RESOURCES ACCOUNTING IN CHINA

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Resources Accounting in China

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Preface

Following the presentation of China's *Agenda XXI* in 1994, the Fondazione Eni Enrico Mattei began a fruitful collaboration with the SSTC (State Science and Technology Commission) on Natural Resource Accounting of the People's Republic of China. Among other initiatives, the Fondazione organised a seminar held in Beijing in March 1996, entitled "Resources Accounting in China". This volume brings together 11 papers as the result of that seminar.

Our main attempt was to compare approaches and knowledge of specific issues in this area. As far as the approach is concerned there appear to be some interesting comparisons to be drawn considering the authors' different fields of experience.

Seven papers are written by Chinese participants and four by visiting experts from the West. All the Chinese contributions point out the importance of the environment in economic development and a determination to measure the effects as a means to successful management of natural resources. They concentrate on rather specific issues within the constraints of the prevailing economic conditions where identification and pricing of assets tend to be specified by administrative norms. Although the general framework of the Chinese approach tends to be scientific and administrative, all papers contain interesting and useful statistical information.

The papers by visiting experts also stress the importance of taking into account environmental aspects in deriving indicators relating to economic development. In contrast to the Chinese contributions, however, they tend to be more abstract and more clearly based on economic theory.

The two groups of papers also reflect the different degree of specialisation of environmental economics in both areas. The main focus of the Chinese papers is a detailed description of an area or problem and its possible pragmatic solutions. Few references to economic theory are present and environmental accounting is more an accounting issue than an economic one. The Western contributions tend to be less descriptive of problems with an immediate relevance to the Chinese situation.

A. Lanza (ed.), Resources Accounting in China, vii–viii.

Together they provide an interesting snap-shot of completely different approaches in an area which is evolving very quickly and sometimes in unexpected directions.

This particular mix of approaches is a valuable record of the situation at a point in time when concerns with the environment in China were still in their infancy. It will be interesting to see how far the approaches have converged after a few years.

The collaboration of SSTC has been essential to produce this book. Particularly, I wish to thank Dr. Wang Zhixiong. I am also grateful to Andrea Beltratti for his efforts and enthusiasm during the first stage of this project.

Alessandro Lanza

CHAPTER 1

Alternative Resource and Environmental Accounting Approaches and their Contribution to Policy

Henry M. Peskin[1]

1.1. Introduction

It has now been over 25 years since researchers and statisticians around the world began serious efforts in resource and environmental accounting. While interest in these efforts remains reasonably strong (as evidenced by the continual scheduling of workshops such as this), the interest still appears to be confined to those in academics or research or to those in the environmental movement who hope (in vain, I believe) that such accounting will have a major role to play in preserving and protecting the natural environment. Official efforts in resource and environmental accounting on the part of governments remains sparse, being confined to tiny staff efforts in a handful of countries around the world.

While the relative lack of support for these efforts could be explained by the same shortage of funds that plague other governmental programmes, there is also the possibility that proponents of resource and environmental accounting have failed to convince politicians and governmental leaders that these accounting efforts will yield any significant contributions to the policy process. Is there a failure in communication or is it the fact that resource and environmental accounting is only of academic interest and really provides little help to the policymaker?

As will be discussed below, addressing this question is complicated by the fact that the term 'resource and environmental accounting' is open to several interpretations. Each interpretation, in turn, suggests different concepts, different data needs, and different implementation strategies. Furthermore, each interpretation appears to address different issues. Some of these are important for policy, while others are primarily of theoretical, intellectual or historical interest.

1.2. What is meant by accounting?

One reason for some of the major dissimilarities between different versions of resource and environmental accounting is that not all practitioners use the

A. Lanza (ed.), Resources Accounting in China, 1–20.

word accounting in the same way. Some are clearly using the term to mean 'to take account of' or 'to keep track of'. In this sense, an account is, loosely speaking, a report or similar body of descriptive information. Thus, one may praise Mrs. Jones for the good account she gave of her trip to Europe last summer. Similarly, the police officer may want an account of your time during the period when a crime was committed.

However, there is another, more formal use of accounting. In this formal sense, an accounting is also a report or descriptive body of information but, more importantly, it is a structured body of information that describes a system, often at a single point in time, defined by the 'accounting period'. A system, in turn, is a dynamic process that relates outputs to inputs. In a business, for example, the outputs are usually sales and the inputs are the costs of labour and materials necessary to support the sales. The role of the business accountant is to describe this system of production and sales. In order to assure that the system is described consistently and completely – that is, to insure that inputs and outputs are in balance – the accounting profession has adopted a number of conventions and practices. Environmental and resource accounting in this more formal sense adopts many of the same conventions and practices.

It should be noted that the word accounting, whether interpreted formally or informally, can refer to particular objects (that is, a set of accounts or an accounting of something) or to a process. Thus, it is not always clear whether a recommendation to undertake environmental accounting refers to a recommendation to produce a set of environmental accounts, to engage in the activity of accounting, or to do both. The activity of accounting does not always guarantee the production of a set of accounts or, at least, a set of accounts that would be universally accepted as valid and complete. Yet, in terms of the value of the activity for policy, the process of accounting can be quite valuable even if a final set of accounts never emerges. Thus, the distinction between accounting as a noun and accounting as a process is important in evaluating the benefits of the exercise. Indeed, it can be argued (see below) that if the principal purpose of resource and environmental accounting is only to produce a set of national economic accounts with theoretically 'better' numbers, the resulting improved accounts may be far more of academic interest than of policy interest.

1.3. Functions of accounting: scorekeeping and management

Not only has discourse among practitioners of resource and environmental accounting been confused by a lack of unambiguous terminology, there does not appear to be general agreement on what these practitioners expect resource and environmental accounting to accomplish. I have distinguished between two principal functions of accounting: scorekeeping and management. By scorekeeping, I mean the function of maintaining a record of performance. In a business, this recording may be of profits, production, or sales. In formal national economic accounting, such as represented by the United Nations

System of National Accounts (SNA), the scorekeeping function is fulfilled by aggregate measures such as gross domestic product (GDP) and net domestic product (NDP). Other national scorekeeping statistics, such as price levels, employment, and unemployment come from less formal accounting procedures – procedures that are more representative of accounting in the less formal sense of taking account of something. In fact, while formal accounting may assist in the generation of scorekeeping statistics (as is the case with national economic accounting), generally formal systems accounting is not necessary for this purpose.

Formal systems accounting, such as those practised by the modern corporation, has a more significant role to play with respect to the management function of accounting. By the management function, I mean the production of statistics needed support policy actions, either by a business, household, or by the government. The 'bottom line' – the statement of profits and losses – provided by business accounting serves the scorekeeping function of letting the manager know how well he or she is doing, but it is the detailed set of consistent statistics on sales and expenses that guides the manager towards those policy decisions that, hopefully, will improve the score in the future. Indeed, scorekeeping itself can be of little policy interest. One of the criticisms of the publication of improved net domestic product figures (improved because they account for the deterioration of natural resource stocks) is that the figures themselves give very little indication of what policy actions should have been different in the past and what policy actions are called for in the future (see below).

1.4. Historical impetus for resource and environmental accounting

While criticisms of the national economic accounts as a measure of societal well-being has origins well before the second world war, the main academic and popular interest in resource and environmental accounting dates from around the late 1960s or early 1970s. Both the popular press and the academic literature made three general criticisms of the conventional national economic accounts as a measure of social performance.

Of the three, the best-known criticism was that the common economic measures of economic performance, such as the gross national product (GNP), net national product (NNP), GDP and NDP, did not adequately reflect any degradation of the nation's environment. Indeed, the movement of these indicators is often perverse: GNP, GDP and their net counterparts could increase in response to environmental degradation. Efforts to clean up an oil spill or health expenditures necessitated by poor air quality would tend to increase national production even though these actions could be no more than an attempt to maintain environmental quality at an acceptable, pre-pollution level.

Many economists join environmentalists in questioning the usefulness of these aggregate economic performance measures as indicators of social welfare. At best, as Professor Hicks pointed out over 50 years ago,[2] GNP could be an index of economic welfare. But economic welfare is not necessarily social welfare. Furthermore, if relative prices change over time and if some of the goods desired by society increase while other goods decrease, the GNP index could either increase or decrease depending on whether 'old' or 'new' prices are used in the calculation. Finally, at best, GNP can be interpreted as a linear approximation to some non-linear social welfare function. As Arrow pointed out,[3] there are no assurances that such a welfare function even exists, at least a function that consistently reflects the preferences of members of the society. It is no surprise, therefore, that economists are not especially impressed with the criticism that GNP overstates well-being because of its neglect of environmental degradation.

However, there are two other criticisms of the conventional national economic accounts and their neglect of the environment that should have more appeal to the professional economist. A second criticism is that the conventional accounts treat reproducible wealth and natural wealth inconsistently. Specifically, the stock of reproducible wealth is depreciated in order to calculate an income measure (NNP) that measures a nation's sustainable income – income that allows for replacement of losses in the capital stock. However, losses in the stock of natural resources are not similarly depreciated, suggesting that true net national product is overstated.

A third criticism is that the conventional national accounts are incomplete in that they neglect important inputs and outputs in the nation's 'production function': inputs and outputs that have economic significance but are neglected because they lack market-determined values and prices. A example of neglected inputs, which are of special interest to environmental policy makers, are the waste disposal services provided by the natural environment. These services are typically scarce (and thus have economic value) because they compete with other services also provided by the natural environment such as recreational and ecological services. Because all these environmental services are not bought and sold in conventional markets they lack prices, and therefore are neglected by conventional economic accounting.

For reasons that are not especially clear to me, of these two additional criticisms, the first has received most of the attention by those promoting resource and environmental accounting. Certainly, developing a truer measure of net or sustainable product is of important policy interest. However, without further information on environmental inputs and outputs in the national production function, it is very difficult to develop policy that achieves a socially-acceptable balance between national economic objectives and environmental objectives or politically acceptable sustainable output goals. Given the interest in this issue, especially in developing countries, one would think that the third criticism would have received far more attention than it has up to now.

1.5. Responses to the criticisms: alternative approaches

Responses to these criticisms of the conventional economic accounts have varied across countries. The differences in approach appear to reflect differences in the relative emphasis on the three criticisms and between the emphasis placed on the scorekeeping and management functions of accounting. For purposes of exposition, the various approaches can be grouped under four headings.

1.5.1. Pollution expenditure accounting

One of the earliest reactions to perceived weaknesses in the conventional economic accounts was to develop data series on pollution-abatement and other environmental expenditures. Such data series have been maintained in the United States since 1972 (with, unfortunately, several breaks in the series) and are available in other countries.

As these data refer to measured expenditures already incurred, either due to policy or to standard business and household practice, they should not be considered as additions to the conventional economic accounts but rather as a delineation or re-specification of information already accounted for. Merely identifying such data serves neither the scorekeeping or the management functions of accounting. Also, without a further accounting of the sources of the expenditures, mere assembly of expenditure data does not meet the criteria for formal, systems accounting either.

However, some would like to use such data for scorekeeping purposes. In particular, critics of the conventional accounts have argued that such environmental expenditures are inherently intermediate and, therefore, should be deducted from final product indicators in order to generate an appropriately 'green' GDP. The idea of deducting environmental protection and similarly defensive expenditures from GDP has a long origin,[4] but has never been adopted by national accountants, presumably because of difficulties in drawing the line between defensive and non-defensive outlays.[5] Such an adjustment has never been made in the United States or in any other country to my knowledge. The motivation, therefore, for the statistical series on pollution abatement expenditures appears not to be for better scorekeeping but rather for better management of the economy. Specifically, several investigators believe that such information may provide for an explanation for changes in measured productivity.[6] The argument is that these these abatement (and other regulatory) expenditures divert resources from conventionally-measured production.

While this hypothesis may be valid, the argument assumes that observed abatement expenditures are a good representation of the true opportunity costs of environmental protection. Yet, while expenditures may reflect true economic costs, costs and expenditures are two very different concepts. In fact, observed environmental protection expenditures probably underestimate true opportunity costs, primarily due to a failure of expenditures to adequately reflect process and product-mix responses to environmental protection needs on the part of business. How large is this underestimate? Data on this point is very sparse. However, several years ago, during a detailed investigation of the costs of meeting water pollution regulations, a research team under my direction found that many plants met the US regulations without any expenditures on abatement equipment.[7] They simply ceased producing certain products, such as bright, highly coated writing papers, that were highly polluting. In these cases, abatement expenditures were zero, although costs, in terms of lost profits on the foregone products, were greater than zero. Furthermore, we found that in nearly all cases where there were purchases of end-of-pipe control equipment, changes in process were also necessary. Expenditures associated with these process changes often are not separable from ordinary production costs and, thus, get missed in the pollution-abatement expenditure data.

On the other hand, abatement expenditure data can tend to overestimate true opportunity costs due to the fact that that the reported expenditures include outlays for materials, the values of which may include pollution abatement expenditures of the sector producing the materials. Thus, there may be double counting. For this reason, the frequent practice of comparing pollution abatement expenditures with GDP is misleading since the latter covers only primary costs and is free from double counting. The expenditure data can be corrected using input–output techniques but not easily.[8]

Finally, it should be noted that reported environmental expenditures probably overestimate those pollution control costs that are engendered by regulations. Many pollution abatement activities are voluntary and are not in response to policy. Thus, a major component of the US pollution abatement expenditure series is expenditures associated with sewer connections and septic tanks for newly constructed housing. Such sanitary practices have a history that far pre-dates the environmental movement. If expenditures associated with such conventional practices are not excluded from pollution abatement expenditure series, the use of such series to explain productivity changes can be very misleading.[9] How large might this overestimate be? In the investigation referred to above, we found that, on average, about 20% of reported pollution abatement expenditures did not have origins in federal regulatory policy. In some sectors, nearly all reported expenditures pre-dated federal regulations.

1.5.2. Physical accounting

A second response to criticisms of the conventional economic accounts is to supplement these accounts with data bases containing physical information describing the natural environment and status of natural resources. The information can be arranged in a formal accounting system such as the material flow accounts as suggested, for example, by Ayres and Kneese (1969). As shown by Leontief (1970) the integration can be made quite tight by supplementing the conventional input–output matrix with row and columns that trace the flows of environmental pollutants and that account for changes in the levels of environmental assets. This approach was implemented in the 1972 US input–output matrix as published by *Scientific American.* Far more sophisticated versions of these input–output matrices have been generated by Fay Duchin and her colleagues at New York University.[10] A very complete input–output matrix system, the National Accounting Matrix including Environmental Accounts (NAMEA), which fully integrates economic and physical environmental information, has also been developed by Steven Keuning and his colleagues in the Netherlands.[11] Similar physical accounting systems exist in Norway and in France although in both these cases the coverage in terms of assets covered and pollutants is not as complete as in the Netherlands.

To the extent that the accounting covers the processes that cause the changes in physical stock and environmental quality, and not just records the changes, a physical accounting meets the more formal definition of systems accounting. Those physical systems that are closely linked with the economic input–output matrix are clearly formal accounting systems in the sense I have used this term. However, other physical accounting efforts also exist that do not meet the definition of formal systems accounting. These approaches attempt to take account of the environment by assembling large quantities of physical descriptive information such as indicators of air and water quality, species accounts, area of forest cover, etc. Typically, these informal accounting systems take the form of national state of the environment reports or in large physical environmental data bases such as the STRESS system in Canada and similarly large data bases maintained by several US governmental agencies (e.g. EPA's STORET,the USGS NASQAN system, and many others).

A physical accounting, whether formal or informal, can provide the inputs for the construction of various environmental indicators and thus be used for scorekeeping purposes. In addition, they are often used to support policy analyses and assessments. In particular, the formal matrix systems lend themselves to input–output and linear programming modelling and simulations. In Norway, for example, where this approach has been followed for many years, the intent is to generate information and analyses to support the nation's economic planning process. Of course, the more informal physical data systems available in many countries can be equally useful and are often essential for the development of complex environmental regulations.

While the concept of physical accounting is straightforward, and while such physical information has a central role to play in policy formulation, there are several factors that complicate their use for policy purposes. In the first place, the choice of appropriate physical units of measure is not obvious. Typically, a decision must be made to chose a physical measure that is relevant for some environmental policy concern. A forest, for example, can be physically measured in terms of its acreage, the volume of its timber, the variety of its biota (as evidenced by the number of available species), the stock of non-timber resources such as firewood and grasses, etc. Which of these alternatives is chosen as the physical measure of the forest will depend on what are the relevant policy objectives: commercial timber management, assurance of firewood supply, adequate species diversity, etc. Secondly, there is the matter of incomparability of units. Unfortunately, numbers do not speak for themselves. While at times environmental priorities seem obvious, more often the policy-makers needs some way of deciding whether limited budgets should be directed at one environmental problem or another or at one set of pollutants or another set. Physical information, alone, provides little help.

Related to this second issue are questions of coverage, detail, and aggregation. In an effort to anticipate potential policy needs, the systems can become quite large and detailed. Yet, large data systems are almost useless for scorekeeping purposes and also for many modelling uses unless they can be collapsed through aggregation. With physical systems this aggregation is accomplished by finding some common physical unit of measure such as weight, volume, or energy content. One interesting solution to the aggregation problem is suggested by the Dutch NAMEA system. Dissimilar pollutants are converted to common units based on their contribution to environmental themes such as global warming or acid rain. Thus, individual pollutants can be measured in terms of their CO_2 equivalents, with respect to the first problem, or their contribution to acidity, with respect to the second. These aggregates can be further measured in terms of their contribution to environmental pressure by comparing the common unit aggregates to policy target levels. The procedures lead to an index which is larger the more emissions and the more the common-unit aggregate exceeds the policy target. Of course, the procedure assumes that the policymakers know what these targets are, *a priori*. While setting target levels may not be a problem in the Netherlands, it is in the United States. Policymakers often want to know the potential severity of the environmental problem, and often, the value of this severity in dollar terms, before policy targets are set.

In sum, physical accounting systems appear to most valuable for policy support when overall environmental objectives are already clear. The more formal systems can be used to provide data for linear programming, input–output, and other simulation models. Solutions from these models, in turn, can yield shadow prices that can be used to provide monetary values for environmental assets and pollutants. When policy objectives are less clear, purely physical accounting may be less valuable. However, detailed physical information from both formal and informal accounting systems is an essential component of all rational environmental policy action.

1.5.3. Green idicators

A third approach to resource and environmental accounting, and perhaps the one with the longest history, is to construct a green GDP or some other economic index to replace the conventional GDP and NDP. This work has proceeded along two parallel paths. First, there has been the effort to construct entirely new indicators of social well-being, usually by altering one or more of the components of the conventional aggregates (subtracting out pollution-abatement expenditures would be an example) or by adding some new components (such as a factor measuring the negative effects of urbanization). The best known example of this approach is the Nordhaus–Tobin MEW (Measure of Economic Welfare) indicator.[12] Similar indicator approaches have been developed by the Japanese (the NNW, Net National Welfare)[13] and, more recently, by Daly and Cobb.[14]

If these indicator approaches are considered accounting, then they provide a clear example of the use of the word accounting being interpreted to mean 'to take account of'. They are also provide a clear example of where accounting is intended to support scorekeeping rather than management. Indeed, one criticism of these approaches is that while the various indexes may indicate that society is worse off than might be suggested by the conventional GDP, they give the policymaker little indication what to do about it. Even if it is fairly clear that the index is falling due to, say, a combination of increased pollution, more crime, and unemployment, there is no guidance on how scarce resources should be directed towards remedying these evils. Of course another problem is that the components of the index and their weights may appear politically arbitrary. While pollution is generally accepted as a bad thing, what about increases in urbanization or increases in defence? Increases in these social conditions, can be a source of comfort to some and an evil to others. Even if there is general agreement that both are bad, it is not obvious how they should be weighted in an overall social performance index.

Because of a lack of rigor in their construction, the development of social performance indicators has not received much support in the policy community, especially from economists. However, it should be noted that one strong feature of these performance indicators is that, in their development, they draw on a wide range of social and economic information that affect social well-being. The integration of this information could serve an extremely valuable service to policymakers who exist in a world of specialists who rarely talk the same language. Therefore in spite of the problems referred to above, I, for one, would encourage continual efforts in the development of these indicators. These efforts would be a good example of where the action or process of accounting may be far more significant than the accounts (or, in this case, the index) themselves.

Another, perhaps more conservative, example of the green indicators approach has been provided by Robert Repetto and his colleagues at the World Resources Institute (WRI).[15] The principal thrust of this effort is not to replace the conventional gross income aggregates. Rather the purpose is to modify the conventional measures of net product: NNP or NDP, defined as gross product less depreciation. Essentially, the idea is to depreciate natural assets such as forests, mineral stocks, fish stocks, and soils in order that reproducible capital and natural capital receive equal treatment in the computation of net income.

The idea of treating natural assets the same as plant and equipment with respect to depreciation seems, at first, quite sensible and noncontroversial. But upon reflection, whether this is a good idea and, more importantly, whether it serves interests of policy will depend on what is meant by 'depreciation' and net income. Not all definitions of depreciation and net income are mutually consistent or have the same implications for policy.

The idea of calculating net income, defined as gross income less depreciation, has its origins in a concern of Professor Hicks that conventionally defined income as a flow of payments is inherently ambiguous. For example, if one is paid monthly, do we conclude that on dates between the monthly paychecks income is zero? To get around this absurdity, Hicks suggested that income be defined not in terms of payments but in terms of potential consumption: "... the amount [people] can consume without impoverishing themselves".[16] Prevention of such self-impoverishment is assured if the individual maintains his or her wealth. Conversely, any loss in wealth should be deducted from gross income. The amount of money identified with the loss of wealth is depreciation.

While a less ambiguous concept of income than mere payments, Hicks recognized that this definition of income – which economists identify with Hicksian income or sustainable income – also can be criticized for a lack of precision since it is based on *ex ante* assumptions of future consumption and a related fuzziness regarding what it means to keep wealth intact. Does maintaining capital mean maintaining its original physical properties or does it mean maintaining its value? This issue is especially important when one is considering natural or environmental capital since there may be very little association between a natural asset's physical condition and its value.

For the scorekeeping purposes of accounting, it can be shown that the choice between a physical and a value concept of depreciation depends on how capital is valued. Specifically, if the value of an asset is defined in terms of the gross incomes (net of costs but not of depreciation) it can generate over its lifetime, then the only definition of depreciation that is consistent with Hicksian income is the change in value of the asset. This change could occur with or without a change in the physical condition of the asset. This concept of depreciation is identified as economic depreciation to distinguish it from other concepts such as physical depreciation or depreciation as defined in the tax laws.[17]

To further clarify the difference between economic (value) depreciation and physical depreciation, suppose, for example, that the capital stock consisted of only machines and suppose further that the stock was depleted by one unit because a machine wore out. To calculate the economic depreciation, one would estimate the change in present value of the machines, defined as the discounted value of services associated with the original stock less the discounted value of the stock depleted by one machine. In contrast, physical deprecation would be calculated as the cost of replacing the machine and, thus, restoring the stock to its original condition. The distinction between these two depreciation concepts is not of any practical importance as long as the market for machines is essentially competitive. With competitive markets, the cost of the machine and its contribution to the present value of the stock of machines are brought into line through the competitive process.

However, these equilibrating forces cannot function if capital markets are not very competitive or, as is the case with natural resource capital, the markets do not exist in the first place. In these non-market circumstances, there is no reason why replacement or restoration costs should have anything to do with the loss in value. Thus, while it may be easier (e.g. the calculation need not involve estimates of rates of return and lifetimes) and more convenient to measure the depreciation of the natural environment or of natural resources by the estimated costs of restoring the environment or the resources to some pre-existing condition, these costs need not in any way approximate true economic depreciation.

What are the policy consequences of these differences in calculation? Just how important is it to have a theoretically correct depreciation and a correct NDP? As an empirical matter, the distinction can be very significant indeed. When one calculates natural resource depreciation both ways, there are orders of magnitude differences in value between estimated economic depreciation and depreciation based on replacement cost concepts. For example, for Colombian forests, depreciation based on the Repetto net rent approach – in essence depreciation based on restoration of lost rent due to timber extraction – was about 1.3×10^{10} pesos in 1995 while economic depreciation was estimated to be only 1.0×10^{6} pesos.[18] Similar results were found in the Philippines for forests, fisheries, and a number of minerals. These may be extreme examples. Other depreciation approaches, such as those based on the El Serafy methods,[19] provide results that are much closer to the economic depreciation estimates.

However, while there may be significant empirical differences between using the correct depreciation estimate and those that are based on replacement cost concepts, the policy implications of choosing one over the other may be of less importance. Of course, if the interest in NDP is to compare the well-being of one country to another at one point in time, it would be important to have a correct depreciation and, thus, a correct NDP. However, for many reasons such cross-country comparisons are extremely difficult to interpret even without the inclusion of non-market assets. Perhaps of more policy interest is the movement of NDP over time. Presumably, a falling NDP could be a sign of asset deterioration (including deterioration of the natural environment). Although it is possible for physical depreciation and economic depreciation to move in different directions over time, the empirical evidence seems to indicate that physical depreciation and true economic depreciation move in the same direction. Thus, for scorekeeping purposes, the differences between the two concepts may not be of much importance.

The policy management role of NDP and associated depreciation estimates seem less important than the scorekeeping role. The problem is that even if there were general agreement that particular NDP values, suitably adjusted for natural resource and environmental depreciation, were correct, the numbers themselves do not point in any particular policy direction. Thus, even if, for example, it were true that the Indonesians are overestimating their true income by not accounting for the depletion of their forests, petroleum, and soils assets, it does not necessarily follow that Indonesia would have been better off by not depleting these assets in the first place. Depletion of these natural assets may have supported more than offsetting increases in other man-made assets and in human capital. Therefore, with respect to the management role of environmentally adjusted NDP estimates, the story is much the same as with the social accounting indicators such as MEW: the management role is quite limited.

1.5.4. Extensions of SNA-type systems

The fourth group of approaches builds upon the existing systems of national accounts. In this sense, they are quite conservative. However, because they do not focus on just one element of the conventional accounts, such as depreciation, but rather seek to cover all sectors that may interact with the environment, they are the most ambitious of all the four groups of approaches. In practice, these approaches require most of the same information used by the above approaches plus much more sector-specific information.

Examples are the UN SEEA (United Nations System for Integrated Environmental and Economic Accounting) approach and the Environmental and Natural Resources Accounting Project (ENRAP) or Peskin framework. These two approaches have much in common. As noted, they both build on the conventional system of national economic accounts (and, thus, they are accounting in the more formal sense), they both require sector-specific information on the use of environmental assets, and they both are concerned with the management as well as the scorekeeping functions of accounting. Yet there are significant differences, especially in how they view the economic–environmental interaction, in their ties to economic theory, and their adherence to SNA concepts. With respect to these latter differences, SEEA appears much more concerned with consistency with the SNA and less concerned with consistency with economic theory. The ENRAP framework appears much more concerned with consistency with economic theory and less concerned with consistency with the SNA.

Perhaps one explanation for this difference in emphasis is a different view of the role of the accounts *per se* vs. the role of accounting. SEEA appears to emphasize the importance of attaining a defensible set of accounts. To meet this objective, a theoretically correct approach might be abandoned in favor of another method if the correct approach is felt to be impractical. Since those employing the ENRAP framework are more interested in developing the information and data systems that support the correct accounts rather than in the accounts themselves, there is no reason not to try the theoretically correct methods even if they prove unsuccessful in attaining a complete set of accounts. Thus, if willingness to pay to avoid environmental insult is the correct way to measure the value of pollution damage while calculating the cost of pollution controls the incorrect way, the ENRAP framework chooses the former over the latter, even though the latter is easier to measure. The gain in information from even an unsuccessful attempt to measure willingness to pay is felt to be of great value for policy purposes – especially since the ENRAP approach also measures cost of pollution controls anyway, although it uses the cost information for different purposes.

SEEA

In one sense, SEEA is more 'politically correct' than the ENRAP framework in that it attempts to encompass a wide variety of approaches, including the ENRAP framework. It accomplishes this trick by putting forth six versions of the system, some of which are subdivided into a number of sub-versions. This form of exposition makes it extremely difficult to criticize or even describe the system. If you find fault with something, the response can be: "You are describing version IV.x. Don't worry, your concerns will be met in version V.y". Therefore, the following attempts to cover features common to most of the versions, with the understanding that there may be at least one for which the criticisms are not relevant. In the spirit of the theme of this paper, the focus will be on policy implications of these common features.

One notable feature of SEEA is its emphasis on costs. Not only does the system identify *ex post* costs (actually environmental protection expenditures) but also the *ex ante* costs of maintaining the environment at an essentially undisturbed and sustainable level. As discussed above, SEEA's identification of these prospective costs with environmental and natural resource depreciation is theoretically questionable. Their use to derive an environmentally adjusted GDP is equally objectionable, regardless of whether these costs are being interpreted as uncounted environmental depreciation or, alternatively, as a measure of environmental damage. In either case, the use of restoration or maintenance costs for these purposes does not yield a measure of income that is consistent with Hicksian or economically sustainable income.

Nevertheless, the cost and expenditure data can be extremely useful for policy purposes, especially if they can be compared with the benefits of attaining the levels of restoration underlying the cost estimates. As a practical policy matter, there may be concern over the sustainability of specific environmental assets such such as forests, agricultural land, water, etc. (as opposed to the sustainability of general economic income). As long as there are such environmental concerns and as long as there are policy actions to protect the environment (as opposed to the economy), maintenance and restoration cost information will be important. In addition, *ex post* expenditure data, if used with the understanding that these expenditures may not reflect true opportunity costs, can support analyses of the effect of environmental policy on conventional economic activity.

Not only is there a concern for costs but SEEA also displays a concern for the incidence of costs – a distinction between costs that are caused by economic units as opposed to costs that are borne by economic units but are caused by others. Unfortunately, SEEA's exposition on this distinction is not altogether clear since at times both costs caused and costs borne appear identified with environmental damage and, at other times, with actual expenditures to prevent this damage. Thus, the important distinction in the environmental management literature between environmental policy benefits and the costs to attain these benefits is clouded. Therefore, while the SEEA handbook compares total cost caused with total cost borne (Table 4.2), it is hard to interpret this comparison. However, the concern over incidence and, by extension, the distribution of costs among establishments and households, should be encouraged since policymakers working in a political environment may share this concern.

Another notable feature of SEEA is its reliance on an input–output framework for arraying information, whether in physical or in monetary terms. This use of input–output is reminiscent of the Dutch (NAMEA) system and is justified for similar reasons: an input-output framework clearly displays the interactions between environmental and conventional economic activities. However, there are problems with input–output that could have policy implications. One problem is that the input–output framework assumes that activities can be uniquely classified: for example, a sector can produce hammers or produce nails, but not both. Usually, when there is such 'jointness' the approach is to define a new sector, such as hardware, which receives the hammers and nails as inputs. However, this solution is less than satisfactory. One cannot tell whether the consumers of hardware are consuming hammers or nails.

Unfortunately, jointness is often a characteristic of environmental protection. There may be distinct sectors that produce equipment that is exclusively used for environmental protection. However, often a sector responds to pollution regulations by altering processes and product mix as well as by purchasing pollution abatement equipment from other sectors. Thus the product 'pollution abatement' is inherently a joint product produced with the primary output of the sector. The problem is further complicated by the fact that product mix changes and process changes are usually not reflected in clear expenditure numbers that can unambiguously be associated with the activity 'pollution abatement'. It is not clear how this problem is addressed in the SEEA framework. It would be unfortunate if the jointness problem were ignored since it can be the case that, with certain sectors, the majority of the costs associated with environmental protection are due to responses that do not require equipment purchases and are not reflected in expenditure records.

A third characteristic of SEEA is its close adherence to the SNA production boundaries. The close adherence to SNA concepts is an obvious strength since it will help assure consistency with the conventional accounts. Also, since the SNA framework is widely adopted, the close adherence of SEEA with the SNA will help assure international comparability. However, this consistency comes at a price. In particular, presumably because coverage of the production activities of households is limited in the current revised SNA, SEEA also has a limited coverage of household production. Yet, some of this production, such as the production of non-marketed firewood, can have serious environmental consequences. My guess is that for those countries for which non-market household production can have a major environmental role, implementations of SEEA will go beyond the SNA production boundaries.

Of course, if countries do begin to tailor SEEA to their own needs, international comparability may be lost. How important is it to maintain such comparability? I feel the answer depends first on the perceived relative importance of the scorekeeping and management roles of accounting, and second on the cost of data development relative to the benefits. If it really is important to score one nation's performance against another, perhaps to provide a rule of thumb for the dispersal of assistance funds, then obviously standardization is essential. However, in the absence of some international policy control mechanisms, such standardization is (or, at least, should be) irrelevant for national policy development. There is no reason why one country's choice of policy instruments to deal with some environmental problem should be influenced by the country's environmental performance relative to another country. Of course, I realize that in the real political world, policy actions are often justified based on what a neighbouring country is doing.

However, even if there are advantages to international comparability, it should be recognized that uniform standardization may be inconsistent with efficient data development. Presumably, efficient data development should strive for a balance between the marginal cost of data development and the marginal benefits. Yet, there is no reason why these marginal values should be the same for all countries. For some countries, the marginal cost of attaining a piece of SEEA-relevant data may be quite high and the benefits of this data element, quite low. The opposite may be the case in a neighbouring country. One would think, for example, that Nepal would want a full accounting of non-market household fuelwood production, given that non-market fuelwood constitutes about 75% of the nation's energy consumption. The importance of this sector is far less in many other countries. If so, why would it be in the interest of Nepal to adopt a system that contains the exact same pieces of information as, say, the United States?

The ENRAP framework

Like SEEA, the ENRAP framework is a formal accounting that integrates closely with the conventional economic accounts. Indeed, I have seen the system arranged as a large input–output matrix. In this form, it looks quite like SEEA. However, there are significant differences: there are additional production sectors not in the conventional SNA; there is a close adherence to neo-classical economic theory; there is explicit recognition that because of non-market assets, there may not be a balance between sector and aggregate inputs and outputs; there is less concern about consistency with the SNA; and there is more emphasis on the system as a guide to accounting as opposed to a guide to a particular set of accounts.

The two most significant sectors that are added to the conventional SNA are household production (primarily the production of non-market firewood) and

Nature. In the ENRAP framework, the natural environment or Nature is viewed as a productive sector generating scarce, economic goods and services demanded both by households and by industry. Some of these goods are marketed, such as minerals, but most are non-marketed. The most significant non-marketed service demanded by industry is waste disposal, treated in the system as a productive input. Households also demand waste disposal services (for example, the disposal of automobile wastes or wastes from home heating and cooking) but they also demand more positive services of Nature such as recreation, support of wildlife, and purely esthetic enjoyment. These services are considered additions to the productive outputs of the economy.

Consumption of these services, even waste disposal services and the associated pollution, is not inherently bad in the ENRAP framework. What may be bad is that consumption of one service, e.g. waste disposal, may limit the consumption of another service, e.g. recreation if, for example, the waste disposal generates pollutants that degrades air and water that supports recreation activity. Thus, with the ENRAP system damaging pollutants are considered negative outputs.

Consistent with neo-classical economic theory, the services of Nature are valued in terms of what members of society are willing to pay for them while damaging pollutants are valued in terms of what members of society are will to pay to avoid them. ENRAP recognizes that such economic valuation, consistent with the principles of consumers' sovereignty, may undervalue the true social value of Nature. Not all values are economic values. Furthermore, by relying on consumers' sovereignty, the interests of future generations are lost. However, the economic valuation was chosen simply because there appears to be no other alternative that is equally as democratic and non-arbitrary.

The underlying economic theory is neo-classical in that environmental service values reflect both supply (cost) and demand as opposed to classical economic theory, which posited that value depends solely on costs. The neo-classical economic model implicitly recognizes that in the absence of market equilibration, such as would be brought about by competition, there is no reason why costs should provide a unique measure of value. Thus, the theory would not support the idea that the costs of maintaining the environment necessarily equal true economic depreciation, an issue that was discussed earlier. Furthermore, the neo-classical theory suggests that if certain inputs and outputs are non-marketed, the sum of all inputs need not equal the sum of all outputs. Therefore, in the ENRAP system, in order to assure accounting balance, a residual is included (termed net environmental benefit). The size of this term provides an approximation of how much the allocation of environmental services lacks an optimal economic balance. Indeed, one of the management goals of environmental policy is to allocate non-marketed environmental services in such a way as to make net environmental benefit as small as possible.

As with the conventional SNA and SEEA, the linkage between current and capital account is through investment (saving) and depreciation. The only difference between ENRAP and SEEA on this point is that ENRAP tries to estimate true economic depreciation for all natural assets including conventional natural resources such as minerals. In principle, the depreciation of minerals and other natural assets, such as water bodies and air sheds, is treated similarly. Depreciation is not equal to a restoration or maintenance number but rather is defined as the change in the discounted value of generated services over time.

It is recognized that implementation of the ENRAP concepts is extremely difficult and that full implementation may not be possible. Thus, all the empirical accounts that have been developed to date (in the United States and the Philippines) have had to rely on rather crude assumptions and approaches. Thus, for example, the willingness to pay for waste disposal services has been approximated by the costs that would have to be incurred by the user of the services were this use severely limited or denied. In practice, these costs are estimated as the costs necessary to attain environmental standards[20] and are thus comparable to the maintenance costs estimated in the SEEA system. The values of environmental damage and positive environmental services have been based on a number of environmental benefit estimates, some of which rely on travel demand, hedonic, and contingent valuation methods.

While these methods are controversial and crude, the resulting estimates can still be informative for the policy process. Specifically, crude estimates of environmental damage, which can be linked to the costs of eliminating this damage, may be all the policymaker requires. Often it is clear that little will be gained by obtaining more refined estimates. Thus, the crude ENRAP estimates made in the Philippines have pointed the way towards a number of policy responses with respect to the role of industrial vs. household and non-point pollution and the importance of renewable vs. non-renewable assets as a source of environmental depreciation. It is unlikely that less crude estimates would have suggested different policy responses.

More importantly, even crude implementation requires data that are valuable in their own right for policy management. Specifically, ENRAP implementation have generated a coherent body of physical, cost, and benefits data that are essential for the development of rational environmental policy. These data have been assembled at a level of detail that will support policy both nationally and regionally. This aspect of ENRAP highlights the philosophy that accounting can be as important or more important than the accounts themselves. While it is true that the ENRAP accounts can provide scorekeeping numbers such as a GDP adjusted for non-marketed environmental services, pollution, and natural asset depreciation, the crudeness of the numbers may lead some to have doubts about the score's credibility. Even if these account aggregate indices are rejected, the accounting process is nevertheless essential if there is to be rational environmental policy. The data needed to implement ENRAP are essentially the same data needed to support efficient environmental management.

1.6. Summary: policy contribution of environmental and resource accounting

When all the above approaches are assessed in terms of their potential contribution to the policy process, it is apparent that none of the systems really dominates the others. Even the more comprehensive ones such as SEEA or ENRAP fail to provide the full spectrum of physical environmental information provided by the more descriptive, informal physical accounting systems found in state of the environment reports. Certainly, no environmental protection agency could function very well without access to such physical information. Yet, given the intimate interconnection between the state of the environment, the state of the economy, and the general social and political condition of a country, it is equally clear that physical accounting systems are not enough either.

Each of the approaches has its own comparative advantages for the policy process. Cost and expenditure accounting is well suited for macro and sectoral economic impact analyses; physical input–output accounting is ideal as a provider of inputs to policy simulation and other programming models; informal descriptive physical accounts provide the scientific support for regulatory policies; adjusted GDP and similar green accounting indexes serve an important scorekeeping function; SEEA provides close integration with the SNA; and ENRAP is well suited to support benefit-cost assessments and rational policy targeting. One might conclude that the ideal approach would be one that combined all of the others and, certainly, SEEA seems to be going in that direction. However, I feel that construction of an all-purpose environmental and resource accounting system would be a mistake since it neglects the fact that data development is not without real costs. The fact is that many countries do not need a SEEA or an ENRAP. Even if these systems were affordable in every country, the marginal benefits of the additional information generated may not nearly approximate their marginal costs.

Therefore, those of us who have authored and promulgated our own approaches should be careful with our missionary zeal. What we are doing may be the correct course in the countries for which we have gained our experience. They may be totally inappropriate elsewhere.

Notes

1. Paper prepared for the international conference 'Applications of Environmental Accounting' sponsored by the Fondazione Eni Enrico Mattei and the State and Science Technological Commission of the People's Republic of China, 11–13 March, 1996, China. Also, a contributed paper for the International Symposium on Integrated Environmental and Economic Accounting in Theory and Practice sponsored by the Economic Planning Agency of Japan, the United Nations University, and the International Association for Research in Income and Wealth, Tokyo, Japan, 5–8 March, 1996.
2. Hicks, 1940.
3. Arrow, 1963.

4. See, for example, Juster, 1973.
5. See Jaszi's criticism of Juster, *op. cit.*
6. See, for example, Denison, 1979; Jorgenson and Wilcoxen, 1990.
7. See Gianessi and Peskin, 1976.
8. See Nestor and Pasurka, 1995.
9. It should be noted that Ed Denison, after talking with my colleagues, was careful to make the necessary adjustments in his study of the possible relationship between regulatory and productivity changes. See Denison, 1979.
10. See, for example, Duchin and Lange, 1993.
11. See Keuning, 1995.
12. Nordhaus and Tobin, 1973.
13. Japan, Economic Council, 1973.
14. Daly and Cobb, 1989.
15. Repetto et al., 1989.
16. Hicks, 1946.
17. The above definition of economic depreciation as the change in asset value is slightly different from the definition used by Hartwick and Hageman (1993). They define depreciation as the change in asset value under optimal use. This condition allows them to show an equivalence to Hotelling rent but it is not especially useful in a national accounting context. The accountant must measure things as they are and not as they could be under optimal use. To follow Hartwick and Hageman, it would also be necessary to adjust all observed market prices since they all reflect the lack of optimality that exists in the real world.
18. Peskin and Michaels, 1991.
19. El Serafy, 1989.
20. This approach is reasonable as long as the regulations call for a near-zero level of residual's discharge. In practice, the costs estimated assume at least a 90% reduction in discharges.

References

Arrow, K.J., 1963, Social Choice and Individual Values, 2nd edn, New York: Wiley.

Ayres, R.U. and A.V. Kneese, 1969, Production, consumption, and externalities, American Economic Review, LIX, 282–297.

Daly, H.E. and J.B. Cobb Jr., 1989, For the Common Good: Redirecting the Economy Toward Community, The Environment, and a Sustainable Future Boston: Beacon Press.

Denison, E.F., 1979, Pollution abatement programs: estimates of their effect upon output per unit of input, 1975–78, Survey of Current Business, 59, 58–59.

Duchin, F. and G. Lange, 1993, Development and the environment in Indonesia: an input–output analysis of natural resource issues. Final Report to the Canadian International Development Agency (August).

El Serafy, S., 1989, The proper calculation of income for depletable natural resources, in Y.J. Ahmad, S. El Serafy and E. Lutz (eds.) Environmental Accounting for Sustainable Development, Washington, DC: World Bank.

Gianessi, L.P. and H.M. Peskin, 1976, The Costs to Industries of Meeting the 1977 Provisions of the Water Pollution Control Act Amendments of 1972. A report to the US Environmental Protection Agency.

Hartwick, J. and A. Hageman, 1993, Economic depreciation of mineral stocks and the contribution of El Serafy, in E. Lutz (ed.) Toward Improved Accounting for the Environment, Washington, DC: World Bank.

Hicks, J.R., 1940, The valuation of the social income, Economica, VII, 105–124.

Hicks, J.R., 1946, Value and Capital, 2nd edn, Oxford: Oxford University Press.

