three radio channels and a data channel with the available bandwidth. That is, 1.53MHz per eight channels for a total of 12MHz of bandwidth. T-DMB service is intended to be provided free, with revenue accruing from advertisers. Another motivation to diffuse T-DMB service lies in the potential to contribute to public welfare and impact on the related broadcasting and telecommunications industries.

Convergence is being realized as the boundary between traditional broadcasting and telecommunication services becomes ambiguous due to technological change. In the digital era, bi-directional broadband transmission is feasible via broadcasting technology innovation. To prepare for convergence, network consolidation, and the merging of both services and industry players is occurring rapidly. Additionally, service providers are able to generate additional revenue streams by providing a wider range of high-quality services. The emerging bi-directional broadcasting market, provided through the telecommunications network, is forecasted to generate revenues of €17 billion in 2005. With the mobile telephony network used as the return channel, handsets are an ideal multi-functional portable terminal. Accordingly, in Korea T-DMB terminals are being combined with mobile phone handsets. Further, due to free service provision and the mobility feature T-DMB is deemed an appropriate technology to carry the primary broadcasting service function. Extant TV services are currently only available at locations with dedicated receivers, with service usually viewed by groups. Therefore, as T-DMB service can be delivered via a hand-held device, broadcasting has the potential to become personalized. This feature means that T-DMB service can contribute to the reduction of the digital divide between age groups and social strata. Finally, with information delivery an important capability of T-DMB technology, the service also has the potential to enhance social assimilation. Finally, T-DMB services are a potential catalyst to terminal and system market expansion through the creation of a new demand dimension for mobile TV service. This potential will be reinforced when a T-DMB TV or radio function is added to mobile phone handsets. In terms of service, T-DMB technology may stimulate the market for advertising by further diversifying digital media.

Contingent Valuation Survey

To provide quantitative estimates of the value of the introduction of DMB service a stated-preference market experiment is conducted. The CVM relies on several methodologies, viz., the analytic hierarchy process, multi-attribute utility theory and Delphi theory. Since Cameron and James (1987) convincingly argued that the CVM is a suitable method with which to derive willingness-to-pay (WTP) values for non-market ecological goods the method has become widely applied. Recently, the CVM has been used to evaluate potential value from the introduction of new technology or products. The CVM is based on the microeconomic theory of choice that considers that consumers are able to order goods in terms of personal preference. Korean studies have employed the CVM to measure the value of artificial seed potatoes (Hyun et al. 1997), network externality effects from PC communications (Shin 1998), near video-on-demand technology for the educational service on cable TV (Yoo et al. 2000) and the commercial viability of IMT-2000 service (Byun et al. 2002). To make a CVM survey operational, a hypothetical market is created and options (alternatives from which to choose) from this market are presented to respondents. From these stated choices respondent WTP for the service is inferred.

For the current survey a subscription fee based on a business model for T-DMB is designed. The study design also assumes that the right to levy fees is held by a representative multiplexer. This market is created to resemble the Korean terrestrial TV market to ensure that respondents understand more clearly the choice contexts that are confronted with so as to ensure plausible WTP values. The WTP values derived for the T-DMB market from the experiment should be considered as representing the combined value for all channels as the levy is assumed granted to a representative multiplexer. Additionally, consumers are likely to be more sensitive to the subscription fee imposed rather than that for terrestrial TV service. Furthermore, the survey is designed not only to determine the commercial potential of T-DMB market but also to derive implications for service diffusion. That is, an economically viable T-DMB market helps operators plan their network investment strategy. That is, a high T-DMB market value provides potential T-DMB broadcasters (via a new business model) an incentive to invest. Also, a high T-DMB market value assists potential entrants with a small financial base to be better able to procure investment funds.

The current analysis employs a double-bounded dichotomous choice (DBDC) approach in the design of CVM questions. The DBDC approach is proposed by Hanemann (1985) and a set of typical questions are provided in the Appendix. In the questionnaire design, a question is specified to require a respondent to indicate whether she is willing to pay a specified sum for the monthly provision of T-DMB service. When the respondent answers ‘yes’, a follow-up questions asks whether she is willing to pay double that amount for monthly T-DMB service. Conversely, when the initial response is ‘no’, a subsequent question asks whether the respondent is willing to pay half the initial amount for T-DMB service. While this dichotomous question is similar to a consumer making a purchase decision in a market the double-bounded structure gathers more information than the price and selected alternative. To induce sample variation—an aid in statistical analysis of responses—four prices are used in the experiment, viz., US$ 2, US$ 4, US$ 6 and US$ 8.[1] The prices are selected from experimentation in a preliminary survey of 50 respondents where the amounts are randomly chosen. The survey was conducted during October 2003 in the Seoul metropolitan area and other Korean cities. The survey provided 1000 valid responses from face-to-face interviews.[2]

Table 14.1. Survey Design and Sampling Method

Feature	Description
Survey period	October 6–27, 2003
Survey location	Seoul metropolitan area, Busan, Daegu, Incheon, Gwangju, Daejeon
Strata	Resident citizens aged 15-50 years
Sample size	1,000 respondents
Sampling	Random sampling with strata by residential area, age and gender
Survey mode	Face-to-face interview via structured questionnaire
Sampling error	Confidence level 95%±3.1%

The ratio of male and female respondents is exogenously stratified to be equal. The age groups that are comprised of 160 respondents are also specified exogenously. The age groups employed are: 15–20 years, 20–25 years, 25–30 years, 30–35 years and 35–40 years. Another 200 persons aged 40–50 years are also surveyed. Persons younger than 15 years are not included in the sample as they are deemed unlikely to be capable of sensibly responding to survey questions. Persons older than 50 years are also excluded from the sample. Survey responses indicate that the most widely diffused broadcasting service is terrestrial TV at 99.5% of respondents.[3] The next most diffused service is cable TV (68.5%), followed by satellite TV (10.2%). Radio service diffusion is 59.9% (see Fig. 14.1). With regard to telecommunications services, 91.1% of the respondents subscribe to mobile telephony, while 34.4% of respondents are wireless Internet subscribers. Among mobile telephony subscribers, only 8.1% (6.4% of respondents) use June or Fimm services, viz., 3G mobile Internet services based on CDMA2000 1xEV-DO that offer video products. This finding suggests that multi-media services are yet to become an established niche in the mobile telephony market. That is, video products are mostly provided via broadcasting media.

[1] In 2005, US$ 1 approximately corresponds to 1,000 Korean won.
[2] Refer to Table 14.1 for details on the sample design method.
[3] In apartments, the most pervasive form of Korean housing, the terrestrial TV audience watches real-time content via the cable network with no alternative. Therefore, terrestrial TV content provided via cable network in real time are classified as the terrestrial TV user group.

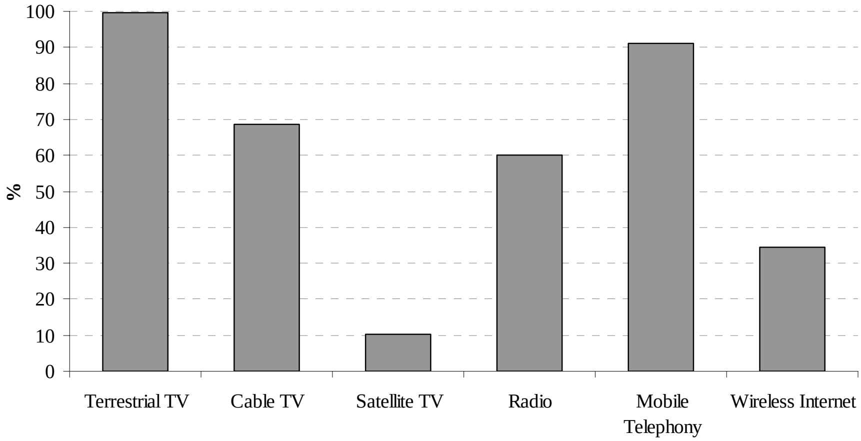

Fig. 14.1. IT Service Diffusion. Note. Multiple responses allowed

Compensating Variation Valuation of T-DMB Services

Denote variables explaining monthly T-DMB subscription x. Also, let y_i^* denote the unobserved 'true' respondent WTP for T-DMB service. Further, assume the relationship between the variables is linear, viz.:

$$y_i^* = x_i'\beta + u_i \,, \tag{14.1}$$

where β is a vector of unknown parameters to be estimated and u_i is a normally distributed disturbance term described by $u_i \sim N(0,\sigma^2)$. The corresponding log-likelihood function for the DBDC model is:

$$\begin{aligned}\ln L = \sum_{i=1}^{n} \ln[I_i^{YY}(1-\Phi(\frac{B_{Hi}-x_i'\beta}{\sigma})) + I_i^{YN}(\Phi(\frac{B_{Hi}-x_i'\beta}{\sigma}) - \Phi(\frac{B_i-x_i'\beta}{\sigma}))\\ + I_i^{NY}(\Phi(\frac{B_i-x_i'\beta}{\sigma}) - \Phi(\frac{B_{Li}-x_i'\beta}{\sigma})) + I_i^{NN}\Phi(\frac{B_{Li}-x_i'\beta}{\sigma})] \,,\end{aligned} \tag{14.2}$$

where $\Phi(\cdot)$ is the cumulative normal distribution, B_i is the initial subscription fee, B_{Hi} and B_{Li} are sample question high- and low-subscription fees, respectively. The indicator variable I_i is defined by the rule:

$I_i^{YY} = 1$ if respondent i answers 'yes' and 'yes', respectively, $= 0$ otherwise;
$I_i^{YN} = 1$ if respondent i answers 'yes' and 'no', respectively, $= 0$ otherwise;
$I_i^{NY} = 1$ if respondent i answers 'no' and 'yes', respectively, $= 0$ otherwise;
and
$I_i^{NN} = 1$ if respondent i answers 'no' and 'no', respectively, $= 0$ otherwise.