Japan, Economic Council, NNW Measurement Committee, 1973, Measuring Net National Welfare of Japan.

Jorgenson, D.W. and P.J. Wilcoxen.,1990, Environmental regulation and U.S. economic growth, Rand Journal of Economics, 21.

Juster, F.T., 1973, A framework for the measurement of economic and social performance, in M. Moss (ed.) The Measurement of Economic and Social Performance, Studies in Income and Wealth, vol. 38, New York: Columbia University Press for the National Bureau of Economic Research.

Keuning, S.J., 1995, An information system for environmental indicators in relation to the national accounts, in deVries, W.F.M., G.P. den Bakker, M.B.G. Gircour, S.J. Keuning and A. Lenson (eds.) The Value Added of National Accounting, Netherlands Central Bureau of Statistics.

Leontief, W., 1970, Environmental repercussions and the economic structure: an input–output approach, Review of Economics and Statistics, 52, 262–271.

Nestor, D.V. and C.A. Pasurka, Jr., 1995, Environmental–economic accounting and indicators of the economic importance of environmental protection activities, Review of Income and Wealth, 41, 265–287.

Nordhaus, W. and J. Tobin, 1973, Is growth obsolete? in M. Moss (ed.) The Measurement of Economic and Social Performance, Studies in Income and Wealth, vol. 38, New York: Columbia University Press for the National Bureau of Economic Research.

Peskin, H.M. and R.G. Michaels, 1991, Environmental and Natural Resource Accounting in Colombia, Report to the World Bank (February).

Repetto, R., W. Magrath, M. Wells, C. Beer and F. Rossini, 1989, Wasting Assets: Natural Resources in the National Income Accounts, Washington, DC: World Resources Institute.

CHAPTER 2

Green Accounting in China: The Role of Damage Estimation[1]

A. Markandya and I. Milborrow

2.1. Background

Since the late 1980s, the discussion of environmentally sound and sustainable socioeconomic development has received increased attention from the international community. This new development concept requires clarification, and appropriate methodologies for its assessment and implementation need to be developed. With this aim, several research programmes have been organized by UNEP, the World Bank and other organizations, to examine the feasibility of physical and monetary accounting in the areas of natural resources and the environment and to develop alternative macro indicators of ecologically adjusted/sustainable income and product.[2]

The idea of resource and environmental accounting, however, is not new. Although, it has been considered by academics for over 25 years, it is only recently that international institutions and governments have shown serious interest (Peskin, 1996). Official efforts at the national level remain fairly sparse, despite the international recognition that the preparation of a coherent set of environmental accounts that establish the impacts of economic and social activities on the environment is an important issue. The position of the UN is that integrated economic and environmental accounts should be presented in a satellite format and should be seen as a complement to, rather than a substitute for, traditional accounting practices for the foreseeable future (United Nations, 1993).

A set of guidelines have now been established for this purpose. This sets out the methodology to be followed for the valuation of natural resources and environmental degradation caused by anthropogenic activity. The UN decided that enough progress had been achieved to develop links between environmental accounting and the UN System of National Accounts (SNA), and to elaborate certain aspects of environmental accounting in the ongoing revision of the SNA. The result has been the evolution of the System for Integrated

A. Lanza (ed.), Resources Accounting in China, 21-52.

Environmental and Economic Accounting (SEEA). In this chapter, the issues arising in the debate on the preparations of SEEA, as well as the methodology presented in the UN handbook *Integrated Environmental and Economic Accounting* (1993) will be discussed.

There are a number of approaches to environmental accounting, which stem from how economy–environment inter-relationships are perceived.[3] The two extreme positions are anthropocentric (human centred) or biocentric (ecology centred). The concept of sustainability is often presented as a synthesis of these ideas. Correspondingly, statistical descriptions can focus on the natural environment (and present data in terms of physical flows, energy balances etc.) or focus on the economy (and present monetary data on actual transactions in market values). Approaches that are located between these two extremes could be classified according to the extent to which they incorporate monetary values. These issues are discussed in more detail in section 2.4. Developments in approaches will be important for the future of green accounting; the concept needs to be clarified academically if it is to be taken seriously by policy makers. There will, however, never be a textbook 'best' approach, since the marginal costs and benefits (efficiency) of data management will differ among countries.

The UN guidelines (and others which are similar) are being used in a number of countries in preparing environmental accounts, both at the monetary and non-monetary level, including Brazil, Canada, Costa Rica, France, Germany, the Netherlands and Norway. Some attempts at adjusting national income accounts for environmental effects has also been undertaken in Australia, Japan, India, Indonesia, Mexico, New Zealand, Papua New Guinea, Sweden, the United Kingdom, the United States and Zimbabwe. References to the related studies are given at the end of this paper.

2.2. The Chinese context

The international experience in this area is relevant to China, which is endowed with a huge stock of natural resources of global significance. At the same time, the scale of use of these resources is also vast, as are the environmental impacts and damages. In the past, the use of these resources was not always governed by prices or considerations of scarcity. As China moves to a market based economy, the correct valuation of these resources will play a critical part in determining how they are used.

China understands the importance of monitoring the state of its natural resources. Since 1986, research has been undertaken by the Development Research Center of the State Council on Natural Resource Accounting (NRA).[4] China also understands the importance of sustainable development. Subsequent to the 1993 UN Conference on Environment and Development (UNCED) and in response to the UN's 21st Agenda, the Chinese Government instructed the State Science and Technology Commission to prepare a strategy document. The result was entitled China's Agenda 21 (CA21): White Paper on China's Population, Environment and Development for the 21st Century and was adopted by the State Council in March 1994. CA21 recognizes sustainable development as a crucial element in the socialist modernization process. In the Chinese context, the issue is the transformation from a traditional economic pattern that emphasized quantity to one that emphasizes quality.

Natural resource accounting is accepted as being a necessary component in order to promote sustainable development. In the former economic system, natural resources were not priced and environmental exploitation unaccounted for. The new strategy aims to rectify this and calls for 'study and practice on a trial basis of integration of natural resources and environment considerations into the national accounting system so as to make statistic indexes and market prices accurately reflect the resources and environment changes caused by economic activities'.

The aim is to develop stock and flow accounts for natural resources to facilitate the establishment of a new integrated national accounting system. These will be consistent with the UN SEEA framework. Once the new methods are in place they can give guidance for economic (resource efficient) and social policy formulation. In order to achieve this, the Chinese national science and technology research plan for the period 1996–2000 has allocated $3 million for research into resource accounting.

2.3. The UN SEEA methodology

Extensions of SNA-type systems aim to build upon the existing system of national accounts and to cover all sectors that interact with the environment. The SEEA complements the current SNA in two important respects: depletion of natural resources in both production and final demand and changes in environmental quality. A broader concept of capital, that includes natural capital is also included. The SEEA contains both physical and monetary accounts. The asset boundaries in the physical accounts are very general and include, in principle, all assets (United Nations, 1993). In transforming physical data to monetary units a number of approaches are suggested, including market valuation, direct methods (e.g. contingent valuation) and indirect valuation.[5] A notable feature of the SEEA is the emphasis on costs, classed under indirect valuation. Not only does the system identify *ex post* costs (actual environmental protection expenditures) but also the *ex ante* costs of maintaining the environment at an undisturbed and sustainable level.

2.4. The international debate on SEEA

There is a large variety of approaches in the design of statistical systems describing the interrelationships between the natural environment and the economy (United Nations, 1991). Two extreme positions can be identified. On the one hand, there is the statistical description that focuses on the natural environment. Environmental–economic linkages are described with regard to impacts on the environment. Much of the statistical framework is concentrated on the spatial description of the natural environment, involving the use, for instance, of maps of particular regions (ecosystems or eco-zones). The information is normally presented in physical units. At the other extreme, some statistical frameworks focus on the economy and take environmental–economic linkages into account only in so far as they are connected with actual economic transactions (for example, environmental protection expenditures and actual damage costs). These data systems are more closely related to the conventional national accounts, as they present monetary data on actual transactions in market values.

In Figure 2.1 these two concepts; physical data collection and monetary accounting, are indicated in boxes 1 and 6. Approaches that are located between these two extremes could be classified with regard to the extent to which they incorporate monetary values. Systems that mainly use physical units could extend the description of the natural environment to include information on the physical flows between the environment and the and the economy (use of natural resources, flow of residual products). The existing systems of natural resource accounting and environment statistics comprise such data (boxes 1 and 2). This description in physical terms could be further extended to include information on transformation processes within the economy. Material/energy balances comprise a physical description of the use of natural resources, their transformation by production and consumption activities and the flow of residuals back to the natural environment (boxes 2 and 3). Natural resource accounting and material/energy balances overlap, especially with regard to flows between the economy and the environment (box 2).

The description of economic activities in monetary terms has been extended in the case of the SEEA to the valuation of the use of natural environment. Different methods are discussed below. A comprehensive measurement of costs and benefits of economic activities and their environmental impacts is the purpose of such calculations (boxes 5 and 6) (see, for example, Bartelmus et al., 1991). Such valuation not only facilitates the incorporation of environmental concerns into economic analysis but also creates a common scale of measurement that allows the compilation of economic-environmental aggregates on a highly condensed level.

The SEEA thus covers in principle both national accounts describing economic activities and environmental accounts including all monetary and physical flows that describe the inter-relationship between the environment and the economy (Figure 2.1, boxes 1, 2, 3, 5 and 6). This ideal concept cannot be fully realized at present, since comprehensive data systems for describing the natural environment and its interaction with the economy are still missing. Some ambitious approaches have been advanced in several countries, but no

NATURAL ENVIRONMENT ————————————————> ECONOMY

Physical description (with spatial orientation)	Physical flows between the natural environment and the economy	Physical flows within the economy
1	2	3
No economic valuation	Additional market (imputed) and non-market valuation	Disaggregation of the national accounts
4	5	6

NATURAL ENVIRONMENT <———————————————— ECONOMY

DIFFERENT ACCOUNTING SYSTEMS:

1:	Environment statistics in a narrow sense
1+2:	Natural resource accounts and environment in a broader sense
6:	Economic accounting system (SNA)
2+3:	Materials/energy balances
1+2+3+5+6:	(Satellite) system of integrated environmental and economic accounting (SEEA)
5+6:	Extended economic accounting system

Source: United Nations (1993)

Figure 2.1. Data sources for integrated environmental and economic accounting

overall description of the natural environment has been realized so far. This is partly, but not exclusively due to inadequate financial support. While it is true that additional financial resources would have brought about more success in developing comprehensive statistical systems in the field of environment, the main reasons for the absence of comprehensive environmental accounting are the difficulties in describing the natural environment with its climatic, biological, physical and chemical changes, within a generic model of complex interrelationships. To date, most environmental assessments describe the state of the natural environment at a certain point in time. In general, except for selected regional case-studies, it has been impossible to fully portray the dynamics of natural processes. A complete integration of existing environmental and economic data systems seems, therefore, to be still an elusive objective.

It is, therefore, necessary to concentrate first of all on improving basic environment statistics and to develop, as a second step, consistent systems for describing the natural environment. The Framework for the Development of Environment Statistics (FDES) of the United Nations and the work of the Economic Commission for Europe in the field of environmental statistics are pertinent initiatives in this regard (United Nations, 1984, 1988, 1991). The SEEA includes the following four elements:

(i) Transaction and other economic flow and stock elements of the established economic accounting system of the national accounts which are of special relevance to the measurement of the environmental impact of economic activities. Examples are defensive expenditures undertaken to protect materials and human beings against environmental pollution. (Figure 2.1, parts of box 6).

(ii) Environmental stocks and flows to which alternative monetary (non-market) valuations for the use of the environment are applied (box 5). Examples are damages to soils, degradation of forests, damage from mining of minerals etc.

(iii) Physical data on the flows of natural resources from the natural environment to the economy and their transformation within the economy; and on the flows of residuals of economic activities to the natural environment (boxes 2 and 3). Examples of the former are uses of natural resources not accounted for in the conventional accounts, such as some non-timber resources, hunting of wild animals, recreational use of parks etc. Examples of the latter are generation of solid waste, emissions of pollutants to the air and water etc.

(iv) A description of the natural environment in physical terms in so far as it is necessary for the purpose of analyzing the impacts of human use. This part would thus not represent a comprehensive description of the state of the environment (parts of box 1). The present cadastre provides data that will fulfill this function.

It can be seen from the above that there is a wide range of views about how environmental accounts should be constructed. The main difference is between those who favour the valuation of environmental impacts in monetary terms and those who argue that the accounts should be restricted to physical information only. We take the view that monetary valuation is an important step in linking economic and environmental accounts. By doing this we are not necessarily taking a purely economic view of environmental concerns. Rather, the method permits the introduction of ecological elements into economic thinking and decision making through the employment of a common framework. If ecological issues can be translated into monetary terms, the possibility of economic decisions, taking environmental problems into account is much improved. The aim of the SEEA is thus to establish a suitable database for policies of sustainable development that incorporate the issue of the environment into mainstream policies.

The focus of this paper is to present a framework to show how the role of damage estimation can be integrated into environmental accounts. As mentioned previously, the SEEA offers very little guidance on how damages should actually be measured. It is the purpose of this paper to illustrate how a comprehensive, consistent valuation of damages could be undertaken for China using the damage estimation approach.

2.5. The European GARP studies

The basis for the analysis presented here is a methodology developed by the ExternE Project of the EC Directorate General XII (JOULE II Programme). The ExternE Project is a major multidisciplinary study which has developed a detailed 'bottom-up' approach for the assessment of the social costs of fuel cycles (European Commission, 1995). This methodology incorporates state of the art models and data which have been the subject of international peer review.

In order to evaluate the possibility of constructing a set of coherent monetary damages estimates in the EU, a further study was undertaken with financing from the European Commission (DGXII). The title is Green Accounting Research Project, referred to under the acronym GARPI. This project is now in its second phase (GARPII), which hopes to improve both on the methodology employed and the quality of the results obtained. The GARP project has the following objectives:

(a) Assessing the feasibility of preparing, at the EU level, monetary valuations of environmental damages caused by economic activities. The assessment should focus on the scope for making the valuations in a consistent manner for all the countries, on the accuracy of the estimates obtained, and on the extent of the damages covered by the monetary valuation. Issues to be discussed include the transferability of studies of damage across countries and over time, and the extent to which damages are already internalized through the costs of pollution control.

(b) Reporting some initial estimates of national level damages for the countries studied (Germany, Italy, Netherlands and the UK). Where monetary valuation is not feasible, the results have been reported in terms of physical impacts.

The objective of this report is to present the framework used for GARP and comment on its applicability for the Chinese context. The study has covered a very wide range of environmental impacts, yet only some of these are relevant to China. Recommendations will be made on the impacts that should receive priority along with any special modifications needed.

2.6. Methodological issues in damage estimation for green accounting

In preparing environmental accounts, a number of issues need to be addressed. These include:

- Treatment of environmental services, such as waste disposal.
- Treatment of environmental damages, such as air and water pollution, noise etc.
- Treatment of defensive expenditures.
- Treatment of depletion of resources (or their augmentation).

There are a number of problems associated with all of these. For a discussion of the issues see, Ahmadet al. (1989), United Nations (1993), Markandya and Costanza (1993). This paper does not seek to resolve the controversies surrounding the questions of whether or not any of the above should be added or subtracted from the national income accounts. Instead it focuses on the question, if the item under considerations is to be treated as part of the national income accounting framework, what is the most practicable way of measuring it, how should be valuation be carried out, and what issues need to be flagged in the conduct of the valuation?

The area in which research is most advanced and which forms the main emphasis of this paper is the treatment of environmental damages. Natural resource depletion and the corresponding valuation of changes in mineral stocks are acknowledged to be important issues and have received considerable attention in China.[6] They are, however, not addressed in this paper.

The correct approach to be taken would be based on a spatially disaggregated analysis of damages in China. Such a disaggregation is essential to achieve the kind of detail that is required for an adequate valuation, as well as providing regional information likely to be of great value to policy makers. Regional data and regional income accounts are probably the most valuable for a country as administratively vast as China. Given data on the levels of these pollutants, damage estimates could be made using dose-response functions and unit valuations based, as far as possible, on a willingness to pay approach (WTP). The method is a somewhat restricted version of a full bottom up analysis.[7] Sources of pollution are not estimated directly, only by attribution after the analysis is complete. The method used is known as an impact pathway approach and is illustrated below:

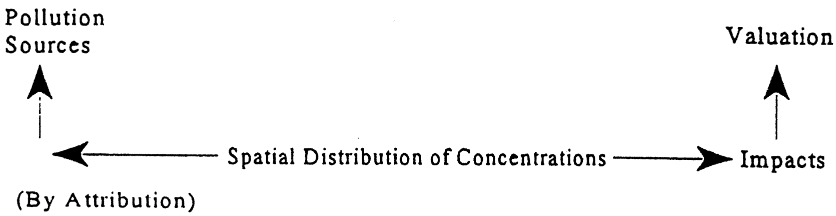

Figure 2.2. Impact pathway approach

Table 2.1 presents a classification of damage related impacts. It shows what impacts have been assessed in previous studies (GARP) and also identifies what impacts we believe should be addressed as a priority for China.

A number of issues arose at this methodological stage. The key ones were:

(i) How should transboundary pollution be treated?

(ii) How should background levels of pollution be determined?

Table 2.1. Possible impacts assessment for China

	Health	Materials	Crops	Forests	Amenity	Ecosystems[3]
PM_{10}	A, P	A, P	NE	NE	NA, NP	NE
SO_2^1	A, P	A, P	A, P	A, P	NA, NP	A, NP
NO_x^1	A, P	A, P	A, P	A, P	NA, NP	A, NP
Ozone	A, P	A, P	A, P	NA, NP	NE	NE
GHG[3]	A, P	A, P	A, P	A, P	A, NP	A, NP
Noise	NA, NP	NE	NE	NE	A, NP	NE

Note: The first letter refers to the results from the GARP study, the second indicates whether the impact is identified as a priority for the Chinese context

A: Assessed in at least some studies.
NA: Not assessed, although it is believed the impact may be important.
NE: No effect of significance is anticipated.
P: Priority impact.
NP: Non-priority impact.

[1]SO_2 and NO_x include acid deposition impacts.
[2]Effects of PM_{10}, NO_x and SO_2 on amenity arise with respect to visibility. In previous studies these have not been found to be significance in Europe, although they are important in the US.
[3]Greenhouse gases (i.e. those that affect climate globally).

(iii) How should defensive expenditures be treated?

(iv) How should intertemporal damages be valued?

In addressing these questions the guiding principle has been the idea that one is seeking to measure human welfare, or more precisely changes in human welfare in the Chinese context. The extent to which national income is an adequate measure of 'national welfare' is certainly questionable, but it is an important dimension of that welfare. Whether one decides to modify it in the light of estimates of national damage, or whether one simply presents these data alongside the national income accounts, it is desirable that the calculations be based on a clearly defined economic principle. The one most appropriate for the measurement of environmental damages is willingness to pay (see Markandya et al. 1996).

2.6.1. How should transboundary pollution be treated?

National accounts attempt to measure the flow of welfare to the residents of a given country. Damages caused by country 1's pollution to country 2 are not directly relevant to the welfare of country 1's residents, although the received pollution from other countries is relevant. Hence estimates should be receptor based rather than source based. This is particularly important for damages related to climate change. Most damage estimates for CO_2 are global damages which cannot be subtracted from a national level calculations of benefits. Following this approach, an estimate of the likely damages occurring in China as a result of climate change could be made.

2.6.2. What should be the background level of pollution?

This issue has emerged as extremely important. Background levels (defined as levels that would exist in the absence of human activity) will vary from region to region, let alone from country to country. The calculated damages are very sensitive to the choice of these values. On the basis of the GARP results, it is clear that further research will be required on this issue.

2.6.3. How should defensive expenditures be treated?

Different levels of expenditure on pollution abatement are likely to exist within the various regions of China. It is also likely that such abatement expenditures will increase over time. Therefore, it would be very difficult to make regional or intertemporal comparisons of the costs of environmental damage if one did not allow for changes in the levels of defensive expenditure. The authors believe that such information is important for the purposes of environmental accounting, irrespective of whether or not national income accounts are adjusted for it. The GARP study has made a limited start on collecting the relevant information, which is reported here. The issue of whether such data can be collected at reasonable cost and within a common framework is addressed in the concluding section.

2.6.4. How should intertemporal damage impacts of pollution be treated?

In some cases, particularly with regard to forestry and climate change, current damages are a function of both present and past pollution concentrations, and present emissions cause damages both now and in the future. Conceptually, national income measures the flow of welfare, both now and in the future, emanating from the current flow of activities (Weizmann, 1976). Hence in so far as future damages are being generated, they should be measured and allowed for. In practice, this is difficult to do, and the case of climate change is the only one where serious attention is paid to this issue. Where it arises, the issue of what discount rate to apply to future damages also arises. This question has been discussed at length elsewhere (see European Commission, 1995) and is not covered here again.

The basic argument presented there is that a 'social' rate of around 3% in real terms is justified for most costs, but that impacts which occur over very long periods, or which involve significant changes in the sustainability of ecosystems, should be treated differently. One possible method of treating them is to look at the costs of restoring the system or limiting the damage at a level consistent with overall 'sustainability'.

2.6.5. Sustainable income

In the current discussion of environmental accounting there is much interest in the concept of sustainable income. The idea is that one should seek to measure the flow of goods and services that the present asset base would permit, in perpetuity. This is the value of all that is produced, less the amount that has to be set aside to allow for depletion in the asset base through depreciation, degradation etc. The asset base includes physical capital, human capital and natural capital. For examples of this approach see Costanza and Daly (1992), da Motta and Young (1992; for Brazil), 1992; Bryant and Cook (1992; for the UK), Young (1992; for Australia), Repetto et al. (1989; for Indonesia), Solorzano et al. (1991; for Costa Rica), Uno (1989; Japan), van Tongeren et al. (1991; for Mexico).

The framework presented here for analysis contributes to the measurement of sustainable income by correcting the measure of the flow of goods and services that flow from the present capital stock. Thus an economy that is generating increases in emissions should account for those emissions as part of the flow of goods and services (negative ones in this case).

A different way of looking at environmental damages is to view the emissions as causing damage to the stock of natural capital, and thereby depleting the stock of that capital. Consequently, there will be a fall in the flow of services in the future, other things being equal. In some cases, the emissions generated do cause damages to an identified natural asset. Examples would be damages caused by agricultural runoff to water reservoirs, or damages caused by acidification to forest growth. One can then calculate the damages by estimating the reduced value of the natural capital stock, and the reduced flow of services that the stock will generate.

Two points need to be made here. First, not all environmental 'damages' impact on the natural (or other) capital stock. Noise and crop damages are examples. For these it is necessary to measure the damages in terms of the reduced flow of goods and services. Second, where there is an impact on the 'capital stock', the present calculations intend, in principle, to pick up effects of that impact on the flow of goods and services over time. Hence, if the calculations are done correctly, the estimation of damages as carried out here does pick up the effects over time, and hence the impact of the pollution on the value of the natural (or other) asset. This can be seen as follows:

Suppose an asset has current value A, and will generate a stream of services of value $H_1, H_2, \ldots H_n$ over n time periods. By the definition of the value of an asset:

$$A = \sum_{i}^{n} H_i \cdot (1 + r)^{-i}$$

where r is the discount rate.

If an increase in pollution reduces the flow of services to $L_1, L_2, \ldots L_n$, then the present methodology seeks to measure environmental damage D, where:

$$D = \sum_{1}^{N} (H_i - L_i) \cdot (1 + r)^{-i}$$

The change in the value of the asset, however, is also D. A sustainable income approach would then deduct from present national income an amount equal to D, to allow for the depreciation in the asset base (and therefore what has to be put aside to maintain that base). Thus the two approaches are equivalent in terms of the correction to national income. It does imply, however, that, in correcting measures of GDP for environmental damages, one should work with net national income i.e. income after depreciation. In practice, of course, both a sustainable income approach from a capital perspective or from the flow of services perspective needs careful measurement of changes in environmental service flows, choices of discount rates etc. Approximations are often taken which will result in a capital approach and a flow of services approach giving different answers.

2.6.6. Other measures of welfare

National income, even after correcting for environmental damages is not the only, or even the best measure of social welfare. There are attempts at producing better measures that include environmental, social and other considerations of welfare. See, for example, the UNDP Index of welfare (United Nations Development Programme, 1990 et seq.), the Daly-Cobb index or sustainable welfare (Daly and Cobb, 1989). In the GARP study, the team was not wedded to the notion that monetary estimates of environmental damage should only be used to adjust national income accounts. There is a case for making such adjustments on the grounds that national income statistics are widely used in making government policy, and a better measure of the value of goods and services (which national income seeks to quantify) will result in better policy. But in many areas other measures are more appropriate. In those circumstances, one would argue that a careful assessment of the environmental damages will be an important input into the construction of the index. The authors recommend the same approach be taken when considering Chinese welfare issues.

2.6.7. Monetary and non-monetary valuation of impacts

The GARP study has sought to obtain the maximum monetary valuation of environmental impacts. The argument is that with monetary values it is easier to integrate environmental costs with other costs and benefits, a stated goal of the CA21 Agenda. However, it is important to be aware that not all impacts can be valued in monetary terms. This paper will provide guidance on identifying those areas where such valuation is not possible or credible. In such cases a careful, consistent reporting of the physical impacts is seen as important. In the GARP study, this has been done where monetary valuation was not possible. For those deriving indices of welfare, it may be possible to use such information directly. In policy terms it can form part of indicators of environmental pressure of environmental sustainability.

2.7. Air quality data requirements

2.7.1. Air pollution concentration data

The GARP study made use of spatially disaggregated data on pollution concentrations to estimate damages. The level of disaggregation selected varied from country to country. Although pan-European data sets exist with resolutions of 50–100 km^2, finer resolutions are available in some countries, and for some pollutants. Where they were available and accessible, they were chosen. The quality of data is obviously influenced by the number of monitoring stations, the sophistication of the atmospheric transport models used to move from point sources to grid values and the grid resolutions. Where gaps are present interpolation may be required. Although data are not available on such a comprehensive basis for China, there is quite a lot of detail on air quality for the populated locations. This can be used to contruct a grid, based on interpolation.[8]

2.7.2. Background concentrations

In the context of the GARP study, the objective of the analysis, to relate environmental impacts to human activity, dictates that the damages resulting from 1990 emissions of pollution are compared to the level that would exist in the absence of human activity. For some pollutants an estimate of these levels can be gauged from the concentrations measured in remote areas. The most appropriate data for SO_2 and NO_x levels in Northern Europe seems likely to come from North West Scotland. This region is remote from major industrial activity and the prevailing south westerly winds are unlikely to carry a high pollution load from other countries. The Review Group on Acid Rain (RGAR, 1990) provide values of about 1ppb SO_2 and 2ppb NO_2 for this region. Data modelled for the UK using the Harwell Trajectory Model agree well with these figures. Background levels of acid deposition (H^+) were estimated from a 20×20 km rainfall map for the UK and the assumption of pH 5 rain in pristine areas (RGAR, 1990). Background PM_{10} concentrations are more difficult to predict, because of diverse sources of particulates of natural origin. The GARP study utilized a range of values from 5–15 $\mu g/m^3$. Finally background levels had to be agreed for ozone. These are also difficult to estimate as they will vary considerably with altitude, sunlight and other climatic factors. The GARP study utilized a range of values, with a central estimate of around 20 ppb. As mentioned previously, it is clear that damages will be highly dependent on background levels. At present, there is still uncertainty in this area and further research is needed. The GARPII study aims to fulfil this requirement.

ISSUES ARISING IN VALUING IMPACTS AND INTERPRETING RESULTS

2.1. Health impacts

Health impacts resulting from air pollution are probably the most important of all to value and also the most difficult conceptually. Impacts to be valued were divided into mortality, morbidity and accidents. The methodology used is the impact pathway approach, as discussed in section 1.5. The set of exposure–response functions used are generally based on US epidemiological studies. This is an acceptable procedure in an area where the literature is world wide, and where the analyses carried out in the US have resulted in careful, sound studies. A similar dependence applies to valuation techniques. It is necessary here, however, to consider carefully the cultural dependence of the estimates and thus there applicability to the China situation.

2.1.1. Valuing mortality impacts

The mortality approach in the valuation literature is based on the estimation of the willingness-to-pay for a change in the risk of death. This is converted into the 'value of a statistical life' (VOSL) by dividing the WTP by the change in risk. So, for example, if the estimated WTP is ECU100 for a reduction in the risk of death of 1/10 000, the value of a statistical life is estimated at $100 \times 10\,000$, which equals one million ECU. This way of conceptualizing the willingness to pay for a change in the risk of death has many assumptions, primary among them being the 'linearity' between risk and payment. For example, a risk of death of 1/1000 would then be valued at ECU 1 million/1000, or 1000 ECU using the VOSL approach. Within a small range of the risk of death at which the VOSL is established this may not be a bad assumption, but it is clearly indefensible for risk levels very different from the one used in obtaining the original estimate. In the GARPI study, a value of ECU2.6 million in 1990 prices was used as a best central estimate for VOSL. A range of problems using this approach were identified. The most important is the fact that pollution related deaths involve a much smaller loss of life years than the deaths on which VOSL is based. Hence, using VOSL results in a substantial overvaluation of health costs. For example, in the GARP study, the total health costs of environmental pollution were estimated at ECU15 billion. (Germany), ECU196 billion (Italy) and ECU97 billion (UK). These are clearly implausibly high values.

An alternative method to value mortality impacts is to use the concept of the value of life years lost (VLYL). In this paper we present estimates using the VLYL method and indeed, we conclude that this approach is preferable for assessing impacts in China. It is possible to estimate the VLYL from the estimates of the VOSL, if one has data on the age of the reference group, and some way of estimating the discount factor applied to present versus future years of life. Some work along these lines is cited in a US Study (Harrison and Rubinfeld, 1990), and indicates that the implied value of a year of life lost, when used to value average years of life lost from premature death caused by cancer, cardiovascular disease etc., is only around 30% of the value that would emerge from an application of the value of a statistical life. There are several assumptions that are made in arriving at this calculation and more work is needed if the result is to be validated, but the issue is important enough to be analysed further.

Pursuing this line of reasoning, one can calculate the value of a life year lost as follows. Consider a 'prime age male' with 37 years of life expectancy, for whom the VOSL of ECU2.6 million is correct. Applying a discount rate of 3% to the annual value of a life year results in a value for a life year lost (VLYL) of ECU115 000.[9] Using this value will have an impact on estimated health costs that is dependent on the number of years lost. This value was adopted in the GARPI study. Pollution related deaths were divided into acute and chronic. It was further estimated that, for acute effects the loss of life years was about 1.25, whereas for chronic effects it was 3. Hence the central estimates for VLYL are ECU145 000 for acute mortality and ECU325 000 for chronic mortality. With this method, the GARP study reported total health costs of environmental pollution of ECU2.9 billion. (Germany), ECU33.4 billion. (Italy) and ECU10 billion (UK).

A valuation of mortality impacts for China, following this discussion, is given below.

2.1.2. Valuing morbidity impacts

For morbidity impacts, the US literature is the main basis for identifying suitable methodologies. In GARP I study impacts were categorised into estimates of restrictive activity days (RADs) and variants of that; estimates of chronic illness (COI), symptom-days (SDs), and altruistic impacts. For RADs and variants, US estimates were employed, with conversion into ECU made using a purchasing power parity exchange rate. Further details can be found in Markandya et al. (1996).

Using a VLYL approach, morbidity costs are around 30% of total costs. Most significantly morbidity costs arise from symptom days and restrictive activity days, both of which need to be investigated further. Other morbidity costs were not found to be significant. With a VOSL basis, morbidity costs are 3–4% of total health costs and therefore insignificant in this kind of valuation.

2.1.3. Some preliminary estimates for China

In this section we discuss the literature pertaining to, and present some figures for, the damages associated with particulate air pollution.

One study that has estimated the costs of particulate pollution in China is that of Florig (1993). He looked at mortality and morbidity costs in urban areas, valuing life using a Value of Statistical Life (VOSL) approach, based on a US value of $3.5 million, adjusted downwards by the percentage by which China's GDP is less that of the US. For a discussion of this assumption see Krupnick et al. (1996). For morbidity, he estimated restricted activity days (RADs), using a cost equal to one day's GDP. Recently Pearce (1996) has updated Florig's figures, by adjusting for the changes in China's GDP relative to that of the US. The estimates of damages are:

Mortality cost:	$41.67 billion
Morbidity cost:	$19.30 billion
Total	$60.97 billion

This amounts to a per capita cost of $52, or 11.1% of per capita GDP.

These estimates can be modified in a number of ways. First, purchasing power parity (PPP) estimates of GDP instead of the actual value of GDP should be used since they reflect the influence of changing prices. This would make China's GDP equal to 9.8% of US GDP. China's VOSL can then be calculated as 9.8% of that of the US. Therefore 9.8% of \$3.5 million gives a VOSL of \$343 400.

For morbidity costs, the value of RAD can be taken as 9.8% of the US value of \$74.4, which would amount to \$7.3. Alternatively, 1/365 of the PPP per capita GDP figure can be taken which would give a figure of \$6.87. In the calculations reported below the lower figure has been used.

Making these two adjustments gives the following values for particulate pollution cost:

Mortality cost:	\$314.20 bn
Morbidity cost:	\$102.78 bn
Total	\$416.98 bn

The morbidity costs seem high, but this is a reflection of the size of the population affected. The above estimates provide two transferable values: the cost per capita and cost as a percentage of GDP. An estimate of the total Chinese population for mid-1994 is 1 191 million (World Bank, 1996). Hence the total cost per capita is \$350. As a percentage of per capita GDP it is 13.8%.

It is worth comparing these estimates with those from the GARP I study; in particular for the UK and the Netherlands. For the UK particulate damage was estimated at \$1702 per capita for the whole country, equivalent to 10.6% of GDP. For the Netherlands, the costs amounted to over \$6000, yet we believe these need adjusting. Both sets of numbers are national estimates using the VOSL of \$3.12 million, and a value for a RAD of \$74.4.

Compared to the UK estimates, the China figures are plausible but it should be noted that the GARP figures based on a VOSL approach are regarded as too high. The values based on the VLYL are 15.9% of the values with a VOSL. As discussed above there are good arguments for taking a VLYL approach for air pollution valuation. If we do that for China we get the following values per case:

Acute mortality cost:	\$19 150
Chronic mortality cost:	\$42 930

Based on the above values, the estimates of damages from particulate pollution in China cannot be computed without knowing the number of estimated chronic and acute cases. It may be possible to obtain that data from applying dose-response functions for particulate pollution to the population at risk, given the concentrations to which the population is exposed. Alternatively we can get a crude estimate by taking 15.9% in going from VOSL to VLYL. This gives the following values:

Mortality cost:	\$50.00 billion
Morbidity cost:	\$109.20 billion
Total	\$159.20 billion

As per capita of the urban population this is $461, and as a percentage of GDP it is 5.34%. We recommend that such values can be used in preparing a damage estimate of health impacts for China.

2.2. Crop damage

In this impact category several European studies[10] have established dose–response functions for the effect of air pollutants on crops. We do not discuss them in detail here but refer the reader to the individual country studies. There are a number of issues arising in the estimation of the crops damages. These are:

- Prices changes and adaptation to different pollution levels by farmers.
- Valuation of damages, choice of gross or net damages.
- Selection of prices for the valuation.
- Use of defensive expenditures.

2.2.1. Price changes and other adaptations

In valuing crop damages, the estimates will depend on how much prices are affected by the changes in concentrations. The earliest crop damage estimate studies simply multiplied the reduction in output attributable to the pollutant (according to the biological dose–response relationship) by the market price. This only gives a partial equilibrium analysis and can only be taken as a rough estimate. It ignores behavioural responses or price changes which would be included in a general equilibrium analysis.

Indeed, in the context of higher pollution levels, producers are likely to switch to those crop varieties which can give a better resistance to the air pollutants in the region. Alternatively, the farmers may alter the use of other inputs such as calcium carbonate, which mitigates the pollution impact. In relation to price changes, a fall in the yield as a result of pollution will generally mean less output at a higher market price. Consumers will lose when pollution increases if the market prices are at all sensitive to output. This was shown clearly in the European studies referred to above. In addition to these studies, US studies have also shown the importance of the price effects, where the percentage of the total loss attributable to consumers ranged from 50% (Adams et al., 1985) to 100% (Adams and McCarl, 1985). Given that producers can sometimes gain from an increase in air pollution, not including the consumer impacts can overestimate total losses and misrepresent the distribution of welfare effects. Producers, on the other hand, will lose or gain depending on the price elasticities of their particular crops.

The crucial issue is to what extent the prices for crops will change as a result of the changes in concentrations of pollution. To address this fully, it would be necessary to construct a model of demand and supply for the different products and, based on elasticities, calculate the resulting damages from the present levels of air pollution. This was not possible in the GARP study. The results reported are for damages assuming that prices are unaffected by the pollution levels. This probably results in an overestimation of damages but, given the small amount of damages anyway, it did not seem important to give priority to this refinement at this stage. In subsequent work the analysis is hoped to be refined.

2.2.2. *Selection of gross or net values*

The next issue is whether one should take the change in value, net of costs of production, or the gross value. Ideally what one wants to measure is the change in the value of the rents derived from the production. In the case where there is a change in an exogenous factor such as the deposition of pollutants, it can be shown that the change in the net income after deducting the costs of inputs is given by the gross value of the change in production. This conclusion is dependent on the assumptions that (a) the producers are price takers, (b) there is no change in the prices of the inputs or outputs and, related to that, (c) the changes in the quantities are marginal. In the case of overall pollution damages, the assumption of changes being marginal may not always hold, although in most cases we are looking at changes in yields of only 1–3%.

2.2.3. *Selection of prices*

In the European context, for many of the crops affected, the prices are not determined by market forces but are influenced by the Common Agricultural Policy (CAP). In such cases, it has been argued by many economists that the changes in the value of the output should be valued at international or border prices and not the actual prices that are prevailing in the market in question (see, for example, Squire and van der Tak, 1975). The GARP team decided that it is appropriate to use border prices as long as the reason for the divergence between the domestic and international price is not the correction of some externality. For major crops produced in the EU there is no direct externality involved and it is therefore appropriate to use the international price in valuing the changes. The teams worked on the basis of international prices, but these appear to vary not insignificantly from country to country. For example the price of 'wheat' was taken as (ECU/ton): 107 (Italy), 150 (Netherlands), 96 (UK and Germany). Differences are partly due to different categories of wheat, and to differences in c.i.f. costs. Nevertheless, it was recognized that this issue that needs further investigation.

2.2.4. Use of defensive expenditures

In the GARP analysis for the UK, 'defensive' expenditures for crops were considered in two areas: the benefits of nitrogen oxide depositions, the damages from soil acidification. For the former, it concluded that there were benefits in the fertilization and these were valued in terms of the cost of fertilizer, taking the view that the application of nitrogen in fertilizer was reduced by that amount. At the margin this is not too bad an assumption to make. The benefits appear to be of the order of ECU23 million. for the UK. For acidification, the estimates were based on the additional calcium carbonate required to neutralize the deposition of H^+. This will result in an overestimate of damages in so far as full neutralization is not required, or lower cost adjustments are possible. Given the small cost involved, however, the use of neutralization costs is acceptable.

The results obtained from the GARP study reflect the different coverage in terms of crops. The main gaps in terms of pollutant impacts are for ozone damages. Overall damages were found to be small, even when coverage is fairly complete, as in the case of the UK. For that country they amount to 0.004% of GDP, or about ECU35 per person. The estimates were found to be much higher for the Netherlands (0.076% of GDP, or ECU176 per person). In conclusion it is recognised that the full estimates for crop damages are not going to dominate the overall calculations of environmental damages. Improvements need to be made include more consistent use of dose response functions, wider coverage of crops, and allowance for changes in prices resulting from the present pollution levels.

2.2.5. Recommendations for China

Sections 2.2.1–2.2.4 discuss the important methodological issues that need to be considered before making an assessment of crop damages. In general, these are all applicable to China. A specific issue likely to influence the analysis, however, will be the nature and effect of any remaining agricultural price controls or quotas that have a significant effect on the allocative role of the price mechanism. In this case, it may well be more difficult to identify the change in the value of rents derived in production and the response of farmers to changed yields as a result of pollution damage.

2.3. Forests

Depositions of sulphur dioxide and nitrous oxides have become a major threat to the health and survival of forests. The valuation of this damage is, unfortunately, handicapped by uncertainties over the relative contribution of air pollution compared to other factors. There are many European studies of interest in this damage category which include the estimation of commercial timber loss due to air pollution and also the loss in the recreational value of forestry. The major studies are discussed in Chapter 6 of Markandya et al., (1996).

There are several data limitations in this impact category, similar to those for crops. Despite the large number of European studies, virtually none contain details regarding SO_2 deposits in a localized scenario. There are many difficulties in actually translating the physical impacts into monetary damages. A forest has many functions including those of providing timber, other non-timber products, ensuring a habitat for animal and plant species and acting as a natural buffer against environmental shocks (e.g. global warming). It is thus not unreasonable to suggest that a significant portion of the total value of a forest is from non-market values.

Quantification of forest damage is further complicated by issues of transferability. It is unlikely that estimated valuations will be applicable or transferable to other locations since the blame and causation of forest damage tends to be very 'site specific'. All physical impacts and valuations will vary according to location. The complete categories of damages are commercial timber, recreation and non-use functions, although the final one should not be viewed as a priority for the Chinese situation.

Commercial timber is valued by combining information on pollution-induced physical changes in the resource with details of market prices. The chief pollutants which concern forests are those carried in the air: SO_2, NO_x and ozone.

In the case of recreational damage, transferability to other regions or countries is much more limited than for many other categories of damages. The marginal value of forests as a recreational asset may be very different according to local demand and supply conditions. For example, a positive willingness to pay has been estimated in Sweden for the preservation of open agricultural land (open space) in what is a densely forested area; the marginal value of forests was therefore negative. Such a result would be very unlikely in say, the Netherlands, where forests are more scarce and their recreational values have been shown to be largely positive.

Almost all recreational damage valuations rely on the contingent valuation method, in which the marginal impact of pollution on recreation values is very rarely assessed. The valuations obtained are thus average values. Furthermore, there are good reasons to think that the answers given to such questions express a wider concern for the effects of air pollution, not just forest damage (i.e. they 'embed' other values). This makes it incorrect to attribute the damages of the air pollution to forests alone, and adding the 'forest' damages to other damages involves double counting.

In the GARP study, the results for all types of losses showed quite a wide range across the four countries under study. In general, total damages are dominated by losses of recreational value. These amounted to about ECU2.2 billion for Germany, or 0.18% of GDP and ECU35 per person. In contrast, the estimates for The Netherlands, although somewhat uncertain could be as high as ECU130 per person.

China is endowed with very large stocks of forest resources. Total forestry land is around 263 million hectares equivalent to 28% of total land area. However, only 46% of this resource is currently exploited. Statistics estimate that the total forest stock volume in 1993 was 10.17 billion m^3 with coniferous forest accounting for 4.82 billion m^3 and broad-leaf forest accounting for 5.32 billion m^3. The value of this resource is recognized. Under the overall management of The National Science and Technology Commission, the Research Institute of Forestry is conducting a detailed research programme into Forest Resources Valuation. Some estimates have already been published.[11] Within this, special attention has been given to Forest Environment Resources Evaluation. This addresses recreational and purification issues and could well provide a basis for incorporating a damage-estimation-based approach to economic valuation for pollutants identified in Table 2.1. The difficulties discussed above for damage estimation, however, will remain, and it is unlikely that China will be able to achieve more than a partial estimation of forest damages from air pollution.

2.4. Ecosystems

Economic activities impact on natural terrestrial ecosystems and on aquatic environments. Natural terrestrial ecosystems are affected by gaseous pollutants SO_2, NO_X, NH_3 and O_3. The changes in vegetation can have consequent effects on the associated vertebrate and invertebrate faunas and on soils. Indirect effects result from the deposited load of the pollutants S and N and their compounds. Acidic deposition resulting from the burning of fossil fuels can impact indirectly on various water bodies. Water chemistry, which is affected by direct deposition to the surface of the body, is one factor which influences the status of fish stocks.

In the GARP study, the assessment of the impacts in these areas was made in physical terms. The main problem has been the establishment of reliable dose-response functions linking gaseous pollutants to the ‘endpoints’ that we would wish to value, such as plants, fauna etc. The approach adopted has been to establish critical values for specific pollutants. These critical levels tend to be applied to broad natural vegetation groups rather than to individual species or plant communities. They are being refined and revised as knowledge increases. The impact of current, ambient levels of the various pollutants can be assessed by overlaying spatially disaggregated data of pollutant concentrations on spatially disaggregated information regarding the occurrence of relevant receptors to determine the proportion of the area of the stock at risk for which the critical level is exceeded. Damage is assumed to occur in areas where the critical load for a given receptor is exceeded. This methodology does not, however, provide any quantification of the magnitude of the impact on, for example, growth or flowering. It should also be noted that there is little or no data currently available for valuation of air pollution impacts on ecosystems

(European Commission, 1995).

For fisheries, linkages have been established between stream classes and fish stocks, now and in pre-industrial times. This allows on to estimate the loss of fish stocks but the valuation of this loss has not been undertaken as yet.

From a monetary valuation viewpoint, the treatment of damages to terrestrial and aquatic ecosystems is somewhat inadequate. There are some valuation studies that are of varying degrees of usefulness for this purpose, and which can be used to value damages in the context of an environmental accounting exercise. These have been reviewed,[12] divided into studies that start from dose response functions and then estimate damages (using CVM and other studies); studies that seek to establish damages by going directly to the CVM approach, and studies that rely on mitigation costs.

The dose–response function has been used for commercial and recreational fisheries and could be adapted to other countries and situations, although the scope for, and the conditions under which, such transfer can be made are a matter of some discussion. Some of this will be taken up in the next stage of the GARP research project. The 'direct CVM' approach is less suitable for the environmental accounting exercise. Applications were divided into species valuations, amenity valuations, water related recreational benefits, and non-use benefits related to water. The valuations of species have to be linked to damages to species based on anthropogenic activities. This may be feasible in some cases. But that is not enough, we also need valuations of losses that are relevant to the countries and situations. Transferability of species values is more limited than is sometimes suggested. Amenity valuations are generally very site specific and not often related to pollution emissions. Hence they are of limited use in the valuation exercise. They may be of importance, however, in relation to losses of amenity resulting from investments. This is something that was not considered in the GARP study. Water related recreational benefits' studies are becoming more relevant as they relate to the damages caused by specific pollutants, or relate to water quality indicators that can be related to specific pollutants. It is possible to make use of these studies in the context of this Green Accounting exercise, and is something that will be undertaken in the follow up work.

Non-use benefits are generally regarded as difficult to measure using the CVM method. The applications reported here must, therefore, be treated with caution. Nevertheless, some of the research in this area has been impressive and the results may be applicable to the valuation of damages to water bodies suffered by persons who never make use of them.

Finally there are the mitigation costs. These have been used in particularly in connection with the impacts of pollution on general surface water quality, as well as surface and ground water for drinking. Although such a procedure is not generally valid as an estimate of the damages from a polluting source, it can be a measure of the benefits if it can be established that the water treatment measures would have to be taken on grounds of public health, or if the damages would be so high that the treatment costs would be much less than any damages. Since this is not known in general, the use of mitigation data for valuing such benefits needs, therefore, further investigation.

The prospect of being able to obtain damages estimates for Chinese ecosystems is low. It is clear from the above discussion that this receptor category is one of the most difficult to analyse and that research is still in a preliminary phase. It is, nevertheless, a very important area and once techniques improve (both in the development of dose-response functions and valuation methods) the damage estimation methodology will remain the correct approach. At present, it is recommended that this category is not a priority for the Chinese situation.

2.5. Materials damages

Acidic deposition from the burning of fossil fuels is the process most widely associated with the erosion of buildings and materials, primarily stone and steel structures. Details of sulphur emissions and depositions have been available for some of the European studies in this impact category which should, in principle, make it possible to calculation of an external marginal value. The main pollutants considered are acidity, SO_2, particulate matter and chlorides.

For normal residential and commercial buildings, the best method of valuation is to estimate physical damage using a dose–response function, and then to apply values to the damages, as in the case of crops. For special buildings of historic and cultural interest, however, such a method is inappropriate. It is not the physical damage that is critical there but the fact that damages are effectively irreplaceable. For such buildings, use values may be estimated by CVM or travel cost methods. In addition information on defensive expenditures is relevant (this also applies to non-historic buildings). Non-use values can only be obtained from CVM methods, but the success of using the methodology for this purpose is limited.

The studies reviewed in Markandya et al. (1996) raise many problems, and there is some uncertainty as to their validity as far as the monetary estimates are concerned. The most serious problems that arise are with respect to the estimation of the dose–response functions. The ExternE study reviewed the literature on these and found that the forms used in many widely quoted studies are scientifically poor, out of date and sometimes both. Given that an acceptable estimate of the function has been obtained, the next step is to value the damages. Again, experience from US and other studies has shown that there is considerable scope for judgment in linking the physical damages to monetary damages. One key issue is the extent to which individuals can limit damages by suitable choice of materials, (e.g. by using galvanized guttering instead of non-galvanized guttering). However, this relates to behavioural aspects and cannot be addressed outside of a model of human decision-making.

An inventory of building materials affected, and an estimate of the damage is needed as the first step in valuation. Inventories are generally based on extrapolating from a small sample of detailed surveys of materials. As a procedure this is acceptable as long as the initial surveys are representative enough of the areas to which they are applied. This cannot be applied to special buildings, such as those of historical interest. For these, a case by case approach has to be taken.

Damages are estimated at market prices, net of taxes, as there is no reason to believe that the prices that prevail for these materials are significantly different from the social costs of using them.

In the GARP study, the classification of materials and the use of dose–response functions varied widely. This was due, in part, to the way the data on materials are collected, and in part to differences in the agreed dose-response functions. Both these issues need further discussion, to see what standardisation is possible. As an illustration of the results obtained, estimates of damages ranged from 0.1% of GDP (the Netherlands) to 0.26% of GDP (UK); this corresponds in per capita terms to ECU15 and ECU37, respectively.

It would be a major task to prepare a building inventory for China and apply the dose response functions, but it not impossible. Based on our experience with GARP I, we would put this as a second order task, to be undertaken after the health and crop impacts have been valued.

2.6. Global warming

2.6.1. Introduction

The treatment of climate change is somewhat different from the other categories of damages that have been assessed. One reason is the extreme uncertainty surrounding the figures. Although the numbers presented here have relatively small ranges, there are researchers who take the view that the values are extremely high, and others who argue that no one really knows what the damages will be. The second is that one is dealing with impacts far into the future. Hence valuation methods have to look at long time periods. Third, although damages are global, and much of the research has been on estimating global damages, the concern in the present study is at the national level. Hence one has to look at the factors that affect local environments more closely.

2.6.2. Background and methodology

Anthropogenic increases in the concentrations of greenhouse gases in the atmosphere are believed to warm-up the Earth's atmosphere, potentially causing economic damage through a number of different impact pathways, e.g. warming, sea level rise, changes in rainfall patterns, increases in the incidence and severity of storms and hurricanes.

The latest scientific assessment predicts that a doubling of preindustrial greenhouse gas concentrations in the atmosphere will result in a 1.5–4.5°C rise in temperature, which translates to a global mean surface temperature rise of 0.25°C per decade over the next century. However, there may be large regional differences. Warming in the Northern hemisphere, with greater land mass relative to oceans, may be in the order of 0.5°C per decade. This warming is likely to be accompanied by high regional climate variability and 'surprises'. The central estimate for sea level rise is 45 cm by the year 2100 compared with 1990 (Pearce et al., 1994).

A number of gases contribute to the enhanced greenhouse effect, including CH_4, N_2O and CFCs; by far the most important, however, is CO_2. Anthropogenic increases in the concentration of CO_2 in the atmosphere mainly result from the burning of fossil fuels and deforestation. It has been estimated that global emissions of CO_2 in 1990 amounted to 6.9 Giga tons of carbon (GtC), of which 5.6 GtC were caused by fossil fuel burning and 1.3 GtC were caused by deforestation (IPCC, 1992).

Climate change fits somewhat uneasily in the accounting framework presented in this paper. Apart from the large measure of uncertainly related to its causes and effects, the major problem lies in the substantial time-lag between greenhouse gas emissions and the resulting warming effect. Moreover, unlike most other air pollutants, greenhouse gases are so-called stock pollutants. Global warming damage is not caused by the flow of emissions as such, but by their accumulation in the atmosphere (Fankhauser, 1995).

This resembles another stock pollutant that has been previously considered: acid deposition. With acidification, it is not the flow of acid deposition, but rather the stock of acid that causes damage. In the GARP accounting framework, the current (1990) damages were assessed, which are, in part, caused by historical deposition patterns. In theory, this approach could also be used for climate change. This would entail the assessment of current (1990) damage due to the increase in greenhouse gas concentrations in the atmosphere from pre-industrial levels (about 280 p.p.m.) to current levels (about 350 p.p.m.). However, little is known about current damage, neither about its incidence nor its severity.

Research has generally focused on the assessment of future damages, especially the damage associated with a doubling of greenhouse gas concentrations in the atmosphere (the so-called '$2 \times CO_2$ case'). However, we are not interested in a point estimate of damage in a particular year, but rather with the flow of damages over time which can be attributed to an amount of CO_2 emissions in a particular period. This will enable us to be consistent with the theoretical framework for national income accounting.

To remain as close as possible to the 1990 accounting year and the overall methodology of this study, we should calculate the present value of expected future climate change damage in China due to global carbon emissions in the year 1990.

2.6.3. Preliminary estimates for China

Fankhauser (1995) has made some estimates for total damages in China for the $2 \times CO_2$ case. He does not quantify all impacts and issues caution that the range of error may be as high as $\pm 50\%$. The breakdown of results is shown in Table 2.2. Damages for China were the highest as a percentage of GNP out of all the regions that Fankhauser considered. Agricultural, health and ecosystem impacts are particularly severe. Tol (1996) has also made some estimates for Centrally Planned Asia (CPA) which includes China, Laos, Mongolia, Vietnam and North Korea. In the Fankhauser study, world net damage costs are US$270 billion, yielding a central estimate for the damage attributable to 1 ton of carbon (1tC) of US$20. In Tol (1996), the total damage estimate is almost twice as high, at US$523.8 billion. Hence, damage costs per ton of carbon are US$38.8. Of the World damage of US$523.8 billion, US$69.9 billion or 13.3% can be said to impact on CPA. The marginal damage in CPA of 1tC is then $0.133 \times 38.8 = \text{US\$}5.156$.

Table 2.2. Total damage in China due to global warming ($billion;.(1988)

Impact category	Damage estimate
Coastal defence	0.0
Dryland loss	0.0
Wetland loss	0.6
Ecosystems loss	2.2
Agriculture	7.8
Forestry	0.0
Energy	0.7
Water	1.6
Human health (mortality only)	2.9
Air pollution	0.2
Migration	0.6
Natural hazards (hurricanes only)	0.1
Total	16.7
%GNP	4.7

Source: based on Fankhauser (1995)

With reference to our original criteria, the total NPV of damage in CPA (including China) due to global CO2 emissions in 1990 can be calculated as:

$$6.9 \text{ GtC (World global emissions, 1990)} * \text{US\$/tC}5.156 * 10^9 = \text{US\$}35.6 \text{ billion}$$

In an environmental accounting exercise, the above damages suffered by China as a result of emissions in one year should be deducted from estimates of GDP. The numbers are, however, much more uncertain than others that have been discussed in this paper.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

This paper has presented the framework needed in order to use the damage estimation method as a tool in the preparation of a set of comprehensive environmental accounts for China. The approach illustrated was receptor based, i.e. to look at environmental pollution concentrations in a spatially disaggregated fashion, and to estimate damages associated with these pollutants. The paper has presented some initial results of the application of this methodology outside China (the Green Accounting Research Project (GARPI)) and has discussed how the method could be applied in China. The GARPI study has conducted valuations for the damages associated with the major pollutants. It did not cover all pollutants; in particular it focussed on air emissions. Furthermore it does not address the question of whether or not the estimated damages were 'internalized' in the GDP figures; i.e. whether GDP was already at a lower level because of the damages. On account of its receptor-based approach, the study did not look at damages outside national boundaries.

Some of the results have been included and critiqued. They are intended for comparative purposes only: in order to have an idea of sample orders of magnitude for damages in the European context.

An impact assessment and valuation exercise for China is likely to have a different focus. As a first step, impacts will need to be prioritised in order to make the exercise manageable. We believe that the first effort should be on valuing health damages, followed by damages to crops, materials and possibly forests. Once research is initiated, the actual approach will be constrained by the physical data available. Nevertheless, the damage estimation (impact pathway) method used in the GARPI study can provide a reference point for any analysis. The degree of spatial disaggregation is likely to vary by province, as will the availability of data on pollution concentrations and estimates of stocks at risk. A wide range of damage estimates would therefore be likely, if an attempt was made at an overall national analysis, but on a regional basis.

The paper has shown that monetary estimation of the impacts of pollutants on health, materials and crops can be established, with some credibility. Some further work is required to take these estimates to a level where they can be reported in a set of satellite environmental accounts. In addition, we believe that the physical data of environmental impacts is of considerable value and it is recommended that the latter be presented alongside the monetary data. It can also be concluded that obtaining reasonable coverage of the monetary impacts of damages to forests and ecosystems is more difficult. Some improvements in these areas are possible but it is highly unlikely that comprehensive estimates can be developed. It is recommended therefore that a hybrid approach be adopted, where monetary values and physical impacts are presented, with the latter being in the form that is closest to the 'end point' that affects human welfare. This paper has identified which impacts should be considered a priority in the Chinese case.

The estimates of global warming damages reflect the consensus that currently exists among important sections of the scientific research community. But it is important to note that there is a significant group of researchers who challenge the assumptions on which the figures are based. It is recommended that national damage estimates of global warming be reported as a separate category, indicating that they are highly uncertain and possibly subject to major revisions.

Since the damage estimation framework has now been laid out, the next issue arising is how (and to what extent) these estimates can be integrated into a system of national accounts. On the basis of the results obtained in the first phase of GARPI, we would argue that the data are more usefully presented alongside the national income accounts rather than deducted from GDP. One reason is that the extent to which damages have been internalized is not known. Subtracting them, therefore, could result in double counting. The second is that by far the greatest benefit in these data is to guide policy on the economic and environmental interface, and the aggregation of damages is of little value in this regard.

To develop the research further, coverage within a country has to be extended so that it is as uniform as possible. That is important for policy making. Second, damages have to be attributed to sources. This is an essential linkage if the framework is to be of policy relevance. Third, coverage has to be extended to pollutants that affect water resources, as other studies indicate this to be of importance in terms of environmental priorities.

What is the likely cost of carrying out such a study in a country like China? It is our view that this can be done at reasonable cost, because it is not necessary to review all the components that go into the valuation. There are, broadly, three components: data on pollutants and their concentrations, data on stocks at risk and data on valuation of end points. The first will need the most frequent updating, to reflect physical changes in the environmental situation. The second will need to be revised as frequently as similar data is revised in other sections of the national accounts (e.g. data on stocks of buildings, persons resident in different areas, forest stocks etc.). The third need be revised less frequently. Changes in estimates of VLYL or property depreciation per unit of noise etc. can be made, for example, every 3–5 years. When such changes are made, it will be necessary to re-estimate previous damages so as to maintain a consistent time series.[13] This should not, however, be too costly an exercise.

Notes

1. This paper is based on a large study undertaken by many researchers, under the guidance of A. Markandya. The researchers are the following: From Germany: U. Triebswetter (Ifo Institut), W. Krewitt and R. Freidrich (IER); from Italy: M. Pavan, D. Guidi (FEEM); from the Netherlands: O. Kuik (IES); from the UK: M. Holland, C. Johnson and P. Watkiss (ETSU), N. Eyre (EEE), F. Hurley (IOM), M. Hornung and D. Howard (ITE). They must share the credit for this work, but not the blame for any errors in this paper. Acknowledgement must also be

made to the European Commission, DGXII, for financial support, to Mr Leo De Nocker for assistance with and comments on earlier drafts, and to Mr P. Valette for his intellectual support for this project. Those interested in the full analysis should read the Report to the Commission, Markandya et al., 1996.

2. See Ahmad et al., 1989.
3. For a discussion of the theoretical issues in developing environmental accounts see Peskin (1996) or Maeler (1996).
4. The outcome of the research was the publication of two documents; *The Initial Research of Natural Resource Accounting* (1990) and *The Discussion of Resource Accounting* (1991). This was the first time the theory and structure of NRA for China had been put forward.
5. The terminology used is somewhat unusual and is not consistent with that used in the environmental economics literature, e.g. hedonic pricing and travel cost methods are classed as 'direct methods' whereas in the literature these are typically regarded as 'indirect' because the value of the environmental resource is revealed indirectly from associated market goods.
6. See Du Donghai and Wang Zhixiong, *The Study of Mineral Resource Accounting in China.*
7. See European Commission (1995).
8. For details of the interpolation methods used see Markandya et al. (1996).
9. The calculation is $VOSL = \sum VLYL_i \cdot (1.03)^{-i}$. If VLYL is independent of i this gives the figure reported above when the summation is over 37 years.
10. Although the studies are cited above as 'European', they use several estimates of dose–response relationships that have been established in the US. This is particularly true for ozone-related damages, which are based on a Weibull function estimated as part of the US National Crop Loss Assessment Network (NCLAN) project.
11. Details taken from *The Introduction to Forest Resources Evaluation Study in China.* Policy document. The Chinese Academy of Forestry.
12. See Markandya et al. (1996).
13. The same applies, of course, if previous estimates of pollutants are revised.

References

Adams, R.M. and B. McCarl, 1985, Assessing the benefits of alternative oxidant standards on agriculture: the role of response information. Journal of Environmental Economics and Management, 12, 264–276.

Adams, R.M., S.A. Hamilton and B.A. McCarl, 1985, An assessment of the economic effects of ozone on US agriculture. Journal of the Air Pollution Control Association, 35, 938–943.

Adger, W.N., 1993, Sustainable national income and natural resource degradation: initial results for Zimbabwe, in R.K. Turner, ed., Sustainable Environmental Economics and Management: Principles and Practice, London: Belhaven Press.

Adger, W.N. and M. Whitby, 1993, National resource accounting in the land use sector theory and practice. European Review of Agricultural Economics, 20, 77–97.

Ahmad, Y.J., S. El Serafy and Lutz, E., eds., 1989, Environmental Accounting for Sustainable Development, Washington, DC: World Bank.

Anielski, M., 1992, Resource Accounting: Indicators of the Sustainability of Alberta's Forest Resources. Paper presented to the International Society of Ecological Economics Conference, Stockholm.

Bartelmus, P. et al., 1992. Integrated Environmental and Economic Accounting: A Case Study for Papua New Guinea. Environment Department Working Paper No. 54, Washington, DC: World Bank.

Bryant, C. and P. Cook, 1992, Environmental issues and national accounts, Economic Trends, 469, 99–122.

Chinese Academy of Forestry, The Introduction to Forest Resources Evaluation Study in China.

Clough, P., 1991, Natural Resource Accounting for New Zealand's Indigenous Forests. Report to the Ministry of Environment, New Zealand Institute of Economic Research.

Commission Interministerielle Des Comptes Du Patrimonie Naturel, 1986, Les Collection du Patrimonie Naturel, Collection de L'Insee serie C, n. 137–138, Paris.

Constanza, R. and H.E. Daly, 1992, Natural Capital and Sustainable Development, Conservation Biology, 6, 37–46.

CBS Netherlands, 1993, Environmental Statistics in the Netherlands, Voorburg: Central Bureau of Statistics.

CBS Norway, 1992, Natural Resources and the Environment, Oslo, Central Bureau of Statistics.

Daly, H.E. and J.B. Cobb Jr., 1989, For the Common Good, Beacon Press, Boston.

Da Motta Seroa, R. and P.H. Young, 1992, Natural Resources and National Accounts: Sustainable Income from Mineral Extraction, Rio de Janeiro: IPEA.

Development Research Center of State Council, 1990, The Initial Research of Natural Resource Accounting, China.

Development Research Center of State Council, 1991, The Discussion of Resource Accounting, China.

Du, Donghai and Wang Zhixiong, The Study of Mineral Resource Accounting of China, undated.

European Commission DGXII, 1995a–e, Science, Research and Development, JOULE Programme. Externalities of Energy – "ExternE" Project, Report No 1: Summary Report.

Fankhauser, S, 1995, Valuing Climate Change: The Economics of the Greenhouse. CSERGE. Earthscan.

Florig, H.K., 1993, The Benefits of Air Pollution Reduction in China, Resources for the Future, Washington, D.C., mimeo.

German Department of Environment, 1992, The Federal Statistical Office Presents the Idea of an Economic Valuation of the Environment. Press Release 34/92, Bonn.

Harrison, D. and Rubinfeld, D., 1990, Benefits of the 1989 Air Quality Management Plan for the South Coast Air Basin: A Reassessment. Prepared for the California Council of Environmental and Economic Balance. Cambridge, MA: National Economic Research Associates, Inc.

Hueting, R., 1989, Correcting national income for environmental losses: toward a practical solution, in Ahmad, Y.J., S. El Serafy and Lutz, E., eds., 1989, Environmental Accounting for Sustainable Development, Washington, DC: World Bank, pp. 32–39.

Hultkrantz, L., 1992, National account of timber and forest environmental resources in Sweden, Environmental and Resource Economics, 2, 283–305.

IPCC, 1992, Climate Change 1992. The supplementary Report to the IPCC Scientific Assessment, Cambridge: Cambridge University Press.

Krupnick, A. et al., 1996, The value of health benefits from ambient air quality improvements in central and eastern Europe, Environmental and Resource Economics, 7, 307–332.

Li Jingchang, 1991, The Discussion of Resource Accounting, Ocean Press, Beijing, China.

Maeler, K.G., 1996, Resource Accounting, Sustainable Development and Well-Being. Beijer International Institute of Ecological Economics, Discussion Paper Series No. 75.

Markandya, A. C. and Costanza, eds., 1993, Environmental Accounting: A Review of the Current Debate. Environmental Economics Series, No 8, Nairobi: UNEP.

Markandya, A. et al., 1996, Green Accounting in Europe: The Role of Damage Estimation: Four Case Studies. Brussels: European Commission, DGXII.

Nordhaus, W., 1992, Is Growth Sustainable? Reflections on the Concept of Sustainable Economic Growth. Paper presented to the International Economics Society, Varenna, Italy.

Pearce, D.W., W.R. Cline, A.N. Achanta, S. Fankhauser, R.K. Pachauri, R.S.J. Tol and P. Vellinga, 1994, Chapter 6: The Social Costs of Climate Change: Greenhouse Damage and the Benefits of Control. IPCC Working Group.

Pearce, D., 1996, Economic Valuation and Health Damage from Air Pollution in the Developing World, Energy Policy, 24, 627–30.

Parikh K. et al., 1992, Natural Resource Accounting: a Framework for India, Bombay: Indira Ghandi Institute of Development Research.

Peskin, H.M., 1996, Alternative Resource and Environmental Accounting Concepts and their Contribution to Policy. Paper presented at the international conference 'Applications of Environmental Accounting', FEEM/SSTC, Beijing March 11–13th 1996.

Prince, R. and P.L. Gordon, 1994, Greening the National Accounts. Washington, DC: Congressional Budget Office.

Proops, J., 1995, Research Workshop on Indicators of Sustainable Development and Green Accounting. Brussels: Rapporteur's Report.

Repetto, R. et al., 1989, Wasting Assets: Natural Resources in the National Accounts, Washington, DC: World Resources Institute.

RGAR, 1990, Acid Deposition in the United Kingdom 1986–88, Third Report of the Review Group on Acid Rain, Department of the Environment, London.

Solorzano, R. et al., 1991, Accounts Overdue: Natural Resource Depreciation in Costa Rica, Washington, DC: World Resources Institute.

Squire, L. and H. van der Tak, 1975, Economic Analysis of Projects, Johns Hopkins Press, Baltimore.

Tol, R.S.J., 1996, A Decision-analytic Treatise of the Enhanced Greenhouse Effect, Ph.D Thesis, Vrije Universiteit, Amsterdam.

United Nations, 1984, A Framework for the Development of Environment Statistics, E.84.XVII.12, New York.

United Nations, 1988, Concepts and Methods of Environmental Statistics: Human Settlements Statistics – A Technical Report, Ser. F., no. 51, New York.

United Nations, 1991, Revised System of National Accounts, Draft Chapters and Annexes, New York.

United Nations Development Programme, 1991, Human Development Report, New York: United Nations Development Programme.

United Nations, 1993, Integrated Environmental and Economic Accounting. New York: UN Department for Economic and Social Information and Policy Analysis – Statistical Division.

Uno, K., 1989, Economic growth and environmental change in Japan: net national welfare and beyond, in Archibucji, F. and P. Nijkamp, eds., Economy and Ecology: Towards Sustainable Development, London: Kluwer Academic Publishers.

van Tongeren, J. et al., 1991, Integrated Environmental and Economic Accounting: A Case Study for Mexico. Environment Department Working Paper No. 50, Washington DC: World Bank.

Weizmann, M.L., 1976, On the welfare significance of national product in a dynamic economy, Quarterly Journal of Economics, 90, 156–162.

World Bank, 1996, World Tables 1996, Johns Hopkins University Press, Baltimore.

Young, M.D., 1992, Natural Resource Accounting: Some Australian Experiences and Observations, Working Paper 92/1, Canberra: CSIRO.

CHAPTER 3

Economic Valuation of Environmental and Natural Resource Assets: Applications to Environmental Accounting[1]

Raymond J. Kopp

3.1. Introduction

The purpose of this paper is to discuss, at a conceptual level, the task of valuing natural and environmental resources for the purposes of environmental accounting. We do this by presenting a framework for valuation that has at least three desirable properties. First, it is capable of generating economic values. There are many concepts of value that one uses in daily life, but only one concept of value provides for measurable economic value. Since one presumes that the values contained in environmental accounts must be commensurable with the monetary values contained in standard income and product accounts, one is constrained to use economic values. Therefore, the framework presented in the following pages relies exclusively on economic values and methods suitable to their measurement.

Second, the framework can encompass a wide array of heterogeneous environmental and natural resources. However, it must be tractable in the sense that one cannot treat every environmental and natural resource as a special case. Tractability requires a unifying theme that runs through the framework and allows all environmental and natural resources to be related to each other under a common concept. In the framework presented below, that common concept is to treat all environmental and natural resources as assets. That is, as long-lived entities, providing a flow of services to humans and to other environmental and natural resources through time.

Third, the framework provides a mechanism by which anthropocentric activities can affect the economic value of the assets. Since the impetus behind the development of environmental accounting is the belief that the value of environmental and natural resources is being degraded due to human activities, one must specify how that degradation in value comes about. Similarly, if there are human activities that can enhance the value of environmental and natural resources, one must specify how such enhancements take place.

A. Lanza (ed.), Resources Accounting in China, 53–71.

While not absolutely required by an environmental accounting valuation framework, it would be a great benefit if the framework could naturally lend itself to policy analysis. That is, if the framework could be used to assess the effects that alternative policies, designed to modify human behaviour, would have on the values of the environmental and natural resources. The framework presented below possesses this policy analysis capability.

3.2. The concept of economic value

To economists, the term 'value' has a very specific meaning. The most important but often overlooked feature of economic value is that it is a theoretical construct and that monetary measures of economic value are inferred (constructed) by analysts from the choices that individuals make. Economic value cannot exist independent of a choice.

For microeconomists, the study of choice is the raison d'être, and from the study of choice, economic values can be defined and empirically constructed.[2] A choice implies that an individual is confronted with a selection of alternatives and the consideration of the alternatives by the individual defines a tradeoff. Contemporary economic theory of individual behavior when confronted by choices suggests that what is chosen must be at least as desirable, from the perspective of the individual making the choice, as the alternatives that were not chosen. The theory implies that the alternative chosen is at least as good, or as valuable, as the alternatives that were not chosen and thereby defines value for the alternative chosen in terms of the alternatives foregone. For example, if an individual chooses to relinquish three apples for a peach, an observing analyst can state that under the circumstances of the choice (perhaps known in their entirety only to that individual), the economic value to that individual of the peach is at least three apples. If the choice were giving up $1 for the peach, and the individual chose the peach, then the analyst would conclude under the circumstances of the choice that the value of the peach to that person was at least $1.[3]

3.2.1. Objects of choice

Economic values are constructed for objects of choice under particular circumstances of choice. From the analyst's perspective, the object of choice is the thing for which an economic value is desired. Objects of choice may be quite general and extend far beyond our normal conception of private goods sold in markets. Objects of choice can be public goods such as local police protection, ambient air and water quality, or species and habitat protection, but the list does not stop here. Objects of choice can be any tangible or intangible object, process or activity that can be described in a way that allows a choice to be fashioned.

Each object of choice has a set of defining and perhaps unique attributes.

These attributes are perceived by the individuals who confront a choice involving the object, and the attributes may or may not be perceived similarly across all such individuals. Any peach may look attractive to one person but not to others. Should an observing analyst assume that all individuals share a common perception of the attributes of the object of choice? If one observes individuals choosing to live in areas of Los Angeles that are less subject to air pollution than others, the analyst could assume that they are all choosing the less polluted locale (the object of choice) due to reduced risk of minor respiratory discomfort (an attribute of the object of choice). However, it may well be the case that improved visibility of the surrounding mountains is an important attribute to some, if not all, that the analyst has overlooked.

An analyst's failure to capture all of the object's attributes is an important omission in some instances but unimportant in others. Return to the peach example and assume that all the analyst wishes to know is the economic value of the peach to the individual making the choice. The individual perceives the peach's attributes, but the analyst does not. However, the analyst would still use the dollar foregone as the economic value. In this case the information about attributes had no bearing on the construction of the economic value.

On the other hand, lack of information about attributes of an item can lead to errors in the valuation of an object. Consider again the example of the individual choosing to live in a less polluted section of Los Angeles and presumably paying a housing premium. Suppose first that the object to be valued is a reduction in minor respiratory discomfort, and second that the analyst believes that the attribute set fully describing the object of choice (this particular housing location) consists only of reductions to respiratory discomfort. If an individual moves to this locale and foregoes a sum of money equal to the housing premium, the analyst might assign an economic value to reduced respiratory discomfort equal to the housing premium. In fact, that housing premium is the value of a much more expansive object of choice (at least including improved visibility), and the analyst has overstated the value of reduced respiratory discomfort.

The failure to capture the total value of an object of choice is endemic to most economic valuation of objects that do not trade on markets and, indeed, can plague market objects as well. Suppose a decision maker would like to know the economic value of a programme designed to set aside wilderness areas as protected preserves and retains an analyst to construct the value. The analyst assumes (implicitly or explicitly) that the object of choice is characterized by an attribute set that contains outdoor recreational opportunities for individuals and nothing more. The analyst then examines historical choices where values for identical recreational activities have been constructed and uses these values in the analysis of the programme to set aside wilderness areas. If the attribute set as perceived by individuals included other attributes, for example nonuse, the value constructed by the analyst is not a total economic value, but rather a reflection of the assumptions made regarding the attributes of the object of choice.

How could the analyst have constructed a total value for the wilderness set aside programme? Would the analyst have to know the attribute perceptions of all relevant individuals? From the previous peach example, we know that complete knowledge of the attribute set is not required. What is required in the absence of complete knowledge is the ability to provide a choice situation in which individuals can learn of the object of choice, confront a tradeoff and make a choice on the basis of their own perceptions regarding the attribute set. The economic value constructed from such a choice encompasses passive use and thereby captures total value.

3.2.2. Circumstances of choice

Objects of choice, together with the circumstances of choice, completely describe the elements of the choice for the purpose of constructing an economic value. The circumstances of choice describe the context in which a choice is made. At a minimum these circumstances include: (a) the consequences of the choice (the nature of the tradeoff), i.e. what is foregone by the choice and what is gained; (b) the specified rights of assignment, i.e. with what specified individual or group of individuals do elements of control over the object of choice reside; and (c) the choice mechanism, i.e. the manner in which the individual exercises the choice, for example, through private market transactions, political processes like voting, or other unspecified behaviours.

It was argued in the previous section that an analyst need not know the individual's perceptions regarding the attributes of an object of choice to construct an economic value from a choice that involves that object. What is required is that the object to be valued and the object of choice specified by the elements of choice are one and the same. Unfortunately, this acceptable level of analyst ignorance does not carry over to knowledge requirements regarding the circumstances of the choice. With regard to the circumstances, the analyst must know the choice alternatives (what could have been chosen), what was gained and what was foregone. In instances where the analyst has control over the full elements of choice (i.e. specifies the object and circumstances of the choice) as in the case of CV, this information requirement is met. However, when the analyst employs observed historical choices, the information requirement becomes more burdensome and is usually met by making largely unverifiable assumptions.[4]

In addition to other features of the choice, the circumstances of choice specify the rights of assignment over elements of control of the object of choice. There are two choice situations: (1) giving something up to receive the object of choice, corresponding to the willingness to pay (WTP) concept; and (2) receiving something to give up the object of choice, corresponding to the willingness to accept (WTA) concept.

WTP and WTA are the fundamental monetary measures of value in economics. All economic valuation can be shown to correspond to one or the other. In WTP choice situations, the economic value of the object of choice is constrained by the wealth of the individual (i.e. by the personal possessions an individual can give up). Thus, while an individual may be willing to give up all of his/her wealth to obtain some highly desired object of choice, the economic value is constrained by what he/she owns. Constraining the economic value of an object of choice to available wealth does not arise in the WTA choice context. Here the item to be valued is something the individual already possesses and the item is part of his/her wealth. The decision tradeoff requires the specification of something the individual will freely accept in exchange for the object. Because in this choice situation the object is already part of the individual's wealth, the something an individual will freely accept in return for that object is not constrained by the individual's wealth. Instead, a person agrees to give up something in exchange for monetary wealth. The object of choice is what must be given up as part of this tradeoff. While this choice may seem atypical, it is not – selling anything places people in this situation. Thus, when people accept a job (i.e. sell labour services), sell a house or a car, or agree to permit a solid waste facility to be located in their neighbourhood in return for compensation payments, the choices involve a WTA tradeoff and, hence, allow the construction of an economic value for the object of choice foregone. If the choice posed to the individual involves a monetary payment to the individual in exchange for the object of choice, then the compensation payment becomes the basis for the monetary value of the object.

3.3. Valuing natural assets

We wish to argue that for the purposes of economic valuation, it is often convenient to think of environmental and natural resources as natural assets. And further, it is useful to continue the asset analogy and think of them as analogous to reproducible assets like structures and equipment.[5] While economists have considered the asset analogy in the past, it has been confined to discussions of exhaustible natural resources, like minerals, or renewable resources such as forests. In each case, the resource is a private good exchanged on organized markets.[6] In this section of the paper we want to extend the asset concept to all environmental and natural resources which can be characterized as pure public goods or quasi-private/public goods.[7]

The asset analogy is particularly useful in the environmental accounting context where we wish to incorporate the values attributable to environmental and natural resources within a framework consistent with other monetary values derived for reproducible capital and other market goods. Consistent incorporation is made possible by focusing on the flows of services provided by natural and reproducible capital. Changes in the economic value of these service flows can be used to measure changes in the value of the underlying asset whether it be a natural asset or a reproducible capital.[8]

Because people value the services assets provide, values for reproducible capital are linked to its flows of services. In a setting where there are competitive markets for both the asset and the services, arbitrage between the price of service flows and the asset price insures that the value of the asset is equal to the discounted sum of its future service flow prices. Should the quantity or quality of those flows be altered (degraded or enhanced), so too will the value of the flows and, in turn, the value of the underlying asset.[9] The link between the value of services and the value of the underlying asset can be seen with an example drawn from Kopp and Smith (1993).

Consider a commercial office building. Suppose one were asked to appraise the value of this structure for a prospective buyer. Assume that no comparable office buildings had changed hands recently so no information on the market prices for such buildings was readily available. Nevertheless, we know that the building's value must be related to the anticipated stream of profits that could be earned from renting its space (in other words, the market value of the services it provides). In such a situation, a real estate appraiser would examine the rent that tenants pay to occupy space in the building and subtract the operating costs to arrive at an estimate of the annual rental profit. Given an assumed occupancy rate, often outside the owner's direct control, this annual profit is a measure of the value of the rental services provided by this asset. Next, the appraiser would determine the relevant service life of the building (say, 20 years), estimate how the rental rates and costs of operation might change over this period, and then discount this 20-year stream of profits to a present value, using the potential buyer's current rate of return on capital as the discount rate. Any residual value (or perhaps appreciation) of the asset at the end of the 20-year period would also be discounted to the present and added to the discounted present value of the profit stream.[10] The sum of discounted profits and residual value would provide an estimate of the current value of the asset.

Now suppose the building suffers a fire that leaves the upper one-third of the structure smoke damaged. The tenants agree to stay on, but they renegotiate their leases at lower rental payments. The current value of the building is now reduced by the discounted present value of the reduced lease payments. Thus, a formal link exists between the value of the services an asset is capable of providing over time and the value of that asset at any specific date. The existence of markets for both commercial buildings and office space assures that discrepancies between the selling prices for buildings and the discounted profits they can provide will not be great. Otherwise, there are incentives for arbitrage.

With natural and environmental resources, neither the asset nor its services are exchanged on organized markets. Thus, while the economist uses the same approach as the real estate appraiser, there is no market mechanism connecting measures of the value of services to replacement value of natural assets. To implement the process of assessment, the economist first identifies the services provided by the natural asset. Second, he or she seeks to determine how the quantity and quality of those services have been affected and over what time period the effects will take place. Third, the economist places a value on the degradation in each service flow over the relevant time period. Finally, he or she employs a discount rate to turn each of these decrements in service flow value into present dollars and sum these over the life of the injuries. This summation would be the estimate of the change in the value of the natural asset due to the injury and would serve as the estimate of the natural resource damage.

Measuring changes in the value of natural assets follows the appraiser's approach discussed above. One seeks to place an economic value on the changes in the service flows over time and then discount the sum of the changes in the values of those flows to the present. The market automatically handles this asset revaluation for reproducible capital; but for nature assets, we must mimic the markets' actions and this can make matters quite complex.

The value of a natural asset responds to the value of its services, and the value of natural asset services responds to a variety of factors that must be taken into account when attempting to measure the value or to analyse a policy that might affect the value. Generally one can categorize those factors that influence value into five groups.

- Changes in the value of natural asset services depend on changes in the quality and/or quantity of the services at any point in time and over time.
- Since the services of natural resources are for the most part public goods, the value of the services depends on the number of people who use the services. As the quantity of users changes so, too, does the value of the services.
- The value of services depends on the time and wealth constraints of the individuals enjoying the services. As these constraints change, so does the value.
- In instances where there are substitutes for a particular natural resource service (either another natural resource service, or a marketed good or service), the value will respond to changes in the substitute.
- Finally, to the extent that one asset supplies services to another and that asset supplies services to humans, the value of the first service flow will depend on the value of the later flow.

3.4. Operational issues

The natural asset orientation discussed above states that natural assets provide a flow of diverse services. Some of these services are employed in commercial production, some are utilized by individuals and households and some are utilized by other natural assets. For the most part, these services are public goods and therefore do not generally exchange on markets.

The services provided by natural assets have value to individuals and households because they serve as inputs to the household's production of commodities.[11] These services also have value through an indirect path as inputs to commercial production activities, where those activities produce marketed goods and services consumed by households. For the purposes of environmental accounting, one must identify all the natural assets to be included in the analysis, enumerate the services provided by each asset in time and space and identify the effects that changes in the quality or quantity of these nonmarket services have on households and firms.

To illustrate the process we have in mind and the difficulties one will encounter when attempting to value natural assets for the purposes of environmental accounting, we have chosen two natural assets, groundwater and surface water, and provide in Tables 3.1 and 3.2 lists of services provided and effects caused by changes in service flows from these natural assets.

3.4.1. Valuing the asset, the asset's services or changes in the asset's services

Obviously, before one begins an economic valuation project, one must be clear about what is to be valued. In the case of environmental accounting, it is not always clear what the objective of the exercise ought to be. One can imagine valuing an asset. For example, the economic value of a particular groundwater aquifer. Or one might be interested in just the value of the annual flow of services from the aquifer, that is, the annual value of the services listed in the first column of Table 3.1. Or, one might be interested in the change in the value of the annual service flows, due to say contamination of the aquifer. In this case, one would value the changes reflected in the 'Effects' column of Table 3.1.

Valuing the asset

Of the three valuations that might be performed, the direct valuation of a natural asset providing public services is the most problematic. For example, assume one wanted to value a groundwater aquifer. To obtain an economic value we must observe individuals in a choice situation. In this context we would have to observe them giving up something to retain the aquifer (and the services it provides), or choosing to be compensated for the loss of the aquifer. Generally, we do not observe these types of choices for public goods; however, we could observe the choice if we conducted a contingent valuation (CV) study.[12]

The CV study would ask a sample of people, drawn from the population of households enjoying the services of the aquifer, how much they would pay in increased taxes to prevent the aquifer from being destroyed (by one means or another). The aggregate of these payments would be a lower bound on the economic value of the aquifer. While this procedure seems straightforward enough, it has a limitation when one considers broadening the valuation tasks to include other natural assets that provide service to this same population (a broadening that would be required if one were to establish a system of

Table 3.1. Groundwater services and economic effects

Services	Effects
Provision of drinking water	Change in utility from increase or decrease in availability of drinking water (access value) Change in human health or health risks
Provision of water for crop irrigation	Change in value of crops or production costs Change in human health or health risks
Provision of water for livestock	Change in value of livestock products or production costs Change in human health or health risks
Provision of water for food product processing	Change in value of food products or production costs Change in human health or health risks
Provision of water for other manufacturing processes	Change in value of manufactured goods or production costs
Provision of heated water for geothermal power plants	Change in cost of electricity generation
Provision of cooling water for other power plants	Change in cost of electricity generation
Provision of water/soil support system for preventing land subsidence	Change in cost of maintaining public or private property
Provision of erosion and flood control through absorption of surface water run-off	Change in cost of maintaining public or private property
Provision of medium for wastes and other by-products of human economic activity	Change in human health or health risks attributable to change in groundwater quality Change in animal health or health risks attributable to change in groundwater quality Change in economic output attributable to use of groundwater resource as 'sink' for wastes
Provision of passive use services associated with groundwater resource itself	Change in utility

Source: The information in this table has been drawn from John C. Bergstrom and Kevin J. Boyle, 'Using Benefits Transfer to Value Groundwater Benefits: Conceptual Issues', discussion paper prepared for presentation at the joint AAEA/AERE meetings in Orlando, Florida, August 1993.