Estimation

Definitions of the explanatory variables employed in estimation are contained in Table 14.2. Equation 14.3 is the final estimating equation, i.e.,

$$
\begin{aligned}
WTP = {} & \beta_0 + \beta_1 Sex + \beta_2 Age + \beta_3 Job + \beta_4 Income + \beta_5 PC \\
& + \beta_6 Mint + \beta_7 SatSat + \beta_8 Aware + \beta_9 Pref + \beta_{10} DMBTtm\,.
\end{aligned}
\tag{14.3}
$$

Equation 14.3 includes demographic variables *Sex*, *Age*, *Job* and *Income*. *PC*, *Mint*, and *SatSat* are variables that indicate respondent subscription to broadcasting and telecommunications services which are substitutes or complements to T-DMB services. Finally, the variables *Aware*, *Pref* and *DMBTtm* measure respondent attitudes toward T-DMB service.

Results from maximum likelihood estimation are combined in Table 14.3. The Wald statistic suggests that the estimated equation is statistically meaningful. Namely, respondents treated the virtual market experiment for subscription fee-based T-DMB services as meaningful. The WTP estimate is significant at the 1%–5% level, depending on individual characteristics. In terms of demographic variables, males have a higher WTP, while the valuation increases with respondent age. These findings contradict a belief that females are more loyal to broadcasting media while young persons adopt early non-basic telecommunications services.[4] The WTP is also identified as relatively low among employed persons. Also, WTP rises proportionately with household income. PC ownership is associated with lower WTP, probably because PC users have mobile Internet access via ADSL or cable—so a diverse range of broadcasting content is already available at a relatively low price. Moreover, T-DMB subscription fees may add an unacceptable additional burden to current monthly network payments. Conversely, wireless Internet service mobile phone subscribers and viewers of satellite TV (Skylife) show a willingness to spend relatively more for T-DMB service. Mobile Internet services such as June and Fimm provide video content in an on-demand format but high prices are an obstacle to service proliferation. Therefore, relatively inex-

[4] Byun and Yeo (2004) reveal females view more TV, with the exception of cable TV. Mobile Internet users are mostly aged 15–30 years. Furthermore, June/Fimm subscribers are concentrated in the 15–20 years age bracket. Clearly, younger persons are leaders in the adoption of leading-edge IT service (Byun and Yeo 2004).

pensive T-DMB service may provide an alternative service, especially when the portability and AV functions of mobile handsets are considered. T-DMB service is also likely to appeal to satellite TV subscribers who have restricted mobility. Finally, WTP is higher for respondents aware of T-DMB services. This suggests that advance promotion activity to enhance adoption is viable. Additionally, WTP is higher among respondents who indicate an interest in subscribing to T-DMB service after having the services described during the interview. Finally, US$ 4.95 is the conditional mean monthly subscription fee, i.e., respondents are willing to pay for T-DMB.[5] The corresponding 95% confidence interval is US$ 4.70 to US$ 5.20, viz., WTP is non-zero.

Table 14.2. Variables

Variable	Description	Definition
Sex	Gender	$=1$ if respondent female; $=0$ otherwise
Age	Age	$=1$ if respondent age 15-19 years; $=2$ if respondent age 20-25 years; $=3$ if respondent age 26-29 years; $=4$ if respondent age 30-35 years; $=5$ if respondent age 36-39 years; or $=6$ if respondent age >40 years
Job	Employment	$=1$ if respondent employed; $=0$ otherwise
Income	Monthly income	$=1$ if household income $<$ US\$2,000 ; $=2$ if household income US\$2,000-3,000 ; $=3$ if household income US\$3,000-4,000 ; $=4$ if household income US\$4,000-5,000 ; or $=5$ if household income $>$ US\$5,000
PC	PC ownership	$=1$ if household owns PC; $=0$ otherwise
Mint	Mobile Internet	$=1$ if home mobile Internet use; $=0$ otherwise
SatSat	Satellite TV satisfaction	$=1$ if respondent very dissatisfied; $=2$ if respondent neutral; or $=3$ if respondent very satisfied
Aware	DMB TV awareness	$=1$ if respondent aware of DMB; $=0$ otherwise
Pref	DMB TV preference	$=1$ if respondent not prefer DMB TV; $=2$ if respondent neutral toward DMB TV; or $=3$ if respondent Prefer DMB TV
DMBTtm	Daily viewing	Respondent expected DMB TV viewing (hours)

[5] The average sample respondent value is used, hence ‘conditional’ is added.

Table 14.3. Maximum Likelihood Model Estimates

Variable	Value	t-statistic
Constant	805.35	1.012
Sex	911.52	3.343**
Age	203.55	2.248*
Job	-628.07	-2.034*
Income	154.88	2.187*
PC	-930.79	-2.041*
Mint	1051.10	3.536**
SatSat	350.90	2.842**
Aware	1330.80	4.034**
Pref	811.53	5.883**
DMBTtm	4.97	2.163*
σ	3752.81	31.642**
Observations	1000	
Log likelihood	–1339.46	
p-value	0.000	
Wald statistic	2467.54	

Note. ** is significant at 1%; * is significant at 5%

T-DMB service is to be delivered free in Korea despite some potential subscribers having a high WTP. Clearly, free provision is likely to be a decisive factor in spurring the early adoption of T-DMB services. The impact of T-DMB markets on the Korean economy can also be assessed using sample WTP values.[6] The expected T-DMB market revenue is estimated by multiplying the forecast T-DMB subscriber data by monthly WTP estimates. The expected investment for T-DMB is estimated at US$ 46.6 million for per multiplexer (KBS 2003). When three operators share or reutilize existing FM radio networks, the collective investment is expected to be lower than US$ 120 million. Accordingly, as shown in Fig. 14.3, the cumulative rate of return until 2015 to their T-DMB investment is 3,680%.

[6] To forecast revenues, data on T-DMB subscription is obtained from, ‘Study on the demand estimation of DMB broadcasting’ (Byun et al. 2004). These data are derived from a Bass diffusion model.

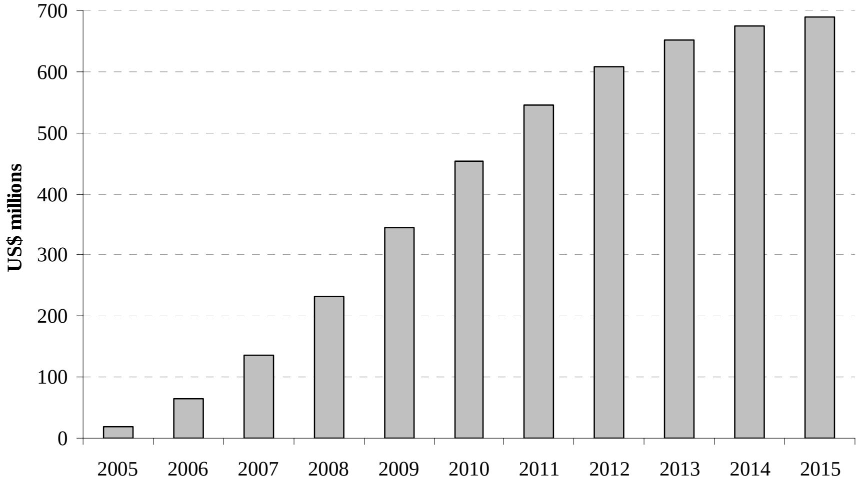

Fig. 14.2. Revenue Forecasts for T-DMB Service

The sample WTP value for T-DMB is estimated at twice the monthly subscription fee for terrestrial TV (US$ 2.50). Subscription fees collected by KBS1, which receives no advertising revenue, are US$ 482 million in 2002 (see Table 14.4) and is approximately equivalent to forecast revenues received by T-DMB in 2010. Clearly, the outlook for terrestrial TV is uncertain given the saturation of subscription fees, which increased by only 3.8% compound average growth rate (CAGR) between 1998 and 2002. In contrast, T-DMB revenues are expected to increase at a CAGR of 91% between 2005 and 2010, and eventually overshadow terrestrial TV subscription revenues. Accordingly, T-DMB is likely to create a promising business opportunity for extant broadcasters—rather than just providing a supplementary service to terrestrial TV.

Table 14.4. Terrestrial TV Broadcaster Annual Subscription Revenue

Item	1998	1999	2000	2001	2002	CAGR (1998-2002)
Subscription fee[a]	415	433	447	482	482	-
Growth (%)	-	4.4	3.3	7.8	–0.02	3.8

Note. *a* US$ million. Source: Korean Broadcasting Commission (2002, 2003)

An evaluation of the potential size of the T-DMB market can also be made from the regulators standpoint of aiming to ensure efficient frequency use. The combined revenue from domestic terrestrial TV broadcasting operations, which is comprised of advertising and subscription fee income, is US$ 2.94 billion in 2002. Operators employed 5 channels or 30MHz of bandwidth. Revenue per unit of bandwidth (1MHz) is US$ 97.9 million. In the realm of mobile telecommunications service, a cellular and two PCS operators are offering CDMA-based service in Korea. As of 2003, the spectrum resource assigned to mobile telecommunications is 110MHz, which generates annual revenues of US$ 15.5 billion. Therefore, the revenue from a unit band amounted to US$ 140.5 million on average. Meanwhile, three T-DMB multiplexers will only use a total 6MHz of bandwidth. The annual revenue per frequency unit (1MHz) is expected to reach US$ 114.9 million at 2015. This amount is somewhat lower than that for mobile telephony, and surpasses that for terrestrial TV. Hence, T-DMB is competitive with regard to the efficient use of frequency.

Conclusion

This study assesses the potential economic value of T-DMB services which are emerging as market leader in an era of convergence between broadcasting and telecommunications markets. Here, a quantitative analysis is undertaken by CVM to estimate the subscription fee that users are willing to pay subject to their demographic characteristics, experience with telecommunications services and attitude toward T-DMB services. The CVM is starting to be utilized in making assessments of the value of new technology and related services. Implications for commercial viability and spectrum management are deduced by integrating previously disclosed data. Additionally, information from the analysis is useful for the operators in terms of directing their marketing activity. Due to the absence of market data for T-DMB, experimental data collected are obtained from a survey of potential users. The estimated virtual market for T-DMB services is based on a monthly subscription fee provided to respondents in a DBDC questionnaire. The questionnaire is carefully designed and presented to respondents. Comparison with terrestrial TV data indicates that T-DMB has a promising business model based on a relatively high (compared to terrestrial TV) subscription fee. Revenue per frequency for T-DMB is higher compared to that for terrestrial TV, but is lower relative to mobile telephony service. Consequently, T-DMB has the potential to provide a new catalyst to growth for Korean IT industries. This chapter, however, assumes that subscription fees are not levied on consumers of T-DMB services. Therefore, the study outcomes are deemed to have a unique value that is independent of non-economic exogenous environments such as the levying of subscription fees. As digital technology continues to advance, T-DMB can proliferate, thereby increasing consumers' utility and acting as a catalyst for new high value-added manufacturing sectors. IT, which is already established as a growth engine of the Korean economy is also expected to make a substantial contribution to enhancing public welfare.

Appendix: DMB Contingent Valuation Question

Q1. The subscription fee currently levied by KBS is US$ 2.50 (2,500 Korean won) every month. Taking into account your income and expenditure as well as your spending on IT services (fixed-line telephony, mobile telephony and ADSL), would you be willing to pay X won for T-DMB services (TV + radio + data) every month?

Suggest one of the four specified amounts sequentially.

That is, US$ 2 for the first respondent, US$ 4 for the second respondent, US$ 2 for the fifth respondent

1. Yes **(go to Q1.1)**	2. No **(go to Q1.2)**

Q1.1. Then, are you willing to pay 2X won? **(go to Q2)**

1. Yes	2. No

Q1.2. Then, are you willing to pay X/2 won?

1. Yes	2. No

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15 Consumer Preference for New Wireless Data Services

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Introduction

The Korean telecommunications services market has recently experienced an unprecedented growth in the wire-line broadband Internet access and mobile telephony markets. At 2004, 11 million households had broadband Internet access, while mobile telephony subscription reached 36 million—the corresponding penetration rates are 73% and 75%, respectively. However, wire-line, wireless voice, and broadband Internet access market growth have reached a plateau as those markets near saturation (see Fig. 15.1). Wireless Internet services, in particular public wireless local area network (WLAN) and 2.5G/3G services were introduced to stimulate this flagging telecommunications market demand. While these services offer access to the Internet, multimedia, banking and online gaming services, only minimal growth in market demand has resulted. In investigating factors inhibiting market growth several customer complaint surveys reveal that WLAN is not of a satisfactory quality due to technical vulnerability to interference and limited coverage. Further, 2.5G/3G prices are high for the low-speed transmission.

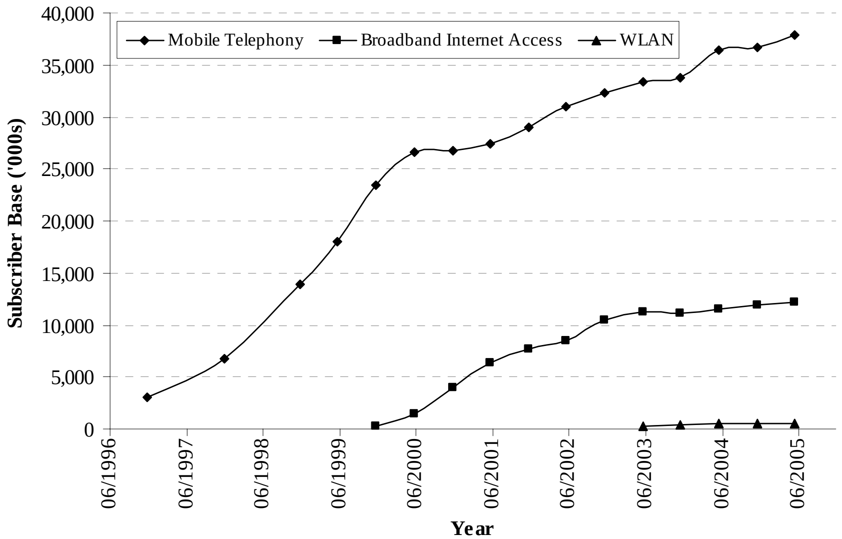

Fig. 15.1. Korean Telecommunications Subscription by Service. Source: MIC

In spite of service provider pre-market launch testing for best product design the new mobile Internet service market is yet to reach a minimum viable size (Kim 2003; Kim and Lee 2004). A possible reason for the market not attaining a high penetration may be due to service providers' lack of ability to understand consumer preference—especially in the early stages of market evolution.

From a consumer's perspective it is difficult to reveal 'true' preference for an experience good prior to consumption of the good. In particular, a consumer finds the task of understanding service concepts difficult without having experience gained through evaluating alternative technical service specifications. Without this consumption experience the revelation of consumers' preference for new Internet services is likely to be confounded. Considering WLAN, e.g., based on subscription intention questions early market surveys estimated a potential 5 to 10 million subscribers—however the current realized base is at most 500,000 subscribers. Further, a clear understanding of customer potential demand for service attributes helps managers improve product design and strategically position services. That is, companies are better able to respond to customers' needs by improving transmission speed, mobility and coverage. Conversely, when it is not technologically feasible to reconfigure service features—due to service deployment schedule or expenditure limitations—then the strategic repositioning of the service is considered without technological modification to service attributes.

To obtain a better appreciation of consumer attitudes this study develops a hierarchical decision structure of consumer choice for emerging mobile services by breaking down the choice problem into a hierarchical decision structure for interrelated service attributes, e.g., transmission speed, mobility, coverage and price. The analytic hierarchy process (AHP) allows managers to analyze consumers' preference for service attributes to determine the relative attractiveness of alternative new mobile services. Additionally, implications of the results are discussed, especially for the successful implementation of portable Internet service (PIS). This chapter is organized as follows. In the next section, a brief description of emerging mobile services in the Korean telecommunications market is sketched. A research model is then developed using the AHP. Next the results of the analysis are discussed. Finally, implications of the study and areas for further research are presented in the final section.

Emerging Mobile Data Services in Korea

Figure 15.2 displays mobile data and broadcasting services including: WLAN, terrestrial and satellite digital multimedia broadcasting (DMB), PIS and high-speed downlink packet access (HSDPA), in terms of their relative mobility and speed. WLAN offers very high-speed broadband Internet access in hot spots, but due to limited service coverage and poor quality the service is not widely deployed. Currently, Korea Telecom and Hanaro Telecom are providing 10Mbps Internet access service via 2.4GHz radio frequency and are expected to launch 54Mbps service via 5GHz.

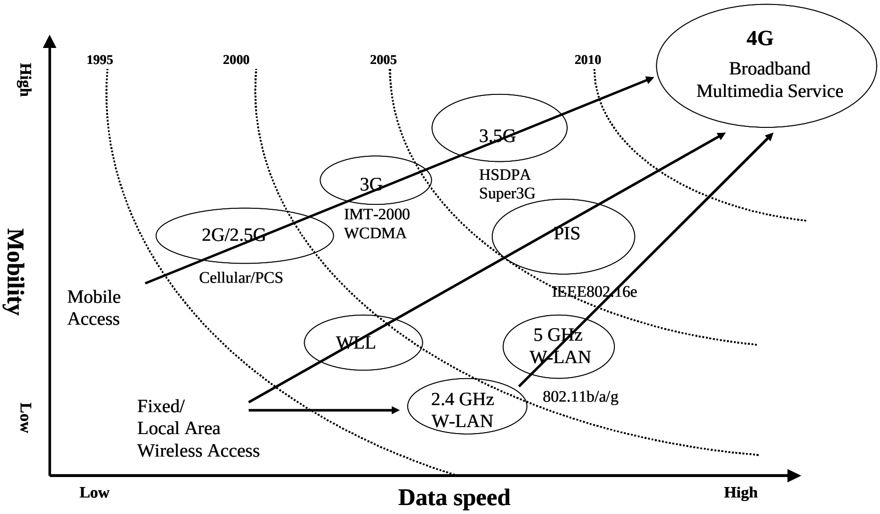

Fig. 15.2. Mobile Internet Service by Mobility and Speed. Source: ETRI

DMB provides TV and cable channels via satellite and terrestrial networks. TU Media—satellite DMB provider launched on 1 May 2005—offers 7 video and 20 audio channels from which subscribers choose at most three channels, at US$ 10 per month. Despite transmission of terrestrial broadcasting channels by the satellite DMB service being forbidden, TU Media has gained more than 300,000 subscribers in the first seven months (ETNEWS, 2 December 2005). Provided by major terrestrial broadcasting companies, terrestrial DMB services were launched as a free service on 1 December 2005. PIS is a wireless broadband (WiBro) facility that provides mobile Internet access at current wire-line broadband service (about 2Mbps) speeds. The Ministry of Information and Communication (MIC) allocated licenses to KT, SK Telecom and Hanaro Telecom in February 2005. Meanwhile, Hanaro Telecom recently withdrew from the PIS market, while SK Telecom has not commenced investment. Only KT has embarked on PIS network investment and is intending to launch commercial service in June 2006 (Korea Times, 25 April 2005). HSDPA evolved as a wireless technology that enhances EVDO and W-CDMA technology. HSDPA is more mobile than PIS but with a lower transmission speed. SK Telecom and KT Freetel will test HSDPA in 2005 and commence commercial operations in June 2006 (Digital Times, 12 July 2005).

Consumer Preference for Emerging Services

Kim (2003) considers IMT-2000 service as comprised the attributes of high-speed Internet access, video phone and global roaming in conducting a conjoint analysis to determine attribute part-worth values. Kim and Lee (2004) also use a conjoint model to develop quantitative forecasts for the market shares of emerging mobile data and broadcasting services. However, their data collection period does not allow consideration of hierarchical decision processes. Also, respondents are required to rate or rank a choice set comprised of alternative product bundles. Trade-offs by consumers between attributes in the rating or ranking of bundles implies attribute valuations (Green and Srinivasan 1990; Lilien and Rangaswamy 2002). Considering respondents are often not familiar with technical service descriptions responses may be inconsistent or invalid, viz., responses may not accurately reflect 'true' respondent preferences. Further, this lack of understanding of new emerging mobile services often dilutes the reliability of responses. For example, a market survey on consumers' intention to subscribe to PIS, conducted in April 2004 by a Korean government sponsored research institute, reports a willingness-to-pay (WTP) value that is different for respondents who intend to become PIS subscribers (prospects) and those who do not (non prospects). Surprisingly, prospects' WTP is approximately US$ 10 per month but US$ 20 per month for non-prospects.[1] This outcome shows that WTP and subscriber intention responses are not consistent. Clearly, during the experiment respondents should be assisted to better understand service concepts in terms of constituent attributes, especially for yet deployed high-tech services.