Table 3.2. Surface water services and economic effects

Services	Effects
Provision of drinking water	Change in utility from increase or decrease in the availability of drinking water (access value) Change in human health or health risks
Provision of water for crop irrigation	Change in value of crops or production costs Change in human health or health risks
Provision of water for livestock	Change in value of livestock products or production costs Change in human health or health risks
Provision of water for food product processing	Change in value of food products or production costs Change in human health or health risks
Provision of water for other manufacturing processes	Change in value of manufactured goods or production costs
Provision of cooling water for power plants	Change in cost of electricity generation
Provision of erosion, flood, and storm protection	Change in cost of maintaining public or private property Change in human health or health risks through personal injury protection
Transport and treatment of wastes and other by-products of human economic activity	Change in human health or health risks attributable to change in surface water quality Change in animal health or health risks attributable to change in surface water quality Change in economic output attributable to use of surface water supplies for disposing wastes
Support of recreational fishing, hunting/trapping, plant gathering	Change in recreational fishing quantity or quality Change in recreational hunting/trapping quantity or quality Change in recreational plant gathering quantity or quality
Support of recreational swimming	Change in recreational swimming quantity or quality
Support of recreational boating	Change in recreational boating quantity or quality

Table 3.2. (cont).

Services	Effects
Support of commercial fishing, hunting/trapping, plant gathering	Change in value of commercial fish harvest or costs Change in value of commercial hunting/trapping harvest or costs Change in value of commercial plant harvest or costs
Support of on-site observation or study of fish, wildlife, and plants for leisure, educational, or scientific purposes	Change in quantity or quality of on-site observation or study activities
Support of indirect, off-site fish, wildlife, and plant uses (e.g. viewing wildlife photos)	Change in quantity or quality of indirect, off-site activities
Provision of clean air through support of living organisms	Change in human health or health risks attributable to change in air quality Change in animal health or health risks attributable to change in air quality
Provision of clean water through support of living organisms	Change in human health or health risks attributable to change in water quality Change in animal health or health risks attributable to change in water quality Change in value of economic output or production costs attributable to change in water quality
Regulation of climate through support of plants	Change in human health or health risks attributable to change in climate Change in animal health or health risks attributable to change in climate Change in value of economic output or production costs attributable to change in climate
Provision of passive use services associated with surface water body or wetlands environments or ecosystems	Change in utility

The information in this table has been drawn from John C. Bergstrom and Kevin J. Boyle, 'Using Benefits Transfer to Value Groundwater Benefits: Conceptual Issues', discussion paper prepared for presentation at the joint AAEA/AERE meetings in Orlando, Florida, August 1993.

environmental accounts). For example, suppose we want to value a surface water body in addition to the aquifer. We could ask the same sample two alternative questions such as, how much would you be WTP in increased taxes to prevent the aquifer from being destroyed, and how much would you pay in increased taxes to prevent the surface water body from being destroyed? Economic theory suggests that the value obtained from the first question (aquifer alone with no mention of the surface water) would be greater than the WTP for the aquifer when the respondent was asked about the surface water also. Which aquifer value is correct?

As it turns out, both valuation questions are correct. It is simply the circumstances of the choice that are different. In the second case, the surface water body provides some services that are substitutes for the aquifer, thereby lowering the value of the aquifer services. But more important, since the income (and wealth) of the respondents is fixed, the more things they are asked to pay for, the lower will be the values for each individual item. This income constraint is particularly important when one attempts to value entire assets.

Unfortunately, if one wants to value all natural assets in a country, one cannot follow the approach laid out by the first question. That is, one cannot simply draw repeated samples of respondents from the relevant population and ask them to value only one asset until values for all assets are obtained. Following such an approach fails to take substitutes and income constraints into account. Natural asset values obtained in this manner could be used to rank the relative importance of one natural asset vis-à-vis the others, but cannot be used for the purposes of environmental accounting. Since substitutes and income constraints are not accounted for in the first questioning approach, but are accounted for in the valuation of reproducible capital assets and all other items found in the usual income and product accounts of nations, values obtained from the first questioning approach would be inconsistent with other values in those accounts.

Valuing the asset's services

The above discussion argues that the direct valuation of natural assets is generally not possible. Thus, if one wants asset values for the purposes of environmental accounting, one must pursue alternative approaches. One approach mentioned earlier would be to delineate all the services an asset provides (producing tables like 3.1 and 3.2) and then use the capital asset pricing model (CAPM) to construct an estimate of the natural asset's value.[13] This approach relies on knowledge of each service, its flow over time, the services' value at each point in time and a rate of discount. One can assume a rate of discount (a common approach), and further assume that the flows of services will be constant and that the value of the flows will increase with some expected rate of inflation. Making these assumptions, one is left with the task of valuing the service flows.

If the values of the services can be inferred from actual observed choices (e.g. in the case of surface water, the value of recreational swimming, boating and fishing inferred from a travel cost model, or the value of commercial fishing, inferred from market prices), the CAPM approach to natural asset valuation might be appropriate. However, if one cannot infer values of services from actual choices and must rely on stated preference approaches like CV, some of the same problems that plague direct valuation of the asset come into play. That is, all the services must be valued in a unified context, so that substitutes and income constraints are properly taken into account. Since the income constraint would not bind so quickly, it is somewhat more realistic to think of valuing the services of a natural asset in a unified context rather than the natural asset itself. However, given the wide array of asset services that exist, income constraints will still be a problem for the type of large scale valuation work necessary to support an environmental accounting agenda.

We note in passing that some have proposed valuing the services of natural assets by equating the value of the services to the cost of obtaining replacement services. For example, the value to a household of drinking water from an aquifer would be equated to the cost of providing households with bottled water. The first thing to note is that the asset's service and the proposed replacement must be identical in the eyes of the household. Whether the provision of bottled water is identical to water provision provided by an underground aquifer, is an open question. But more important, cost is simply not a proxy for value. For example, if a drinking water aquifer were to become contaminated and households viewed the bottled water and water from the aquifer as perfect substitutes, and chose to purchase the bottled water, then the cost of the bottled water would be an estimate of the value of the aquifer's drinking water services. However, if households moved to areas that had an uncontaminated aquifer because of the high cost of purchasing bottled water, the cost of providing the bottled water would overstate the value of the aquifer.

Valuing changes in the asset's services

Valuing a natural asset directly, or valuing it indirectly via the CAPM approach, has the desirable goal of establishing the value of a nation's natural asset wealth. The intellectual attraction of environmental accounting lies in its ability to monitor a nation's whole wealth – natural and man made – to determine if this wealth is increasing over time and to track changes in each of the wealth components. Unfortunately, both the direct and indirect asset valuation approaches are problematic.

One can, however, track the movement in natural asset wealth and compare it to changes in man-made wealth without the need for direct asset valuation. To do this, one needs only track factors that influence services' value and then value the change in the services.[14] Using the CAPM approach, changes in the values of services map into changes in natural asset value and therefore changes in natural asset wealth.

Focusing on factors that can change service values, makes the valuation portion of environmental accounting more manageable: one must engage in a valuation exercise only when there is evidence that a service flow has been seriously disturbed. For example, the groundwater aquifer discussed above becoming contaminated and no longer providing drinking water services. From an operational perspective, one could identify all the relevant services changes (hopefully a manageable number), and use a CV study to value all of them jointly.[15] Remember, we are not valuing the services, but rather just the change in the service.[16]

3.5. Concluding remarks

The purpose of this paper has been to discuss, at a conceptual level, the task of valuing natural and environmental resources for the purposes of environmental accounting. We did this by presenting a framework for valuation that views environmental and natural resources as assets. We then discussed how the asset orientation would be applied in practice and underscored the difficulties one would encounter when attempting to value natural and environmental resources for the purposes of environmental accounting.

One topic that has been left largely untouched is the issue of non-use values. In the context of the groundwater aquifer example used above, a non-use value would manifest itself if an individual were willing to pay some amount of money to protect an aquifer from contamination even though that individual is not a user of the resource's services and would not be impacted in any manner by the contamination. The existence of non-use values does not complicate the valuation tasks at a conceptual level – CV is perfectly capable of measuring total value which includes non-use value. Rather, the problem is due to the possibility that non-use values might exist for many resources and be widespread among the population. If this is true, then accurately accounting for non-use values can involve a substantial surveying effort.

If one looks honestly to the future of environmental accounting on the scale required to mesh with national income and product accounts, one has to admit that the size of the task is daunting. Not only will the valuation tasks be extremely large and complicated, but one must first assemble an inventory of all the natural assets and their services. Even for wealthy countries, this will require a huge investment of resources. For poor countries, this is simply an impossible task. What then will be the future of environmental accounting? One can imagine that it will be pursued on a very local or regional level, itemizing only a subset of the resources and services within that region. If done well, such local efforts could become the building blocks for a full scale environmental accounting system. Even if these regional efforts fail to add up to an actual environmental accounting system, they will provide policy makers with much needed information about the value of services provided by resources upon which environment and development policy can be based.

However, while environmental accounting has a reasonably bright future even if a system of environmental accounts never comes into being, there is a down side. The downside stems from a rush to establish such accounts in efforts to appease special interests, or for larger reasons of international politics. Since there are almost an infinite number of ways in which one can do environmental accounting wrong, the probability that haste will lead one down the wrong path is high. Once down that erroneous path, policy reliance on the information contained in these flawed accounts could be quite disastrous.

Notes

1. Paper prepared for the conference on 'Applications of Environmental Accounting', sponsored by the Fondazione Eni Enrico Mattei and the State Science and Technology Commission of the People's Republic of China, March 11–13, 1996, Beijing China.
2. One may be inclined to say that the analyst estimates the economic value rather than constructs the value. In fact, the economic literature routinely refers to 'value estimates'. However, we use the verb constructs to underscore the notion that economic value does not exist in a free standing fashion amenable to empirical measurement. Rather, economic value can only be measured with reference to a choice, and the characteristics of that choice largely determine the measured value.
3. This simple example points out three important properties of economic value. First, economic value is constructed by the analyst from a choice and the value depends on that choice. Second, economic value does not have to be expressed in monetary units; and third, economists do not assume that individuals maintain in memory monetary economic values for the many possible choices they confront.
4. One approach, termed revealed preference, uses observed past choices and attempts to gather all relevant information pertinent to the past choice (i.e. object and circumstances of the choice). Generally, records of the choice are incomplete, and the analyst is left with partial information at best, and at worst, partial and erroneous information. Moreover, because all of the pertinent aspects of past choices can never match exactly the new choice involving the object one wishes to value (i.e. at the very least, we know that time has passed since the past decisions were made), the analysis usually rests on important assumptions that are introduced in an effort to make past choices relevant for the current valuation.
5. The natural asset analogy is used extensively in Kopp and Smith (1993).
6. Private goods have the following properties: they are normally exchanged in markets; one person's consumption of a private good precludes others' enjoyment of the good; access to private goods can be controlled; and the quantity of a private good exchanged can be directly observed in a market.
7. Pure public goods have the following properties: they are not exchanged on markets; any number of individuals can enjoy the good while not reducing the enjoyment of anyone else; access cannot be controlled; and the quantity of the good cannot in general be determined by observations and inference. On the other hand, quasi-private/public goods have the following characteristics: they are usually not exchanged on markets; up to a point, one individual's enjoyment does not affect others enjoyment, but beyond that point congestion reduces the enjoyment of all; access can be controlled but often is not regulated; the quantity of the good consumed is inferred from observations of individual behaviour.
8. Dowlatabadi et al. (1994) proposed the integrated behaviour and environmental response (IBER) modelling structure for the analysis of public policies that would have both economic and ecological effects. Those familiar with that modelling approach will recall that we used the terms anthropogenic assets and natural assets. Within that structure, anthropogenic assets refer to the normal types of reproducible capital, e.g. structures, equipment, inventories, etc. Natural assets refer to natural resources such as wildlife, surface and groundwater, forests, various types of ecosystems, airsheds, wilderness areas, global climate, mineral deposits, agricultural land,

etc. In this current paper, where definitional rigor is not as important as it would be in a modelling exercise, we use the term reproducible capital as a synonym for anthropogenic assets.

9. The asset analogy has pedagogical limitations. In particular, its usefulness fails when the value of an environmental or natural resource depends heavily on non-use characteristics.

10. The need for a residual value estimate seems to imply some circular reasoning since we are trying to formulate an initial estimate of the value, and the residual value must in some way be linked to the initial estimate. This is true, but, owing to discounting, the initial estimate is insensitive to the residual value. For example, the present value of a building providing annual profits of $1 million, discounted at 15% for 20 years with a residual value of zero, is $6.25 million, while the value of the same building with a residual value of $10 million is $6.8 million.

11. The model of time and household production developed by Becker (1965, 1976) serves as a valuable starting point for a general household model serving as a basis for natural asset valuation. In the Becker model the household combines household time, market services and non-market services, to produce entities termed commodities. Commodities are the direct objects of choice and provide utility to the household. The Becker framework permits households to use time to enjoy the services provided by natural assets, permits these same non-market services to enhance or degrade the productivity of the household as it seeks to generate 'commodities' giving rise to utility, and it permits the commodities to affect the productivity of natural resources to produce non-market services.

12. A brief overview of contingent valuation as it pertains to natural asset valuation is provided in the appendix to this paper.

13. The capital asset pricing model is an approach to asset valuation that views the asset's value (natural or reproducible) at any point in time, as the discounted present value of all future services the asset will provide.

14. The factors affecting the value of services generally include: (1) changes in the quality and/or quantity of the services at any point in time and over time; (2) changes in the number of people who use the services; (3) changes in the time and wealth constraints of the individuals enjoying the services; and (4) changes in available substitutes.

15. To the extent that the services are enjoyed by distinct populations, multiple surveys would be required.

16. Of course, if the change is such that it drives the flow of services to zero, we are valuing the entire service flow.

References

Arrow, K., R. Solow, P.R. Portney, E.E. Leamer, R. Radner and H. Schuman, 1993, Report of the NOAA panel on contingent valuation', Federal Register, 58, 4601–4614.

Becker, G.S., 1965, A theory of the allocation of time, Economic Journal, 75, 493–517.

Becker, G.S., 1976, The economic approach to human behavior, Chicago, IL: University of Chicago Press.

Carson, R.T., J.L. Wright, T.N.J. Carson, A. Alberini, and N.E. Flores, 1994, A bibliography of contingent valuation studies and papers, La Jolla, CA: Natural Resource Damage Assessment, Inc.

Davis, R.K., 1963, The value of outdoor recreation: an economic study of the Maine Woods, Dissertation, Harvard University.

Kopp, R.J. and V.K. Smith, 1993, Valuing natural assets: the economics of natural resource damage assessment, Washington, DC: Resources for the Future.

Mitchell, R.C. and R.T. Carson, 1989, Using surveys to value public goods: the contingent valuation method, Washington, DC: Resources for the Future.

United States Court of Appeals for the District of Columbia, 1989, Ohio v. United States Department of Interior, 880 F.2nd 432 (D.C. Cir. 1989).

United States Water Resources Council, 1979, Procedures for evaluation of national economic development (NED): benefits and costs in water resources planning (Level C), final rule, Federal Register, 44, 72892–72976.

Appendix: Contingent valuation method

A3.1. Overview

The contingent valuation method was first proposed in 1947 and its first reported application was by Davis (1963) in his Harvard Ph.D. dissertation on the economic value of recreation in the Maine woods. Additional applications of the method to various public goods, and studies of its methodological properties were conducted in the 1970s and 1980s both in the United States and, increasingly, in other countries. A review of the theoretical and empirical basis of contingent valuation at the end of this period is presented in Mitchell and Carson (1989). A recent contingent valuation bibliography (Carson et al., 1994) contains over 1600 references to books, articles, and reports on the method.

The CV method has increasingly become accepted for measuring the benefits of policy actions, and thereby used to inform public policy decision making. In 1979, the Water Resources Council included CV as one of three recommended methods for determining the benefits of federal water and related land resource projects. Since that time, various federal and state agencies have used the method for policy purposes and, as mentioned, it has been recognized by the Ohio Court and the NOAA Panel (Arrow et al., 1993) as a method capable of providing useful information for the evaluation of natural resource damages.

The contingent valuation method uses the same logic that underlies the definition of all economic monetary valuation concepts, that is, choice. In CV studies, choices are posed to people in surveys; analysts then use the responses to these choice questions to construct monetary measures of value. The specific mechanism used to elicit respondents' choices can take a variety of forms, including asking survey respondents whether they would purchase, vote, or pay for a programme or some other well defined object of choice. It can also be a direct elicitation of the amount each respondent would pay (WTP) to obtain an object of choice or the amount each respondent would accept in compensation (WTA) to give it up.

When used for the purposes of valuing natural assets, a contingent valuation survey presents each individual with an opportunity to make a choice, where the object of choice is usually a plan or programme to protect a resource from degradation. The context for that choice can be any setting that is regarded as credible by survey respondents. Because the elements of the choice can be presented in some detail to each respondent, there is no need to rely on historical choices and impose the assumptions required to link those choices to the object to be valued. Rather, in natural asset valuation relying on CV, respondents' choices are directly linked to the object of choice (e.g. through a specified protection programme that addresses the relevant degradation), thereby enabling the analyst to construct the appropriate measure of total value.

In a CV survey, respondents are presented with material which can be described as three separate (but integral) components:

1. The key elements of a CV survey are the object of choice and the circumstances of the choice (including the method proposed for each individual to pay or receive compensation, the time period over which the object or decision is relevant, the relationship of the object to available substitutes, and other elements of the choice relevant to decision making). When using CV to value natural assets the object of choice can be a programme or a set of activities to protect the resource and its service flows from degradation. To understand the programme, each respondent must understand the nature of the resources and the service provided and the character of the degradation to those services.

2. After the description of the object and circumstances of choice, the CV survey elicits a choice outcome which can be used to construct each individual's total value for the object of choice that has been presented. The choice can be a direct elicitation for a single value or repeated questions for an interval estimate of the value. In all cases, it will describe a specific choice mechanism and elicit choice information used to construct value.

3. Because individuals have different preferences and face different constraints, questions are also asked about respondents' attitudes, social characteristics (e.g. age, education, gender, race, etc.) and economic characteristics (e.g. income).

A3.2. Format of a contingent valuation survey

The first part of a CV survey introduces the general topic of the survey. The topic can be described to each potential respondent in an advance letter and by the interviewer in the course of seeking the respondent's participation. Following this initial description, the CV survey introduces the specific topic of the survey and then provides the information describing the elements of the choice. From this point CV surveys and general public opinion surveys differ in fundamental ways. CV surveys typically focus on a single situation which is described in some detail. In the context of a natural asset valuation, the elements of choice that are presented include a carefully worded description of the natural resource and its services. As noted above, this description presents the resource so that the respondent will perceive his or her relationship to available substitutes and other factors relevant to the individual's choice.

The description of the resource and services is followed by a description of the plan or programme – for example a set of activities that can protect a resource from degradation. The description of the programme includes a discussion of the program's activities, how they will be implemented, and the method of payment. The information about the programme coupled with a description of the nature of the resource and its services define the object of choice. The survey then turns to the circumstances of the choice: the disposition of rights to the resources in their baseline conditions, a description of how the choice will be made (i.e. the choice mechanism), and what must be foregone to obtain the object. In a WTP setting, the respondent faces a simple choice: give up a specified dollar amount in a one-time tax payment in return for the object of choice (a programme to protect a resource) or keep the money and experience a loss in the resource and its services.

Many surveys use a referendum as the mechanism to elicit choices. This mechanism provides the respondent with the opportunity to articulate his or her choice by voting for or against the programme, where voting for implies getting the programme and having the financial burden of paying the tax, while voting against implies retention of the money corresponding to the tax amount and continuance of the time profile of injuries associated with natural recovery. This choice mechanism is adopted in western countries for a number of reasons, but can be adapted to other countries and cultures. This mechanism is consistent with the mechanisms frequently used in western countries to decide public issues and, therefore, is familiar and credible for these types of activities. Furthermore, it satisfies the incentive–compatibility conditions required for truthful responses; that is, it meets the condition that respondents evaluate the elements of choice in the same way they would an actual referendum.

Questions that provide information about each respondent's evaluation of the object of choice follow the elicitation of a respondent's choice. They help gauge whether the respondent understood and perceived the information as intended and collect information about the reasons that motivated the reported choices.

Following this series of 'debriefing questions', respondents who voted for the programme are offered the opportunity to reconsider their decision. Later in the survey, respondents who were still in favour of the programme can be asked how difficult it would be for them to pay, given the highest tax amount for which they voted, and how strongly they felt about their vote. Respondents indicating that it would be 'very difficult', 'somewhat difficult', or who said that they were 'not sure' how difficult it would be to pay, or indicating that they were 'not too strongly', or 'not at all strongly' in favour of the programme, or 'not sure' how strongly they favoured the programme, would be given another opportunity to change their vote. In accordance with conventional practice, the survey concludes with demographic questions.

CHAPTER 4

Resource Accounting, Sustainable Development and Well-Being[1]

Karl-Göran Mäler

4.1 The resource basis

That all economics depend on their natural resources, such as soil and its cover, water, forests, animals, and fisheries should be self-evident: ignore the environmental resource base, and we are bound to obtain a misleading picture of productive activity in the economy. Nevertheless, in most economic analyses, there has been a neglect of the resource base, and in particular in analysis of economic development in poor countries, which rely heavily on their environmental and natural resource base. Until very recently, environmental resources made but perfunctory appearances in government planning models, and they were cheerfully ignored in most of what goes by the name development economics.

The situation is now different. As regards timing, the shift in attitude can probably be identified with the publication the Brundtland Report (*Our Common Future*; World Commission, 1987), and today no account of economic development in poor or rich countries would be regarded as adequate if the environmental resource base were absent from it. What I will try in this chapter is to discuss how one could design a framework to incorporate environmental and natural resources into the national income accounting framework.

4.2. Eco-systems: functions and services

The ecological services we rely upon are produced by ecological systems (eco-systems for short), which comprise by interactions among organisms, populations of organisms, communities of populations, and the physical and chemical environment in which they reside. Eco-systems are involved in a number of functions and offer a wide range of services. Many are indispensible, as they provide the underpinning for all human activities; they are, therefore, of

A. Lanza (ed.), Resources Accounting in China, 73–116.

fundamental value. Among other things, eco-systems are the sources of water, of animal and plant food and other renewable resources. They also maintain a genetic library, sustain the processes that preserve and regenerate a soil, recycle nutrients, control floods, filter pollutants, assimilate waste, pollinate crops, operate the hydrological cycle and maintain the gaseous composition of the atmosphere. The totality of all the eco-systems of the world represent a large part of what we may call our natural capital base. The natural capital base also includes minerals, ores and other exhaustible resources. However, for the moment let me focus on the renewable resource base, which, I will often refer to as the environmental resource base. Environmental problems are almost always associated with resources that are regenerative but in danger of exhaustion from excessive use. We can, therefore, identify environmental resources with renewable natural resources.

Environmental economists find it very often useful to base their studies on ecosystem ecology. Here, the focus is on such objects as energy at different trophic levels and its rate of flow among them, the distribution and flows of biochemical substances in soils and bodies of water, and of gases and particulates in the atmosphere. The motivation here is to study the biotic and abiotic processes underlying the various functions that are performed by ecosystems. Holling's characterization of ecological processes as one of cycles of birth, growth, death, and renewal, is a particularly illuminating example of this viewpoint. In such settings, the central concern of the economist is the valuation of the services that are provided by ecosystems, studies of efficient management plans and analysis of the appropriate institutional setup for implementing these plans.

Since the services provided by the environmental resource base are essential for our survival, it would seem prudent to monitor it in much the same way as we routinely monitor our manufactured capital stocks, such as roads, buildings and machinery. Unhappily, this has not been standard practice, and even today is not conducted in any systematic way. Instead, reliance is often placed on time trends in gross outputs of commodities, for example agricultural crops, and trends in their prices for obtaining a sense of, for example, whether growth in the world's population has been imposing strains on the environmental resource base. This is a mistake. Agricultural output could in principle display a rising trend even while the soils are being mined. Increasing production is consistent with unsustainable production. Growing and sustainable output are not the same and it is a fundamental error to think that they are so.

There is, therefore, a substantial need for the construction of systems of monitoring our use of environmental and non-renewable resources. In economics, the most important monitoring system we have is the system of national accounts. It therefore seems to be worthwhile to try to extend these accounts to include the flow of environmental services and changes in the stocks of the resource base.

4.3. Introduction to national accounts

The systematic compilation of economic data into national accounts ranks among the most important innovations in the social sciences. With roots in Quesnay's tables and William Petty's 17th century assessment of England's national income, the current system of national accounts (SNA) integrates a wealth of information pertainingn to the economic state of a nation. Its importance in today's economic life cannot be overestimated. The SNA remains the basis for the construction, evaluation, and comparison of economic performance throughout the world. At a more mundale level, the information presented in the SNA belongs to everyday economic drama. Witness, for example, the flurry of activities triggered by the publication of the quarterly US figures on gross domestic product (GDP) or, say, the Japanese current account figures.

Traditionally, the purpose of the SNA has been closely related to analyses of an economy's productive capacity. When James Meade and Richard Stone developed the first versions of the SNA in the early years of World War II they attempted to shed light on the extent to which Great Britain's resources could be allocated to fighting the war. Generally, the development of the SNA and other similar systems have been triggered by the particular resource allocation problems of the day. With the emergence of 'environmental problems', it is only natural that the scope of the SNA is scrutinized.

While the SNA contains a rich source of information about an economy, it is fair to say that the gross national product is the most important concept in the system. First, GNP is often used as an index of welfare in a country – if GNP increases, then this is taken as a sign that the average welfare in the country increases. Second, if GNP in one country is greater than GNP in another, then the first country is thought to have a higher welfare. Indeed, the notion of GNP as a measure of 'material' well being is deeply routed in the minds of generations of economists, journalists, politicians and other participants in the public debate.

This chapter has two purposes. The first is to discuss the theoretical basis for using a national product concept as an index of well being, as well as to show how a proper environmentally adjusted national product should be calculated. I stress at the outset that national income accounts serve other purposes, they do not merely measure well being. In particular, it may be of substantial importance to include environmental resources into national accounts in order to establish a database that could be used for modelling purposes. There seems to be an increasing demand for quantitative analysis of the connection between macroeconomic performance and the environment, not the least in connection with global warming. Much is being invested in the establishment of extended national accounts including flows of pollutants, harvest of environmental resources, production of exhaustible resources, etc. In spite of the importance of these developments, I will not touch upon them further. I will focus on the 'green national product' and, in particular, how it should be based on a conceptual basis that permits a welfare–theoretical interpretation of the measure. This is a point to which I will return several times. The second purpose is to review some of the major empirical studies on resource accounting.

Before going into the discussion of the theoretical basis for the construction of the NNP index, it may be as well to present some of the issues that are being debated in this connection:

- The treatment of labour
- The inclusion of human capital
- The inclusion of environmental damages
- The treatment of 'defensive' expenditures
- The calculation of depreciation charges on stocks of environmental and natural resources

4.4. The national product as a welfare measure

Provided certain technical restrictions are met, which I will return to, for any conception of social well being, and for any set of technological, transaction, information, and ecological constraints, there exists a set of shadow (or accounting) prices of goods and services that can be used in the estimation of real net national production (NNP). The index in question has the property that small investment projects that improve the index are at once those that increase social well being. We may state the matter more generally: provided the set of accounting prices is unaffected, an improvement in the index owing to an alteration in economic activities reflects an increase in social well being. Moreover, the sense persists no matter what is the basis upon which social well being is founded.[2]

The emphasis on small projects is deliberate: NNP is a linear index. If the alterations in economic activities were not small (i.e. if they were to affect the accounting prices), the appropriate index of social well being would be non-linear, because the index would then have to include changes in consumers' and producers' surpluses, and changes in income distributional weights.

Notice that, in this reckoning, NNP should be thought of as the criterion function on the basis of which social cost–benefit analyses of economic policies ought to be conducted. However, depending upon the basis on which accounting prices are estimated, it could be computed in a number of ways. One possibility (the one we explore in detail in this chapter) would be to use prices that sustain an optimal plan. An alternative would be to use 'local prices' (e.g. the prices households actually face when they make consumption decisions). A third possibility would be to rely on local prices for the current period and optimal prices for future periods.

In order to illustrate these ideas, consider an economy consisting of two consumer goods and a single individual. In Figure 4.1, X and Y denote the two goods and the curve TT′ denotes the production possibility frontier. Let W(X, Y) be the individual's well being function and II′ the indifference curve which is tangential to TT′ (tangency is at the point A). In the figure we have assumed that the production possibility set is convex and that W(X, Y) is a concave function. The common tangent at A, which we have denoted as pp′, defines the optimal prices, p_x and p_y. We may then define NNP at any production point, (X, Y), as $p_xX + p_yY$.

Let us assume that the economy is at C (a point on the production frontier). We wish to check whether a move to B (also on the frontier), which is an improvement in the individual's well being, records an increase in NNP defined as above. As Figure 4.1 shows, it does record an increase. Moreover, it can be confirmed that a move f rom C to any point on the fronter that records an improvement in NNP also reflects an improvement in the individual's well being.

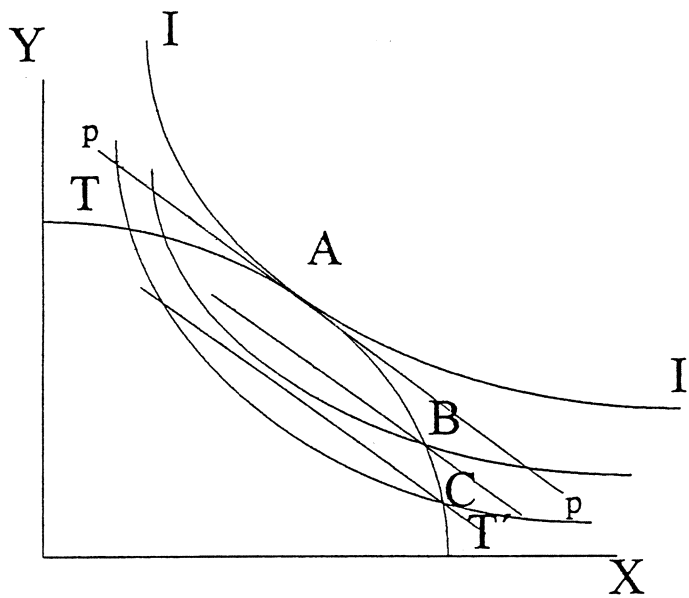

Figure 4.1. NNP as a cost benefit rule

Thus far we have illustrated the use of optimal prices for measuring NNP. For points inside the production possibility set, these prices are inappropriate for the estimation of NNP. Instead, local prices ought to be used.[3] The idea is simple enough. Let (X, Y) be the current consumption point. Then the individual's well being is W(X, Y). Consider now a small change in consumption (dX, dY). Then, to a first approximation, the resulting change in the individual's well being is $W_x dX + W_y dY$, where W_x and W_y are the two partial derivatives of W at (X, Y). The change is desirable if $W_x dX + W_y dY > 0$; it is undesirable if $W_x dX + W_y dY < 0$. This means that W_x and W_y could be used as the accounting prices. In other words, NNP, evaluated on the basis of current marginal valuations, is an appropriate measure of social well being.

Now it can be shown that an indefinite sequence of improvements of this kind (where the improvement at each stage is measured at the prevailing marginal valuations) would eventually lead to the optimal consumption point, A (Arrow and Hurwicz, 1958). This is called the gradient process.

The simple ideas expounded above will now be used to develop a framework for the construction of an index for a more complicated economy. The restriction to two commodities is in fact more general than we need. Thus we will in fact limit ourselves to one consumer good, without restricting the generality of the analysis. Maintaining the assumption of only one individual also allows us to bypass distributional issues.

4.5. Issues in the construction of a green national product

We use an optimal growth model to study the most important characteristics of an accounting framework. This approach has many advantages, one being that it provides insights into the nature of the shadow prices we need. The analysis depends heavily on Mäler (1991), Dasgupta and Mäler (1991) and Dasgupta, Kriström and Mäler (1995).

4.5.1. Labour

Imagine two countries, both with perfectly competitive markets, that differ only in the number of hours worked. If leisure time is valued positively, should our welfare indicator record any difference between the countries?[4] Given that the two countries' national products are equal, the conventionally computed GNP suggests that welfare in both countries is also equal. Thus under the current accounting systems the answer would be no. In this section we show how such conclusions would be modified, if the purpose were to obtain a welfare indicator.

We assume, for the time being, that there is only one factor of production – labour. We also assume that there is a perfect market for labour that is in equilibrium at each point of time. If the supply of labour were completely inelastic we need not consider the issue of labour further. The individual works a given amount of time and there is no leisure–labour choice. Instead assume that the labour supply is elastic. At the margin, the individual is indifferent between working one more hour or having one more hour for leisure. This being the case, and given the fact that we are only trying to evaluate marginal projects, wage income should not be part of our index. This may not be obvious, but the following example may clarify our point.

Consider a constant returns to scale project which increases labour hours worked, at the expense of reduced leisure time. Such a project has no effect on well being. This is because the gains from increased production of consumer goods are completely offset by the opportunity cost of lost leisure time. Thus, with perfect, equilibrating labour markets, labour income should not be included in the national product measure.

This is a rather startling conclusion in view of the historical fact that national income measures were originally constructed as an aid in designing demand-side economic policies. Obviously then, the national product has at least two different uses. The appropriate concept for one purpose is typically different from that which is appropriate for another. It is, in fact, necessary to distinguish between different concepts of national products. Preferrably, we should give the different concepts different names. In spite of this we will in this chapter continue to use national product as the generic name for our index for evaluating marginal projects.

Our conclusion above is based on a number of implicit assumptions. The most questionable is that labour markets equilibrate. Although obviously this condition does not always hold, we can still construct an index, proceeding as if the labour markets are in equilibrium. Alternatively, we can use the local prices, i.e. the workers marginal reservation price for taking a job. Assume for simplicity that the reservation price is zero, i.e. the worker is willing to take a job as long as he gets something above zero. The accounting price for labour is then zero and the wage bill, evaluated at this price, would also be zero.[5]

This discussion has important implications for the discussion on how to treat 'defensive expenditures'. Such expenditures are dedicated to cleaning up damaged environments.[6] It has been suggested that conventional national income accounts would register an increase in GNP because of damage to the environment due to pollution because companies (or the public sector) will hire labour to clean up the environment. This will show up as an increase in GNP, and it is argued, therefore, that defensive expenditures should be deducted from GNP. This conclusion is clearly not correct. If the economy is in full employment, then hiring of people in the clean-up industry will be offset by a reduction in production somewhere else in the economy. If the economy is not in full employment, then (assuming we are using local prices) the wage bill should be zero, and there will be no increase in GNP.

I have assumed that labour time and leisure are substitutes. This assumption needs to be modified when workers carry human capital. Part of their salaries is a return on that capital and cannot be regarded as a substitute for leisure. Only the part of their salaries that correspond to 'raw' labour, on the margin, will be valued at the same rate as leisure. The return on human capital should therefore be included in our index. This may create severe practical problems, because there does not exist any reasonable empirical approach to separate returns on human capital from the 'return' to raw labour.

4.5.2. Flows of goods and services

Human welfare depends on many non-market goods and services. A few of these are already included in the SNA. For example, production in the public sector is in general not marketed but included in GNP. Needless to say, many important goods and services are neglected in the current SNA. In fact, human life depends crucially on services provided by fundamental ecological systems. Inclusion of these services changes the national accounts in two ways. First, it changes the current flow of goods and services. Secondly, it changes the future flows via current changes in the resource base.

The current flow of services from natural capital affects human well being in at least two ways. First, the flow can directly affect human well being, as exemplified by clean air, recreational opportunities and food gathering. It can also affect human well being indirectly when the services are used as inputs in production. If the relevant production units are included in the national accounts, then changes in the flow of current services are measured by the conventional GNP; a change in the quantity of one service will affect the operating surplus and the operating surplus is accounted for in the value added of the production unit. This means that indirect uses will already be reflected in the current SNA, if the relevant production units are included.

The direct use of ecological services is not accounted for in SNA. There is a considerable confusion in the literature as how to include the direct services in an adjusted national product. The confusion arises largely from problems of definition. One example illustrates this point. Assume that an individual is disturbed by noise from a nearby highway. An increase in traffic volume will raise the noise level and reduce the well being of the individual. In response, the individual might invest in three-pane windows and increased insulation. Should these defensive expenditures be subtracted in order to obtain a more appropriate national product index? In other words, are the expenditures reasonable money measures of the utility loss?

The answer to these questions lies in the way we are measuring the environmental damage. Let N be the outdoor noise level. As a result of the increased traffic, the noise level increases from N^0 to N^1. Let the origian indoor noise level by M^0 and assume that the level is maintained through defensive expenditures. Let D(N) be the damage function (the willingness to pay for a quiet neighbourhood).

One correct way of adjusting the national product index is to substract

$$D'(N^0) \times (N^1 - N^0) = D(N^1) - D(N^0)$$

from the conventional national product. Because we are studying a marginal change, $D'(N)$, we use the marginal damage function. Note that this implies that we are using local prices, i.e. the marginal willingness to pay for noise reduction in the actual situation (where noise is N^0). In this case, we should ensure that all prices used in computing the index are reflecting the actual marginal willingness to pay for the goods and services. We could also have made use of the optimal prices. If N^* is the optimal noise level, then the adjustment would have been $D'(N^*)(N^1 - N^0)$.

Sometimes a different formulation is used, where the damage function is D(M). Because of the defensive expenditures, the indoor noise level is unchanged. Thus, the national product should therefore be subtracted by these expenditures. This is correct, if the defensive expenditures are approximately equal to $D'(N^0) \times (N^1 - N^0)$.

It is important to remember that there is no reason to assume that defensive expenditures are a good approximation of the true environmental damage. In fact, one can imagine cases where environmental damages are negatively correlated with the defensive expenditures. It may therefore be dangerous to use defensive expenditures uncritically as a measure of the environmental damage.

4.5.3. Valuation issues

During the last 20 years or so, the techniques for estimating environmental damages in monetary terms have been extensively developed.[7] These techniques have been developed for use in particular situations where a cost–benefit analysis is needed for making a specific decision, and not for use in the production of national product estimates. If these rather sophisticated techniques were to be used, the cost for adjusting the national product measures would likely be prohibitive. Therefore, more simple, but still robust methods are needed.

The conventional way of including the public sector in SNA may give some clues as to how to find reasonably accurate and inexpensive valuation methods. Because the output from the public sector is, in general, not marketed there is no way of assessing the value of that output directly. SNA has solved the problem by looking at the cost of production in the public sector (mainly labour cost). This is a correct approach if the public output corresponds to the demand. In fact, if politicians are able to make correct decisions on the size and composition of the public sector, then the cost of production (including cost of capital) in the public sector would exactly correspond to the value of the output. Thus one possibility would be to use the same basic idea when approximating the value of environmental damage.

The use of a 'politically determined' willingness to pay would require that there are politically determined targets for environmental policies – ambient standards, emissions targets, etc. The situation is illustrated in Figure 4.2. Here MC is the marginal cost of abating emissions and MD is the marginal damage from the emissions. The total abatement and damage cost is minimized when marginal abatement cost equals marginal damage cost, i.e. at the point A.

Assume that the current emissions are at D. It would then be desirable to reduce the emissions to C. The total cost of doing that is the area of ACDE. The

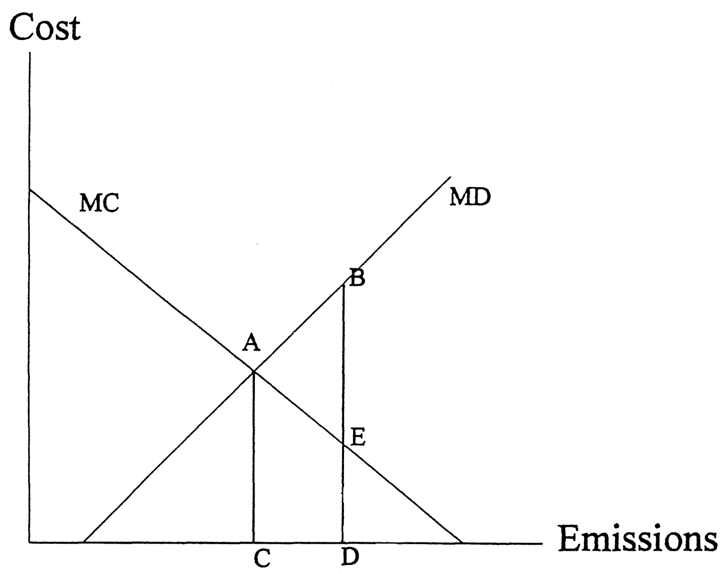

Figure 4.2. Cost of abatement as an environmental value

reduction in the environmental damages from such an emission reduction is ACDB. We immediately see that these two areas are correlated. An increase in this as well as the accounts. An increase in the environmental damages from an increase in the emissions will be accompanied by an increase in the abatement costs necessary to achieve the optimum level of pollution. Therefore, the cost of achieving the target emission reduction is, although hardly perfect, an approximation of the environmental damage. If the political system has determined explicit targets for environmental policies, then one could use the costs of achieving these targets as approximations when adjusting the conventional national product concepts for the flow of environmental services. However, politicians very seldom determine specific targets in environmental policies, and the scope of this approach to evaluating environmental damage is therefore limited.

Similarly, if the political bodies have determined emission taxes instead of quantity targets, these taxes could be interpreted as proxies for the social marginal damage from further pollution. In Sweden, the emission tax on sulphur is 30 000 SEK per ton. This reveals implicity that society values the damage from one more ton as 30 000 SEK. Unfortunately, there are very few such emission taxes and in most countries there are no environmental taxes at all.

4.5.4. Transboundary pollution

The discussion has so far focused on the situation in one country and has not included the interactions between a given country and the rest of the world. Obviously, modifying the analysis to consider such interactions involves accounting for transboundary pollution. Typical examples of transboundary pollution are upstream–downstream problems, where an upstream country effects a downstream neighbouring country.

To construct a welfare index, and more generally a consistent accounting system, we need to return to the fundamental question; whose well being should be considered? Should we consider the global population, or should we limit ourselves to the citizens of the own country? Either approach is equally valid, but they lead to different formulations of the indices as well as the accounts. Begin by assuming that we are interested in a marginal cost–benefit rule for projects in one country. Then we should deduct the environmental damage 'our projects' give rise to abroad. Thus, export of pollution should be counted negatively. Furthermore, as the cost–benefit rule applies to domestic projects only, the import of pollution should not be accounted for. If the objective is to create an index measuring the impact on global well being from projects in one country, then environmentally damaging activities in other countries should not be included. If all countries based their accounts on this objective, all accounts would be consistent, and could thus be summed. In fact, the global national product calculated in this way would give the same result as the result from a calculation in which we would have considered the whole globe as one country.

Another way of doing the calculation would be to base them on a cost–benefit rule that considers all changes as the project, but limit the consequences to citizens in the home country. This is an equally valid starting point, though it will, in general, give a different answer. If all countries apply the same rule, we would once again have consistent systems. The difference between the two approaches is similar to the difference between gross domestic product and gross national product, the difference being the treatment of factor payment across national borders.

The second issue in accounting for trade has to do with environmental assets. A good example is an oil-based country such as Saudi Arabia. If Saudi Arabia is considered as an isolated island, it follows that NNP, properly measured, is zero. For a proof, see the appendix. Before we discuss this issue further, it will be helpful to discuss environmental assets in more detail.

4.5.5. Environmental assets

Some projects have effects on future welfare, through the accumulation and decumulation of productive assets. The well being of future generations are reflected in the stock of assets the current generation is leaving to the future. If we are interested in the well being of future generations, we should obviously include the net changes in the productive assets in the accounts.

In SNA (before 1993), changes in only two such assets are included – man-made capital and human capital. In the GNP gross investments in real capital are included. If we are interested in a welfare index that includes future generations, it is clear that NNP is a better index than GNP. What matters for future generations is the capital stock they inherit, and we should measure how much we add to this stock by focusing on net investments.