In response to the above arguments AHP methodology is employed for this study. AHP procedures assist a decision-maker to organize judgments so as to make effective decisions (Saaty 1977, 1980; Vargas 1990; Saaty and Vargas 1994). Unstructured problems are addressed by using a hierarchical decomposition which reflects a natural and flexible human thinking process (Simon 1962). While respondents in a conjoint experiment are confronted with a choice, ranking or rating task that implies an attribute trade-off, AHP develops a trade-off in the course of structuring and analyzing a series of simple reciprocal pairwise comparison matrices (Wind and Saaty 1980) and deals with stated preferences at all levels of the decision process (Javalgi et al. 1989). That is, to construct a hierarchy of goals, decision criteria, attributes and alternatives are arranged so that a complex decision problem is decomposed into manageably smaller parts. Namely, a judgment process begins in such a way that the decision criteria, attributes and alternatives are compared in relation to the elements of the next (higher) level (Saaty and Vargas 1994). Moreover, pairwise comparisons provide a measure of any inconsistency from the responses and can be used to improve the consistency of judgments. In particular, respondents are encouraged to consider alternative decision criteria. AHP provides decision-markers with an ability to integrate multi attribute consumer preference to assess the relative attractiveness of new services. AHP methods have been applied to decision making, resource allocation, marketing decisions, long-range planning, business case evaluation and credit scoring (Wind and Saaty 1980; Zahedi 1986; Javalgi et al. 1989; Davies 1994; Cho and Han 2002).

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[1] During the survey, all respondents are asked to reveal their WTP for PIS prior to deciding whether to subscribe. This procedure provides a WTP for both non-prospects and prospects.

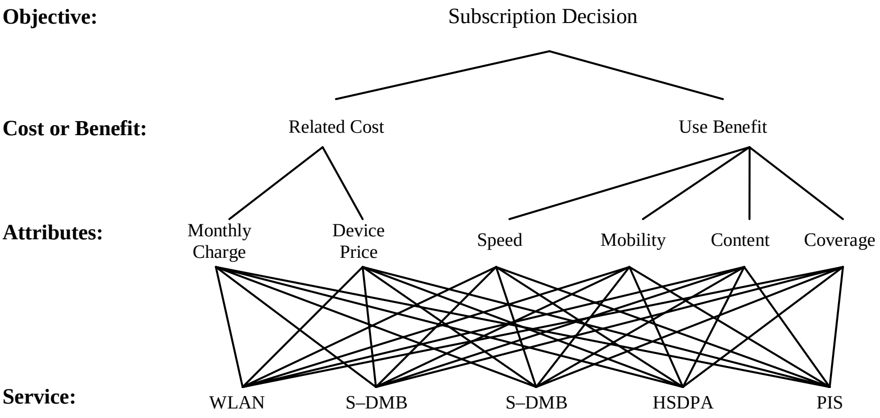

Fig. 15.3. Decision Hierarchy for Emerging Mobile Services
Note. Speed refers to transmission speed.

Hierarchical Preference Structure

A consumer decision hierarchy for new mobile services is developed in Fig. 15.3. The hierarchy is based on the cost and benefit expressed as objectives reflecting related cost and use benefit, and service attributes comprising cost- and benefit-related elements, viz., monthly subscription fee, device price, transmission speed, content, mobility and coverage. Table 15.1 shows that with little available information concerning consumer criteria for subscribing to new mobile services basic decision elements are constructed mostly as service related technical features and other commonly used attributes from received consumer surveys (Ahn 2004; Hong et al. 2004). These decision criteria are reviewed by a panel of field experts from a leading telecommunications company.

AHP Procedures

The AHP procedure consists of distinct steps: developing a decision hierarchy of the multi criteria multi attribute problem; making pairwise judgments; calculating the consistency of responses and weighting the criteria and attributes; and aggregating relative weights of decision elements to determine a set of relative preferences for the alternatives (Saaty 1980; Saaty and Vargas 1982). In Step 1, the relative contribution of related cost and use benefit on the subscription to new mobile services is evaluated. Pairwise judgments are based on a ratio from 1 to 9 —rising from equal to extreme importance. Similarly, the relative impact of a monthly charge and device price on related cost at the next level are measured. Also, the relative contribution of service features, i.e., transmission speed, mobility, content and coverage, to use benefit are measured (see questionnaire document in the Appendix). In Step 2, the relative preference for a service in terms of monthly charge and price of the respondent's favorite device are based on actual fees, rather than by comparing price pairs using the 9-point evaluative scale. Pre-test results indicate that for related cost most respondents prefer a less expensive alternative, irrespective of the price difference. Accordingly, this study assumes that for the related cost, consumer preference for a service relative to another alternative is linearly associated to the inverse of the actual price ratio between service pairs. For example, an alternative with a monthly charge of US$ 10 is coded three times preferred to an alternative with a US$ 30 monthly subscription fee.[2] Conversely, for device price respondents are required to nominate a preferred device by service. This price is treated as the device price for that service, and consumer preference for a service relative to another in terms of device price is calculated as the inverse of the actual device price ratio between service pairs.

Table 15.1. Decision Criteria and Service Attributes

<table>
<tr><th rowspan="2">Criteria</th><th colspan="5">Services</th></tr>
<tr><th>WLAN</th><th>S-DMB</th><th>T-DMB</th><th>HSDPA</th><th>PIS</th></tr>
<tr><td>Monthly charge</td><td>US$ 8
(fixed)</td><td>US$ 10
(fixed)</td><td>Free</td><td>US$ 33
(average)</td><td>US$ 25
(average)</td></tr>
<tr><td>Device price</td><td colspan="5">Cell phone: US$ 650
PDA phone: US$ 980 plus US$ 120 for an add-on module
Handheld PC: US$ 830 plus US$ 120 for an add-on module
Notebook: US$ 2,800 plus US$ 120 for an add-on module</td></tr>
<tr><td>Speed</td><td>Very high
(4 Mbps)</td><td colspan="2">HQ TV via 7 inch device</td><td>High
(2 Mbps)</td><td>Intermediate
(1 Mbps)</td></tr>
<tr><td>Mobility</td><td>Fixed or
cordless</td><td colspan="2">To 250km/h</td><td>To 100km/h</td><td>To 60km/h</td></tr>
<tr><td>Content</td><td>Wireline
Internet
content</td><td>Three
terrestrial
channels</td><td>Eleven cable
channels</td><td colspan="2">Wireless Internet content</td></tr>
<tr><td>Coverage</td><td>Hot spots</td><td colspan="2">National</td><td colspan="2">84 major cities</td></tr>
</table>

Note. US$ 1 is approximately KRW 1,000. Initial subscription fees are ignored as they are similar among services or not available. Device price is the category average based on a Korean online price comparison Web site. Two prices, device purchase and add-on module are applicable to PDA, handheld PC and notebook. Speed refers to transmission speed.

[2] For terrestrial DMB, as a free service, the related cost of terrestrial DMB is assumed always preferred to other alternatives, viz., using the 9-point evaluative scale DMB is coded nine times preferred to other alternatives for the monthly charge.

In Step 3, the relative importance of a service by feature is measured via pairwise comparison. However, when the value of a feature is identical for a pair of services then the comparison is redundant. Therefore, comparison for equivalent values is excluded, viz., the services are coded 1 for equal importance. For example, both satellite DMB (S-DMB) and terrestrial DMB (T-DMB) have an identical national service coverage feature. In Step 4, a respondent's consistency is evaluated at all levels of the hierarchy using an eigenvalue method.[3] In Step 5, when the consistency ratio (CR) is less than 0.2 responses, a respondent is included in the sample.[4] In Step 6, a combined group judgment (CGJ) is used to aggregate individual judgments by calculating the geometric average for relative importance or preference judgment values across all respondents. The resulting comparison matrix of CGJ scores is then used to derive priority values (Davies 1994). Finally, in Step 7, a composite priority of the element within a level and relative preference for alternative services is derived by applying the eigenvalue method to the CGJ obtained in Step 6.

Results

Following Step 1 to Step 4, data for the study is obtained from a face-to-face survey conducted in September 2004 from a sample of 650 respondents (see the questionnaire document). Stratified sampling is implemented by demographic strata, e.g., respondent age, gender and residential location, based on Korean year 2000 census data. The survey is conducted in six cities for respondents aged from 14 to 50 years. Respondents are solicited on the street, primarily in downtown areas on an understanding that US$ 20-US$ 30 is to be paid in compensation. The computer software package *Expert Choice* (Forman and Saaty 1983) is used to validate respondent consistency for a particular level of the hierarchy in Step 5. Among the 650 survey respondents, 110 are selected based on consistency index analysis, i.e., the respondents have a $\mathrm{CR} \le 0.2$.[5] Step 6 requires that the 110 consistent respondents be aggregated via a geometric mean resulting in a comparison matrix for every hierarchy level. For example, Table 15.2 shows aggregated pairwise judgments comparing related cost and use benefit for subscription to new

[3] Pairwise comparison data are collected and entered as reciprocals with n unit entries on the main diagonal in a comparison matrix (A). The eigenvalue problem $Aw = \lambda \max w$ is solved for a vector w that denotes attribute priority (Wind and Saaty 1980). The consistency index of a matrix of comparison is calculated by the rule, $\mathrm{CI} = (\lambda \max - n)/(n-1)$, and the consistency ratio is obtained by comparing CI with the average random consistency index (Saaty and Vargas 1994).

[4] Judgments whose CR is lower than 0.1 are reasonable, lower than 0.2 is tolerable and higher than 0.2 should be revised or discarded (Saaty 1980).

[5] The reason for the small number of consistent respondents is explained by the respondents' lack of clear understanding of concepts of new mobile services or not being expert and so unable to make considered choices or both.

mobile services.[6] Table 15.3 and Table 15.4 list combined group judgments for service attributes for the related cost and use benefit, respectively.