A particularly difficult stock of capital to measure in the context of NNP – measurement is human capital. Changes in the stock of human capital are consequences of education, research and development. Some of the costs for these activities are included in the standard GNP measure. They are typically classified as public expenditures. It seems reasonable to reclassify expenditures on human capital as investments. The largest cost for investments in human capital is neglected, however. This is the opportunity costs of the time students allocate to their studies. It seems reasonable that these costs should be part of the gross capital formation. On the other hand, it seems extremely difficult to define the depreciation charges needed for the calculation of the net change in the stock of human capital.

Changes in stocks of natural resources have typically not been included in SNA. As many of these resources generate essential life supporting services, their exclusion may severely distort the net national product estimates. It should be of highest priority to try to include changes in the complete asset base in the accounts.

Exactly how changes in these assets should be included in the national accounts is still controversial, though it should not be. Once again, starting with the objective of creating a marginal social cost–benefit rule, we have to determine the impact current projects have on welfare. To do this it will be necessary to make some assumptions on what the future will look like. In deriving the appropriate accounting prices, the simplest and most practical assumption is to assume that the economy will follow an optimal path from now on; recall the discussion involving Figure 4.1. There we concluded that we could use the optimal prices even if the economy is not at the optimum. The same is true in a dynamic setting. We use the optimal path as a vehicle to compute accounting prices which are then used to value the current changes in resource stocks. Basically, these prices will reflect the present value of the future welfare stream from one more unit of the resource today. Having computed these accounting prices, it follows that we should add the value of changes of resource stocks at these prices to the conventional national product.

This conclusion has important implications. One implication is that we must include the price times the change in the resource stock. The change in the accounting price is not included. That is, we do not consider capital gains (or losses). Another implication involves exhaustible resources and the proper treatment of new discoveries. If discoveries are deterministic in that one can predict with some certainty that new reserves will be found, if investments are made in explorations, then the net stock may increase. On the other hand, if discoveries are completely random, then changes in the stock should be valued with accounting prices then take into account possible (but not certain) future discovery.[8]

Furthermore, the so-called El Serafy[9] model for computing the depreciation charges for exhaustible resources is incorrect, due to the fact that it is based on an arbitrary prediction of the future – a prediction which is not self-consistent. El Serafy considers the case when a resource has a fixed lifespan and generates a constant revenue for each of the remaining years. He then transforms this revenue to a consumption charge that can go on forever. This enables him to compute the depreciation charge. However, as the assumptions are arbitrary, the computed depreciation charge will also be arbitrary.

For many of the resources included in the stock of natural capital, the same valuation problems arise as did with the flow of services discussed in the previous section. There are no market prices for these assets because they are not subject to transactions. Instead, one has to follow the same rather ad hoc approaches as were discussed. However, there are important resources for which there are market prices. Most of the exhaustible resources are traded on markets, and the established market prices could be used as a first approximation to compute the appropriate depreciation charges.

With the above details spelled out, we can now easily see how to properly handle capital flows. Consider a small open economy with a single asset, oil. As we explained above, without trading possibilities, the country has an NNP of zero. Assume now that the country can invest its proceeds in a resource elsewhere, which gives a rate of return equal to the world market interest rate. It then turns out, see the appendix, that we need to add the return on this additional stock to obtain a proper welfare measure. Again, the reason is intuitively clear. We have added an additional stock that may be used to provide for future generations. Additions to, or depletions of, this stock should be included in the welfare measure.

Let us try to summarize the findings so far. We are looking for a linear index that will show whether or not the performance of the economy during a specific time period has been improving the present value of current and future well being. Such an index should look like the following:

> Net national product = consumption of marketed goods + public expenditures + the value of the net change of real capital – wage bill for raw labour + opportunity costs of time for students – flow of environmental damages + the value of the net change in the environmental resource base.

4.5.6. Sustainable development and sustainable income

It is possible to show that the net national product concept that was introduced in the previous section has some rather interesting properties:[10]

(i) If the optimum of is approximately a steady state, NNP will be the return on the total wealth in the economy, including real capital, human capital and natural capital.

(ii) NNP will be the maximum constant well being that, in the absence of non-anticipated technical progress, is feasible. A higher well being today than NNP will reduce well being in the future.

The NNP is a linear measure and if we are following an optimal path, it is a linear approximation of the optimal present value of future welfare. It can be shown that this optimal present value of future welfare will correspond to the return on the total wealth if the optimum is approximately a steady state. NNP can thus be viewed, not only as an index for marginal cost–benefit analysis but also as an index for whether the development is sustainable or not. A rigorous treatment of this is provided in the appendix.

4.6. An accounting system

The theoretical arguments put forward in the previous sections are obviously far different from the basic idea underlying the SNA. Furthermore, they are also quite different from the ideas underlying the System of Integrated Environmental and Economic Accounting (SEEA).[11] Obviously, the ideas expounded in this paper will be very difficult to implement, particularly because of the inherent difficulties of valuing environmental services.[12] However, it is possible to embed the arguments above in an accounting framework, similar to SNA. A brief presentation of such a framework is given in this section. The basic building block is a SAM – a Social Accounting Matrix – which can be used to summarize the accounting system in a compact way (Table 4.1). The illustration below does not take into account the fact that wages for raw labour should not be included. It does not include international relations and it does not include the input/output structure of the economy. Furthermore, it would be much desirable to include a finer classification of

Table 4.1. A social accounting matrix (SAM)

	Households	Labour	Capital	Production	Abatement	Savings investment	Environment
Households		Wages	Profits				Rent
Labour				Wages	Wages		
Capital				Profits	Profits		
Production	Consumption				Inputs	Gross investment	
Abatement				Abatement			
Savings investment	Household savings			Depreciation	Depreciation		
Environment	Environmental services			Environmental damages	Environmental damages	Value of the net change of resources	

institutions, including the public sector, instead of having households as the only institutions.

The economy has been divided into seven different accounts: households, two factors of production, one for production, one for abatement (or for expenditures for environmental improvements in general), capital/savings account and one for the environment. Each row corresponds to incomings for the corresponding account, while the columns correspond to the outgoings. The households' incomes is the sum of wages, profits and an implicit rent on the environmental assets. These incomes are spent on purchases of consumer goods, savings (including savings in the form of net additions to the environmental assets), and the imputed value of the environmental services consumed by the households. In a corresponding way, the ingoings to the production account are the incomes from sales to household, the sales to firms for investment goods and from the sales to the account for abatement. The total gross savings in the economy consists of households' savings and depreciation of capital stocks. This saving corresponds to investment in real capital and net additions to the stock of natural capital.

The net national product is given as the sum in the first column, i.e. the value of consumption plus net savings less the reduction in environmental services, i.e. environmental damages. The net national income is given in the usual way as the sum in the first row, i.e. wages plus profits plus the return on environmental capital.

4.7. Survey of applications

In this section we survey a number of existing and proposed applications of resource accounting. Given the pace of development in this area, it is difficult to compile an exhaustive survey. The interested reader is encouraged to consult the original sources for details.

Japan was one of the first countries to adjust the national product in a welfare-oriented way. Uno (1973) followed Nordhaus and Tobin (1973) in proposing a measure of economic welfare by adjusting the national product in a number of ways.[13] The most interesting adjustment, in this context, was the way in which environmental damages was monetized. Uno suggested that the damages could be approximated by the cost for reaching an environmental goal. Thus, if the officially stated goal is to reduce sulphur emissions by 30%, then one can approximate current sulphur damages by the cost of reaching this goal. Uno's suggestion is interesting and theoretically quite appealing, as we discussed above. The Statistical Bureau of the Netherlands is particularly active in promoting 'green GDP' calculations. In the early 1970s, the bureau made several attempts to correct the national income by taking into account environmental damages. The work has continued in the 1990s (see Hueting, 1990 for an overview).

Denmark and Sweden have recently completed two studies on resource accounting, each reaching widely different conclusions (Danish Bureau of

Statistics, 1990; SOU 1991:37). The Danish position is strongly negative towards monetary accounts, while the Swedish commission expressed cautious optimism. Currently, a number of Swedish governmental bodies are involved in developing resource accounting systems. The Swedish National Institute of Economic Research is responsible for developing monetary accounts, while Statistics Sweden (SCB) pursues the work on physical accounts. Also, the Swedish Environmental Protection Agency is involved in these efforts and is currently compiling 'environmental indices'.

Work is currently under way in a number of other countries, particularly Australia, Canada and Germany. Several international organizations, such as OECD, the World Bank and the United Nations are actively supporting the development of resource accounting systems. A particularly significant publication is the recently published Handbook of Integrated Environmental and Economic accounts by the UN statistical office. Finally, I would like to note that the president of the United States has instructed the Bureau of Economic Analysis to develop a green GDP.[14] Such work is now undertaken both in Congress and in government. Unfortunately, I am not that familiar with that work and I will therefore not comment upon it.

4.7.1. Indonesia

The study of Indonesia by Repetto and co-workers (1989) is perhaps the best known application of resource accounting. Central to this work is the observation that in the SNA (before 1993) depreciation of man-made capital was treated differently than depreciation of natural assets. Hence, while the cost of 'using up' a machine is reflected in the net national product through depreciation allowances, the cost of 'using up' a natural asset is not. Because both a machine and a forest provide for the welfare of current and future generations, they are productive assets. Thus, according to Repetto et al. (1989), these assets should be treated symmetrically in the national accounts. Such a treatment is consistent with the theoretical considerations above.

Repetto et al. (1989) studied Indonesia during 1971–84, a period of rapid economic growth; GDP increased 7.1% per year on average. This growth was, to a large extent, based on intensive exploitation of oil, gas, minerals, forest products and other natural resources. They challenge the view that (given Indonesia's dependency on natural resources) GDP provides an accurate picture of the country's economic success.

As a first step, the authors construct physical resource accounts. Specifically, they focus on three major assets: forest, oil, and soil. For each asset a physical and monetary account is constructed. A key issue is valuing the change, in monetary terms, of the asset stock. The basic approach to the economics of depreciation, outlined by Hotelling (Hotelling, 1925) is to analyse the present value of future services from a machine or a resource. Repetto et al. chose to use the net rent method. The depreciation allowance is equal to price minus the costs of extraction.

Forests are divided into 'primary' and 'secondary'. The stumpage value of timer in 'primary' forests is obtained by subtracting the costs of extraction and transportation from export value. The stumpage value for 'secondary' forests are calculated to be roughly half the value of primary forests. Finally, plantation forests are provisionally assigned a value of zero, since they constitute a minor fraction of the total stock.

Hartwick (1990) has shown that the value of the change of a homogenous renewable resource should be valued at the 'marginal' stumpage value per unit (price minus marginal cost). Since the forest stock is heterogeneous, i.e. price and marginal cost varies across different quality classes, Hartwick's formula needs to be modified. If it is assumed that the stock changes symmetrically over all classes, Hultkrantz (1991) suggests using the 'average' stumpage value. Thus, for each quality class one may use the average, rather than the marginal, costs. This idea provides some support for Repetto et al.'s use of average stumpage value in their calculations.

The petroleum resources are valued by subtracting the average extraction and transportation costs from the market price of oil (f.o.b. export price). Note that one would ideally like to compute the marginal costs, but in this case using average costs appears to be an innocuous simplification.

The third and final asset considered by Repetto et al. is soil. Indonesia has experienced familiar problems of a rapidly growing population. Clearing of land and clearing of hillsides has, for example, meant an erosion of 60 tonne/ha/year, according to the authors. Their estimates of erosion are based on erosion models that relate data on topography, climate, soil characteristics and land use to erosion. The models predict, among other things, that a shift from forest to agriculture implies a soil loss of 133 tonne/h. The authors also estimate that the depreciation of soil fertility is roughly the size of the annual production increase, or 4% of the value of crop production.

Repetto et al. propose a measure of income, defined as 'EDP' = GDP − depreciation of natural assets. Depreciation of man-made real capital is not included in this measure. While this omission is not theoretically correct, in practice it is likely an innocuous simplification.

A summary of the findings is reported in Figure 4.3.

Critiques of the study have focused on both the valuation procedures and the choice of income measure. Clarke and Dragun (1989) argue that the net rent method is not an appropriate valuation method (in the case of a renewable resource) when decreasing the stock may be part of a programme to increase future growth of the forests; compare the use of cleanings and thinnings. El Serafy also contends that the net rent method is not a correct depreciation approach. He advocates the approach which we dismissed as arbitrary. Clarke and Dragun's point about the forest calculations can be approached from a number of standpoints. The simplest is to separate final fellings from the investment-like cleanings and thinnings in the accounting procedure. It is difficult to assess how such reclassifications affect the final results calculated by Repetto et al.[15] If we compare Repetto et al.'s EDP concept with the welfare

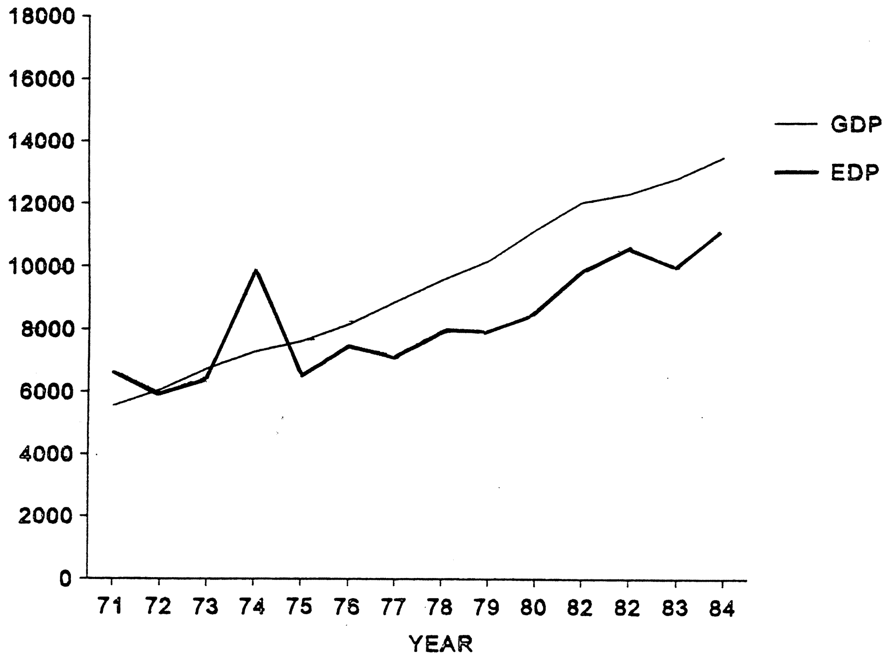

Figure 4.3. GDP and EDP for Indonesia. Source: Repetto et al. (1989)

index proposed in Section 4.5.5 there is a number of differences. The treatment of labour, human capital and environmental quality are main dissimilarities. It should also be pointed out that Repetto et al. use gross rather than net investments in real capital. Furthermore, one could add that Repetto and his team only concentrated on the value of timber in looking at the economics of forests. There are indications that forests play a much wider and more important role for economics. The forest is an ecological system. While Repetto et al.'s study has been criticised for various errors it remains the first important study to show how resource accounting can be used to shed light on particular resource allocation problems. Our review has concentrated on the 'EDP' concept presented in the report, which is only a part of the material compiled. The effort of Repetto et al. to construct the Indonesian resource accounts paves the way for a wide variety of analyses pertaining to relationships between the economy and the environment. This is perhaps its most important contribution. A similar application is made for Costa Rica (see World Resources Institute, 1991).

4.7.2. Malaysia

Vincent (1993) has examined resource use in Malaysia. Like Indonesia, Malaysia is rich in natural resources: Vincent focuses on minerals and timber, the two most important. A geographical breakdown of resource use shows that net investments were positive in Peninsular Malaysia in the 1970s and 1980s, while net investments were negative in Eastern Malaysia during the same period. While the Peninsula has depleted its natural resources, it has used the proceeds to invest in man-made capital. The total capital stock appears to be larger than in the beginning of the 1970s. The evidence on the net change of the total (measured) capital stock in the other parts of the country is somewhat mixed, although the evidence points to a future economic decline in these areas – the current level of consumption is not sustainable.

For various reasons, human capital is not included in the calculations, but substantial decreases in the illiteracy rate and significant expansions of the education system since 1970 suggests that the human capital stock has increased. This increase possibly outweighs the negative net investments in the Eastern parts.

Vincent's (1993) analysis can be seen as an attempt to check whether different parts of Malaysia satisfies Hartwick's rule. This rule says that if production possibilities in a country with only non-renewable resources are such that it is feasible to sustain positive consumption, then the economy can enjoy the maximum constant consumption, if the resource rents are invested in reproducible capital. Given such an objective, much of Vincent's analysis is consistent with our discussions on how to value resource stocks. There is one difference, however. According to Vincent (1993, p.8), discoveries should not be included as measures of net depletion of a nonrenewable resource. As I have already said we should include the net change of the stock, if it can be predicted with some certainty that explorations lead to new discoveries.

4.7.3. Swedish forests

Hultkranz (1991) made an attempt to adjust the sectoral forest accounts by including several non-priced services provided by forests. Table 4.2 illustrates the components included in his analysis.

To the extent possible, Hultkranz (1991) utilizes market prices to evaluate each component. Such data are available on timber, berries and mushrooms. The value of meat from hunting and recreational values are obtained from a contingent valuation study. Biodiversity is valued by considering the area of protected lands that must be set aside to protect biological diversity, and then computing the opportunity costs. The hydrological effects, e.g. forest absorbation of water that could have been used for power generation, are not valued explicitly. Carbon fixing is valued by using the effluent fee of carbon dioxide (c.f. our theoretical discussion above). Note that Hultkrantz counts the increase of growing forest stock twice. First, the timber value and then the value of

Table 4.2. Components included in modified forest accounts

Yield	Maintenance	Stock
Timber	Maintenance	Forest inventory
Harvest of berries		Berry-yielding Herbs
Mushroom		Mycelium
Meat (bag)	Game protection	Game population
Recreation	Various activities	Various
Biodiversity	Fauna/flora protection	Survival conditions
Effects on hydrological flows	Measures that effect runoff	Forest inventory, bare lands, ditches, etc.
Fixing of carbon	Silviculture and boarding (non-harvesting)	Carbon pools
Buffering of acid, rain, tree nutrition	Liming, fertilization	Content of exchangeable base cations insoil and vegetation
Nitrogen leaching Reindeer forage	Construction of nitrogen sinks	Nitrogen-fixing capacity Lichen stocks

Source: Hultkrantz (1991)

carbon fixing. The annual depletion of exchangable cations in forest soils can be compensated by liming, and this cost is used as a proxy. For lack of data, nitrogen leaking is not considered explicitly. Forests (in the north of Sweden) also provide reindeer forage. Because changes in lichen stocks are not included in the current accounts, Hultkrantz (1991) utilizes studies on opportunity costs to obtain a value of the change in stocks. His final results are reported in Table 4.3.

4.7.4. Regional Colombian accounts

All the studies reviewed above have focused on very tangible outputs from forests – timber, berries, etc. Repetto et al., in their studies of Indonesia and Costa Rica, extended the role of forests to the control of the soil layers. That this is important has been shown by Molinas who, in an unpublished study (now being translated into English) showed that this function of the forest may be extremely important. Using ecological information he calculated the erosion

Table 4.3. Modified NNP accounts for income from Swedish forests, 1987

Market value of timber	18.63
Inputs from other sectors	–3.14
Stock growth	3.8
Silviculture	–1.55
Subtotal 1	**17.75**
Berries	0.5
Mushrooms	0.55
Meat from game	0.47
Subtotal 2	**1.52**
Biodiversity	–0.6
Carbon pools	3.8
Exchangeable cations in soil	–0.6
Lichen stocks	–0.02
Subtotal 3	**2.58**
Total net income	21.85

Adapted from Hultkranz (1991, Table IV, p. 390). The figures are in billion SEK

of soils at the rather steep sides of hills in a specific region in Colombia that would follow clear cutting of the slopes. The effects on the rivers running in the valleys were then calculated. The increased turbidity of the waters made them unfit for human consumption, which increased the cost of water supply to the villages in the area: in fact, the value of the forest in controlling erosion and water quality was higher than the value of the potential timber output. This shows the necessity of including a wide set of functions and services of ecosystems in order to make realistic and comprehensive estimates of the systems contributions to the net national product.

4.7.5. The SEEA

The SEEA complements the current SNA in two important respects: (i) depletion of natural resources in both production and final demand and (ii) changes in environmental quality. The SEEA also includes a broader concept of capital, this includes not only man-made capital but also natural capital. The SEEA contains both physical and monetary accounts. The physical accounts have a structure which is similar to the Norwegian accounts presented in Section 5.2.[16] The asset boundary is very general and includes, in principle, all assets (United Nations, 1993, p.8; referred to as 'the Handbook'). It is acknowledged than an application of the SEEA probably needs to restrict the number of assets included. In any case, the asset boundary is much wider compared to the ordinary SNA.

In transforming the physical data to monetary units, the Handbook discusses three different approaches: (i) market valuation, (ii) direct methods (e.g. contingent valuation) and (iii) indirect methods (e.g. environmental protection costs).[17] The most important of these in the SEEA are the indirect methods, in particular the maintenance cost concept. While the exact definition of this concept is unclear, it is stated that "The (hypothetical) maintenance costs are – mainly prevention costs that would have been necessary to prevent negative impacts of economic activities on the environment and/or to meet given sustainability standards –" (Handbook, p.19).

As illustrated in the studies of Mexico and Papua New Guinea above, the SEEA also suggests an environmentally adjusted domestic product (EDP). It is defined (Bartelmus, 1992, p.67) as:

EDP = Final consumption + Net capital formation +
Net exports of goods and services + Net exports of residuals[18]

The SEEA integrates use/value added tables, balance sheets for environmental and economic assets, and tables for intermediate, final consumption and capital accumulation. The structure is as follows:

(1) Opening stocks (produced and non-produced)
(2) Use/value added tables (GDP, NDP, EDP)
(3) Supply tables (goods and services, imports of residuals)
(4) Revaluation and other volume changes
(5) Closing stocks

Defensive expenditures are identified and classified in a number of ways. The argument for not deducting them from EDP is, according to Bartelmus, based on reductio ad absurdum – food could, for example, be considered a defensive expenditure against starvation and, in the limit, the adjusted national product is zero.

Regarding valuation of non-financial assets, the SEEA discusses three main approaches; (i) actual prices of natural assets; (ii) present value of expected net proceeds; and (iii) the net price method (used by Repetto et al., 1989). El Serafy's approach is considered for depletion of (exhaustible) mineral resources. The Handbook suggests using different approaches for different assets. For changes in land quality, market prices (to the extent it is possible) should be used. For depletion of natural assets such as wild biota, subsoil assets or water, the net price method "could be used" (p. 61). For forests, stumpage values are considered appropriate.

The Handbook is a work-in-progress report. Several issues remain to be clarified and discussed before the system matures in to a powerful vehicle in exploring and understanding the linkages between the economy and the environment. Nevertheless, its appeal to economists is limited by the fact that the welfare economics foundations are weak. The presented EDP concepts have not been shown to correspond to any sign-preserving measure of welfare change. This severely limits the interpretation of the adjusted national products in the SEEA and therefore the value of the system itself.

Mexico

Van Tongeren et al. (1992) present an integrated environmental and economic accounting system of Mexico.[19] The study followed the guidelines set forth in UNSO's draft handbook on environmental accounting. Oil depletion, deforestation, land use and environmental asset depletion (air and water pollution, soil erosion, gound water and solid waste) were focused upon. In the sense that physical accounts were established first and then later transformed into monetary accounts the general strategy followed closely that of the Indonesian study. Two EDPs are calculated: EDP1 is based on market transactions, while EDP2 includes calculations involving less generally agreed upon principles (such as the avoidance cost method).

Valuation of changes in oil and timber stocks was carried out by using both the net rent method and El Serafy's approach. In the second case, one needs to calculate the discounted sum of depletion allowances necessary in keeping income constant. The study year (1985) gives different results for the two approaches; net rent is 1162 pesos/barrel, the depletion allowance is 160 pesos/barrel. Average stumpage values for forests were computed to be 21.5 and 1.6 pesos/m^3 respectively. The Van Tongeren et al. study also includes environmental quality changes. Besides valuing soil erosion and solid waste generation (by households), the authors also includes sulphur dioxide, nitrogen oxide, carbon monoxide and emissions of suspended particulates. Land erosion was valued at the cost of fertilizer to maintain the productivity of the land. Ground water loss was valued at the cost of re-injecting water back into underground water reservoirs. Finally, water and air pollution were valued at the cost of reducing such pollution "to acceptable levels" (p.7).

The main findings of the monetary valuations are summarized in Table 4.4.

EDP1 includes degradation of natural capital. By subtracting these costs from NDP, one finds that the value of this degradation is about 6% of NDP. If

Table 4.4. Conventional and environmental accounts, Mexico 1985

	Conventional accounts	EDP1	EDP2
NDP	42.1	39.7	36.4
EDP/NDP	–	0.94	0.87
C/NDP	0.83	0.88	0.96
CAP	4.7	2.3	–0.85

Source: Van Tongeren et al. (1991, p. 24)
Figures are in billion pesos
C, consumption; CAP, net capital formation; EDP1(2), environmentally adjusted net domestic product (see text for details); NDP, net domestic product

additional environmental damages are taken into account, the adjusted Mexican income is about 13% less than the conventional NDP. It can also be seen that consumption is the major component in the studied income measures. Computation of changes in the capital stock (net) gives different results, depending upon which measure is selected. The most comprehensive measure, EDP2, suggests a negative build-up of real capital in Mexico. Both EDP1 and EDP2 differ substantially from our suggestion of how to adjust the national product. First, the wage bill and the human capital stock is not given a correct treatment in this study. It is difficult to say, based on the data in the report, how a correct treatment would have changed the conclusions. Second, new finds of oil are not included in the net change of the oil stock. As in the Vincent (1993) study, this is not a correct treatment. Third, changes of the stock of forests are only accounted for if the harvests are larger than the maximum sustainable yield. No compelling arguments are presented to support that treatment. Several similar points can be made, but they all point in one direction, namely that the system is ad hoc. The proposed concepts of adjusted national products may have some connections to a welfare index, but this is very difficult to know. One example of the generic problem in this study is the following quote (p.22): "It should furthermore be noted that in the derivation of Yn2 [EDP2], an additional deduction has been made for environmental services produced by the government in the form of sanitation services. They are treated as intermediate consumption of (domestic) household protection activities". Again, no compelling reasons are presented to support this argument.

Papua New Guinea

Bartelmus et al. (1992) provide an analysis of an integrated economic and environmental accounting system for Papua New Guinea, using the SEEA as the main tool. The country under study is rich in natural resources, but has only a small industrial base. A small number of mines contribute to 60% of the export earnings from copper, gold and silver. Following closely the case study of Mexico, Bartelmus et al. use both the net rent method and El Serafy's method in calculating the value of resource depletion due to mining. While forests cover about 75% of the total area of Papua New Guinea, the forest industry is relatively small, providing about 4% of GDP and roughly 8% of total export value (Bartelmus et al., p.20). Following the Mexico study, a depletion allowance is not calculated, as the rate of forest cutting is judged to be below the sustainable rate.

The institutional structure of ownership in NPG allows an unusual approach to valuing certain environmental damages in monetary terms. Land, water, and related natural resources are owned by tribal groups and clans. According to Bartelmus et al. these groups, or rather their communities, bargain for compensation for resource exploitation following long-time tradition in the country. Such information has been used to value the impact of the construction of hydroelectric power plants. The main findings are summarized in Table 4.5.

Table 4.5. Adjusted national product for Papua New Guinea, 1986–1990

	1986	1987	1988	1989	1990
NDP	2313	2569	2862	2698	2760
EDP1	2187	2359	2755	2673	2579
EDP2	2133	2351	2697	2614	2521

Source: Bartelmus et al. (1992, p. 35)
Figures are in million Kina

As can be seen from Table 4.5, the differences between the various income measures are very small. This is presumably due to the fact that the country is not, to any significant extent, industrialized. About 80% of the population lives in remote villages and does not take part in ordinary market transactions. In a sense, therefore, the presented NDP, EDP1 and EDP2 measures cover only 20% of the population.

This study has the same generic weakness as the Mexico study. The conceptual foundations, from a welfare–theoretical point of view, for the suggested EDP measures are weak (or even non-existent). It is difficult to tell exactly what question(s) the EDP measures are supposed to answer.

4.8. Concluding remarks

I have tried to explore the consequences of basing resource accounting on firm theoretical grounds. I hope the arguments have been convincing that if certain technical restrictions are met, for any conception of social well being, and for any set of technological, transaction, information, and ecological constraints, there exists a set of shadow (or accounting) prices of goods and services that can be used in the estimation of real NNP. This holds no matter what is the basis upon which social well being is founded. On the basis of this I hope I have shown how an accounting system can be constructed using conventional tools of welfare economics.

The scrutiny of existing applications showed that the approach I have tried to outline is different from the ones currently used. This should not be surprising, given the fact that resource accounting is still in its formative stage. Nevertheless, it is important to begin with the fundamental question: what is it that we want to measure? If we want to measure well being, then our suggestions follow naturally from received welfare economics. My fundamental point is that measurement without theory is as dangerous in resource accounting as elsewhere. Therefore I agree whole-heartedly with Erik Lindahl, who made exactly the same point, when he developed his accounting system in the 1930s.[20] Without supporting theory we run the risk of developing accounting systems that are inherently useless when it comes to increasing our understanding of the proper husbandry of our environment and natural resources.

Appendix

4A.1. Optimal paths

Received theory on national income accounting and natural resources is based on the optimal growth model. Along an optimal development path, there will be a price system and this system of imputed prices will define the proper net national product. This idea was first proposed by Weitzman (1976) and later applied to the problem of the inclusion of environmental resources in national accounts by Hartwick (1990), Mäler (1991), Dasgupta and Mäler (1991) and many others. In the form it will be presented here, it was first outlined in Mäler (1974) and in Dasgupta and Heal (1979). I will explore that approach in a series of simplified models.

4A.1.1. Flow of services

I will start by assets and instead focus on the flow of services from consumer goods, the environment, and leisure. Let L be the total amount time available per period. It can be used for labour L_1 and leisure L_2. Thus,

$$L_1 + L_2 = L.$$

The following analysis can be done by letting C be a vector of consumption goods and services and let Q be the vector of flow of environmental services, but no essential insights are lost if we consider composite goods C and Q. Let p be the price of C and denote the wage rate w. Finally, let other incomes be I. The budget equation is

$$pC = wL_1 + I.$$

I will consistently neglect income distribution, not because it is unimportant but because I do not believe that national accounting systems are well adapted to include such considerations. Because of this I will assume that there is only one individual in the economy. Let

$$U(C, Q, L_2)$$

be the utility function of that individual.

A change from (C^0, Q^0, L_2^0) to (C^1, Q^1, L_2^1) corresponds to a change in utility:

$$\Delta U = U(C^1, Q^1, L_2^1) - U(C^0, Q0, L_2^0)$$

ΔU is the correct non-linear measure of the change in welfare. However, we want a linear measure and we therefore linearize (using superscripts to denote partial derivatives):

$$\Delta U \cong U_C(C^1 - C^0) + U_Q(Q^1 - Q^0) + U_L(L_2^1 - L_2^0).$$

We evaluate the utility function either at the optimum or at some other point, the importance being which prices we use: we can use either the prices corresponding to a global optimum or the local prices. Let the consumption good be the numerator (so that p = 1). Then dividing the above expression by the marginal utility of consumption and using the first-order conditions for an interior optimum for the consumer we have:

$$\Delta \text{NNP} = (C^1 - C^0) - w(L_2^1 - L_2^0) + q(Q^1 - Q^0),$$

where NNP is the net national product and $q(= U_Q/U_C)$ is the marginal willingness to pay for environmental services. Using the budget equation we find that

$$\Delta \text{NNP} = I^1 - I^0 + q(Q^1 - Q^0).$$

Thus, (the change in) NNP case corresponds to the change in 'other' incomes and the value of the change of the flow of environmental services. This proves the proposition I made yesterday that the return on raw labour should not be included in NNP. I will return to this issue when I discuss a different approach to the construction of linear index.

Let me now assume that Q corresponds to the environment, but that the individual can improve that environment by allocating resources to 'defensive' measures – increased insulation against noise pollution, cleaning up beaches, etc. By using the vector Y of marketed goods and services, the vector Q can be transformed into the vector Z according to the production function.

$$Z = g(Y, Q).$$

The utility function is (we now neglect labour income)

$$U = U(C, g(Y, Q))$$

To simplify exposition, we can without loss of generality let Y and Z be scalars. The budget constraint is given by

$$p_C C + p_Y Y = R.$$

Using a linear approximation and converting to money units as above, we find that

$$\Delta \text{NNP} = (C^1 - C^0) + p_Y(Y^1 - Y^0) + q(Q^1 - Q^0)$$

This shows that the defensive expenditures should not be subtracted from the

NNP measure. The confusion that can be found in the literature stems from the fact that we can also write ΔNNP as

$$\Delta\text{NNP} = (C^1 - C^0) + p_Z(Z^1 - Z^0),$$

where p_Z is marginal willingness to pay for the 'transformed' environment Z. Thus, one has to be careful about how one defines the flow of enviromental services. In most cases, it seems most appropriate to use the 'external' environment, e.g. the noise level outside a building, the pollution before a clean up etc. This would correspond to the use of the Q variable. In some cases, it is possible to estimate q from estimates of the defensive expenditures, $p_Y(Y^1 - Y^0)$. However, that is not always the case.[21]

Let us now consider an open economy which exports pollution (but so far no goods and services) and which also imports pollution. Let there be two countries S(weden) and F(inland). Let the utility functions in the two countries be $U^S(C^S, Q^S)$ and $U^F(C^F, Q^F)$, respectively. Assume that emissions (M) are generated in the two countries by producing the consumption goods:

$$C^i = \phi^i(M^i), i = S, F.$$

Assume further that the transport of the pollutants across borders can be described by a linear matrix:

$$Q^i = \alpha_{iS}M^S + \alpha_{iF}M^F, i = S, F.$$

We can now define a number of different net national product measures. Proceeding as above, invoking a first-ordering approximation and converting into money units, the change in welfare in S from all changes during a period is

$$\Delta\text{NNP}^S = (C^{S1} - C^{S0}) + q^S(Q^1 - Q^0) = (C^{S1} - C^{S0}) + q^S(\alpha_{SS}(M^{S1} - M^{S0}) + \alpha_{SF}(M^{F1} - M^{F0})$$

and correspondingly for the other country. With this measure, it is easily seen that if we add the measures for the two countries, then we will end up with a measure of the welfare change for the two countries together. This definition of NNP is therefore internationally consistent.

A different definition would be to define NNP in terms of the change in welfare from activities in one country, irrespective of where the welfare is changing:

$$\Delta\text{NNP}^{SF} = (C^{S1} - C^{S0} + q^S\alpha_{SS}(M^{S1} - M^{S0} + q^F\alpha_{FS}(M^{S1} - M^{S0}).$$

and correspondingly for the other country. Once again, the definition is internationally consistent and if we add the NNP for the two countries, we will end up with the welfare change for the two countries together. The difference between the two definitions is similar to the usual distinction between national product and domestic product.

4A.1.2. Human capital

Let me now introduce one stock – human capital. Total production is given by the production function

$$Y = F(TL),$$

where T is the stock of human capital and L is the number of hours worked. Total production is allocated to investment E in human capital and to consumption C.[22] Let us assume that the dynamics of the stock can be written

$$\mathrm{d}T/\mathrm{d}t = \mu ET$$

where μ is a constant. The individual maximizes the present value of his future utilities, i.e.

$$\mathrm{Max} \int_0^\infty \mathrm{U(C, L)e^{-rt}d}t$$

subject to

$$C = F(TL) - E$$
$$\mathrm{d}T/\mathrm{d}t = \mu ET$$

It is important to note that r is a utility discount factor, which need not be equal to a market discount rate.[23]

The current value Hamiltonian for this optimal control problem is

$$H = U(F(TL) - E, L) + p_{\mathrm{T}}\mu ET$$

with p_{T} denoting a multiplier. The optimality conditions are

$$U_{\mathrm{C}}TF'(TL) = -U_{\mathrm{L}}$$
$$\mathrm{U_C} = \mu p_{\mathrm{T}}T.$$

The accounting price on T is determined by

$$\mathrm{d}p/\mathrm{d}t = rp_{\mathrm{T}} - LF_{\mathrm{T}}\,(TL) - \mu p_{\mathrm{T}}E.$$

The Hamiltonian now plays the same role as the utility function played in the previous section. It incorporates both the flow of current services and the value in the future from the current addition to the stock by investments. Thus, the

Hamiltonian is the correct non-linear welfare measure. In order to get a linear measure, we linearize it. Using consumption as the numerator and dividing by the marginal utility of consumption we have,

$$\mathrm{NNP} = C - wL + (p_T/U_C)\mathrm{d}T/\mathrm{d}t$$

Once again, we see that the wage bill should be deducted and the difference between C and wL reflects the return on human capital.

4A.1.3. Stocks of environmental resources

Let S be a vector of stocks of resources which are harvested at the rate X. Let the dynamics of the resources be represented by the growth functions $g(S)$. Thus

$$\mathrm{d}S/\mathrm{d}t = g(S) - X$$

For exhaustible resources, the corresponding growth is of course zero and let us begin by exploring the implication of this for NNP in an extremely simple case. Suppose a country exports its non-renewable resource in return for a consumption good. We assume that it faces the following maximization problem;

$$Max \int_0^\infty u(C_m)\exp(-rt)\mathrm{d}t$$

$$\mathrm{d}S/\mathrm{d}t = -X$$

$$p_x X - q_m C_m \geq 0$$

$$S(0) = S_0 > 0$$

$$\frac{\lim}{C_m \to 0}\partial U(C_m)/\partial C_m = \infty$$

C_m is the consumption of the imported good, r is world market interest rate, p_x is the export price of X in foreign currency and q_m is the price of the imported good (in foreign currency). The last constraint is the budget constraint for the country; it is the balance of payment in foreign currency when we assume that no capital markets exist. In this simple model, the country cannot save by selling the resource on the world market by investing the proceeds from the exhaustible resource. It will be assumed that the market for the exhaustible resource is in equilibrium for all t. To solve the maximization problem, construct the following Lagrangian;

$$L = U(C_m) - \gamma X + \zeta(p_x X - q_m C_m) = H + b(p_x X - q_m C_m)$$

where γ and ζ are multipliers. The first order conditions are:

$$\partial U/\partial C_m = \zeta q_m$$
$$\gamma = \zeta p_x$$
$$\zeta >= 0 (= 0 \text{ if } p_x X - q_m C_m > 0$$
$$(\mathrm{d}\gamma/\mathrm{d}t)/\gamma a = r$$

It is seen that the marginal utility of consuming the imported good is equal to aq/p; the benfits of consuming the imported good today balances on the margin with the benefits forgone 'tomorrow' of keeping the unit in the ground. Proceeding as above we find that:

$$H/(\partial U/\partial C_m) = C_m - (p_x/q_m)^* X = 0$$

In other words, NNP is equal to zero; a common result in 'cake-eating' models. In fact, this equation simply states that the country must obey its budget constraint in every period. Sooner or later, exports must go to zero and it is impossible to find a sustainable consumption path (at given prices). Dasgupta and Mäler (1991, p.109) give a verbal description of the above model in the 'cake eating' tradition, concluding "Such an economy cannot manage a positive, sustainable consumption path. It is this fact which is reflected in NNP, when correctly measured". The key insight is that NNP includes information not only about the welfare of the present but also of the future; this information is merged into the market prices.

Sometimes it is possible to discover more of a resource. Assume that this process is deterministic, i.e. that one knows with certainty that following a certain amount of investments in exploration, the stocks will increase in a deterministic fashion.[24] This idea can be incorporated by including Y used in exploration activities in the growth function. For some reasons, Y can also be interpreted as expenditures on maintenance, fertilizers, etc. Thus let us write

$$\mathrm{d}S/\mathrm{d}t = \theta(S, Y) - X$$

The production in society is described by the production function

$$W = F(K, S, X),$$

where K is the stock of real capital. We thus exclude labour in this particular study as it would not give any further insights.

Total output can be used for consumption C, investment in real capital I and in investments in environmental resources X.

$$W = C + I + Y.$$

The utility of the representative individual is $U(C,S)$. We thus neglect the flow of environmental services since that flow has been discussed in a previous section. As before, we assume that the individual is maximizing the present value of future utilities.

$$\mathrm{Max} \int_0^4 U(C,S)e^{\partial t}\mathrm{d}t.$$

subject to the conditions above. The current value Hamiltonian is

$$H = U(C,S) + p_K \mathrm{d}K/\mathrm{d}t + p_S \mathrm{d}S/\mathrm{d}t.$$

The accounting prices follow the differential equations

$$\mathrm{d}K/\mathrm{d}t = \delta t - \partial H/\partial K$$
$$\mathrm{d}S_i\,/\mathrm{d}t = \delta S_i - \partial H/\partial S_i$$

The NNP can now be written, again using consumption as a numerator

$$\mathrm{NNP} = C + (U_S/U_C)S + (p_K/U_C)\mathrm{d}K/\mathrm{d}t + (p_S/U_C)\mathrm{d}S/\mathrm{d}t$$

The NNP is again equal to the value of the consumption plus the value of the net change in the stocks of all resources and the 'flow' value of the stocks, S. This last value occurs because we have assumed that the individual has preference for the stock of some resources, such as biodiversity, such as the population of blue whales, etc.

Note that the NNP equals the current utility value plus the value of the change in the resource stock and not the change of the value of the stock. Thus capital gains should not be included. However, this result depends critically on the assumption that the Hamiltonian is stationary. If there are exogenous changes in say international prices, then of course some countries may gain and others will lose. In this case capital gains should be included, as has been shown by Sefton and Weale.

The above analysis can now easily be adapted to study the case where a country can trade a non-renewable resource in return for a renewable one. Specifically, assume that a country can export its non-renewable resource and use an international capital market to invest the proceeds. To analyse this case, the current account surplus will be defined as follows:

$$\mathrm{d}B/\mathrm{d}t = rB + p_x X - q_m C_m$$

where B denotes the country's foreign assets. The country is assumed to obey its intertemporal budget constraint in the sense that:

$$\frac{\lim}{t \to \infty} B_t \exp(-rt) = \frac{\lim}{\mathrm{T} \to \infty} \int_0^{\mathrm{T}} (p_x R - q_m C_m) \exp(-rt) \mathrm{d}t = 0$$

Thus, in the long run the present value of the net trade surplus must go to zero. Proceeding as above it is easy to see that we should deduct that value of the decrease in the resource stock and add the value of the change of the stock B when constructing the welfare measure. For additional details, see Kriström (1993).

4A.1.4. NNP and sustainable development

I will end this survey of existing approaches by commentingn on the relation between an adjusted national product measure and its possible links to a notion of sustainable development. We begin this analysis by using properties of time-independent Hamiltonians. Consider

$$H = U(C, S) + p_K \mathrm{d}K/\mathrm{d}t + p_S \mathrm{d}S/\mathrm{d}t$$

I will now prove that this Hamiltonian is time-independent and then use this result to derive a notion of sustainable development. Thus, totally differentiate *H* with respect to time to obtain,

$$\frac{\mathrm{d}H}{\mathrm{d}t} = \frac{\partial H \mathrm{d}K}{\partial K \mathrm{d}t} + \frac{\partial H \mathrm{d}p_k}{\partial p \mathrm{d}t} + \frac{\partial H \mathrm{d}S}{\partial S \mathrm{d}t} + \frac{\partial H \mathrm{d}p_s}{\partial p \mathrm{d}t} + \frac{\partial H \mathrm{d}u}{\partial u \mathrm{d}t}$$

where *u* is the vector of controls, *I*, *Y* and *C*. Using the optimality conditions, one finds that:

$$\frac{\mathrm{d}H}{\mathrm{d}t} = (-\frac{\mathrm{d}p_k}{\mathrm{d}t} + \mathrm{rp_k})\frac{\mathrm{d}K}{\mathrm{d}t} + \frac{\mathrm{d}K\mathrm{d}p_k}{\mathrm{d}t\mathrm{d}t} + (\mathrm{rp_s} - \frac{\mathrm{d}p_s}{\mathrm{d}t})\frac{\mathrm{d}S}{\mathrm{d}t} + \frac{\mathrm{d}S\mathrm{d}p_s}{\mathrm{d}t\mathrm{d}t} =$$

$$r(p_k \frac{\mathrm{d}K}{\mathrm{d}t} + p_s \frac{\mathrm{d}S}{\mathrm{d}t}) = r(H^* - U)$$

which shows that the Hamiltonian is time-independent, or that the total time derivative of H is equal to the partial time-derivative. Using this result one could argue (see Solow, 1986) that if prices are constant during the period (i.e. we consider only marginal changes), then we could for that period define an aggregate capital stock:

$$K^* = p_k K + p_s S.$$

If that stock is non-decreasing, then the Hamiltonian will also be non-decreasing. This reflects what has been called sustainable development. Furthermore, it follows from the discussion above that (with constant prices)

$$H^* = rK^*$$

where H^* is the maximum value of the Hamiltonian. Thus, if we are at an optimal trajectory (and if the time span is short enough (constant prices)), then the value of the Hamiltonian can be interpreted as the return on the aggregate capital stock.[25] This interpretation is not possible if the economy is far from the optimal trajectory. If the economy is at an optimal trajectomy then it follows from the above that

$$\int_t^\infty H_t^* e^{-r} d\tau = \max \int_t^\infty e^{-r} U d\tau$$

so that H* is the maximum constant stream of utility the economy can have. This was first derived by Weitzman for an economy with only a consumption good and a capital good and when the utility was linear in consumption. Furthermore, Weitzman did not use an optimal trajectory but looked at a competitive economy. A couple of years ago I applied the optimal control approach to the same problem I have just discussed (Mäler, 1991), and since then there has been a huge production of papers on this topic. In one strand of papers, the Weitzman result has been extended to situations when the pure rate of time preference is variable. This has in particular been pursued by Geir Asheim of Oslo. In another strand of papers, technical change and endogenous growth have been included. This has been pursued by Thomas Aronson and Karl-Gustaf Löfgren in Umeå. There is, however, one substantial difference between these extensions and the analysis I have presented to you. I have been interested in finding a linear social cost–benefit rule and in the search for such a rule, Weitzman types of results were obtained as interesting side products. These side products were not, however, the main products of the kind of research that Professor Dasgupta and I initiated a couple of years ago. The more recent studies have not been interested in the questions we were interested in, but only in obtaining extensions of Weitzman's results. Although very interesting, I do not believe they have made contributions to the design of accounting systems, but only to the interpretation of some measures that never will be included in an accounting system.

4A.2. Basic framework with local prices

The framework I have discussed above can be criticized for relying on an optimal growth path as a vehicle to establish both an accounting system and the imputed prices to be used in finding the appropriate values of flows and stocks to be included in the system. Therefore, I would like to present a different approach, which never the less gives approximately the same results as those presented earlier. This new approach is based on the use of local prices, i.e. prices that reflect the marginal valuations of the individual along the real path and not along a hypothetical growth path. The basic idea is to approximate linearly the social welfare function directly, before any attempt to optimize is made. I used this approach in 1974 for establishing a very simple relation between flows of environmental amenities and net national product. However, as far as I know, no one has developed the theory further. I want present to you an outline of such an approach. Unfortunately, my analysis is not complete and there are some results that at this moment are only conjectures and not proven theorems. For convenience, I will change to discreet time.

4A.2.1. A consumption capital model

Let $U(C_t)$ be the instantaneous utility function where C_t is the consumption in period *t*.

Let $f(K_t, L_t)$ be the production function, where K_t is the capital stock and L_t is the input of labour. The output can be used for consumption and investment in capital, i.e.

$$C_t + K_{t+1} = K_t + f(K_{+t}, L_t)$$

Here we have not accounted explicitly for depreciation of capital, but the production function f may be interpreted as the net output production function.

Let the social welfare V be defined as the discounted present value of future utilities, that is social welfare is defined as

$$V = \sum_0^\infty U(C_t, L_t)/(1+r)^t$$

This means that I do not consider distributional issues. Note that I do not assume that V is maximized. On the contrary, the basic idea behind the following presentation is that the net national product should be defined as a linear approximation to the social welfare function irrespective whether we are on an optimal trajectory or not. This will become clear in a short while.

Assume that we are given a time path of consumption and labour supply $\{C_t, L_t\}$. Associated with this consumption path is a corresponding path of capital stocks $\{K_t\}$. A project is a perturbation of these paths. Let us look at the particular perturbation $\{dC_t, dL_t\}$ and let us find out the effect of this perturbation on social welfare U.

$$dV = \sum_0^\infty [U'_C(C_t, L_t)dC_t + U'_L(C_t, L_t)dL_t]/(1+r)^t.$$

Let the present value of the marginal utility of consumption in period t, with consumption in period 0 as the numerator be

$$p_t = [U'(C_t, L_t)/U'(C_0, L_0)]^* 1/(1+r)^t.$$

and let the present value of the marginal (dis)utility of labour in period t be w_t. Then

$$w_t = -U_L'(C_t, L_t)/U_C'(C_t, L_0)^* 1/(1+r)^t.$$

It follows that $p_0 = 1$. It is obvious that p_t can be interpreted as the imputed price on consumption in period t with consumption in period 0 as the numerator and that w_t can be interpreted as the imputed price on labour.

The index we are going to define is simply $\mathrm{d}V/U'(C_0)$, i.e. the change in welfare expressed in the numerator, that is consumption in period 0. We will denote this index by dNNP, i.e. the perturbation in net national product.

It now follows that

$$\mathrm{dNNP} = \\ \mathrm{d}C_0 - w_0\mathrm{d}L_0 + \mathrm{d}I_0 + \textstyle\sum_1^\infty (p_t f(K_t) + p_{t+1} - p_t)\mathrm{d}K_t + \sum_1^\infty (p_t f_L - w_t)\mathrm{d}L_t$$

Here I_0 is the increase in the capital stock in the first period, i.e. the net investment in that period, and $\mathrm{d}I_0$ is the perturbation in net investment in the future, i.e.

$$\mathrm{d}I_t = \mathrm{d}K_{t+1} - \mathrm{d}K_t.$$

The last sum represents a measure of the extent labour is not used efficiently. Irrespective of whether the imputed value of the marginal product equals the imputed wage or not, we could make the argument that our index should only incorporate current projects and not projects in the future (that is projects or perturbations that are not due to decisions made today). This means that future perturbations in the employment of labour should be set equal to zero. Note that we cannot use this argument for capital as the future capital stock will depend on current investment decisions. Thus there will be future perturbations in the capital stocks due to decisions made today.

The second last sume represents the deviations from an efficient intertemporal allocation. Each term in that series is

$$p_{t+1} - p_t + p_t f(K_t)$$

Assume that we buy one unit of the capital good in the beginning of period t. This will cost us p_t. During period t, the return on this unit will be $p_t f(K_t)$ and at the end of period t we will have a unit of capital worth p_{t+1}. Along an efficient investment path, it is clear that it should not be possible to make any further gains by buying more capital and p_t must therefore be equal to $p_{t+1} + p_t f(K_t)$. If we are following an efficient investment path (which does not necessarily mean that we are on an optimal path, as C_0, L_0 need not be chosen optimally) the two sums in the expression for dNNP will be zero and

$$\mathrm{dNNP} = \mathrm{d}C_0 - w_0 \mathrm{d}L_0 + \mathrm{d}I_0$$

This expression is rather interesting. It shows that along an efficient path, the wage bill should not be included in the NNP index (or rather the cost of labour valued at the shadow wage rate). The intuition should be clear. We are looking at marginal changes and at the margin, leisure is valued the same as consumption. Thus an increase in labour time that increases consumption will be completely offset by the reduction in leisure. Obviously, this needs to be modified if the economy is not moving along an efficient trajectory. We will return to this later.

Let us, however, not make the assumption of efficiency. In order to find out the actual effect on welfare, one has to know something about the future path of capital accumulation, and in particular the impact on future net investments from the change today. This is important. We are looking at an index that tells us the change in welfare from actions in the current period and not from actions in future periods. Therefore, what are the actions in the current period? They are $\mathrm{d}C_0$ and $\mathrm{d}I_0$. If these changes are small, it seems reasonable to assume that $\mathrm{d}K_t = \mathrm{d}I_0$ for t greater than zero, i.e. constant over time. It is easy to see that in this case we have

$$\mathrm{dNNP} = \mathrm{d}C_0 + \{\textstyle\sum_1^\infty p_t f_K\}\mathrm{d}I_0$$

Thus the change in NNP due to the perturbation in investment in period 0 is equal to the change in current consumption plus the change in net investment multiplied with a shadowy price that reflects the present value of future returns on the change in the net investment.

Why should not the future investment path be efficient? There are obviously many reasons for that – imperfect or missing capital markets, missing risk markets, government policies. Let us study one government policy in some detail, namely taxes on capital income.

Assume that the government has imposed tax on return on capital with the rate s_c. The total marginal return on investments in period t is $p_t f(K_t)$. The private return is only $(1 - s_c)p_t f(K_t)$ and the revenues for the government are $s_c p_t f(K_t)$. The government uses these revenues to buy the aggregate good and provides this as a public good, G_t, to the citizens. The utility function is:

$$U(C_t, G_t).$$

It is now possible to show that if this tax is the only imperfection in the capital markets, then we would once again get the result that

$$\mathrm{dNNP} = \mathrm{d}C_0 + \mathrm{d}I_0 + \mu_0 \mathrm{d}G_0$$

where μ_0 is the shadow prices on public expenditure. If our governments are wise, they willl obviously increase these expenditures until this shadow price equals the cost of the expenditures, i.e. until the shadow price equals 1. If that is the case, we have

$$\mathrm{dNNP} = \mathrm{d}C_0 + \mathrm{d}I_0 + \mathrm{d}G_0.$$

Under these assumptions, the conventional national accounts give the correct net national product measure.

4A.2.2. Environmental resources

Let us now consider a more complicated case. The economy is described by capital accumulation

$$K_{t+1} - K_t = f(K_{t+1}, Q_t, R_t) - C_t$$

where K_t is, as before, the stock of real capital in the beginning of period *t*. *Q* is the emissions from production and R_t is the use of a resource *S*. The resource is governed by the following difference equation:

$$S_{t+1} - S_t = g(S_t) - R_t$$

Here $g(S_t)$ is the growth function of the resource. In case of a non-renewable resource, *g* is equal to zero.

Utility of welfare in time period *t* is a function of C_t, as well as of Q_t and S_t.

$$V = \sum_0^\infty U(C_t, Z_t, S_t)/(1+r)^t$$

Here Z_t is the environmental impact on the individual. The effect is determined first of all by the environmental disturbance Q_t. However, the individual is assumed to be able to modify this disturbance by defensive expenditure D_t. Thus

$$Z_t = h(Q_t, D_t)$$

The main balancing condition is that the total output is used for consumption, gross investment and defensive expenditures. Thus

$$C_t + K_{t+1} - K_t + Z_t = f(K_t, Q_t, R_t).$$

As before, we will study a 'small project' $(\mathrm{d}C_t, \mathrm{d}Q_t, \mathrm{d}R_t)$ to find the first order effect on *V* from such a project.

$$\mathrm{d}V = \sum_0^\infty \{U_c \mathrm{d}C_t + U_z \mathrm{d}Z_t + U_S \mathrm{d}S_t\}/(1+r)^t.$$

However,

$$\begin{aligned} \mathrm{d}C_t &= f_K \mathrm{d}K_t + f_Q \mathrm{d}Q_t + f_R \mathrm{d}R_t + \mathrm{d}K_t - \mathrm{d}K_{t+1} \\ \mathrm{d}Z_i &= h_Q \mathrm{d}Q_t + h_D \mathrm{d}D_t \\ \mathrm{d}S_t &= g' \mathrm{d}S_{t-1} - \mathrm{d}R_{t-1} + \mathrm{d}S_{t-1}. \end{aligned}$$

Let as before use the following notation for imputed prices:

$$p_t = \frac{U_{c_t}}{(1+r)^t U_{c_t}}, q_t = \frac{U_{z_t} h_{Q_t}}{(1+r)^t U_{C_t}}$$

$$s_t = \frac{U_{S_t}}{(1+r)^t U_{C_t}}, b_t = \frac{U_{Z_t} h_{D_t}}{(1+r)^t U_{C_t}}$$

Substitution and rearranging yields

$$\mathrm{dNNP} = \frac{\mathrm{d}V}{U_{C_t}} = \mathrm{d}C_0 - q_0 \mathrm{d}Q_0 + b_0 \mathrm{d}D_0 + \mathrm{d}I_0$$

$$+ \sum_1^\infty [p_{t+1} f_{K_{t+1}} + p_{t+1} - p_t] \mathrm{d}K_t$$

$$+ \sum_0^\infty [e_t \ \mathrm{d}R_t]$$

$$+ \sum_1^\infty [s_t \ \mathrm{d}S_t]$$

The first line represents the contribution to current well being from a perturbation. $\mathrm{d}C_0$ corresponds to consumption as it is usually compiled in the national accounts. The third term in the first line reprsents the defensive expenditures and they are accounted for in present accounts. If the individual is free to choose defensive expenditures, it is obvious that $b_0 = 1$. What is not accounted for is the deduction of current environmental damage $- - q_0 \mathrm{d}Q_0$. Note that q_0 represents the present willingness to pay for an improved environment and not the hypothetical willingness to pay in an optimum. If the individual can compensate a degradation of the environment completely by defensive expenditures, then these expenditures can be used as an approximation of the damage, and the two terms would cancel. However, this does not seem to be a general rule. The basic conclusion is that defensive expenditures should not be deducted.

The second line is the same as we have derived before. It indicates the inefficiencies in capital formation. As was noted above, it seems reasonable to neglect this term because the markets will probably come up with a better approximation of the future value of a unit of capital than an accountant could do.

The third line represents the future cost due to present depletion of the resource. If we can assume that e_t is approximately constant over time and equal to e, then this term is simply $-dR_0$. If that assumption is not valid, then we can always write

$$\sum_{1}^{\infty} e_t \; dR_t = -m_0 \; dR_0$$

where m_0 is the appropriate shadow price on the production of the resource. If we had been following an optimal path, the shadow price would have been equal to the value of the marginal productivity of the resource, i.e. $p_0 \; f_{R0}$. On the other hand, if we assume that the resource is exhaustible (this is $g = 0$) and that the future changes in production of the resource will last for a specified number of periods and will be allocated in such a way that the corresponding change in the value of the production is constant, we would be able to derive the El Sarafy rule. El Sarafy, an economist at the World Bank calculated the Hicksian or Lindahl income from producing from an exhaustible resource under the assumption that the asset would be exhausted during a specified number of years and that the revenues generated would be the same in each year. The rule is obviously based on very arbitrary assumptions. In spite of that, one very often finds references to it. For example, in studies by the UN and the World Bank use was made of the El Sarafy rule. As the output of the resource is sold on markets, it seems possible to use the same argument that I used for capital, namely that the current price on the resource also represents the expected future value of the resource. This implies that we could approximate the sum on the third line by $-p_0 dR_0 = n_0$ (where n_0 is the market price for the resource).

Finally, the last line represents the effect of a change in the stock of the resource on well being. In order to calculate the shadow price, one needs an idea of how the future stocks will develop. Unfortunately, we can no longer rely on markets to solve the problem for us as there are no markets for these stock effects. We need to estimate the shadow price on a marginal change in the resource stock and that shadow price will obviously depend on the future development of the stock. If we are naive and believe that governments will introduce optimal management schemes, then we could once again rely on information on the current marginal willingness to pay for the stock. Another, perhaps more reasonable assumption would be to assume that the marginal willingness to pay for the stock will remain constant over the foreseeable future. This would enable us to calculate the shadow price by computing the present value of the infinite stream of this constant marginal willingness to pay for the stock.

Based on this discussion one would conjecture that the following formulation would give a not too bad approximation:

$$\begin{aligned}\mathrm{dNNP} = \mathrm{d}C_0 + b_0\,\mathrm{d}D_0 + \mathrm{d}I_0 - n_0\,\mathrm{d}R_0 \\ -q_0\,\mathrm{d}Q_0 - a_0\,\mathrm{d}R_0\end{aligned}$$

The first line represents terms for which there are market prices, while the second line represents terms for which shadow prices must be estimated. Of these, the first shadow price, q_0, seems to be easiest as it does not involve any intertemporal considerations. The second shadow price is the present value of the future marginal values of the stock.

As I see it, the estimation of these shadow prices are the real problems when one wants to extend the accounting framework so as to include non-marketed goods. The most popular method for valuing such goods, contingent valuation, has its own problems and is not universally accepted by economists as a valid instrument for valuation. Furthermore, applying contingent valuation is extremely expensive, and it would not be possible to use the method on a routine basis when data for the national accounts are processed. The only possible route, as far as I can see, is to use a revealed preference approach, where the preferences are mainly the ones revealed by political decisions in much the same vain as we now include public expenditures in the accounts. I believe that research in the future, both with regard to valuation of non-marketed goods and with regard to extending the national accounts must be much more focused on revealed preference approaches in order to be really valuable for these rather down to earth problems I have been discussing.

4A.2.3. Sustainability once again

Along the optimal paths, I showed that the Hamiltonian had some interesting properties. Basically, the Hamiltonian is the maximum well being society can afford today without depriving future generations their well being. Is it possible to prove a similar theorem when we are off the optimal trajectory? Obviously, we cannot prove the same theorem, but my conjecture is that the discrete Hamiltonian represents the maximum well being, given the imperfections in the economy, society can afford today in order not to deprive future generations of their well being. I have not been able to prove that conjecture yet, but a number of small studies has made me believe that it is true.

Notes

1. Since the late 1980s I have committed to the research that will be reported in this paper, and some of the conclusions were published as early as 1974. However, the present paper is not really my own. Many of the conclusions are based on joint research with Partha Dasgupta, Cambridge University and Bengt Kriström, Umeå University. As they have not seen this paper, they are excused for all misprints etc. However, they share the credits and the blame for the intellectual content.
2. It should be noted that national income accounts have other important uses; for example, as a tool for assessing the volume and composition of economic activities.
3. Of course, local prices could be used also for points on the frontier.
4. The link between the national product as a welfare measure and the treatment of labour goes back at least to Pigou.
5. We have explored the consequences of labour market disequilibrium in detail elsewhere.
6. See Section 4.5.2 for more on defensive expenditures.
7. See Freeman (1993) and the chapters by Mitchell and Carson, Hanemann and Kriström and Harrison and Kriström in this book.
8. See Dasgupta and Mäler (1991).
9. El Serafy (1989).
10. See Mäler (1991) and Dasgupta and Mäler (1991).
11. See below for a discussion of this system.
12. This is true for any application of resource accounting involving valuation of environmental damages.
13. See Economic Council of Japan (1974).
14. There is also a 'local' application of resource accounting, involving the Chesapeake Bay (USA), bordered by the states of Maryland, Pennsylvania and Virginia. See Peskin, H. (1989).
15. For additional critique of the Repetto et al. study, see e.g. Peskin (1989).
16. The differences between material/energy balances and the French and Norwegian systems are, according to the Handbook (1993, p. 75), e.g. less detailed spatial description of transformation processes (c.f. the French system) and a more comprehensive description of economic activities and their use and production of residuals.
17. The terminology used in the Handbook for different valuation methods is somewhat unusual, in that hedonic pricing and travel cost methods are called direct methods (Handbook, 1993, p. 17). In the literature, these are typically called indirect, because the value of the environmental resource is revealed indirectly from associated market goods.
18. In the Handbook of SEEA, considerable doubt is expressed regarding the possibilities of calculating net exports of residuals. See sections, 78, 110, 192, 216, 243 and 292 in the Handbook for further discussions.
19. The SEEA system has been tested on New Papua Guinea (see below) and Thailand.
20. Lindahl's contributions to national accounting are described in Kriström (1994).
21. See Mäler et al. (1994).
22. The analysis is easily extended to cover other types of human capital models. We focus on the simplest one here.
23. See Dasgupta and Mäler (1991) for a detailed discussion of the implications of this fact.
24. When discoveries are stochastic the analysis needs to be modified as shown in Dasgupta and Mäler (1991). See also the main text for a verbal description of this case.
25. See Aasheim (1993) for detailed investigations of this interpretation.

References

Aasheim, G., 1993, Net National Product as an Indicator for Sustainability, Scandinavian Journal of Economics, 96, 257-65.

Arrow, K.J. and L. Hurwicz, 1958, Gradient Methods for Concave Programming, III: Further Global Results and Applications to Resource Allocations. in K.J. Arrow, L. Hurwicz and H. Uzawa, eds., Studies in Linear and Non-linear Programming (Stanford, CA, Stanford University Press).

Bartelmus, P., Environment, Growth and Development: The Concepts and Strategies of Sustainability. Undated Book Manuscript.

Bartelmus, P., Lutz, E. and S. Schweinfest, 1992, Integrated Environmental and Economic Accounting A Case Study for Papua New Guinea. CIDIE Workshop on Environmental Economics and Natural Resource Management in Developing Countries, World Bank, Washington D.C., 22–24 January 1992.

Clarke, H.R. and A.K. Dragun, 1989, Natural Resource Accounting: East Gippsland case study. Report prepared for the Australian Environment Council.

Statens Informationstjense, Köpenhavn, Denmark.

Dasgupta, P. and G. Heal, 1979, The Economic Theory and Exhaustible Resources, Cambridge, Cambridge University Press.

Dasgupta, P. and K.-G. Mäler, 1991, The Environment and Emerging Development Issues, Proceedings of the Annual World Bank Conference on Development Economics, 1990 (Supplement to the World Bank Economic Review and the World Bank Research Observer), 101-132.

Dasgupta, P., B. Kriström, and K.-G. Mäler, 1995, Current Issues in Resource Accounting in P.O. Johansson, B. Kriström, and K.-G. Mäler, eds. Current Issues in Environmental Economics, Manchester, Manchester University Press, 117–152.

El Serafy, S., 1989, The Proper Calculation of Income from Depletable Natural Resources, in Ahmed, Y.J. et al (ed), Environmental Accounting for Sustainable Development, World Bank, Washington, D.C.

Freeman, A. Myrick III, 1993, The Measurement of Environmental and Resource Values: Theory and Methods. Resources For the Future, Washington, D.C.

Hartwick, J.M., 1990, Natural Resources, National Accounting and Economic Depreciation, Journal of Public Economics, 43, 291–304.

Hotelling H., 1925. A general mathematical theory of depreciation, Journal of the American Statistical Association, 20, 340–343.

Hueting, R., 1990, Correcting National Income for Environmental Losses: A Practical Solution For A Theoretical Dilemma. Paper presented at Conference on Ecological Economics and Sustainability, Washington D.C.

Hultkrantz, L., 1991, National Accounts of Timber and Forest Environmental Resources in Sweden Environmental and Resource Economics, 2, 283–305.

Kriström, B., 1993, Resource Accounting in Small Open Economies. Mimeo, Stockholm School of Economics.

Kriström, B., 1994, Accounting for the Environment in Scandinavia. Forthcoming in Milon, W. & J. Shogren, 1994, Integrating Economic and Ecological Indicators, Preager Publishers/Greenwood Press, New York.

Lone, Ö., 1987, Natural Resource Accounting and Budgeting: A Short History of and Some Critical Reflections on the Norwegian Experience 1975–1987. OECD, Paris.

Mäler, K.-G., 1991, National Accounts and Environmental Resources, Environmental and Resource Economics, 1, 1–15.

Mäler, K.-G., Gren, I.-M. and Folke, C., 1994, Multiple Uses of Environmental Resources: A Household Production Function Approach to Valuing Natural Capital. In Jansson, A.M. Hammer, M., Folke, C. and R. Costanza, Investing in Natural Capital: The Ecological-

Economics Approach to Sustainability. ISEE Press/Island Press, Washington, D.C., pp. 233–249.
Nordhaus, W.M. and J. Tobin, 1973, Is Growth Obsolete? Studies in Income and Wealth, 38, 509-564.
Repetto, R. Magrath, W. Wells, M. Beer, C. and F. Rossini, 1989, Wasting Assets: Natural Resources in the National Income Accounts. World Resources Institute, Washington, D.C.World Resources Institute.
Sefton, J. and M. Weale, 1996, The Net National Product and Exhaustible Resources: The Effects of Foreign Trade, Journal of Public Economics, 61, 21–48
Solow, R. 1986, On the Intertemporal Allocation of Natural Resources, Scandinavian Journal of Economics, 1.
Swedish Commission on Resource Accounting (SOU 1991:37) Räkna med Miljön: Förslag till Miljö- och Miljöräkenskaper, (in Swedish with English summary) Allmänna Förlaget, Stockholm. (Available in condensed form as: Taking Nature into Account: Proposed Scheme of Resource And Environmental Accounting. Ministry of Finance, 1991, Stockholm.)
United Nations, 1993, Handbook of National Accounting: Integrated Environmental and Economic Accounting. Studies in Methods, Series F, No 61, Department of Economic and Social Information and Policy Analysis, Statistical Division, UN, New York.
Van Tongeren, J. Schweinfest, S., Lutz, E., Gomez-Luna, M. and F. Guillen-Martin, 1992, Integrated Environmental and Economic Accounting – the Case of Mexico. CIDIE Workshop on Environmental Economics and Natural Resource Management in Developing Countries, World Bank, Washington D.C., 22–24 January 1992.
Uno, K., 1973, Mimeo.
Vincent, J.R. 1993 Natural Resources and Economic Growth, Mimeo, Harvard Institute for International Development.
Weitzman, M.L., 1976, On the Welfare Significance of the National Product in a Dynamic Economy. Quarterly Journal of Economics, 90, 156–62.
World Commission, 1987, Our Common Future, New York, Oxford University Press.
World Resources Institute (WRI), 1991, Accounts Overdue: Natural Resource Depreciation in Costa Rica. WRI, Washington D.C.

CHAPTER 5

A Case of Mineral Resource Accounting of Xinjiang, China

Du Donghai, Wang Zhixiong and Long Yulin

5.1. Introduction

Taking natural resources (NR) into the system of national economic accounting and calculating the value of NR are necessary requirements for human society which is developing on the background of limited space and resources of the earth.

In the 21st century, the most serious problem that we will be facing is the sustainable development of the society. During the world environment and development conference of 1992, sustainable development was realized by the countries attending the conference and emphasized heavily. In the prerequisite of sustainable development, the United Nations proposed that the NR should be taken into the system of national economic accounting (SNA), and brought up the model of the System of Environmental and Economic Accounting (SEEA) (Sheng, 1995). With NR and environment taken into account, SEEA is an integrated accounting system of environment and economy. Most countries at the meeting approved the proposal of the UN. The conference drew the conclusion that the SEEA will gradually take the place of the SNA to fit in with the requirement of the sustainable development of the human society.

Since 1986, China has set up to carry on the study of natural resource accounting (NRA). The research program was conducted by the Development Research Center of State Council. The outcome of the research was published in The Initial Research of Natural Resource Accounting (Li, 1990) and The Discussion of Resource Accounting (Li, 1991). It was the first time that the theory and structure of the NRA of China were put forward. After the world environment and development conference, in response to UN's Agenda 21, the Chinese government drew up Chinese Agenda 21, in which the study of NRA and taking it into SNA is one of the prior items of the State Science and Technology Commission of China (SSTC). A study of NRA in China was carried out in 1994. In the following year a material The Study of Resource Accounting of China for inner communication was published.

A. Lanza (ed.), Resources Accounting in China, 117–125.

It is necessary to point out that the study of NRA in China is still in its early development. The operation of the NRA and taking the NRA into the SNA of China are determined by the efforts of the Chinese government. Just as the recognition of most of the countries attending the world environment and development conference, taking the NRA into the SNA is necessary requirement of sustainable development. The earlier the NRA is established and taken into the SNA, the earlier the social economic development will be put into the healthy trail of sustainable development.

5.2. The origin of the problem

Natural resources are the material foundation for development of the human society. The socio-economic development of a country is closely connected to the exploitation of its NR. The stock of NR is an important part of national wealth. It is the basic raw material for the improvement of people's living conditions. With economic development, the importance of NR is increasing all over world, but the types and quantities of NR are limited. At certain technological levels the ability of human beings to exploit and utilize NR is also within limits.

The limitation of NR leads to the depletion and the crisis of resources (Li, 1991). The development of the social economy has been restricted by the drastic growth of the world population, ecology destruction and environmental deterioration. In China, NR was once used freely. The maximization of output value without consideration of the protection of the NR base in the process of production leads to depletion of NR. The economic output value increment is based on the constant degradation of the NR. This kind of economic growth may exhaust NR, and cause unrecoverable destruction of environment.

Now the Chinese are faced with the challenge of how to efficiently manage the NR and of how to exploit the NR rationally. In order to use NR at a rate compatible with their reproductive capacity, we must realize the scarceness and the real value of the NR. To be fully conscious of NR, and to exploit NR in a rational way, it is necessary to take the NR into the SNA, to calculate the physical quantities and the value of the NR, and to set up the new SNA with the NRA taken into account.

5.3. The mineral resource condition of China

Mineral resources (MR) are crucial to human society. The production and consumption of MR is directly connected with the degree of economic development. Since MR are exhaustible, their shortage will be a very serious problem. The Chinese economy is developing at more than 10% per year. With such a high rate of economic growth the demand for the raw material and energy is also very high. China is at the beginning of the middle industrialization stage, and resource consumption is increasing steadily: national income increased 6-fold from 1953 to 1985, and the consumption of energy resources, iron ore and non-ferrous metal increased by 14, 24 and 23 times, respectively, over the same period. However, the situation of the MR condition of China is not optimal. China, with its large territory, has abundant resource reserves (Table 5.1). However, because of large population, the per capita resource of China is very low. Some MR are in serious short supply (Table 5.2). In the 21st century, the shortage of the MR of China will be more serious. The estimated demand for some main MR in the year of 2020 is listed in Table 5.3. At that time in China the primary mineral production will not be enough to satisfy the demand and other mineral products will be in serious shortage. This situation cannot be changed by import of the mineral product from international markets, because this will be restricted by foreign exchange reserve. Even if

Table 5.1. Chinese mineral production in the world (1987)

Mineral production	Unit	World output (WO)	China output (CO)	CO/WO (%)	Rank in the world
Coal	10^4 ton	433 600	87 228	20.0	2
Crude oil	10^4 ton	266 900	124 900	4.7	5
Iron ore	10^4 ton	90 510	13 819	15.3	2
Cu	10^4 ton	830	26.5	3.2	9
Al	10^4 ton	356	21.5	5.9	5
Sn	10^4 ton	692	37.1	5.4	5
Wu	10^4 ton	5.38	2.32	43.0	1
Zn	10^4 ton	19.68	298	15.0	2
Ag	Ton	13 321	520	3.9	15
Au	Ton	1 528	48	3.1	7
Mn	10^4 ton	2 274.2	160	7.0	5

Data source: World Metal Statistics, 1987, Beijing: Science Press (in Chinese)

Table 5.2. Per capita reserve comparison between China and the world

MR	Unit	Per capital of the world (Wpc)	Per capital of China (Cpc)	Cpc/Wpc (%)
Raw coal	Ton	180.8	179.6	99
Crude oil	Ton	18.39	2.41	13
Iron	Ton	24.03	8.23	34
Cu	Kg	118.0	28.4	24
Pb	Kg	30.2	10.65	35
Sn	Kg	43.2	25.3	58
Al	Ton	5.74	0.8	14
Mn	Ton	0.29	0.053	18

Data source: The Management of Geological Economy, 1990, Report paper of Institute of Geo-economics, Beijing, China

Table 5.3. The demand for some resources in the year of 2020

Raw coal	Crude oil	Cu	Al	Zn
2.87 billion ton	0.4 billion ton	2.74 million ton	1.40 million ton	1.58 million ton

Data source: Li (1990)

China had enough money, the international market would not be able to supply the demand. The price of mineral products in the international market may increase by many times because of the large demand from China and the rest of the world. With the development of modern sciences and technology, we may find new resources to take the place of minerals. For example, solar energy may become a common source of energy instead of oil or coal, and perhaps we will change the structure of production in the future, so that consumption of mineral resources will bring a great output. However, these are wishes and we do not know whether or not they will be turned into reality. We must start now to deal with the problems that we may face in our future.

5.4. The significance of the mineral resource accounting in China

Resources are the foundation for economic development. The increase in the wealth of a country depends on rational exploitation of its resources. Neither the MPS of the planned economic system, nor the SNA of the market economic system has taken NR into account. They emphasize the output value of economic production and neglect the resource base. This leads to the pursuit of output value increment at the expense of tremendous waste and depletion of resources.

The establishment of NRA can help us to evaluate the quality of development process, and to forecast future development. The NRA will also provide information to enhance the function of resources management of the country and help to set up law and regulation to manage the resources scientifically, and to utilize the resources efficiently.

Mineral resource accounting (MRA) is an important part of NRA because economic production is highly dependent on MR. In China, more than 90% of energy sources and 25–80% of industrial raw material come from MR. Though the output value of mineral industry only accounts for a little part of the GNP, more than 70% of production is supported by minerals. In China, mineral resource demand has increased rapidly. The contradiction between the limitation of MR and social demand is more and more irreconcilable.

5.5. A case of mineral resources accounting in Xinjiang, China

5.5.1. General introduction to Xinjiang

Xinjiang (XJ) Autonomous Region lies in the NW of China and in the centre of the Europe–Asia continent. With a total area of 1 660 000 km, XJ is the largest province in China. The population of XJ is 13 610 000. Urumqi is the capital of XJ. There are abundant MR in XJ: in the 21st century, XJ will become the energy source base of China. The government has invested very large financial resources for the exploitation of MR in XJ. The process of MR exploitation carries serious problems in the depletion and deterioration of the NR and environment: it is, therefore, an ideal place to carry out NRA. The outcome of the research will have a very important influence on protection and exploitation of the NR in XJ. We chose Altai region, in the north part of XJ, as the testing area. The main MR being exploited is gold; this has a great influence on the national economy as well as on the environment of Altai region.

The area of XJ is approximately one-sixth that of China, while the population of XJ is only about 1% of the total Chinese population. The population density of XJ is very low, about 9.67 person/km. The arable land of XJ is 46.79 million Mu, or 2.91 Mu per capita (1 Ha = 15 Mu). Partly because of its large territory, XJ has abundant MR and an excellent exploring prospect. A total of 122 kinds of minerals has been discovered; 76 of which have proved good reserves. The proved reserves of beryllium, mica, feldspar, pot clay, serpentinite, chile saltpeter, vermiculite and bentonite rank first in China. The oil reserve of XJ is prospective. The area of exploitable oil reserve of XJ is about 1/5 of that of China. The forecast reserve of the Talimu and Zhunger basin is 30–50 billion tons. The forecast reserve of Talimu Basin is about 18.45 billion tons. Coal is also abundant in XJ; the forecast reserve is 219 billion tons, which accounts for about 40.6% of that of China. The oil and coal reserves of XJ rank first in China.

XJ used to be a backward region, but things have changed since the abundant mineral resources were discovered. Since 1979 government investment for installations has totalled 35.2 billion yuan. Government investment is still increasing annually because XJ will be the most important energy base of China. The national economy of XJ has been growing very fast recently (Table 5.4). The national income of XJ was only 3.4 billion yuan in 1978, but it rose to 29.2 billion yuan in 1992 and 38.0 billion yuan in 1993.

Table 5.4. National economic index of XJ (billion yuan)

Item	1978	1992	1993	Average annual increment (%)
GNP	3.9	38.2	48.2	10.97
NI	3.4	29.2	38	10.05
Total output	5.5	49	64.6	10.57
Industry output	3.4	31.7	44.8	11.73

Data source: The Geological Economic Valuation of Altai Region, 1995, Research Report of Project 305 Office, China (inner communication, unpublished)

5.5.2. The natural resource of Altai region

Altai lies in the NW of XJ. To the east, north and west of Altai are Mongolia, Russia and Haskstan, respectively, and its border is 1 145 km in length. The population of Altai is 538.3 thousand, which is about 3.35 of that of XJ, and the area of Altai is 117 000 km, which is 7.04% of the area of XJ (Table 5.5).

Table 5.5. General data of Altai region

Item	Unit	Statistic amount	Percent of XJ (%)
Total area	10^3 km^2	117	7.04
Land	10^3 km^2	40.3	34.45
Hills	10^3 km^2	13.2	11.3
Desert	10^3 km^2	12.4	10.63
Plain	10^3 km^2	51	43.59
Population	10^3	538.3	3.35
Average population density	Person/km2	4.6	

Data source: The Geological Economic Valuation of Altai Region, 1995

Altai has a larger territory and abundant mineral resources. The development of mineral production industry is an important impetus to local economic. However, the exploitation of mineral resource cause the pollution and deterioration of the natural resource. Of the 84 MR discovered, 38 have been exploited. There are 220 places producing mineral products and 46 kinds of MR have proven reserves. There are 63 industrial mines. The most important mineral resource of Altai is gold, which has a great influence on the local economy. There are several gold mines in Altai, and Dolanasayi gold mine is one of them: while the exploitation of gold is the main source of income for the local government, it also brings out environment pollution.

The national economy of Altai is developing very fast (Table 5.6). During the last 10 years, the growth rate of XJ's economy has been around 10%. The condition of the environment and the natural resources is deteriorating however, and arable land has been decreasing since 1992. The most important reason for this deterioration is exploitation of the natural resource. It is,

Table 5.6. The economy of Altai

Item	Unit	1949	1985	1992	1993	1993/1994
Arable land	thousand Mu	119.8	1112.3	1455.5	1422.5	12.15
Total output	million yuan	16.3	297.1	1231.4	1134.7	75.71
Industry	million yuan	0.67	128.1	576.7	622.11	862.73
Agriculture	million yuan	16.6	169.0	654.7	556.4	41.98

Data source: The Geological Economic Valuation of Altai Region, 1995
* 1 ha = 15 Mu

therefore, necessary to recalculate the economic development from a new prospective, that is, to account for the depletion of natural resources and deterioration of environment, then this way we can get a conclusion about the sustainability and quality of local economic development.

5.5.3. MRA of Dolanasyi gold deposit

Dolanasayi golden deposit lies in the NW of Altai Region. The length of the mine is 12 km and the width is 1 km. The ore amount of grade C + D is 69.95 tons. The metal amount of grade C + D is 4.06 tons. The average grade of the ore is 5.67 g/T. We chose Dolanasayi as the testing area of mineral resource accounting to calculate the output value of the gold mine, taking into account the environment pollution and the loss of the natural resource caused in the production of gold. The calculation formula of the extraction value is:

$$M = Q * K_1 * K_2 * K_3 * P$$

where M = extraction value, Q = amount of reserve, K_1 = reserve utilization rate, K_2 = mining recovery rate, K_3 = ore dressing rate, P = the price of mineral product.

Table 5.7 shows the extraction value of the mine, but this does not include any consideration of damage to the environment and the depletion of MR. When we take the value of natural resources and environment into account, the output value of the gold deposit is not equal to the extraction value, because the depletion of the natural resources and the deterioration of the environment has caused a negative value to society which must be accounted for. In the process of mineral resources exploitation, the government has imposed Resource Tax and Compensation Fee to protect the resource and environment. The Resource Tax accounts for the depletion value of the resource and the fundamental exploration works done the government. For example, the government has invested in finding the deposit, building roads and so on. The Compensation Fee accounts for the deterioration value of the natural resources and environment. The profit of the gold deposit is described in Table 5.8.

China has promulgated The Law of Mineral Resources, in its detail explanation the amount of Compensation Fee of mineral resource is determined by:

$$CP = SI * CFR * K$$

where CP = compensation Fee, CFR = rate of compensation fee, SI = sale income, K = coefficient of mining recover rate.

In addition, $K = K_0/K_1$, where K = coefficient of mining recover rate, K_0 = prescribe mining recover rate, K_1 = practical mining recover rate.

CFR differ according to the kind of mineral. For example, the CFR for oil, gas and coal are same, which is 1%. The CFR of gold is 4%. For the case of

Table 5.7. The output vale of Dolanasayi gold deposit

Mine no.	Ore dressing (10 ton/year)	Grade of ore (g/T)	Amount of metal (kg/year)	Extraction value (million yuan/year)
1	30	4.9	132.3	11.9
2	50	3.14	125.6	11.3
3	75	4.17	284.48	25.3
Total	155	539.38	48.5	

Data source: The Geological Economic Valuation of Altai Region, 1995

Altai, the amount of resource tax and compensation fee are listed in Table 5.8.

The sale income of 4 854.42 thousand yuan is equal to the extraction value of the gold. The extraction value minus the total cost and sale tax is the profit of the mine. When we take into account the value of natural resource and the value of environment, green profit = profit – resource tax – compensation fee, while profit = sale income (extraction value) – total cost – sale tax. In this case: profit = 4854.42 – 1705 – 544.3 = 2605.12 yuan; green profit = 2605.12 – 31 – 194.18 = 2379.93 yuan. Green profit is an index of the sustainable development of local mineral production industry. However, the amounts of resource tax and compensation fee varies in different regions of mining or among different kinds of mineral mines. The formulation and imposition of resource tax and compensation fee lack scientific proof. For example, in the case above, the amount of resource tax is determined by the extraction value (sale profit) of the gold deposit. If the extraction technique improves, the extraction value of the mine will increase, and the resource tax will also rise. The compensation fee is also related to the extraction value, not to the exact damage caused to the ecology and environment.

5.6. Conclusion

China is a developing country, and its economy has grown very fast in the recent 10 years. Mineral resources are one of the main supports for the development of the economy. With the great development in mineral resource exploitation and utilization, there are great damage on ecology and environment as well as the depletion and deterioration of the natural resources. In order to put the development into a sustainable framework, we should evaluate the mineral exploitation not by its profit, but by its green profit. Green profit is to calculate the output value of the mineral product with the value of environment and natural resource taken into account. Green profit equals profit minus the value of the damage of environment and the loss of mineral resource and is an index in the evaluation of the sustainability of the industry.

However, the value of the natural resource and environment are usually difficult to determine exactly, and the methods for determining a more

Table 5.8. The profit of Dolanasayi gold deposit (thousand Yuan)

Item	Mine 1	Mine 2	Mine 3	Total
Sales income	1 190.7	1 130.4	2 533.32	4 854.42
Total cost	405	325	975	1705
Sales tax	134.76	133.55	276	544.3
Profit	**650.94**	**671.85**	**1 282.32**	**2 605.12**
Resource tax	6	10	15	31
Compensation fee	47.63	45.22	101.33	194.18
Green profit	**597.31**	**616.63**	**1 165.99**	**2 379.93**
Income tax	197.11	203.49	384.78	785.37
Net profit	400.20	413.14	781.21	1594.55

Data source: The Geological Economic Valuation of Altai Region, 1995

equitable tax need further study. In the case of Altai gold deposits, we only used the data from the government. We will do more work on the determination of the value of destruction of the environment, and get amore accurate green profit of the local mineral production industry. The next step of our work is to obtain a more accurate account of both the physical gold deposits in the Altai region. We will then try to evaluate the value of environment damage and the value of the natural resource deterioration in the process of mining.

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References

Du, D.H., 1997, Sustainable development and mineral resource accounting of China. Proceedings of the 30th International Geology Congress, Netherlands: VSP Press, 23, 357–365.

Feng, Z., 1994, General outline of resource science, Beijing: Earthquake Press.

Li, J., 1990, The discussion of resource assets, Beijing: Ocean Press.