Table 15.2. Combined Group Judgment with Respect to Overall Goal

	Related cost	Use benefit
Related cost	1	1.27
Use benefit	1/1.27	1

Table 15.3. Combined Group Judgment with Respect to Related Cost

	Monthly charge	Device price
Monthly charge	1	1.15
Device price	1/1.15	1

Table 15.4. Combined Group Judgment with Respect to Use Benefit

	Speed	Content	Mobility	Coverage
Speed	1	1.36	1.37	1/1.04
Content	1/1.36	1	1/1.29	1/1.48
Mobility	1/1.37	1.29	1	1/1.26
Coverage	1.04	1.48	1.26	1

Note. Speed refers to transmission speed

Following Step 7, *Expert Choice* is used to calculate local priorities for an element along with global priorities at a particular level of the hierarchy, and is shown in Table 15.5. Local priorities for related cost and use benefit are rescaled so that the highest value for criterion is set to unity with the remaining values transformed proportionately.[7] For example, local priorities for the monthly charge and device price are 0.535 and 0.465, respectively. Since the weight for the monthly charge is higher it is set at unity and the weight for the device price is 0.869, i.e., 0.465/0.535. Also, composite global priorities are calculated by multiplying local priorities at a level by the weight at the next level. For example, 0.487, a global

[6] 1.27 means that related cost is 1.27 times more important than use benefit, whereas 1/1.27 has the opposite meaning.

[7] This absolute priority determination method is applied when the number of features across a criterion at the same level of the hierarchy is disproportionate to control the size effects of the features under a criterion of the global priorities. For example, this procedure would apply when the number of features in the use benefit criterion is four and the number for the related cost is two. Since the local priorities under relative priority determination are reduced proportionately by the number of sub criteria, the effect of the sub-criteria under the use benefit of the global priorities is reduced to half of that under absolute priority determination.

priority for the device price is derived by multiplying 0.869 (local priority) by 0.560 (weight for related cost). Based on priority results contained in Table 15.5, related cost is slightly more important than use benefit while the most important criterion affecting new mobile service subscription is the monthly charge which is in line with the findings reported by Lee (2004). For use benefit, transmission speed has the highest priority. This finding is also consistent with Lee's (2004) results. Service coverage is also perceived important and suggests that consumers expect their mobile data or broadcasting service use may fluctuate by location and time. Finally, mobility and available content features are relatively less important.

Table 15.5. Local and Global Priority by Feature

Criteria	Sub criteria	Local priority	Global priority	Overall rank
Related cost (0.560)	Monthly charge	1	0.560	1
	Device price	0.869	0.487	2
Use benefit (0.440)	Speed	1	0.440	3
	Content	0.667	0.293	6
	Mobility	0.787	0.346	5
	Coverage	0.979	0.431	4

Note. Speed refers to transmission speed

The attractiveness of mobile data and broadcasting services regarding their cost- and benefit-related features are illustrated in Table 15.6 and Table 15.7, respectively. Also, global priorities for mobile service by feature are contained in Table 15.8. Finally, overall mobile service priorities are listed in Fig. 15.8. The reported priority sequence is T-DMB, S-DMB, WLAN, HSDPA and PIS. That is, T-DMB performance dominates in all service features and importantly it is provided for free. Also, S-DMB has an advantage over other mobile Internet services suggesting that DMB services may gain higher penetration rates than mobile Internet services. Further, only small differences in global priorities among WLAN, HSDPA and PIS are reported.

Table 15.6. Attractiveness of Mobile Service by Related Cost

Sub criteria	Alternative	Weight
Monthly change	WLAN	0.122
	S-DMB	0.104
	T-DMB	0.683
	HSDPA	0.041
	PIS	0.050
Device price	WLAN	0.202
	S-DMB	0.205
	T-DMB	0.205
	HSDPA	0.205
	PIS	0.193

Table 15.7. Attractiveness of Mobile Service by Use Benefit

Sub criteria	Alternative	Weight
Speed	WLAN	0.252
	S-DMB	0.249
	T-DMB	0.249
	HSDPA	0.155
	PIS	0.095
Content	WLAN	0.217
	S-DMB	0.189
	T-DMB	0.198
	HSDPA	0.198
	PIS	0.198
Mobility	WLAN	0.135
	S-DMB	0.231
	T-DMB	0.231
	HSDPA	0.238
	PIS	0.165
Coverage	WLAN	0.064
	S-DMB	0.337
	T-DMB	0.337
	HSDPA	0.131
	PIS	0.131

Note. Speed refers to transmission speed

Finally, comparison of PIS and HSDPA by service feature reveals that the monthly charge provides a small advantage for PIS and suggests that to gain competitive advantage PIS providers should improve transmission speed and mobility capability to at least equal HSDPA. Further, it is arguable that under an expectation that HSDPA providers will reduce their monthly charge the current PIS price advantage will not remain.

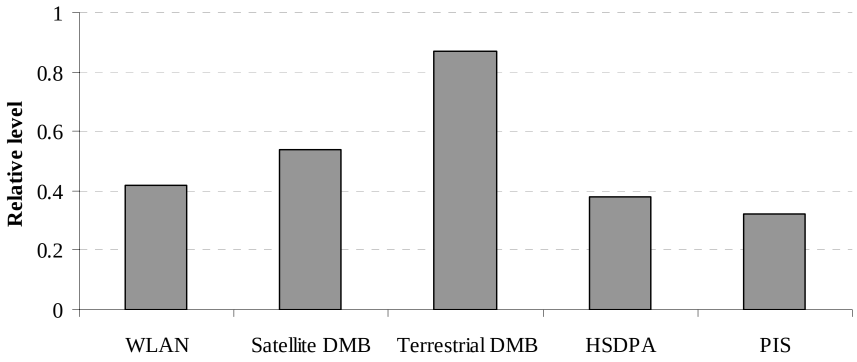

Fig. 15.4. Overall Mobile Service Priority

Table 15.8. Global Priority of Mobile Service by Feature

Level 1	Level 2	Level 3	Level 4	
Mobile service subscription (1.000)	Related cost (0.560)	Monthly charge (0.560)	WLAN	0.068
			S-DMB	0.058
			T-DMB	0.382
			HSDPA	0.024
			PIS	0.028
		Device price (0.487)	WLAN	0.098
			S-DMB	0.100
			T-DMB	0.100
			HSDPA	0.095
			PIS	0.094
	Use benefit (0.440)	Speed (0.440)	WLAN	0.111
			S-DMB	0.110
			T-DMB	0.110
			HSDPA	0.068
			PIS	0.042
		Content (0.293)	WLAN	0.064
			S-DMB	0.055
			T-DMB	0.058
			HSDPA	0.058
			PIS	0.058
		Mobility (0.346)	WLAN	0.047
			S-DMB	0.080
			T-DMB	0.080
			HSDPA	0.082
			PIS	0.057
		Coverage (0.431)	WLAN	0.028
			S-DMB	0.145
			T-DMB	0.145
			HSDPA	0.056
			PIS	0.056

Note. Speed refers to transmission speed

Conclusions

Using the AHP procedure this study derives relative weights for decision criteria and relative preferences for emerging Korean mobile services. The conclusion is threefold. First, the complex decision of whether to subscribe to new mobile services is decomposed into a hierarchy of interrelated decision elements. In particular, following the AHP procedure, respondents are encouraged to reveal their subscription intentions for new mobile services by comparing pairs of elements by decision criteria. Also, to improve the consistency of respondent's judgments a measure of response inconsistency is applied to obtain relative weights by decision element using the eigenvalue method. While it is possible to assign weights directly to an element at a particular level, such direct assignment of weights is too abstract for an evaluator and results in inaccuracy (Zahedi 1986). Second, results from the analysis indicate that the economic costs associated with new mobile service use are perceived more important to subscription than any corresponding benefits. Also, reported is that the monthly charge is more important among cost features and transmission speed and service coverage are the more important features among use benefits. This concern about the national service coverage is shared by managers of mobile service companies. Managers believe that limited coverage will inhibit new mobile service adoption. Third, to successfully introduce PIS service the results suggest—from the perspective of technical performance—that the transmission speed which is relatively slow must be improved. This is especially the case considering that WLAN has an enhanced transmission speed of up to 54Mbps. Also, as T-DMB service is identified as the most preferred mobile service there is some merit in PIS providers offering bundled services with DMB focusing on the broadcasting and PIS on mobile Internet service. This scenario makes possible that bundled services complement one another, viz., a PIS provider can accelerate market penetration in the beginning and eventually preempt the market.

To conclude, several areas that warrant further analysis are identified. First, this study constructs the subscription decision for a new mobile service via AHP procedures through the consideration of two cost-related and four benefit-related service features. However, there is a methodological objection to the approach taken, viz., it is reasonable that attributes employed in a decision problem are not provided to the respondent a priori—the attributes should be chosen by the decision maker (Keeney 1981). Therefore, a potentially better model would arise from allowing respondents to search from a set of attributes to indicate the attributes that are most relevant. Such a procedure is likely to increase the accuracy of the estimated weights and reduce reported inconsistency. Second, the geometric average of individual distinct judgment values is used. Therefore the combined overall service priority may not accurately represent true consumer preferences. Accordingly, aggregation methods can be used to construct a combined group comparison matrix. For example, combining segments can average out effects. Third, potential discrepancy between customers' preference and actual subscription are not distinguished in this study. In a further study it would be possible to improve PIS and other emerging mobile service demand forecasts by considering the gap between respondent subscription intentions and actual behavior. Finally, as customer preference and subscription intention require evaluation by other market research methods for the purpose of comparison conjoint methods are a likely candidate for consideration.

Appendix: AHP Questionnaire

The following are related cost and use benefit questions for mobile data and broadcasting services.

► **Related cost**: monthly charge, device price

► **Use benefit**: access to wireline broadband Internet service, wireless Internet and contents, mobile broadcasting services

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities considered equally important
3	Moderate importance of one over another	One activity is marginally favored over another
5	Essential or strong importance	One activity is strongly favored over another
7	Very strong importance	One activity is very strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order
2, 4, 6, 8		Intermediate values between two adjacent judgments

Q1. Compare the relative importance with respect to the subscription of new mobile services

Evaluation criterion	Numerical scale	Evaluation criterion
Related cost	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Use benefit

Q2. Compare the relative importance with respect to related cost

Evaluation criterion	Numerical scale	Evaluation criterion
Monthly charge	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Device price

► **Transmission speed**: Average transmission speed of services (e.g., Mbps)

► **Contents**: Applications subscribers are actually using (e.g., email, search

► **Mobility:** Maximum speed of vehicles where subscribers are able to use services without any interruption (e.g., if a certain service is available in a car, then its mobility is up to about 100km/h)

► **Coverage:** Areas where services are available (e.g., hotspots, indoors, nationwide, etc.)