Li, J., 1991, The discussion of resource accounting, Beijing: Ocean Press.

Sheng, F., 1995, Real value for nature: an over view of globe efforts to achieve true measure of economic progress, Gland, Switzerland: WWF international.

CHAPTER 6

China's Agenda 21 and Natural Resource Accounting

Zhou Hongchun

6.1. Introduction

As the Earth Summit made clear, the world community today is engaged in an unprecedented process of civilizational change, the result of which will determine whether our planet will remain a secure and hospitable home for its inhabitants in a manner compatible with their hopes, values and aspirations (Strong, 1994). After the United Nations Conference on Environment and Development (UNCED), the Chinese Government immediately entrusted the State Planning Commission (SPC) and the State Science and Technology Commission (SSTC) with the task of drafting China's Agenda 21 (CA21). Through the efforts of more than 300 experts from 52 line ministries and with the help of the United Nations Development Programme (UNDP), the draft was finally completed. It was adopted by the State Council at its 16th Executive Meeting on 25 March 1994, and subtitled the White Paper on China's Population, Environment and Development in the 21st Century (Gan, 1993).

The SPC, the SSTC, the Ministry of Foreign Affairs and UNDP Beijing jointly convened the High-Level Round Table Conference (RTC) on China's Agenda 21 in Beijing on 7–9 July 1994. The RTC mobilized and organized the entire nation's strength and resources to jointly promote the implementation of CA21. While CA21 sets out the principles, objectives and activities for achieving sustainable development, the Priority Programme for China's Agenda 21 (PPCA21) translates these principles and objectives into practical action-oriented projects that will help China achieve sustainable social and economic development in harmony with the environment. In other words, PPCA21 is a workable and directive plan for implementing China's Agenda 21. As Mr. James Gustave Speth, Administrator of UNDP said during the July RTC: "I believe you have accomplished the most thorough and most broadly supported implementation to date of the Earth Summit's Agenda 21" (Speth, 1994).

As one of the priority projects, project 5.1, natural resource accounting:

A. Lanza (ed.), Resources Accounting in China, 127–136.

research and experimental application, seeks to develop methods of natural resource and environment accounting and apply them on an experimental basis in order to lay the groundwork for an integrated national environmental and economic system. It will contribute to China's overall strategy for sustainable development in every sector (China's Agenda 21, 1994).

China is now actively engaged in studying the theory and methods of natural resource accounting and applying its possible consolidation with the national resource accounting system. It is developing and implementing pricing systems for forestry, water, land, mineral, and marine resources. All of these activities in natural resource accounting will foster China's transformation from a resource-intensive economic development pattern to one of eco-efficiency and resource-saving.

6.2. Sustainable development strategy in China's Agenda 21

6.2.1. The concept of sustainable development

The definition of sustainable development as repeated often at UNCED is that sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs". From my point of view, sustainable development should address the following issues in China. First, as stated in CA21, sustainable development is about the transformation from the traditional economic development pattern that emphasizes increases in quantity into development that emphasizes quality, that is changing the economic development pattern from extensive, low efficiency, and high pollution into intensive, high efficiency, and minimum waste of economic growth. Sustainable social and economic development is closely interrelated with good ecological sustainability. Economic development covers quantity growth and quality improvement. Only when economic, social, and ecological sustainability reaches through science and technology advancement can human sustainability be achieved.

Second, development should be grounded in a respect for the natural eco-capacity and the environment. Sustainable development should rely mainly on renewables. We should strive for rational resource use and development, promote the use of energy efficiency and water, materials, and other conservation technologies, implement sustainable resource use and environmental protection legislation and regulations. Family planning, maintaining ecological balance, protecting air, water and other environmental pollution are necessary for China's sustainable development. In other words, sustainable development should seek harmony of economic and social development with the environment, and maintain the balance between human activities and the environment.

Third, sustainable development has to meet the basic needs of present and future generations. As one of the largest developing nations with a population of over 1.2 billion people, China recognizes that only when economic growth reaches and is sustained at a certain level can poverty be eradicated, livelihoods improved and sustainable development be achieved. Therefore, control of environmental pollution, improvement of environmental quality, and protection of living support systems and biodiversity must go hand in hand with development.

In short, natural resource sustainability is the basis for development; economic sustainability is the condition for development, and social sustainability is the purpose of development. Mankind should seek harmony of economic, social development with the environment.

6.2.2. The substance of China's Agenda 21

The framework and format of China's Agenda 21 were prepared taking the UN's Agenda 21 into account. It has four parts, 20 chapters and 78 programme areas (Gan, 1993).

Part 1: Overall strategy for sustainable development. It includes six chapters: preamble, strategy and policy for sustainable development, legislation for sustainable development and its enforcement, financial resources and mechanisms, education and capacity building for sustainable development, and public participation in sustainable development. It has 18 programme areas with activities.

Part 2: Sustainable social development. It has five chapters, including population, consumption and social services, eradication of poverty, health and sanitation, development of sustainable human settlement and disaster mitigation. It contains 19 programme areas with activities.

Part 3: Sustainable economic development. It contains four chapters: economic policy for sustainable development, sustainable development of industry, transportation and communication, sustainable energy production and consumption, sustainable agriculture and rural development. It contains 20 programme areas with activities.

Part 4: Sustainable utilization of resources and the environmental protection. It mainly includes conservation of biodiversity, conservation and sustainable use of natural resources, combating desertification, protection of the atmosphere, and environmentally sound management of solid wastes. It has 21 programme areas with activities.

The structure and contents of CA21 are shown in Figure 6.1.

Figure 6.1. China's Agenda 21

Overall strategy for sustainable development

1. Preamble (7)
2. Strategy and policy for sustainable development (2)
3. Legislation for sustainable development and its enforcement (2)
5. Financial resources and mechanics (3)
6. Education and capacity building for sustainable development (6)
20. Public participation in sustainable development (5)

Sustainable social development

7. Population, consumption and social services (3)
8. Eradication of poverty (1)
9. Health and sanitation (6)
10. Development of sustainable human settlement (6)
17. Disaster mitigation

Sustainable economic development

4. Economic policy for sustainable development (4)
11. Sustainable agriculture and rural development (7)
12. Sustainable development of industry, transportation and communication (5)
13. Sustainble energy production and consumption (4)

Sustainable utilization and production of resources and environment

14. Conservation of biodiversity (1)
15. Conservation and sustainable use of natural resources (7)
16. Combating desertification (4)
18. Protection of the atmosphere (4)
19. Environmentally sound management of solid wastes

6.3. Development and use of natural resources in China

Natural resources are an important material basis for sustainable social and economic development in China. China is, however, confronted with tough challenges with respect to sustainable use and conservation of natural resources. Although China has abundant land, mineral, forestry, and water resources which are vital to the national economy, the per capita share is actually much lower than the world average. In 1989 the per capita fresh water, cultivated land, forest, and grassland of China comprised 28.1%, 32.3%, 14.3% and 32.3%, respectively. Meanwhile, the per-capita resource figures and ecological quality are still declining or deteriorating. All of these will become a constraint to sustainable, rapid, and healthy development of society and economy in China (Table 6.1).

Table 6.1. Per capita use of natural resource in China and the World

	Arable land (ha)	Forest (ha)	Grassland (ha)	Freshwater (m^3)
China	0.084	0.11	0.20	2484.4
World	0.26	0.77	0.62	8843.5
Ratio (%)	32.3	14.3	32.3	28.1

China is now in the process of increasing urbanization and industrialization. China's economy grew rapidly in the 1990s, reaching more than 10% growth in the last 4 years. The resulting growth in the production of energy and raw materials will increase the number of pollution intensive industries and places a greater strain on China's environment. This will affect the overall quality of national economic growth and impair national development.

As the economy grows, there will be an inevitable transformation of resources to wastes or emissions. It is estimated that only 20–30% of raw materials result in final products whereas 70–80% of resources become wastes discharged into the environment. According to the statistical report of environmental status in 1994, air emissions totalled 11400 billion cubic meters, total wastewater reached 36.53 billion tonnes, and solid wastes from industries 620 million tonnes in China. Moreover, as township and village enterprises (TVE) develop rapidly, wastes from TVEs increase year by year, and spread to increasingly large areas, particularly in the southeast coastal zone of China. The quantity of wastewater from TVEs reached 4.3 billion tonnes, suspended particles 5.8 million tonnes, and solid wastes from TVEs 120 million tonnes, increases of 65.4%, 23.4% and 65.9% respectively from 1989. But, the ratio of wastes or emissions to the amount treated and disposed of is relatively lower. For example, the treatment ratio of wastewater from industries was 68.8%, and the ratio of solid waste was about 21.1%, leaving much to be done in the area of the environmental protection (Statistical Report of the Environment in China, 1994).

A statistical report of 84 cities in 1994 reported that the monthly mean dust in cities was 3.2–64.61 tonnes/km^2, with cities in the north of China averaging 89 $\mu g/m^3$. Forty-eight cities surpassed the second level in the standard of environmental quality of China, and 85 cities averaged 44–120 $\mu g/m^3$ NOx. Of these Beijing, Urumqi, and An'shan surpassed the second level. All of the cities were polluted mainly from industry.

China is still underdeveloped in economy and technology and remains a high consumption, low efficiency, and highly polluting country compared to the outside world (Table 6.2). Raw materials are used inefficiently, with energy and raw material consumption per unit product far greater than that found in developed countries. In 1992, China's energy use (oil equivalency) was 602 kg per capita, but GDP output was only US$ 0.5/kg, 15.2 times lower than that of Japan, six times lower than that of Brazil (Table 6.3) (World Bank, 1994).

Table 6.2. Resources use and output in China and other countries

Country	GNP: Total (million US$)	GNP: Per capita (US$)	Energy use (oil equivalents): Per capita (kg)	Energy use (oil equivalents): GDP output per kg (US$, 1991)	Water use[a]: as % of total water resource 1970–89	Water use[a]: Per capita (m^3) 1970–89	Forest coverage: Total area (000 km^2) 1989	Forest coverage: As % of total land area 1989
Brazil	425 421	2 770	908	3.0	1	248	5 531	65
Canada	565 787	20 320	9 390	2.3	2	1 684	3 580	39
China	442 346	380	602	0.5	16	462	1 246	13
France	1 278 652	22 300	3 854	5.5	24	783	148	27
Germany	1 846 064	23 030	3 463	5.7	28	729	104	30
Italy	1 186 568	20 510	2 756	7.2	30	984	67	23
Japan	3 507 841	28 220	3 552	7.6	16	733	251	67
Spain	547 947	14 020	2 229	6.1	41	1 184	157	31
Russian F.	397 786	2 680	[b]	–	–	–	–	–
UK	1 024 769	17 760	3 688	4.8	12	253	24	10
USA	5 904 822	22 340	7 681	2.9	19	1 952	2 939	32

[a]Water use data refer to any year from 1970–1989 (from the World Bank Atlas 1994).
[b]No data.

Table 6.3. Ratios of parameters between China and other countries

	GNP[a]	GDP output/kg (oil eq.)[b]	Water per capita[c]
Brazil	7.29	6	0.54
Canada	53.47	4.6	3.65
France	58.68	11	1.69
Germany	60.61	11.4	1.58
Italy	53.97	14.4	2.13
Japan	74.26	15.2	1.58
Spain	36.89	12.2	2.56
Russian F.	7.05		
UK	46.73	9.6	0.55
USA	58.79	5.8	4.23

a. China's GNP per capita of US$380 as 1.
b. China's GDP output of US$0.5/kg oil as 1.
c. China's water per capita of 462 m^3 as 1.

6.4. Impact analysis of resource accounting on sustainable development in China

China is very underdeveloped according to the magnitude of GNP. China reached 442346 million US$ GNP in 1992, 380 US$ per capita GNP and 136th in the world (Table 6.3).

The most obvious issue concerning sustainable development is population. Family planning is a fundamental state policy, and China has made remarkable achievements in implementing effective policies for population control. Nevertheless, the vast size of the population, the low educational level and social imbalance present formidable challenges. In February 1995, the population reached 1.2 billion, had the family planning policy not been in place, the figure would have been 1.5 billion. China supports 22% of the world's population with only 7% of the world's total arable land. It is crucial for China to slow down the rate of the population growth, enhance the quality of life for its citizens and foster rational and sustainable consumption patterns. The population growth has exerted tremendous pressure on the natural resources such as land, forest, grassland, energy, and water resources. Although township enterprises can absorb a quantity of labour forces, but bring about spreading pollution in the rural areas. In the urban areas, population growth has increased the burden of both infrastructural development and environmental protection.

Resources have different prices at different production stages. Owing to the centrally planned economic system in China, natural resources were valued at nothing during their development or utilization, raw materials were priced in the market with a very low value, and final products were expensive. The irrational pricing system has vicious results, such as:

(1) Waste of natural resource. Taking arable land resource as example, although arable land is limited in China, nearly 500 000 hectares of arable land was used annually for construction and other purposes, which threatens the supply of food and clothing.

(2) Irrational use of resources. Forestry resources are not sustainably utilized. Development of the timber industry has caused deforestation leading to the shortage of timber. It is estimated that about 0.23–0.3 billion m^3 of timber are required for the purpose of construction in different areas.

(3) Environmental problems. Water, the most essential and valuable resource, has been over-exploited and contaminated. Groundwater is abstracted without valuation, which leads to water level decrease and land subsidence, land fissure, saltwater intrusion, and other environmental problems. Eighty percent of the country's polluted water goes directly into water bodies without treatment, and over 90% of urban water sources are seriously polluted. China is confronted with the arduous task of bringing back clean water to their citizens.

(4) Resource hollow phenomenon (for further discussion see Li et al., 1990).

The pattern of development that erodes the environmental resources is obviously unsustainable. There is a lack of economic instruments in the legislation system for unsustainable use of natural resources are now facing the challenge of the market-oriented economy. In addition, economic development is traditionally unduly dependent on intensive resources and energy input, and high resource consumption and outflow of pollution. Natural resources are distributed by means of administrative intervention which seriously hinders the effective allocation of resources, the establishment of a resource property system and the creation of a resource market, and an irrational resource pricing methodology has resulted in undervaluing resource and over-consuming resources. In addition, there is a lack of instruments for analysing resource policies as well as supporting a system of decision making.

From now on, China should seek to integrate sustainable development strategy into the national economic and social development plan, establish better measurements crucial to the environment, apply theoretical and methodological research in the development of the necessary concepts and system of natural resource and environment accounting, and develop and implement a system for integrating natural resource and environment accounting into the national economic accounting system.

The socialist market should be set up to not only optimally develop resource, but also strengthen economic control of resource exploitation, development and utilization. Natural resource such as land, water, forests, marine areas, and grasslands are state-owned in China. Natural resource accounting can provide an appropriate price for any natural resource, which is the first step to the socialist market. The value of natural resources should be accounted for in the national accounting system, then owners of resources should benefit from market activities of resources lent or transfered. Prices should represent the abundance or shortage of any resource, supply and requirement, productive value, and finally put into the international market.

Resource industry is an important base for economic and social development in China. Resource industry we refer to here is the production of natural resource conservation, restoration, recycling, renewal, value added and accumulation through human and financial input by relevant sectors. For resources without market prices, or when there are relevant externalities, a licensing system should be put into place for the development of resources. For the sake of the optimal disposition of resource use, China should enact a series of legislation, regulations and policy for industrial management, strengthen research on the natural resource and environmental accounting system to promote the efficient development and use of natural resources.

China should examine the dynamics of resource stock, flow and valuation through material measurement, statistical analyses and use of market price and resource change in order to lay a foundation for integrated environmental and economic accounting; emphasize the consideration of environmental resource accounting issues during research on natural resource accounting; develop and propose concepts, classifications, theoretical frameworks and principle methods for natural resource and environmental accounting; research and design a material statistical index system to correspond to the natural resource accounting system; develop and refine a natural resource pricing system and a standard system of changes for environmental services in light of market conditions in China's economy; and build up a more complete natural resource and environmental accounting framework and explore methods of integrating it into the national environmental accounting system.

In short, we must study natural resource and environment accounting and strategies for resource development so that we can put forward some suggestions and countermeasures to economic development pattern of resource saving according to the requirement of resource, supply and need of the market in China and in the international community.

6.5. Conclusions

Sustainable development in China aims at the transformation of the traditional economic development pattern from extensive, low efficiency and high pollution into intensive, more efficient and less polluting. Sustainable development should be grounded in resource base so that we strive for rational resource use and development, promote energy efficiency and sensible use of water, minerals and other conservation technologies, implement sustainable resource use and environmental protection. Sustainable development has to meet the basic needs of present and future generations as well as their desire for higher living standards.

Although China has abundant land, mineral, forestry and water resources which are vital to the national economy, the per capita share is actually much lower than that of developed countries, and energy is used inefficiently at US$ 0.5 GDP output/kg oil. For this reason, China should continue to implement its family planning policy to cope with the excessive growth of the population. The country expects to bring the average natural growth rate of population under 12.5 per thousand by the year 2000 and maintain its population at 1.5–1.6 billion by the middle of the next century.

Resource accounting can promote the development of the resource industry and an appropriate pricing system so that China can achieve sustainable development. It will not be easy to change old patterns but as China enters the twenty-first century and develops, we must embrace sustainable development principles and practices. Only by adopting new development patterns can China alleviate the problems created by poor infrastructure, over-population and lack of natural resources.

More importantly, China should seek to integrate sustainable development strategy into the national economic and social development plans, to establish and complete the socialist market system in order to optimally develop resource and strengthen economic instrument of resource exploitement, to enact a series of legislation, regulations, criteria and policies for the industrial management, and explore methods of integrating resource acounting into the national acounting system.

The environment is our most precious resource. We must nurture it and care for it. The survival of human beings depends on the earth on which we all live. We cannot only look out for our own individual interests. We have some experience in natural resource acounting and we will share and exchange information on resource and environment acounting for environmental protection and for our common future.

References

Strong, M.F., 1994, in Proceedings of the high-level round table conference on China's Agenda 21, Beijing: Science Press, 7–10.

Gan S., 1993, Report on the Formulation of China's Agenda 21, Sustainable Development in China, International Workshop on China's Agenda 21, Beijing: Ocean Press, 175–185.

Speth, J. G., 1994, in Proceedings of the high-level round table conference on China's Agenda 21, Beijing: Science Press, 4–6.

China's Agenda 21, 1994, Beijing: China Environmental Science Press, 31–33.

Statistical Report of the Environment in China, 1994, National EPA of China.

World Bank, 1994, World Bank Atlas, Washington DC: World Bank.

Li J. et al., 1990, Natural resource Acounting for Sustainable Development, Beijing: China Environmental Science Press, 3–11.

CHAPTER 7

Some Points of Asset Administration and Natural Resources Accounting in China

Qian Kuo, Du Donghai and Long Yulin

7.1. Introduction

China has many resources as well as a large population, which has a strong pressure on the environment. Like other developing countries, China must solve the problem to achieve efficient resource utilization and environmental protection. In the short term, the primary goal is for efficient use of resources, for if resource are exploited in a self-improving way, the pressure of environmental problems would be relatively small. Here we will pay more attention to the administration of natural resources, discuss the role of the asset administration for natural resource and the framework of natural resource accounting which is closely related with it.

7.2. Main problems in resource asset administration of China

The natural resources' property right structure of China is prescribed in Constitution of China and some other laws of China, that all natural resources belong to the state and natural resources are important for the wealth of the country. The natural resource is a kind of national asset, but practically, there are many problems in resources asset administration.

7.2.1. Confusing of the three rights

In the natural resources administration system of China, there are three kinds of right towards natural resources: property right, administration right and operation right. The three rights are the outcome of a socialist economic system: when reform of the economic system occurs, there is much confusion about the three rights.

The first is that property right of the state is shared by the local government and by different departments of the country. For example, in China, at state level, there are seven special departments responsible for the administration of natural resources. They are Ministry of Geology and Mineral Resources, Ministry of Coal Industry, Ministry of Water Resources, Ministry of Forest

A. Lanza (ed.), Resources Accounting in China, 137–147.

Resources, State Land Bureau, State Ocean Bureau and Ministry of Agriculture. There are also some industrial sections and even many companies concerned with natural resource exploitation and operation. Each industrial section or company takes charge of some kinds of resources. Such a resource administration framework makes resources property rights unclear and has weakened the authority of resource administration. Under such conditions, some enterprises become the owner, administrator and the operator of the resource: the state's property right over the natural resource exist in name only. In order to maximize profit in a short period of time, corporations put a great deal of resources into production, exhaust resources and cause the deterioration of the environment. In the mean time, there are many conflicts among the corporations in the operation and occupation of the resources.

Although the Chinese government has a property right over the natural resources, this has not been realized in terms of economic profit. The benefit of state-owned natural resources was mostly transferred to profits of certain sections, collectives and individuals, while the country suffered great loss of its assets. The essence of property right should be reflected by who benefits from the resource, otherwise property right is denied. The ownership of state natural resources in China in practice only exists in name.

Since the state's ownership of natural resource cannot be realized in economic benefit, it is difficult to construct and maintain natural resource projects, which leads to the damage and degradation of existing natural resources and maintenance of projects at different levels every year. Lack of money means that protection and maintenance projects cannot reach the planned standards, natural disasters cannot be eradicated, and integrated projects cannot be carried out. Moreover, the intersection of functions between different specialized departments has led to continuous conflicts. In consequence, this makes it difficult to carry out any measures or policies relating to natural resources administration. It also needs great effort to coordinate the relationship between different function departments and industrial departments. The promulgated measures are formulated by the comparisons of different departments in stead of under the guidance of object and economic rules. New problems are often brought out while the old ones still exist.

7.2.2. The free utilization of natural resources

Due to the socialist economic system, utilization of natural resources is in a free way which leads enterprises to put much more attention on maximization of their profit by the use of natural resources than on administration or protection of the natural resource. Because depletion of natural resources and profit from natural resources is turned to central government, so areas abounding in resource always become poorer and poorer. Many problems have been caused by poorly efficient resource exploitation, and there is a great waste in the process of exploitation as well as in utilization: this causes a great loss both in environmental and social economic terms.

The free utilization of natural resources has great shortage in terms of its integrated utilization, and the low profit makes it impossible for capital accumulation; in consequence, technologies for natural resource industry have been improved slowly, which greatly hampered the development of reasonable exploitation and utilization of natural resources. Each year central government invests a large amount of money in the natural resource industry, but this has not allowed the resource industry to grow into an independent business up to now, because of the deficiency of the administration mechanism. The natural resource departments are just the workshop subordinated to industry, and can hardly enter into the favourable cycle of self-sufficiency.

7.2.3. Lack of economic management mechanism and competent mechanism

Due to the lack of competent economic management, the administration of natural resources becomes more and more difficult. Most prohibitions are broken again and again, and it is hard to protect and utilize natural resources efficiently. Therefore, it is necessary to reform the current administration system of state natural resources in order to make it conform with scientific rules, economic rules and production rules.

7.3. Administration of state natural resources

7.3.1. Administering natural resources as state assets

As required by the socialist market economy
During the primary stage of socialism there exist multiple economic components, including state-run, collective, individual and those run by foreign capital. To distinguish between the property right and operation right in natural resource administration is a result of deepening of the economic system reform of China. As the owner of natural resources, the government is objectively required by the socialist market economy to administer resources with the owner's right, and ensure the hedge and increment of its natural resource asset in monetary sense. Just as we see, corresponding administration of natural resources would follow every economic running model. Since asset administration should suit the market economy, administration of state natural resources is also necessary in socialist market economy.

It is required by reform of the national economic system
In response to the economic reform of China, it is necessary to reform the system of national accounting to fit the requirement of a market economic system. According to the UN's proposal, the System of Environment and Economic Accounting (SEEA) will gradually take the place of the System of National Accounting (SNA). SEEA is an integrated economic accounting system because the value of natural resources and environment are taken into

account. So in SEEA, natural resources and environment will have their value, they will be regarded as wealth of the country, and this makes it necessary to administer natural resources as state assets.

As required by the rational exploitation, utilization and conservation of natural resources

The confusion existing in the exploitation and utilization of Chinese resource assets is by no means settled thoroughly. The inefficient natural resource utilization and the deterioration of the environment are attributed to a lack of administration methods which have self-adjusting and self-restraining mechanisms. The problem that the state is personalized as the representative of the owner of natural resources has not yet been solved. This problem has led to interference in the ownership, operation and utilization of state natural resources. Natural resources are usually occupied by whoever is exploiting it or taking it forcibly. Consequently, enterprises make their profits at the cost of excessive consumption of natural resources. There exist a great deal of restrained exploitation, and aims of rational utilization and conservation of natural resource have long been nothing but meaningless words.

As is required by implementing governmental administration functions

Administration sections of Chinese government are responsible for supervising exploitation, rational utilization and conservation of state natural resources. It is also their duty to defend the rights and benefits of state natural resources by law. However, there are so many administrators that detractions are often made by different departments. The development of a market economy makes it urgent for an administration department to take comprehensive charge of state natural resources. It must have high authority and administration ability with special technology, and it should be empowered by law to carry out the ownership. Only by this way can the utilization of natural resource with true overall planning be undertaken and government's macrocosmic adjustment can be achieved.

7.3.2. Administration of state assets in China

The state assets are divided into three classes in China: operational assets, non-operational assets and resource assets. The main function of administration departments in charge of state assets is to administrate the assets owned by the state both inside and outside China. The main task of administration departments of natural resources and other related departments is to participate in dealing with property right disputes, to conduct fundamental administrative activities such as circumscribing and registering the property rights of natural resources.

7.3.3. Chinese characteristics in state resource asset administration

The overall condition and natural resource conditions of China are different from both developed capitalist countries and former socialist countries, so asset administration in China would not copy that of any other countries. It must concentrate on increasing the profits of using natural resources and saving natural resources. China has a large population and relatively scarce resources, and it is just at the stage of economic development with an ever-growing consumption of natural resources. The state should have the single ownership of the state natural resources, while multi-ownership concurrently exist in natural resources exploitation. The Chinese government has dual status and dual functions as both the administrator and the owner of its natural resources. Therefore, on one hand, property rights should be separated from exploitation and operation. On the other hand, the management of ownership, to a certain degree, should be combined with the administration of natural resources in a given period. In other words, to strengthen the administration and combine the administration and ownership of the natural resources organically, while separating them only in an inner sense, which would lead to a new administration system for natural resources assets.

Resources differ from other kinds of assets: they are gained by transference of occupancy from government instead of by investing. Moreover, they could be used again and again, or be exhausted or polluted to uselessness. The existence of natural resources can bring humans not only wealth but also ecological benefits. Therefore it is important for people to restore natural resources in order for its sustainable utilization. It is also necessary to administer them economically. This requires the government to extend the circulation of property rights of natural resources to any possible degree, and build favourable transferring forms adaptable to a socialist market economy, while not manipulating directly the operation and utilization of natural resources.

7.4. Some rudimentary ideas of natural resource asset administration

7.4.1. Natural resources asset administration

The meaning of natural resources asset administration is, in simple words, to administer natural resources as assets which are included in production. That is to say, to manage the input and output of resource business and change the past non-profitable resource business into a profitable one during all the stages of exploitation, production and reproduction of natural resources according to natural rules, practical conditions and economic rules; to enforce the regulation that exploitation and utilization of natural resources must be compensated; to put the privileges of these activities into market; to use the income from resources assets to maintain and improve resource administration; to establish regulations of resource accounting, planning, compensation and supervising system; in the end to build up a favourable cycle of resource development in which resource business is fed by itself. It may bring society both better economic benefit and better ecological environment.

There are both close inter-relationships and differences between resource and resource assets. The management of resource is the basis of that of resource assets administration. To turn resource into resource assets is the goal of resource business. Therefore it is important to distinguish the management of the two as well as combine them organically. To pay enough attention to both of them is the only way to good management of both resource and resource assets.

7.4.2. Criteria that should be followed in resources asset administration

The administration system of resource assets must meet the requirements of socialist market economy. That is to say , it must be oriented basically to the requirements of market economy, and no longer be cross-cut, and it must have distinctive features of natural resources assets administration. The system must ensure the completion and unity of ownership of the state, ensure the economic realization of the ownership in a true sense; and it should lead to the maximization of the profit per unit resource assets.

It will help to coordinate the relationship between different beneficial subjects such as that between the central government and the local government, and that between enterprises of resources and approach their integrated exploitation and rational utilization, which would turn natural resource advantages into economic advantages and promote both national and local economic development.

7.4.3. Basic jobs of resource assets administration

These are:

- To sum up the former work and lay out a set of indicators of resource assets;
- To set up a basic price system of resource assets and draw up a set of appraising methods and standards for the basic price of resource assets;
- To formulate a set of methods for circumscribing property rights of resource assets and settling property right disputes;
- To formulate physical quantity accounts and value accounts of resource assets;
- To formulate a set of methods for property right administration of resource assets;
- To formulate a set of standard and methods for the statistics and accounting of resource assets;

- To formulate a set of administrational methods for the running and supervising of resource assets;
- To formulate a set of methods to administrate the benefit of resource assets;
- To formulate a set of methods to administrate the transferring of resource assets property rights.

The term 'set of' here means that all kinds of natural resources are concerned. If conditions for regulations for all natural resources are not yet ripe, some resources should be concerned firstly and then progress the rest.

7.4.4. Integrating resource assets into enterprise accounting system

Resources assets administration is focused on the value management, which is based on enterprising accounting. However, due to the effects of priceless resource theory, the consumption of resources has not been required to be compensated for some time, neither has the value implementation of natural resource been considered. In the present accounting system of China, from the setting up of accounts to the setting up of items including detail accounting items, resource assets are not integrated into the accounting system as a kind of enterprise assets; nor do the related laws or regulations deal with the accounting of resource assets. It is an important work in enterprise accounting that should be fulfilled urgently in China.

It is authors' view that the primary requirement of asset administration of natural resources is to account and administer them as asset: enterprise accounting is the premise and basis of natural resource asset administration. Resourse assets accounting must encircle closely around goals of assets administration and ensure the maintenance and increasing of state resource assets. This may lead to the economic realization of the state's ownership of natural resources; this will help to optimize the allocation of resource and improve the level of economic benefit and management of resource assets. Resource assets accounting must conform with the criteria of enterprise accounting and be connected with the enterprise capital rules. It should also handle the relationship between value compensation of resource assets and value realization, and organically integrate the value accounting into the physical quantity management, in the end, provide highly qualified accountant information of resource assets.

Valuation of resource assets

The valuation of the resource assets formed by human inputs should be based on the cost accumulated historically. If it is impossible to obtain historical data, the actual cost in recent years can be used in the accounting. Resource assets accessed from property right transferring should be carried to accounts by purchasing cost or appraised price of the assets. Resource assets subscribed by law may enter into the accounts by appraised price. For resource assets, which have entered into accounts but have succeeding inputs, additional cost should be carried to the accounts. The consumption, transference of property rights and abnormal loss of resource assets should be deducted from their stock by actual number or average sum of cost.

Enterprise accounting of resource assets

Set aside an item Resource Assets on enterprise's resource assets accounts. To account correctly stock and flow of each kind of resource assets and gradually accomplish asset accounting during whole process of formulating and using of assets. For the resource assets formed naturally, carry their appraised value to the accounts; For those formed with human inputs, carry the accumulated production cost in addition to their original value to their accounts. For the resource assets subscribed or got from property right transference, carrying purchasing cost or appraised price to their accounts. The accounts should contain two more items: the debt side is kept with resource assets, and the credit side with related items.

Set aside detailed resource assets accounts in primary enterprises' accounts with such items as the purchasing price, apprised value of resource assets, production cost and aggregated number are kept down annually for data accumulation and economic analysis.

For abnormal resource assets lost in their exploitation, utilization or eligible transference, subtract the loss from the stock according to the criteria concerned with the carrying over of assets.

The profit accounting of resource assets

According to Tentative Measures for Examining the Hedge and Increment of State Assets of China, state assets include both the investment by the state to enterprises and its benefit, and the assets eligible to state ownership. It is the same for state resource assets. The property rights of this kind of assets should include what formulated both in the investment of the state, the special allotment, the funds for resource exploitation and utilization, and in the benefits produced by eligible subscribed natural resource.

For the benefits produced by state resource assets. its value should be carried to capital common accumulation (i.e. resource capital) in the accounts. The debt side should be kept with the item 'special sum to be paid – expense of resource occupying', while the credit side kept with the item 'capital common accumulation – resource capital'.

According to related regulations, when large property right changes take place, in the case of rebuilding of enterprise or co-partnership, it is necessary to evaluate and subscribe all the properties, including resource assets, and register the actual capital in order to account correctly the benefit of each investing subject.

For the resource assets that have not been integrated into resource assets accounts, it is necessary to account and examine them by the present regulations during the process of their exploitation and utilization.

Financial statement and the examination
After the accounting, the number of resource assets and concerned benefits should be reflected specifically in the assets and liabilities accounts, The remainder of resource assets should be listed in resource asset following the invisible and deferred assets item. The content of the two items, the paid-in-capital and resource capital, and the capital common accumulation–resource capital item, should be accounted into the resource capital following the paid-in capital item.

The appraisal indicators for integration resource assets into accounting system are to be drawn up additionally by Ministry of Finance together with the State Assets Administration Bureau and other departments which are concerned woth natural resource administration. Other administration problems are to be solved the same way. Before the new financial indicator system and examining measures are drawn up, the old indicators and accounting specification should be kept unchanged. The sum of resource assets and concerned benefits may be deducted from the total capital and total benefit respectively.

After accounting of resource assets, enterprises are able to analyse the dynamic state of resource assets according to indicators of physical quantity, so they can strengthen the basic management of the physical quantity in terms of the hedge and increment of resource assets.

7.5. Steps of asset administration of state natural resources

We should make it clear that state natural resources are a kind of asset, and their management should be integrated into state assets administration system as a subsystem. It is necessary for state resource administrational departments together with state asset administrational departments to draw up policies and legislation for the administration of resource assets. The administration of natural resources' operation right should follow the management system of enterprises.

We should set up market mechanism for the exploitation and utilization of natural resources which has the following features, functions and goals:

- the use of natural resource must be compensated;
- natural resource production is commercialized;
- the money for natural resource projects is provided by loans instead of allotments;
- natural resource exploitation funds are established by the money compensated form the use of natural resource and is used to develop new natural resource outcomes, thus fulfill the favourable cycle of natural resources and

provide more financial sources for the state and the development of national economy.

For some critical resources, such as gold, nuclear elements, major forestry and territorial waters, which are decisive to the nation and the living of people in terms of national economic development, the improvement of ecological environment and national security. So it must be left to the state resource administration departments to direct by their function and guide the management of such resource including those have not yet been exploited, and separate social administrational function from those of the ownership of natural resources inner the department.

The reform of transferring the management mechanism of enterprises engaged in state natural resources is to be directed by Regulations of Transferring Management Mechanisms of State-run Industrial Enterprises of China. Meanwhile, the operating, exploiting and using of natural resource of every kind of ownership subject such as collectives, individuals, are to be greatly bolstered. It is also necessary to help subjects to become legal persons and have equal positions in competition, which is a basic rule in market economies.

The experimentation and extension of such administration mechanism in each administrative region must be directed by local natural resource administration departments and state assets administration departments who are the representatives of the state authorities. The management should be guided by laws, regulations and policies, and should be supervised by local government, central administration department of natural resource and state asset administration departments. The progress of state natural resource administration can be approached in three steps: First, rebuild the present balance sheet of natural resources into physical quantity accounts which can reflect the quantity of resource assets available to national development as well as the potential and basis of natural resources which can not be use temporary. The accounts should reflect the changes of natural resources resulted form more efficient work or inputs and reflect occupied or consumed quantity of resource assets.

Second, develop and fulfill the theory of resource assets value and set up the price system of natural resources to settle the problems of price less resource and build the value accounts of resource assets. When resource assets are use by enterprises, compensations fee are imposed by the state who is the owner of natural resources. The compensation fee is managed by center administration and local financial department, in the end, all to be used by resource business and be integrated in to tax system.

The third step is, on the bases of physical accounts and value accounts of resource assets, and guided by the idea that ownership should be separated from operation properly, statements of assets and liabilities can be set up, on which asset side is the state and the liability side is enterprises using resources. Thus a new management framework focused on the property rights of resource assets can be established.

7.6. Conclusion

In consideration of the overall conditions of China, the process of the asset administration of natural resource can be progressed by the following steps. First, to research deeply into the concerned theory and reform fully natural resources management system to achieve common recognition by present departments of both natural resources and state asset administration. To carry out asset administration of natural resources is essential to extricate China from the difficult resource conditions. The benefit of resources assets administration gained by center government and local government must be coordinated according to the criterion that natural resource must be used scientifically, comprehensively and economically. The second step, to unite the departments of state asset administration and natural resource administration, to take investigation and experiments in construction administrational model of natural resources. The third step, based on the above steps, draws up regulations concerned with the asset administration of natural resources, and establishes a new relationship between the two kinds of department. In the new relationship, each part has its own functions and responsible for its own duties: the departments in charge of state assets focus their functions on the economic management. Those in charge of natural resource focus their function on resource administration. Inside the latter, two administration groups are formed: one takes charge mainly of social administration which includes the overall planning and protection of natural resources administration; the other is engaged in the functional administration of the property right, and connected with the state asset administration departments.

By these steps an organic administration system of state natural resource assets can be established. The last step is, to establish a quantified supervising and controlling system for the optimization of the allocation of natural resources and for the analyzing of natural resource industry. This quantified system can provide fundamental data to national decisions and industry development.

CHAPTER 8

Resource Accounting in China

Wang Zhixiong

8.1. Introduction

Sustainable development is a major issue concerning the survival of human beings and social progress. The Chinese Government has formulated China's Agenda 21, which calls for the study and practice, on a trial basis, of integration of natural resources and environmental considerations into the national economic accounting system so as to make statistical indices and market prices accurately reflect the resources and environment changes caused by economic activities. This has become an important input to China's sustainable development strategies. It emphasizes the establishment of stock and flow accounts for natural resources to support the establishment of an integrated environment and economic accounting system. This facilitates the establishment of a new, integrated national economic accounting system. These efforts have demonstrated the vision and determination of the Chinese Government to implement Agenda 21.

As a developing country, China is acutely aware of the importance of a coordinated development of population, resources and environment in securing a stable and healthy economy. The Chinese Government has fully recognized the role of natural resource and environmental accounting in promoting sustainable development. In 1994, the State Science and Technology Commission of China took the lead and organized experts from Ministry of Geology and Mineral Resources, Ministry of Forestry, State Commission for Education, Chinese Academy of Sciences, State Oceanography Administration, State Administration of Land, Ministry of Water Resources, State Statistics Bureau and National Assets Administration to conduct physical and monetary accounting of China's major natural resources such as minerals, forests, land, water, marine resources, wildlife, grassland and recycled resources. They have conducted research on accounting theory, methodology, modelling and integration of resource accounting into China's national economic accounting system. The efforts have resulted in the completion of

A. Lanza (ed.), Resources Accounting in China, 149–153.

the Comprehensive Report on the Studies of China's Natural Resource Accounting.

8.2. The necessity for resource accounting and its integration in the national economic accounting system

8.2.1. Natural resources are the core physical basis of sustainable development

China is the largest country in the world in terms of its population. It will be difficult for a country with 1.2 billion people to achieve a sustainable, steady and coordinated development without massive amounts of natural resources and their sustained supply. China is vast in its territories and rich in resources, but it is also resource-poor in per capita terms. China's per capita arable land is only one-third of the world average, water resources one-fourth, forest one-seventh and mineral resources less than half. The massive consumption of natural resources and rapid growth of population will further reduce per capita resource availability.

China's land is heavily burdened. China has to feed 22% of the world population with only 6.97% of the world's arable land. The development of industry and urbanization have nibbled away the limited arable land in the country. During the period 1957–1980, 53 3000 hectares of land were taken away annually. In 1993, 400 000 hectares were converted. The irrational development and utilization of land over a long time has caused serious soil degradation with the erosion area reaching 1.53 million km^2 and desertification of 3.22 million km^2. The forest coverage is only 13.92%. Of 570 cities, 300 face serious shortages of water. It is estimated that by the end of year 2000, China's existing iron and manganese mines will show 10% reduction in productivity, copper, lead and zinc mines will reduce productivity by 40%.

China's natural resources will face serious gaps between total demand and total supply. In this context, it is important to formulate policies guiding the wise and rational protection, development and utilization of natural resources.

At present, China is undergoing rapid industrial development and economic take off. China's economic growth was 11.8% in 1994, the third consecutive year since 1992 for such high growth rate. It will obviously be difficult to achieve social and economic progress without resource and environment consciousness, without policies on rational exploitation of resources and environment protection. It is an urgent task to strengthen resource accounting so that we become aware of changes in the stock and flow of natural resources.

8.2.2. Resource accounting is important for industrial restructuring and for the establishment of a resource-efficient economic system

The excessive exploitation of natural resources and continuously reduced resource volume have exerted impacts on the development of the world economy, threatening the survival of human beings. China is facing a more serious shortage of resources than other countries: its economic growth is achieved at the expense of high energy consumption and serious waste of resources, which may worsen the shortage. In this context, it is necessary to conduct studies on resource and environmental accounting, resource strategy, demand of economic development on resources and discrepancy between resource demand and supply so as to provide a theoretical foundation and basic data necessary for the establishment of a resource-efficient economic system.

8.2.3. Resource accounting is important for the establishment of a socialist market economic system

China is in the transition from a planned economic system to a market-oriented one. Under the market economic system with Chinese characteristics, the old concepts and policies such as zero-price of resources, free use of resources and associated distribution and management systems must change. Resource accounting will provide theoretical, methodological and information bases for such changes and will be helpful for the healthy development of Chinese market economy. Studies on resource accounting will help integrate resource values and environment benefits into product costs. This is a basic aspect for the establishment of Chinese market economic system.

8.2.4. Integration of resource accounting into China's national economic accounting system

Natural resources are important components of national wealth. Natural resources have values. China's current national economic accounting system, including both SNA and balance sheets of material products, has not taken into account the quantity and quality changes of natural resource assets. The current system therefore does not fully reflect national strength. It is important to have a new national economic accounting system by giving value to natural resources and the environment and integrating resource and environmental accounting in the calculation of GDP, NDP, national income and capital formation. These efforts will enable us to understand the status and changes of resources and the environment, predict the availability of natural resources and health of the environment for economic and social development, and provide accurate guidance for the macro-control of national economic development.

We are planning to formulate schemes for integrating natural resource accounting into China's new national economic accounting system especially for the components such as GDP accounting, investment and output accounting, economic cycle account and assets and liabilities statement.

8.2.5. Resource accounting provides the scientific basis for the Government's national economic and social development plans

In studies of resource accounting, relevant theory, methodology and options have to be worked out for integrating resource accounting into our new national economic accounting system. The government could then use this instrument to make dynamic analysis of resources and the environment, and formulate associated policies and measures. It could develop policies, laws and regulations on rational exploitation of natural resources and environment protection. It could establish a system for assessing the sustainability of natural resources and assessing integrated economic, social and environment benefits. It could also establish a warning system for sustainable utilization of resources and the environment.

8.3. The future research plan for promoting resource accounting in China

In 1994, under the auspices of the State Science and Technology Commission of China, a coordination panel for the studies on resource accounting was established with US$200 000 investment in the preliminary study of China's natural resource accounting system, China is now in the process of formulating its national scientific and technology research plan for the period of 1996–2000. In the next 5-year period, the Chinese Government will invest US$3 million into research on natural resource accounting with the following major objectives:

(1) To study natural resource accounting theory, methodology and pilot accounts consistent with the UN SEEA framework.

(2) To compile accounts in both physical and monetary terms for classified resources, and to establish individual resource accounts and integrated monetary accounts, to gradually establish and improve China's natural resource accounting system.