Q3. Compare the relative importance with respect to use benefit		
Evaluation criterion	Numerical Scale	Evaluation Criterion
Transmission Speed	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Contents
Transmission Speed	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Mobility
Transmission Speed	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Coverage
Contents	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Mobility
Contents	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Coverage
Mobility	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Coverage

The following questions concern devices.

Q4. Mark all devices that you own now					
					
Devices	① Smart phone	② PDA phone	③ Handheld PC	④ Notebook	⑤ DMB device (vehicles only)

Q5. Choose one device you are most likely to use with each service. (Note: add-on modules are available only when you have owned the device for which you are to add on module.)

Devices	Smart phone	PDA phone		Handheld PC		Notebook		DMB device (vehicle only)
	New purchase	Add-on module	New purchase	Add-on module	New purchase	Add-on module	New purchase	New purchase
WLAN	①	②	③	④	⑤	⑥	⑦	-
Terres-trial DMB	①	②	③	④	⑤	⑥	⑦	⑧
Satellite DMB	①	②	③	④	⑤	⑥	⑦	⑧
HSDPA	①	②	③	-	-	-	-	-
PIS	①	②	③	④	⑤	⑥	⑦	-

The following questions concern use benefits from mobile data and broadcasting services. Transmission speeds are those currently available.

► **Transmission speed of some telecommunications services**

- Broadband Internet access with ADSL technology: 1 Mbps
- Broadband Internet access with VDSL technology: 4 Mbps
- WLAN: 4 Mbps

Q6. Compare the relative importance with respect to transmission speed

Evaluation criterion	Numerical Scale	Evaluation criterion
Data transmission Intermediate (1 Mbps)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Data transmission High (2 Mbps)
Data transmission Intermediate (1 Mbps)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Data transmission Very high (4 Mbps)
Data transmission Intermediate (1 Mbps)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Broadcast transmission Moderately high enough to watch TV channels via 7 inch device
Data transmission High (2 Mbps)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Data transmission Very high (4 Mbps)
Data transmission High (2 Mbps)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Broadcasting transmission Moderately high enough to watch TV channels via 7 inch device
Data transmission Very high (4 Mbps)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Broadcasting transmission Moderately high enough to watch TV channels via 7 inch device

Q7. Compare the relative preference with respect to contents

Evaluation criterion	Numerical scale	Evaluation criterion
Wireline Internet Contents	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	3 terrestrial TV Channels
Wireline Internet Contents	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	11 cable TV channels (excluding terrestrial)
Wireline Internet Contents	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Wireless Internet contents
3 terrestrial TV Channels	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	11 cable TV channels (excluding terrestrial)
3 terrestrial TV Channels	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Wireless Internet contents
11 cable TV Channels (excluding terrestrial)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Wireless Internet contents

Q8. Compare the relative preference with respect to mobility		
Evaluation criterion	Numerical scale	Evaluation criterion
Fixed or cordless	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Moderate (up to 60km/h)
Fixed or cordless	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	High (up to 100km/h)
Fixed or cordless	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Very high (up to 250km/h)
Moderate (up to 60km/h)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	High (up to 100km/h)
Moderate (up to 60km/h)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	High (up to 100km/h)
High (up to 100km/h)	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Very high (up to 250km/h)

Q9. Compare the relative preference with respect to coverage		
Evaluation criterion	Numerical scale	Evaluation criterion
Hotspots	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	84 major cities
Hotspots	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Nationwide
84 major cities	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Nationwide

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16 An International SME E-marketplace Networking Model

Jaechon Park and Jemin Yang

Introduction

E-trade is an emerging paradigm that concerns trade in services such as marketing, consulting, contracting, procurement, transportation, customs clearance and settlements in real-time. Naturally, e-trade has become an issue of contention at recent FTA negotiations. A principle of e-trade is that small and medium enterprises (SMEs) are able to enter foreign markets on the same basis as large corporations. However, SMEs typically lack the skilled workforce with necessary expertise and infrastructure to take full advantage of opportunities provided by e-trade. Additionally, SMEs are disadvantaged through their less stable international trading channels, smaller purchasing power and lack of international credibility. Therefore, e-trade adoption is primarily occurring through collaboration with e-trade intermediaries.[1] Accordingly, the Asia Pacific Economic Cooperation (APEC) encouraged the promotion of SME trade via collaboration with international e-marketplaces. The *APEC Global B2B Interoperability Project* (the Project) commenced through a pilot study that ran from 2002 through 2004 (AOEMA 2001). The goal of this APEC collaboration is not only to guarantee the survival of e-marketplaces per se but to enhance SME trade by building their networks in international e-marketplaces. This study analyzes the Project in terms of technical and business implementation, and examines the suitability of the Project as a new business model.

Background

Steinfield (2002) notes that potential corporate benefit from conducting e-trade include the reduction of costs, product differentiation via high value-added services, improved trust and the geographic expansion of product markets. Further, Steinfield et al. (2001) argue that SMEs stand to gain relatively more than large enterprises through the elimination of inefficiency and cost reductions related to ordering and buyer risk. Additionally, Mauboussin and Hiler (1998), and Moon and Lee (2002) emphasize that SMEs adapt better to market changes and so employ e-business applications more effectively—including e-trade. However, the effective

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[1] E-transformation is a transition process whereby SMEs migrate from traditional business processes and move management activity to cyberspace to become virtual companies using and sharing information based on information solutions via the Internet.

use of Web marketing and trade automation requires an established base of expertise and experience (Choi 2004). As e-trade by its nature implies large scale and high-risk transactions, an institutional framework to promote mutual trust among partners is a necessity (DiMaggio and Louch 1998). Intermediaries can act as an independent third party to fulfill this role and promote e-trade. Intermediaries connect buyers and sellers to reduce barriers that arise from spatial and cultural difference. E-marketplaces are online markets where agents transact using communications networks (Moore et al. 2000). That is, product information to assist with purchasing and selling decisions is provided digitally (Simba Information 1999). Furthermore, e-marketplaces ensure seamless processes between buyers and sellers. With many marketplaces being established competition to gain customers and develop innovative business models is fierce (Moore et al. 2000). An important challenge facing e-marketplaces is how to attract and retain a critical mass of buyers and sellers. Other challenges include securing a base of products to trade, increasing brand awareness, providing timely access to markets and reducing costs (Gens 1999). To meet these challenges requires the provision of high-profit and low-cost solutions, convenient and high-value added services, improved market accessibility and secure and reliable services and solutions (Silva 1999; Moore et al. 2000).

Within this environment APEC initiated the Project to promote SME international trade by providing a conduit to link them to e-marketplaces and assist in developing new business models. The Project is consistent with APEC's mission to establish an Asia-Pacific economic community via a short term goal of promoting regional trade with the liberalization of trade and investment a long term goal. Namely, APEC's intention is to promote the economic advance of Member Countries by regional trade. APEC recognizes the importance of e-trade in achieving these goals and has promoted discussion and cooperation among Member Countries since the Vancouver Summit Meeting in 1997. The establishment of the APEC Electronic Commerce Task Force to develop e-commerce related plans is an early response. The Task Force's initial themes are trust in information systems and electronic transactions, access to information infrastructure, e-commerce promotion and facilitation, international regulatory environment enhancement and improved government and business relationships. Subsequent themes include the establishment of principles to promote e-commerce in the APEC region with a focus on the private sector, and in particular SMEs. The Malaysian APEC meeting held in 1998 founded the Electronic Commerce Steering Group. The Steering Group supports e-commerce related activity and the implementation of the action plans set forth in the APEC Blueprint for Action on Electronic Commerce. The Steering Group emphasizes the informatization of SMEs and deals with e-commerce and SME issues in a parallel manner. The Project is significant in that it promotes economic exchange among Member Countries by supporting SME entry into e-commerce markets (Lee 2001).[2]

[2] http://www.apec.org/apec/documents_reports/electronic_commerce_steering_group/pastmeetings.html

Technology

E-marketplaces that are separate entities have a lesser capacity to share information. To deal with these capability constraints requires a solution that manages information in an integrated manner, such as an electronic information repository (Hazzah 1989). A repository is similar to an encyclopedia that contains business planning, modeling and design specification information. That is, an integrated storage space that links different models and promotes information sharing (McGaughey and Gibson 1993; Tannenbaum 1994; Hefner 2000). Standardized business document exchange systems create a unified interface for interoperability and interconnection, while ebXML assists e-commerce partners with the exchange of messages between different business systems (Cho 2004). Therefore, ebXML not only promotes business automation and improves system efficiency but is also useful for B2B trading—which includes process design, information search, negotiation and document exchange (Patil and Newcomer 2003). The APEC ebXML Working Group deals with registry and repository (RegRep) technology for next generation online commerce. RegRep is a standard to register and search metadata related to business processes, partner profiles and contract relations. To link e-marketplaces applications among enterprises must be integrated. Web Service integrates applications more quickly and in a less costly manner than hardware replacement or software integration. When an e-marketplace introduces Web Service only directly related applications are changed to enable interoperability (Ahn et al. 2005). This feature means that Web Service aids communications among customers, suppliers, partners and e-marketplaces via the Internet, thus enabling B2B integration. To sum, repository, ebXML and Web Service are essential technology to link e-marketplaces, provide system interoperability and integrate applications.

APEC Global B2B Interoperability Project

The Project is being undertaken by organizations comprised of government agencies, private organizations and e-marketplaces located in Australia, Hong Kong, Japan, Korea, Malaysia, Singapore and Taiwan for the period 2002 to 2004. The Project is designed to implement international B2B networking specifications and systems, construct online business networks and promote SME regional trade. Further, the pilot project laid the long term foundation for back-end trade automation and front-end transactions generation processes (MIC 2004). In doing so international cooperation is promoted, SME international competitiveness improved and effective online business network infrastructure built. Both horizontal and vertical e-marketplaces are addressed as they have different business processes. Vertical markets specialize in computers, electronics, chemicals, steel products and automobiles that are manufactured from raw materials through to finished goods. Vertical e-marketplaces serve as an intermediary for member corporations. Conversely, horizontal e-marketplaces are not limited to a particular industry and deal with products on a cross-industry basis and include maintenance, repair and operation (MRO) services. Horizontal e-marketplaces typically are agents not intermediaries. To summarize, vertical e-marketplaces connect buyers and suppliers while horizontal marketplaces respond to requests from buyers, negotiate terms with suppliers and send orders to sellers. These market structures indicate that vertical e-marketplaces only link to other vertical marketplaces, while horizontal e-marketplaces connect only to other horizontal marketplaces. However, in the Project the same technology is applied to both networks. A repository system is used to connect e-marketplaces to assist in the storage and sharing of information, and in the improvement of business processes. The repository system is a model based on a client-server relationship that assists an e-marketplace to share, process and provide information. This type of networking is important as it is an international B2B trading application.

Repository System Architecture

A repository system is comprised of the repository, repository client (RC) and marketplace client (MC). A repository stores information on the marketplace profile, marketplace agreement, enterprise profile, catalog index, schema documents and dictionary. An RC registers e-marketplace information, product summaries and searches for (and exchanges) summary information from other e-marketplaces. Finally, an MC searches for detailed information concerning e-marketplaces and deals with standard business processes to enable trading among e-marketplaces. That is, the system has a repository where basic information is stored, an RC is a starting point for networking by registering and searching for e-marketplace information, and an MC that assists e-marketplaces deal with business process. This basic system is shown in Fig. 16.1. To build such a repository system requires information space and interface. The information space is the repository while an interface is a registry. Management features such as registering, changing and deleting information within the e-marketplaces are provided by the MC and RC. The registry and repository are spaces for information that store and manage information shared among e-marketplaces such as product information, company profiles, contract information, mapping information for code discrepancy and provide e-marketplaces with an access to information. In short, a repository stores real data to be shared, while a registry stores and manages meta-data in a repository. Information within an e-marketplace, such as product and company profile information are stored in a repository and shared via an RC and then used for searching for summary material. An MC provides detailed information based on the summary information and facilitates standard business process. The use of an RC and MC is based on Web Service. With Web Service e-marketplaces exchange information across heterogeneous computing environments. Additionally, even when multiple repositories are provided e-marketplaces can share information contained therein.

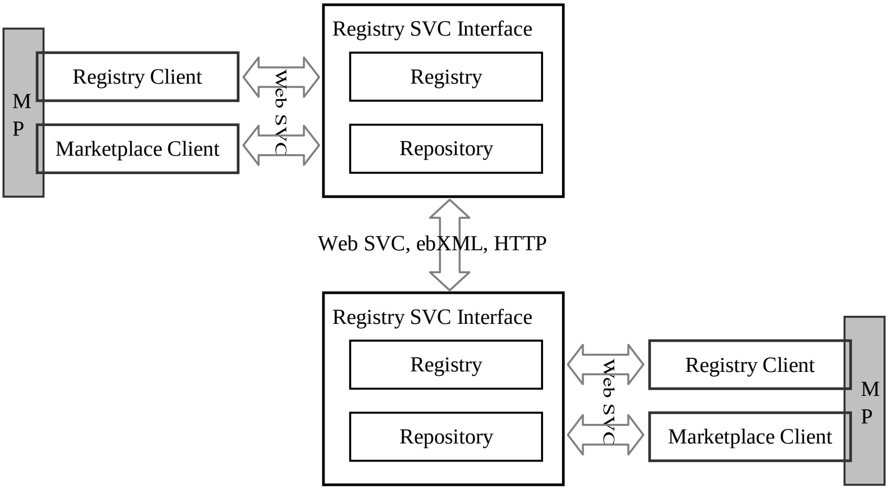

Fig. 16.1. Basic Repository System Architecture

The RC separates the e-marketplace system from the networking system to enable efficient development. As service is requested only via the RC this facility provides security across marketplaces and the repository. With an RC connecting a repository to an e-marketplace—the client-server model—e-marketplaces (Client) register, change and delete information in a repository (Server) without any system change. Operationally the RC provides application connectivity for e-marketplace networking and supports reliable message exchange among enterprises utilizing the message service specification (MSS) of ebXML. MSS defines message sending- and receiving-module behavior to provide format, security and reliability. ebXML is a standard for international trading based on repository systems. Inter-standard conversion and Web Service are introduced to complement ebXML and enable interoperability among e-marketplaces operating with different systems. A repository system based on ebXML and Web Service overcomes XML/EDI limitations and provides a next generation interoperability standard.

Business Process Networking

An e-marketplace records member and product information, and conducts business processes. Buyer and seller information enables network transactions. When an e-marketplace exchanges information across an industry or nation trading is facilitated. Also, product information such as price, delivery method and brand when provided enhance the likelihood of trade. Therefore, e-marketplace information sharing improves competitiveness. Information obtained from e-marketplaces is scanned by potential buyers and suppliers via the RC and MC prior to quotation and order phases. A unique feature of this process is that potential buyers and sellers are not aware that they are searching across e-marketplaces. In the quotation phase buyers send order information via an e-marketplace to decide on product price and quantity, while sellers receive and confirm this information. This process includes quotation request, quotation negotiation request, quotation change request and final quotation. In the ordering process terms of payment, transportation, delivery method, and delivery deadline are defined. The process includes purchase order distribution, ordering, sales proposal, order change request, order cancellation, order status questions and order status distribution. All quotation requests and ordering steps are performed by an MC. Front-end steps, such as information sharing and search, estimation, and ordering are processed online. In the Project back-end processes, such as payment, delivery, transportation, claim and logistics are conducted offline. Notably, the repository system architecture supports both front- and back-end processes thus laying a foundation for online process expansion.

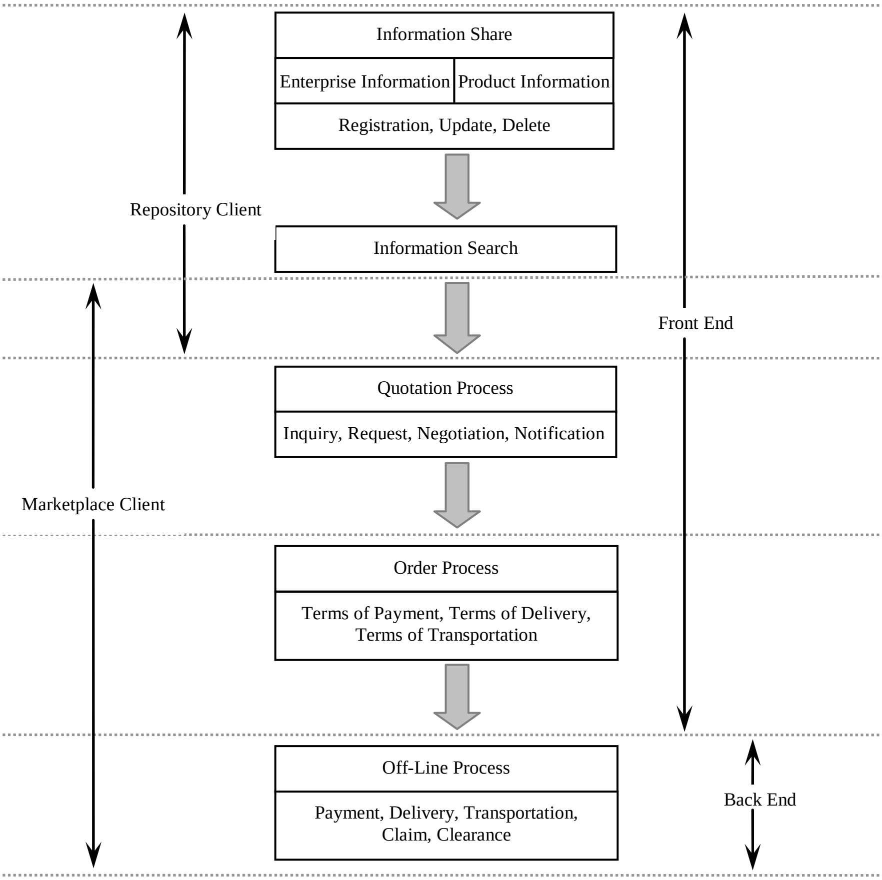

Fig. 16.2. Repository System Business Process

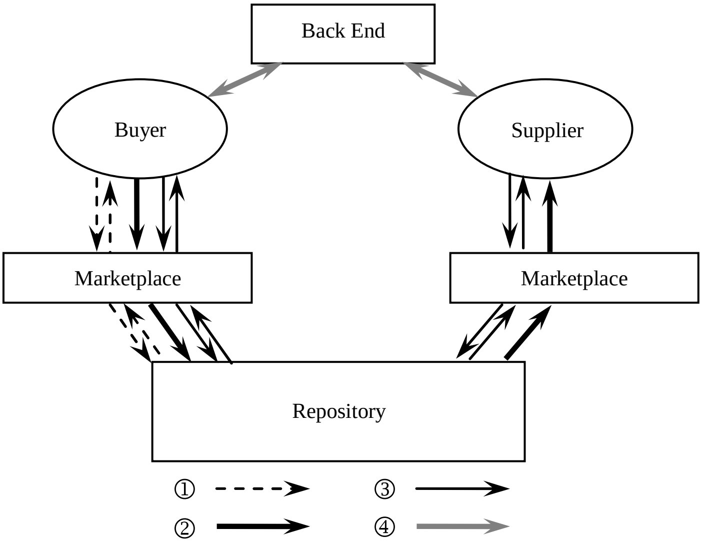

Fig. 16.3. Repository System Information Flows

Fig. 16.3 shows business process flows, in particular information flows among buyers and sellers via e-marketplaces, and third party back-end organizations payment, delivery and customs clearances. To promote such information flows e-marketplaces should prepare and negotiate terms. That is, make agreements on business terms and for the linking of e-marketplaces. This process requires that business needs are well defined, partner e-marketplaces selected, information on partner e-marketplace collected and memorandums of understanding (MOU) closed. Scope of repository system use, e-marketplace roles, business processes, networking scope, offline delivery connection, customs clearance and payment require negotiation. When e-marketplaces are connected trading activity begins by the processes:

(1) Buyers search e-marketplace product catalogues provided by sellers. Buyers obtain product information from a repository that collects information across e-marketplaces;

(2) Merchandisers from buyers purchase products via a shopping cart and initiate quotation through negotiation processes. Buyers create and send quotation requests and negotiation documents to sellers. Documents are transferred to sellers in other e-marketplace via the repository;[3]

(3) When buyers and sellers agree, the buyer issues an order based on quoted information to the seller via a repository while the seller accepts the order.

[3] In general, vertical e-marketplace merchants are from buying or selling companies while horizontal e-marketplaces act as agents for buyers and sellers.

Numerous quotation and order statements are mapped in both e-marketplaces where the buyer and seller reside to provide consistency; and

(4) After order processing the buyer makes payment via a settlement organization within the e-marketplace and the seller delivers products via a transportation company within the e-marketplace. Post order steps are conducted off-line.

Project Evaluation

The Project is based on a repository system that promotes collaboration by providing storage space, document standards and Web Service to connect heterogeneous e-marketplaces. This technology allows the storage and sharing of information concerning marketplace profile and agreements, enterprise profile, catalog index, schema documents and dictionaries. A federal query (or structure) is implemented to connect repositories thus providing flexibility and scalability. Additionally, RC and MC are introduced as interfaces to use information in the repository by offering search features and interoperability among systems.[4] The repository system uses ebXML to define modules such as business process specification schema, collaboration protocol profile, registry and message service to provide a repository infrastructure. Also, conversion or mapping allows compatibility among international standards to assist with document exchange. This feature means that e-marketplaces transact without document conversion.[5] Standard business processes are also developed to reflect process that is unique to particular e-marketplaces. Standard processes are stored in a library for later expansion. Message exchange and business process mapping via repositories are supported by ebXML. Web Service and metadata are also uniquely utilized. Web Service complements ebXML and serves as a means to process information among a repository and e-marketplaces. Further, product and company information within e-marketplaces is processed into metadata—making the management and search for information more efficient. To connect e-marketplaces different processes and information need to be managed effectively. What is unique about the pilot study is that a new standard is created to allow inter-standard communication. That is, while e-marketplaces maintain their peculiar standards and processes—different data types are used in parallel.

With a goal of the Project to promote international SME trade by networking e-marketplaces potential business benefit is considered to evaluate the project. Table 16.1 lists Project achievements for both vertically- and horizontally-integrated e-marketplaces.

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[4] For the pilot project a single Korean repository is built as only a few e-marketplaces participated. However, should many e-marketplaces connect other repositories will be needed to provide equality and reduce time and cost.

[5] Standard specifications for e-marketplaces in the APEC project were ebXML, RosettaNET, xCBL, OAGIS, cXML and UBL.

Table 16.1. Pilot Project Results

Criteria	Repository system Vertical e-marketplace 2003	2004	Horizontal e-marketplace 2003	2004
Dominant product traded	Steel and nonferrous metal		MRO	
E-marketplace shares EPP	300	380	991	2,210
E-marketplace shares catalogue	1,000	1, 100	2,047	16,827
Transactions	20	40	-	-
Valid transactions	9	28	5,696	4,724
Real value	US$ 5.6m	US$ 22.4m	US$ 4.8m	US$ 4.2m

Source: MIC (2004)

In 2003 China, Korea and Taiwan constructed vertical e-marketplace repository systems. By 2004 EPP and catalogue information expanded to increase the volume of trade negotiations and transactions. These initiatives led to a trading volume increase in real terms in 2004 of 300%. Horizontal e-marketplaces in China, Japan, Korea, Malaysia, Singapore and Taiwan concluded an MOU and worked toward networking. These horizontal e-marketplaces shared more information and increased transactions more than APEC vertical marketplaces. However, the horizontal marketplace trading volume in real terms is lower. A reason for this outcome is that vertical e-marketplaces focus on the steel industry where trading volumes are large and product prices high, whereas horizontal marketplaces trade MRO products. Even though information sharing among horizontal e-marketplaces substantially increased during 2004, both the number of transactions and trading volume decreased by 14%. This poor result is attributed to Chinese companies diversifying their supply channels. Additionally, this horizontal e-marketplace trading decrease is explained by companies searching for products online but purchasing offline in an MRO market (Kang 2002). As companies become familiar with e-trading initial product searches are being made in an e-marketplace while offline contact is made with suppliers. Therefore, horizontal e-marketplace networking success is best measured by the level of e-marketplace participation in networking catalogues or EPP sharing, and not reported trading volume. Table 16.1 shows that EPP and catalogue sharing among horizontal e-marketplaces increased sharply by 123% and 722%, respectively.

Table 16.2 provides a comparison of networked e-marketplace and independent intermediary success for 2003–2004. An independent intermediary is an independent vertical or horizontal e-marketplace that does not participate in e-marketplace networking.

Table 16.2. Networked E-marketplace and Independent Intermediary, Korea

Criteria	Networked e-marketplace				Independent intermediary			
	Vertical		Horizontal		Vertical		Horizontals	
	2003	2004	2003	2004	2003	2004	2003	2004
Product	Steel/nonferrous metal		MRO		Steel/nonferrous metal		MRO	
Volume	560	2,240	480	420	38,500	142,583	106,750	259,083
Average	93	187	80	35	2,139	3,960	2,224	2,816
Growth	-	101%	-	– 44%	-	85%	-	27%

Note. Volume is trading volume, Average is average quarterly Volume, Growth is Average quarterly growth. 1,200 won to US$ 1, Volume unit is US$ 10,000, 2003 is 3rd and 4th quarter performance. Source: Korea National Statistics Office

Korea conducted a trade automation project to create a best practice e-trading infrastructure. Korea is also involved in several international e-trading projects, viz., Pan Asian e-commerce Alliance, Korea-Japan Trade Automation Project and Korea-ASEM Trade Automation Project. Importantly, Korea developed an independent intermediary e-trading model. Given Korea's leading role it is interesting to compare networked marketplace and independent intermediary performance. Table 16.3 shows that independent intermediaries perform better. In vertical e-marketplaces, independent intermediaries realize 23 and 21 times more volume than networked e-marketplaces. Horizontal marketplace volumes increased by a scale of 28 in 2003 and 80 in 2004. These results are attributed to e-marketplace networking being in its infancy while the APEC pilot project focused on developing business models and completing networking processes—not generating improved trading performance per se. Therefore, performance oriented strategy including marketing campaigns should boost trade performance. However, quarterly average trading volume for networked vertical e-marketplaces doubled in 2004. Also, the annual growth rate of networked e-marketplaces is higher than for independent intermediaries, which suggests that e-marketplace networking is potentially an e-trading business models especially when more e-marketplaces participate.

Silva (1999) and Moore et al. (2000) list factors that improve e-marketplace performance. First, as e-marketplaces become established in most industries competition is more intense. This competitive pressure means that e-marketplace capability should be strengthened to increase profits. Capability depends on the volume of information collected as e-marketplaces serve an intermediary function. In this regard, a critical factor to improve e-marketplace performance is the attraction of buyers, sellers and products. Second, e-marketplace flexibility must be enhanced to be more customer orientated. Additional service network and innovative solutions must also be developed to entice customers to trade via e-markets, and so reduce transaction costs. Third, customers demand more information to assist their product searches from e-marketplaces. This demand requires an accessibility to realize e-marketplace transaction volume increases. Fourth, trust among e-marketplace agents needs to further improve. Currently, e-marketplaces provide trading intermediation, procurement, delivery, settlement and inventory management services. Therefore, trust in e-marketplace business models is critical to success. Table 16.3 lists e-marketplace performance factors applied during the APEC project.

Table 16.3. e-Marketplace Performance Factors, 2004

Factor	Networking	
	Vertical	Horizontal
Network size	380 enterprises	2,210 enterprises
Shared product catalogue	1,100 catalogues	16,827 catalogues
Service network	Business model solves international e-trade time, space and cost barriers via e-marketplace networks	
Customer access	Expands include to international markets	
Reliability	Based on collaboration among nations	

In terms of network performance size metrics networked e-marketplaces only attracted 380 partners and 1,100 catalogues for vertical and horizontal networks, respectively, which is much less than for extant independent intermediaries. EC21, an independent intermediary, alone lists 160,000 enterprise profiles and 420,000 items of product information. In part, this outcome is attributable to networking being at an early stage of development and the APEC pilot mostly focusing on providing a new business model. However, networked e-marketplaces must strategically market their services to increase participation to improve competitiveness. The APEC project also presented a business model to address space, time and cost constraints and improve SME entry into international e-commerce via networked e-marketplaces. Factors that increase trade such as service and network development and solution provision are reflected in infrastructure and business processes used by networked e-marketplaces. As APEC networked e-marketplaces are internationally certified entities participating agents trust traders. However, with the pilot project completed e-marketplaces should explore how to gain the trust of participating SMEs in their networks.

Conclusion

This study examines the *APEC Global B2B Interoperability Project* where a repository system using ebXML and Web Service is constructed to resolve technical interoperability issues. The project demonstrated that competing e-marketplaces can collaborate through a novel business model. The Project proved the potential of e-marketplace networking, an M2M business model, in terms of technology and business is feasible. However, the Project revealed an inability, at least in the short term to attract a critical mass of buyers, sellers and products. Clearly, a strategic plan is needed to develop the networking model as a profitable business process. That is, the development of marketing campaigns for networked e-marketplaces is a priority. This issue is related to leadership, viz., since the M2M model is a federated system there is no strong leadership with regard to network marketing. Another weakness revealed by the Project is trust. Because APEC conducted the pilot project ethical e-trading activity is presumed by market participants. However, post-incubation e-marketplaces must gain the trust of participants to attract more SMEs to gain a critical mass. Several benefits are expected to be realized from the e-marketplace networking of agents. These benefits include the lowering of SME international market entry barriers. That is, as e-marketplace networking promotes information sharing overseas marketing costs are reduced. Second, the M2M model reduces stagnation of information flow from excessive competition and improves competitiveness thus promoting information sharing. Finally, e-marketplace networking facilitates international trade. To sum, the Project presents the possibility of a novel business model to promote e-commerce by networking e-marketplaces internationally.

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