(3) To plan preliminary implementation of the integration of resource accounting into China's new national accounting system, covering accounting principles, classification criteria, accounting formulas, and an index system to provide a sound basis for policy making.

(4) To select certain resource types and regions for demonstration so as to combine resource accounting with accounting of environment quality, and to integrate resource accounting into regional economic accounting systems.

(5) To establish mechanisms for evaluating the productivity of various natural resources, to establish models and warning systems for analysis and evaluation of resources and the environment, and to establish supporting systems for decision making at the macro-level.

China is a developing country. It is willing to cooperate with other countries, international organizations, and NGOs on the studies of resource and environmental accounting. We are taking action to give value to nature in a substantive and practical way. We are expecting international institutions to take a strong lead in this global endeavor.

References

Department of Science and Technology for Social Development, 1995, Resource accounting studies in China. Unpublished Report.

The State Council of the People's Republic of China, 1994, China's Agenda 21 – White Paper on China's Population, Environment and Development in the 21st Century, Beijing: China Environmental Science Press.

CHAPTER 9

Study on Methodology: Land Resource Accounting in Urbanization Areas

Wang Zheng, Zhou Guirong, Xu Weixuan and Mei Anxin

9.1. Introduction

The urbanization of Chinese rural areas has been taking place rapidly since the reform and open policy of China in the late 1970s. Zhou (1995) indicated that the proportion of urban population in the whole has grown from about 12% to 18.9%, averaging 0.53% each year from 1978 through 1990. We estimated the rate to be about 0.6% in last 5 years, because more and more farmers come into cities but are not formally accounted for in official statistics. About 2.6 million 'farmer-workers' work and live in Shanghai, but are not counted in the urban population (Xu et al., 1996).[1] However, we must point out that the urbanization proportion of China is still very low compared with developed countries, and the urbanization rate in China may not decrease in the future.

It can be reasonably predicted that the process of Chinese urbanization will last a long time. The process of urbanization is obviously accompanied by an increase in built-up areas. Land used by agriculture or other low-income activities in or around cities is transformed to urban use, such as factories, concentrated living area and urban infrastructures. At the same time, urban land may also be transformed into different use, although in early period of urbanization this occurs less frequently. From the view of resource economics, the transformation of land use amounts to more efficient use of land resources. Because of market competition, land employed by less profitable activities is more likely to be changed into other uses. The transformation will, in the end, increase production. The sustainable development theory, however, throws doubt on this view. The new theory looks at such questions over a longer time span and a wider space. When agricultural land, especially arable is continually occupied by urban activities, there may be serious problems, especially for the security of food supply. Without good planning, urbanization may lead to unsustainable urban development. It is therefore of fundamental importance to appraise and account the areas being urbanized or to be urbanized, to have details about land resource stock and its dynamic state, and to plan, to guide and to control the development of cities.

A. Lanza (ed.), Resources Accounting in China, 155–160.

In organizing such valuation and planning activities, two crucial issues are accounting land cost change in urbanization process and estimating the impact on food supply when agriculture land is transformed to urban uses.

3.2. The case of Pudong

In order to analyse the land urbanization question, we choose Pudong as an example. Pudong is a new urban area of Shanghai, whose speed of urbanization has been increasing in the last few years; the features of transformation of land use are very relevant for the problem we consider in this paper.

Pudong is a small part of Yangtze delta. The triangle-shaped area lies to the south of Yangtze estuary, north of Chuanyang River and separated by Huangpu River from Shanghai urbanized area. It has a subtropical monsoon climate, 16.2°C average temperature, 1433 mm precipitation and 1389.3 mm evaporation. Before its recent exploitation, Pudong was a suburban area of Shanghai, mainly used by agriculture, with rice as the main crop. The area is plain, with almost no geomorphic variations, so it would be reasonable to take the changes of land use structure as the results of mere economic activities.

In 1990 the Chinese government decided to exploit Pudong. Since then the superior location and preferential policies have attracted lots of investors from both China and foreign countries. The large investments caused rapid urbanization and the land use structure is changing correspondingly.

3.2.1. Methodology

In land resource accounting, physical quantity accounting is of great importance and must be done beforehand. In China much research on land accounting has been already done. We can build on the work of Professor Mei Anxin who has produced data interpreted from remote sensing images.

The aim of our research is to establish a methodology system of land urbanization results. With such a system one can estimate the environmental and economic value of land urbanization. The system may be included into National Economic Accounting System of China. Since the accounting is closely related to macroeconomic control, it is a problem on meso-economics with a view of methodology. We here emphasize the meso-scope of the accounting subject, since some papers have also used land value assessment. Methods used for assessing the magnitude of land value should be different from those of real estate appraising. Effects of specific microeconomic factors such as individual location, environment quality etc. should be ignored. We will instead pay attention to the usage cost and environment functions of land; here we use the average price level of land to estimate its using cost.

As land resource, it has the features of unremovability, scarcity and earning capacity. According to these points, we use the following method, and apply it to land accounting of Pudong at two times during its urbanization.

Lands for profitable use (type I)
Here we include land which provides working yards for the three industries, that is agriculture, industry and services. This land takes up the main part of the whole area, and its accounting method plays an important role in our studies.

The main distinction of this kind of land from others is that it can produce a direct yield. A time span is necessary for production, so the two relevant factors are ability of yielding and discount rate. We use the *income restoration method* to account for the value of these lands.

According to such a method the value is given by the following formula (Wang and Ding, 1994):

$$V(a) = \int_0^{\infty} Y(t; a)e^{-d(t)t}dt \tag{9.1}$$

where $V(a)$ is land value with area as a, $Y(t; a)$ is land yield with area as a at t^{th} year, $d(t)$ is discount rate. While Y is assumed to grow at annual rate g, g is constant and $d(t)$ is constant, too, one has

$$V(a) = Y_0 a \int_0^{\infty} e^{-(d-g)t}dt \quad (d - g > 0) \tag{9.2}$$

or

$$V(a) = \frac{y_0 a}{d - g} = \frac{Y_0}{d - g} \quad (d - g > 0) \tag{9.3}$$

where y_0 is land yield value of unit area at opening year. Formula (9.3) is common use formula for according land. a, d and g are obtained from official statistic data, land yield $Y_0(= ay_0)$ is defined as

$$Y_0 = aP_0 \tag{9.4}$$

where P_0 is the industrial profit at opening year, a is land capital weight of the industry, it may be estimated using

$$a = \frac{C_0}{G_0} \tag{9.5}$$

where C_0 is the land price at opening, G_0 is gross capital at opening year.

Since few official statistics are available, the income of agricultural land is obtained by sampling the farmers' operation. Growth rate is the rate at which the country's economy can be continually growing. Discount rate is decided by the government. From the formula we can see that the difference, *d–g*, greatly affects the value of the land.

We here emphasize the mesoeconomic aim of the accounting subject. For convenient operating, the average yield numbers of the other two industries are calculated from national economical statistics. As a study on methodology, we chose growth rates, 6% annually. Discount rate, which is promulgated by Ministry of Construction and State Committee of Planning of China, is 12% (by Wang, 1994). Table 9.1 also shows this result.

Table 9.1. Accounting profitable land (1993 current price)

Type of land use	Yield per year (yuan/year/m^2)	Physical quantity (km^2) 1988/1993	Value of land (million yuan) 1988/1993
Agriculture	1.38	315.91/261.14	7265.9/6006.3
Industry	14.0	24.95/28.51	5820.8/6643.3
Commerce	60.0	0.27/0.55	270.2/5436.6

Lands for municipal infrastructure (type II)

The main characteristic of such land is that it has no direct income but is of fundamental importance in economic production. There are many things which play such a role in national economy. Here we consider only those closely connected with lands and are not included in enterprise accounting. Roads, bridges, tunnels, squares are our accounting subjects here because once they are constructed, they are unmovable. The price of lands should not be separated from such 'real estate'.

To account for this type of land, we need to pay more attention to the cost of their construction. Since the profit of this type of land is embodied in other land types, if we account it as profitable land, the profit will be accounted twice,which will lead to incorrect results. So we use the *reconstructing cost method*, which supposes that the price of a project equals the cost of constructing it now deducted by depreciation. By this method, the resource stock can be computed at the opening year, and the quantity of the resource flow would be the net investment in this area of the year deducted by the year's depreciation. Table 9.2 shows the parameters and accounting results.

Table 9.2. Accounting land for municipal infrustructure (1993 current price)

Land use	Value per unit	Physical quantity (km^2) (1988/1993)	Land (project) value (million/yuan) (1988/1993)
Urban roads	500 yuan/km^2	2.22/6.29	1110.0/3144.3
Rural roads	47.5 yuan/km^2	6.07/17.76	288.3/843.3
Bridges	1075 million yuan/unit	0/1	0/1075
Tunnels	270 million yuan/unit	1/1	270/270

Land for housing, public buildings (type III)

This type of land is used more indirectly in terms of economic production. It can be thought as of 'consuming use' by individuals or government. The price of this type of land is considered in two ways: in rural areas we use the price of cultivating land and in urban areas the basic price of housing lands, so we have the *basic land-price method* of accounting. The results are shown in Table 9.3.

Table 9.3. Accounting Lands for consuming (1993 current price)

Land type	Price (yuan/m^2)	Physical quantity (km^2) (1988/1993)	Land value (million yuan) (1988/1993)
Rural housing	23	58.2/80.6	1 338.8/1 851.8
Urban housing	553	13.2/25.3	7 299.6/1 3990.9

The whole accounting is shown in in Table 9.4, which shows the cost of urbanization of Pudong from 1988 to 1993.

Table 9.4. Land accounting table of Pudong (1993 current price; unit: million yuan)

	1988	1993
Type I (income restoration method)	13 356.9	18 086.2
Type II (reconstruction cost method)	1 668.3	5 332.6
Type III (basic land price method)	8 638.4	15 842.7
Total	23 663.6	39 261.5

3.2.2. The impact on food supply with agriculture land transformation to urban use: net loss of urbanization

From the comparison of land use structure and resource values from 1988 to 1993, we can see that the structure is changing to become more profitable. This is the result of market competition. However, it is also obvious that it is the intensive investment that caused the rise of land price. Without the investment on bridges, roads, docks and so on, there would be no such rapid rise in such short a period. In other words, the increase of the land value calculated here is much more than the net increase of urbanization.

At the same time, the urbanization of Pudong is going at the expense of certain agricultural loss. The loss can be calculated from the possible food production of the decreased land during the period; in this calculation, we not only need to calculate cultivating land but also general agricultural land which includes rural road, wet land, moorland, and other bed land in Pudong.

In the case of Pudong, we have no doubt that its exploitation, for the crop production of Pudong, which is just a very small part of the whole country, is far less important than the strategic value of its urbanization for the whole country. The values in Table 9.4 are much larger than those in Table 9.5, which implies that to use Pudong for industry is good. In this paper it is just taken as a specific example to illustrate the change of land resource during urbanization and the accounting methods.

Table 9.5. Net loss of cultivating land (1993 current price)

Year	1989	1990	1991	1992	1993	Total
Decrease in area (km^2)	5.69	5.82	5.68	5.56	5.41	
Price of the year (yuan/km^2)	16.7	18.2	19.7	21.2	23	
Loss per year (million yuan)	99.53	105.92	111.90	117.87	124.43	559.52

3.3. Conclusions

In this paper we applied the methodology of land resource accounting using different methods for different classes of land types. The accounting is based on physical quantity accounting. We choose the methods for both operating convenience and for obtaining the reasonable. Here we paid much attention to the divergence of different types of lands and to the integration of the methods into a system.

The process of urbanization is accompanied by increases of land price and net loss of agriculture. Land resource is different from other natural resources because the use of land means the transformation of land use only. In urbanization, land is transformed to more profitable uses and the transformation is at the cost of agricultural loss. To avoid unsustainable urban development, affective land policies based on land resource accounting must be taken to ensure sustainable development.

There is yet one problem left for our future work. During the process of urbanization, there are changes of ecological environment as well as land use transformation. In history, the world industrialization is accompanied by deterioration of environment. New technologies give men the chance of decreasing the damage to the environment while developing. Good industrial policy guidance, scientific land use planning and effective jurisdiction are necessary to exploit such new technologies in the best possible way. Although the exploitation of Pudong has restricted pollutant enterprises, some damage to the environment has been caused by existing factories and by lags in the implememtation of environmental regulations. We cannot evaluate this damage due to the lack of appropriate data. However, we believe that it is necessary to make up for this unfinished work.

Notes

1. In the People's Republic of China, rights of migration and residence are united. Farmer-workers (Mingong) work in a city to make a living for their families, who used to live in rural areas. They have no residential rights in the city.

References

Xu, S., Z. Wang and J. Ding, 1996, On Redevelopment of Yangtze Delta, Management World, 2, 80–86 (in Chinese).

Wang, J., 1994, Environmental Economics, Beijing: Environmental Sciences Press (in Chinese).

Wang, Z. and J. Ding, 1994, Principle of Regional Science, Beijing: Sciences Press (in Chinese).

CHAPTER 10

A Case Study of Marine Resource Accounting of Coastal Zone Resources in China

Liu Rongzi

10.1. Introduction

The efficient development and management of the world's marine resources is vital to global sustainable development. Governments are paying increasing attention to the importance of the environment and to the management of natural resources, including marine tidal flat resources. The use of marine tidal flats plays an important role in global ecology because of their unique geographical location and ecological functions. Marine tidal flats are one of the most important coastal zone resources in China. The socio-economic development of these coastal regions depends on proper accounting of the value of these resources. In this paper, the theory of natural resource accounting is applied to marine tidal flat resources in China.

Proper management of natural resources depends on a correct valuation of the resource, both its intrinsic value and its value in relationship to alternative uses. Environmental accounting techniques can aid this valuation. In this case study, the value of marine tidal flat resources is obtained by employing the income approach and income multiplier methods. The results from both methods are analysed over a number of possible uses for marine tidal flats.

Establishing a resource accounting system, especially for the management of coastal resources, is important for three reasons:

(1) It will determine how marine resource use affects the marine economy. This will improve the accounting of the marine economy, thus ameliorating the national economic accounting system;

(2) It will aid the introduction of a system of property rights and will promote the establishment of a system of user fees for marine resource development; and

A. Lanza (ed.), Resources Accounting in China, 161–169.

(3) It will introduce competitive management mechanisms into the system of marine resources in order to promote sustainable development in the coastal zone of China.

China has started to register marine resources as property in a test area in the coastal region. At present, the register is limited to a small district, and only the quantity accounting of coastal zone resources has been carried out. In the near future, the method of cost-benefit analysis might be applied to marine resource accounting. The register will cover the entire coastal zone, enabling China to include marine resource accounting in the national economic accounting system. Marine resource accounting is expected to become one of the most important measures in coastal zone resource management.

10.2. Theories and methodologies for assessing the value of marine tidal flat resources

The valuation of natural resources is particularly important in China as the growing requirements of population and development increasingly face the limits of available space and resources. Marine tidal flats are unique because their characteristics are common to resources that can be found both in the ocean and on land. The following features of marine tidal flats are important to their valuation:

(1) Because marine resources are formed by the interaction between the ocean and the land, they are natural and thus are difficult to value.

(2) Marine resources have many uses including the provision of food and industrial materials and of an environment for numerous species; thus a proper valuation is essential.

(3) Marine tidal flats are a scarce resource in a dynamic balance, as the share belonging to the land and that belonging to the sea changes continuously. Overexploitation reduces the rate of production of the goods obtainable from the resource. Due to their unique location, marine tidal flats are non-renewable resources. Thus, the rate of use is important to the valuation.

(4) Given their limited supply, it is important that marine tidal flats are developed efficiently. Their valuation should take into account other possible uses for the coastal zone areas.

The value of marine tidal flats is the sum of two components. The first is the intrinsic value before any input of human activity, and the second includes the value of labor and capital used to extract goods from the resource. Estimating the value of a marine tidal flat is difficult because of the many possible uses for the resource. In addition, the marine tidal flat could be left undeveloped and the return on capital would be an important component of the price.

The formula used here for assessing the value of marine tidal flats is the following:

$$P = P_1 + P_2 \tag{1}$$

where

P = the total value of the marine tidal flat;
P_1 = the intrinsic value of the resource;
P_2 = the additional value after the introduction of labor or capital inputs.

Assuming that R_0 indicates the natural benefit without any input of labor, α indicates the specific use of the resource, such as the marine tidal flats being suitable for salt production, aquaculture and planting, and delineates products of different quality classes, and i indicates the interest rate, then:

$$P_1 = \alpha R_0 / i \tag{2}$$

Similarly,

$$P_2 = R_1 / i \tag{3}$$

where R_1 indicates the enhanced benefit provided by labor or capital inputs.

From equations (1), (2) and (3), equation (4) can be derived as follows:

$$P = P_1 + P_2 = (\alpha R_0 + R_1)/i \tag{4}$$

Equation 4 expresses the value of marine tidal flat resources as the present value of the benefits derived from their use. Because of data limitations, the values for R_1 and R_2 could not be calculated separately, so the present value represents the total net benefit from developing the resource. Equation 4 can be expressed as:

$$P = A/i \tag{5}$$

where A indicates the annual net benefit of marine tidal resources. Equation 5 is the basic theoretical formula for calculating the income approach method.

10.2.1. Income approach method

Basic idea and formula for calculation of net benefit A

Net benefit A is the net income from developing the marine resource. This income is calculated as the annual total value of output (or value per unit area), which is income from the sale of products, less the costs of production and taxes. Production costs are comprised of salaries to labor and expenditure on materials. The opportunity cost of developing the resource is captured by the current bank interest rate, *i*.

Net income = (annual total output value – production costs – taxes)/ opportunity cost of investment

In the case of tidal flats suitable for aquaculture, the income per unit area is expressed as the selling price of the product less unit costs times average output per unit area.

Income per unit area = (average selling price – unit costs) × average output per unit area (I)

Thus the value of aquaculture land can be expressed as:

Price per unit area = income per unit area/interest rate (II)

In the case of tidal flats suitable for salt production, income per unit area consists of the salt tax and profits from the sale of salt divided by the total area of the salt pan. The per unit area value of this resource can be expressed as:

Price per unit area = (average output per unit area × (average selling price – average cost))/interest rate (III)

Selection of interest rate (i)
Theoretically, *i* indicates the price of money or the return from foregoing development of the tidal flat. Due to the risks involved in the development of marine tidal flat resources, the current bank interest rate was selected for the income approach method. The rate of inflation and market risk are usually captured by bank interest rates. For each year, the current interest rate is used in the calculation of the value of the resource.

10.2.2. Income multiplier method

This method is derived from the income approach method but is easier to apply. The method is frequently used in the calculation of land prices where the price is obtained by multiplying the total income by a constant coefficient. In article 27, "The People's Republic of China's Land Law" stipulates that the compensation fee for arable land to be expropriated for other uses is 3 to 6 times the value of average production of the previous year before expropriation.

The marine tidal flat has been described as unique, occupying a special ecological position in the earth's ecosystem. Therefore, the eco-benefits should also be included in the calculation of the total benefits of exploitation. The income approach does not include these eco-benefits. Income from marine tidal flats is more difficult to recover than income from transforming wasteland into arable land. Marine tidal flat resources are important for their special geographical location and biodiversity. Whenever these characteristics are destroyed, the existing form of the tidal flat will be affected directly. Therefore, when calculating the value of the tidal flat, the simple application of the land price method is not acceptable. The selected constant coefficient for the income multiplier method is discussed in the example in the following subsection.

The formula for using the income multiplier method is:

$$\text{Total value} = \text{total annual income from products sold} \times \text{coefficient/cultured area.}$$

10.3. A case study of the accounting value of marine tidal flats

In China, the marine tidal flat area includes 2.2 million hectares, of which 1.46 million hectares are within the shallow water area. According to statistics, there are 0.67 million hectares of shallow water and tidal flats suitable for aquaculture and 0.84 million hectares for salt production. At present, mariculture and sunlight-based salt production are the only industries involved in the development of shallow water tidal flat resources in China. Until 1992, the area of mariculture covered 499 040 hectares, and the area of salt production fields covered 416 347 hectares. Other developments have not yet become economic, so there is no basis for assessing their profits. This case study uses the accounting value of mariculture and of salt production to assess the value of China's marine tidal flat resources.

10.3.1. Accounting the value of tidal flats suitable for aquaculture

Of the shallow water areas, bays, and marine tidal flats suitable for aquaculture, 499 040 hectares have been developed to date. Over 10 species have been cultured, including fish, shrimp, shellfish and seaweed. In the case of aquaculture, the different characteristics of shallow water areas and tidal flats allow different species to be cultured and provide a different profit per unit area. Thus, different kinds of aquaculture are accounted for separately using the income approach and income multiplier methods.

In this case study, economic survey data (for shrimp, kelp and shellfish) of mariculture found in the *Annual Report of China's Aquatic Statistics* from 1991 to 1992 is used. The income approach and income multiplier methods are employed to calculate the price per hectare of mariculture tidal flats. In 1991, the total area surveyed was 1836 hectares, of which 1325 hectares were used for shrimp, 16 hectares for kelp and 351 hectares for shellfish. In 1992, the total area surveyed was 1626.2 hectares, of which 1017.18 hectares were used for shrimp, 13.5 hectares for kelp and 464.9 hectares for shellfish.

The results of separate accounting in accordance with equations (I) and (II) above are presented in Tables 10.1 and 10.2. Cost accounting (in Table 10.1) using the income approach method yields lower costs than those calculated under the income multiplier method.

The general approach is to determine the per hectare price of mariculture resources in shallow water and marine tidal flats. In this case, however, the

Table 10.1. Cost accounting of tidal flats (Unit: RMB yuan/hectare)

	Cost accounting by income approach method				Cost accounting by income multiplier method		
	I 7.56%	II 7.56%	I 10%	II 10%	T=3	T=4.5	T=6
1991							
Shrimp	8.91	8.85	6.73	6.69	10.64	15.95	21.27
Kelp	29.42	28.56	22.24	21.61	17.35	26.03	34.71
Shellfish	32.70	17.63	24.72	13.33	14.38	21.56	28.75
1992							
Shrimp	7.30	7.12	5.52	5.39	10.94	16.41	21.88
Kelp	26.61	26.32	20.11	19.90	13.91	20.87	27.83
Shellfish	33.81	33.61	25.56	25.41	22.75	34.12	45.49

Table 10.2. Total value of utilised tidal flats using income approach method

	1991		1992	
	Total aquacultural area (thousand ha.)	Total value (billion RMB yuan)	Total aquacultural area (thousand ha.)	Total value (billion RMB yuan)
Shrimp	139.02	93.56	147.15	81.23
Kelp	14.43	32.01	11.54	223.21
Shellfish	283.68	701.58	234.92	600.46
Sum	437.13	826.91	393.61	704.88
Total value of whole country	440.37	833.03	499.04	893.69

total value of mariculture is determined using the income approach method. In 1991, the price of maricultural tidal flats per hectare for shrimp was 66 990 to 212 700 RMB yuan, for kelp the price was 173 500 to 347 100 RMB yuan, and for shellfish it was 143 800 to 327 000 RMB yuan. In 1992, the price for shrimp was 53 900 to 218 800 RMB yuan, for kelp 139 100 to 278 300 RMB yuan and for shellfish 227 500 to 454 900 RMB yuan.

10.3.2. Accounting the value of land and tidal flat resources suitable for salt production

In the coastal area of China, there are 8400 kilometres of land and tidal flats which are suitable for salt production. Until 1990, 4200 kilometres had been developed for production, occupying 50% of the total area. Salt production, because of its importance to the Chinese economy, has been managed by the government since ancient times. After the foundation of the People's Republic of China, salt was still among the important goods and materials managed by the national planning organisation, and salt products were purchased and sold by the state. Thus, the government received all of the proceeds from the increasing tax burden on salt production.

This type of management has created a situation in which the salt producing enterprises cannot evaluate the economic value of salt production in their accounts. Therefore, the value of the land and of the tidal flats cannot be estimated from the profits of the enterprises.

Income approach method

Table 10.3 shows the value of the salt producing area in tidal flats from 1989 to 1992 using equation (II) above. The figures in Table 10.3 calculate the status of crude salt. Using a 10% interest rate to determine the price of tidal flats salt production per hectare, the price is 1000.6 RMB yuan per hectare in 1991 and 3376 yuan per hectare in 1992. The profits from salt production are lower than the profits from aquaculture. The total value of developing salt producing tidal flats was 3.926 billion yuan in 1991 and 1.406 billion yuan in 1992. Similarly, the resource values of the land and tidal flats were 8.4 billion yuan in 1991 and 2.8 billion yuan in 1992.

Table 10.3. Accounting of the tidal flat value for salt production using the income approach method, 1989–1992

	1989	1990	1991	1992
Productive area (thousand ha.)	332.3	332.2	340.2	351.6
Salt products (thousand ton)	18 857	11 486	15 118	19 782
Average sell price (RMB yuan/ton)	82.9	123.7	96.8	140[1]
Average cost (RMB yuan/ton)	60.3	81.5	74.4	80[1]
Benefit per unit area (RMB yuan/ha.)	1 288	1 457.8	1 000.6	3 376[1]
Price per unit area (RMB yuan/ha.)				
Rate=7.5%	17 037	19 283.0	13 234.9	44 656.1[1]
Rate=10%	12 880	14 578	10 005.6	33 760[1]
Total area of salt pan (thousand ha.)	368.0	376.1	392.4	416.3
Total value of salt pan (billion RMB yuan, 10%)	4.8	0.55	3.9	1.4
Total value of tidal-flat resources (billion RMB yuan)[2]	10.8	1.2	8.4	2.8

[1]Results calculated based on Tanggu and Hangu saltworks

[2]Tidal-flat area that could be utilized for salt is about 840 thousand ha.

Output value method

Due to data limitations on the output value of crude salt, the output value method could only be applied to salt fields in operation in 1991. The results are shown in Table 10.4.

Table 10.4. The value of salt pan production calculated by the output value method, 1991

Sea-salt productive areas	Area of salt pan *A* (ha.)	Total value of salt *B* (mil. RMB yuan)	*B/A* (RMB yuan)	Price of tidal-flat utilized for salt pan per hectare (RMB yuan) $T_1=3$	$T_2=4.5$	$T_3=6$
Whole country	392 424.28	2 023.87	5 157	15 471	23 206	30 942
Northern	341 668.30	1 713.53	5 015	15 045	22 567	30 090
Tianjin Prov.	39 446.00	270.32	6 853	20 559	30 838	41 118
Hebei Prov.	71 466.58	331.16	4 634	13 902	20 853	27 804
Liaoning Prov.	57 531.37	285.84	4 969	14 907	22 360	29 814
Shandong Prov.	85 750.97	682.55	7 960	23 880	35 820	47 760
Jiangsu Prov.	87 473.38	143.65	1 642	4 926	7 389	9 852
Southern	50 755.98	310.34	6 114	18 342	27 513	36 684
Hainan Prov.	4 846.80	37.11	3 006	9 018	13527	18 036
Zhejiang Prov.	13 690.12	14.56	1 064	3 192	4 788	6 384
Fujian Prov.	16 030.99	174.32	10 874	32 622	48 933	65 244
Guangdong Prov.	11 566.05	57.57	4 977	14 931	22396	29 862
Guangxi Prov.	4 622.02	26.75	5 789	17368	26 050	34 734

Discussion of the results of the two methods

Using 1991 as an example, the results of the two methods vary considerably. The output value method provides results which are generally greater than the results from the income approach. However, setting the coefficient at 3 in the output value method and the interest rate at 7.56% in the income approach yields similar results. Likewise, a coefficient of 6 in the output value case and an interest rate of 10% in the income approach yields similar accounting values for tidal flat resources.

When the output value method is used to calculate the value of salt fields per unit area in coastal provinces and autonomous regions, land prices of salt fields in the southern part of China are found to be greater than those in the northern part. When the multiplier coefficient is set at 3, the price per hectare of a tidal flat used for salt production is highest in the Fujian Province, whereas the lowest land price is found in Zhejiang Province. Based on the calculations in Table 10.4, prices of salt fields along the coast of China vary by a factor of 10.

The two methods yield different results for the price of salt fields per unit area, i.e., in 1991 the price ranged from 10 005.6 yuan using the income approach to 46 012 yuan using the output value approach. Using the income approach method (Table 10.3) to calculate the price and value of salt fields per hectare, the total value of salt fields currently in production was 4.739 billion yuan in 1989, 4.839 billion yuan in 1990, 3.926 billion yuan in 1991, and 1.404 billion yuan in 1992. The total value of land suitable for salt production was 10.8 billion yuan in 1989, 1.2 billion yuan in 1990, 8.4 billion yuan in 1991, and 2.8 billion yuan in 1992.

As a first attempt, the methods used here provide reasonable results. However, it is clear that the method should be carefully chosen depending on data availability, location of the salt pan and production techniques. In the future, efforts should be made to investigate the suitability of methodologies in different regions and testing areas.

10.4. Conclusion

The total net benefit in 1991 from the exploitation of China's marine tidal flat resources is estimated to be 1275.825 billion RMB yuan, of which 1267.425 billion yuan comes from mariculture and 8.4 billion yuan from salt production. The case study shows that the values of marine tidal flats vary across the different regions according to their utilisation and to their natural characteristics. For a particular industry, the value of using tidal flats for mariculture is greater than the value for salt production. There is, however, a wide variation in the tidal flat values within both industries, because of the different utilisation of the resources. In addition to the physical reasons for the variation in accounting values, there are two other probable reasons for the variations: first, the accounting method used now is imperfect, and second, the product prices used in the calculations may not reflect the true market value of the industry.

In this paper, the results are preliminary. To improve on the results presented here, the following work should be carried out: (1) a detailed survey of tidal flat resources, with a division into districts depending on utilisation, should be developed; (2) a value accounting system using statistics from cost-benefit analysis should be established; (3) useful theories and methods with possible application to tidal flats in China should be studied; and (4) a sub-region test area for comprehensive resource accounting research should be established.

Bibliography

Li Jinchang, 1991, Resources Accounting, Ocean Press.
Niu Wenyuan, 1989, The Development Tenets of Natural Resource, Henan University Press.

CHAPTER 11

Introduction to Forest Resources Evaluation Study in China

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11.1. Introduction

Forest, an important resource to mankind, supports in a direct or indirect way the development of human economy and society with its thousands of material or non-material products. The forest is also the main object of the continental ecological system. The successful management of forest inheritance plays a vital role in maintaining the global environment, conserving the other related resources and guaranteeing the sustainable development of economy and society. Therefore, it has become an un-neglectable subject for many countries and the international organizations in the world to conduct an evaluation on the forest resource, made to include them into the national economical evaluation system. Under the overall organization of The State Science and Technology Commission for first-phase achievement has been made on the study of forest resources evaluation, which started in 1993. For the convenience of the domestic and international communication and the successful following research work, the achievement of our first-phase work would be introduced.

11.2. An outline of forest resources in China

11.2.1. Forestry land

The area of forested land in China was 263 million ha in 1992, which occupies 27.85% of the total land area, and equals the land area of 6 Swedens or 7 Japans. But only 45.72% of the forestry land is exploited, which is far less than the level in some forestry-advanced countries in the world.

A. Lanza (ed.), Resources Accounting in China, 171–180.

11.2.2. Forest land area

Forest land area is about 134 million ha, which occupies 13.92% of the total land area. It has increased by 15 million ha compared with 1981, and the percentage forest cover has risen by 1.56%. The average forest cover percentage in the world is 22%, and China is 120th in the world.

11.2.3. Forest stock volume

Forest stock volume is the volume of living stock. According to the fourth survey statistics on the national forest resources, the forest stock volume in the whole country was 10.173 billion m^3 in 1992; of this the stock volume for coniferous forest was 4.818 billion m^3, and for broad-leaf forest 5.319 billion m^3. The ratio between the coniferous forest and broad-leaf forest was 0.48:0.52. The forest stock volume per capita in China is 9.8 m^3, which is far behind the level of some forestry-advanced countries in the world.

Regarding over-mature stock, the volume in 1992 was 2.622 billion m^3, which was 1.224 billion m^3 less than the volume in 1981. More than one-third of over mature forest resources was consumed during these 11 years and the average yearly deficit cutting was 170 million m^3.

11.2.4. Forest age structure

In 1981, the ratio between the area of young forest and half-mature forest was 71:29, and the ratio between the stock volume was 42:58. In 1993, the area ratio was 80:20, and the stock volume ratio was 54:46. Therefore, the forest resources in China are in a young tendency. At present, the low production forest (low productivity is not only in relative volume but also in relative value) makes up a large proportion of the young and half-mature forests.

11.2.5. Tree species structure

In accordance with the fourth forest survey statistics, the present forest stand area is 102.187 million ha, the non-timber product forest area is 13.7438 million ha, and the bamboo forest area is 3.5463 million ha, which occupy respectively 39.10%, 5.26% and 1.36% of the forest land area. In the stand resources, the timber forest area is 80.0696 million ha, 78.36% of the forest land area; the stock volume is 6.1731713 billion m^3 (76.3% of the forest stock volume); the area of protection forest is 14.5573 million ha (14.25%); the stock volume is 1.3996181 billion m^3 (17.3%); the areas of the fuelwood forest and the forest for special use are, respectively 4.4438 million ha and 3.1163 million ha (4.35% and 3.05% of the forest land area). The stock volumes are, respectively, 65.6204 million m^3 and 453.0805 million m^3 (81% and 5.6% of the total stock volume; Table 11.1).

Table 11.1. The area and volume of stand resources in China

	Timber forest	Protection forest	Forest for special use	Fuel wood	Total
Area (10^6 ha)	8 006.96	1 455.73	311.63	444.38	10 218.70
Ratio (%)	78.36	14.25	3.05	4.35	100.00
Volume (10^6 m^3)	617 317.13	138 861.81	45 308.05	6 562.04	809 149.03
Ratio (%)	76.30	17.30	5.60	0.81	100.00
Volume in unit area (m^3/ha)	77.01	96.15	145.39	14.77	79.18

The stand resources in Taiwan Province and outside control border of Tibet are not included

11.2.6. The geographical distribution of the forest resources

The forest resources in China are mainly distributed in Northeast, Southwest and South forest districts, which have the total area of about 5.01 million km^2, 52.2% of the land area in China. The area of forest land is 210 million ha (78.45% of the total forestry land). The forest land area is 108 million ha (86.7% of the national forest land area); the volume is 83.25%, which is 91.1% of the total stock volume in China. The distribution of the forest resources in the remote areas and high mountains, brings some difficulties to the exploitation, but it plays a good role in conserving the water source, adjusting the run-off, and protecting the soil as the forests are mostly in the upper stream of the rivers.

11.2.7. The main tree species

There is a rich variety of tree species in China: for vascular plants alone there are 353 families, 3 221 genera and 277 796 species, which are about 50% of the vascular plants in the world. There are also many endemic and superior tree species, such as *Davidia involuc rata* Baill, *Eucommia Oliv., Ginkgo L., Metasequoia* Miki ex Hu et Cheng. Concerning the superior tree species, there are such tree species as *Pinus massoniana* Lamb., *Pinus yunnanensis* Franch., and different species of deciduous pines, *Cunning hamia lanceolata* Hook., and *Fraxinus mandshurica* Rupr., *Phellodendron Amurense, Juglansmand shuricaetc* in the north, and *Cinnamomum camphora presl., Phoebe nees, Citrusgrandis Osbesk, Melia azedarach, Quercus glauca, Castanopsis fangesii, Quercus*, etc. in the south. Compared with other countries, especially those which are advanced in forestry, the evaluation of the forest resources in China has the speciality and importance in its rich content; this is also the case in comparison with the other natural resources.

11.3. The theory system on forest resources evaluation designed by us

'Forest' is the shortform for the forest ecology system. It refers to an open ecological system, which takes the forestry land as the basis, forest tree as the main object, and interdepend and interaction its living environment. Besides the forest tree, it also includes many stand-relying biological species and non-biological resources. Between the forst ecology system and environment, there exists a two-way circulation of material and energy. The circulation tunnels are quite complicated, but they are in order.

Thus, forest resources evaluation cannot be simply identified as the evaluation of forest volume. Forest value not only refers to the value of standing tree, it is not even only the material value, but also the value of non-material functions. In our opinion, the forest value can only be comprehensively reflected through the realization and evaluation of three components: stand, forestry land and forest environment resources.

Stand evaluation includes natural forest, forest plantation, non-timber product forest, shrub and rural forest network, etc.; forestry land evaluation includes forest land, non-stocked land and changeable wasteland; forest environment resources evaluation includes all other tangible and intangible, or material and non-material, or direct and indirect forest resources besides the above-mentioned stand and forestry land resources.

The other forest material or non-material resources, except the standing tree in the stand and forestry land, are all included in the forest environment resources. The forest environment resources are composed generally of the following main functions:

- Soil nutrition
- Water sources conservation
- Oxygen supply through carbon fixing
- Wild life (conservation of biology diversity)
- Tourism (forest sights, health care and culture)
- Purification (dust, poison, air)
- Noise reduction
- Control in ozonosphere destruction

The functions are, in other words, wealth and resources. It is only through the evaluation of volume, variable and value of the material and non-material functions that the forest value can be reflected in an overall scale. Only through the complete investigation of consumption in these aspects in forestry exploration can the exploration cost be completely shown.

This is the first attempt in China to evaluate the forest resources from three aspects. The former evaluations considered only academic value or the forest, and cannot, therefore, really show the input and output of forestry production. They cannot reveal the real significance of the debt of forestry exploration to nature.

11.4. The research procedure and objective designed by us

Through the above analysis, it is not difficult to see the complexity of the forest resources evaluation. That is, the subspecies resources of different type have to be separately evaluated in each step. The research procedure designed by us is:

(1) Study of forest resources price theory and price-fixing methods
- Stand
- Forestry land
- Forest environment resources

(2) Study of forest resources depreciation theory and methods
- Stand
- Forestry land
- Forest environment resources

(3) Study on forest resources (including non-material function) and circulation evaluation
- Stand stock and flow
- Forestry land stock and flow
- Forest environment resources stock and flow

(4) Forest resources value magnitude evaluation
- Stand value stock and flow
- Forestry land value stock and flow
- Forest environment resources stock and flow

(5) Analysis of the present forestry economy mechanism

(6) Study of the schedule and strategy of the involvement of forest resources into national economy evaluation system

(7) Study of scientific forestry development and the national forestry strategy

Our objective is, using the seven-step studies of the above mentioned three aspects, to establish theory and evaluation system that will realize a fundamental change in the traditional forestry ideology, concepts and management mechanism, and put it into the sustainable development frame in the 21st century. Together with the research engineering in the other fields, a new development model of the combination between environment and development in the 21st century will be formed.

Due to time and scale, we have only performed some initial research work on the first and fourth steps since 1993. Some methods are known and calculations have been conducted in accordance with the official statistics relating to the existing material. They are not comprehensive, even if we only refer to these two steps. The main problems are:

- Some price-fixing methods adopted are not mature enough.
- Many price theories concerning forest environment resources have not been studied (only 5 types have been studied initially).
- The variability of stand and forestry land has not been evaluated; as a result, a variable is lacking. Regarding the value evaluation of the existing volume, there are still some places which need further consideration. A discussion method is proposed, but the evaluation model is extensive, and the data are not completely reliable.
- The proof study is wanting in all parts.
- The measuring methods on many environment resources functions are not sure and reliable, or the scientific methods have not been found. Our evaluation is beginning but there are still many unknown things which need further exploration. Many discoveries are not definite; therefore, there is still much work to be carried out.

11.5. Evaluation methods

11.5.1. Evaluation of the value of forest

Standard price method
Multiplying the forest growing stock by the relevant prices of forest, that is:

$$J = \sum_{i=1}^{m} \cdot \sum_{j=1}^{n} Vij \cdot Tij$$

where J = the value of forest, Vij = forest growing stock of species (i) and age class (j) during the inventory, Tij = standard prices of forests of tree species (i) and age class (j)

Regional level method
According to the principle of area price of forest and the 'Hedelin' rule, Chinese forest was divided into 30 price areas (exclusive of Taiwan Province). The value of forest in Jiangxi Province was calculated based on a survey. Then, the value of different forest categories in each province of China in 1990 and

1992 was calculated with the growing stock and cultivation system productivity index (CSPT) of each were calculated as:

$$J_i' = K_1 \times K_2 \times J'$$

where J_i' = the value of forest in province (i) in China in 1990 (or 1992); K_1 = the coefficient of readjustment to take into account growing stock variation, $K1 > 0$; K_2 the coefficients of readjustment to take into account CSPI's index variation, $K2 > 0$; J' the value of forest in Jiangxi Province in 1990 (or 1992).

$$\mathrm{CSPI} = \mathrm{NP} \cdot \mathrm{EP} = \frac{\sum_{i=1}^{n}(r_i \cdot y_i) \cdot \mathrm{NV}}{\mathrm{S} \cdot \mathrm{AL}}$$

where r_i = the coefficient which turns the catch crop into energy for year *i*; y_i = the total yield of economic product *i*; S = usable soil area of the system; NV = net value of output; AL = the labour force of the system; EP = economic productivity; NP = NV/AL.

11.5.2. Evaluation of the value of forest land

Income method

Forest land price = (net income of forest land per year)/(profit return on the investment)

Net income of forest land = total income of forest land–total expenditure of forest land. According to experience, profit returned on the investment is about 6% and is readjusted to the CSPI. The price and value of forest land in China was calculated by the income method.

Profit multiplier method

Forest land price = (total income per year) × multiplier

Forestry real value of output was taken as 16.9% agricultural total value of output. From getting the mean output value of cultivation crops in China, the value of forest land in China was then calculated by the mean multiplied by 6.

11.5.3. Appraisal on the value of partly-forest environmental resources

Forest for valuing water resources

Water resource value of forest was evaluated by the water balance method of forest area and the price that was set on the cost of water conservation with reservoir.

The value of forest protective soil

Soil erosion in the natural condition with no trees and the amount of soil conservation in forest land were calculated by a comparative study. The value of forest protective soil, that is, the economic value of soil conservation with forest, was calculated in China in 1990 and 1992 according to the amounts and the value that soil erosion causes matter and economic losses.

The value of forest absorbing CO_2 and providing O_2

The value of forest absorbing CO_2 per year was calculated by the cost fixed CO_2 in artificial condition. The value of forest providing O_2 per year was calculated by the cost of planting trees.

In addition, eight appraisal methods of amenity value of forestry that is, direct cost, mean cost, expenditure, opportunity cost, travel cost, contingent value and market method etc. were discussed. Four appraisal methods for the economic value of wildlife in forest were also introduced.

11.6. Results

Table 11.2 is the value calculation of the existing volume in some resources.

Table 11.2. The value of forest resources in China (Unit: trillion yuan (RMB))

	Standard prices method	Regional level method
Stand value	2.500759	1.146645
Forest land value	3.349655	2.015477
Forest environment resources value (only 3 types are calculated)	7.898000 (718.900 billion yuan/year)	
Total	13.748414	11.060122

The above evaluation is extensive, a testing evaluation. It is obvious that such non-timber forests as *Camellia sinensis* Kuntze and *Morusalba L.*, and the wasteland, which can be changed into the forestry land are not included in the evaluation. Most types of forest environment functions were not evaluated. There exists certainly an error in the evaluated part of the existing resources volume.

11.7. Conclusions

In spite of these, this initial achievement is still valuable. First, the forest resources value in China is approximately estimated based on a relatively scientific calculation, which plays a propagation role in improving the forestry position. Second, with reference to the value evaluation of only three forest environment resources, it has been proved that the value of the forest ecology environment is bigger than that of the standing tree. Third, the systmatic regulation of different theories and methods on forest environment resources value evaluation provides a basis for the forest ecology profit compensation mechanism, in which these achievements have been adopted. Fourth, the evaluation of stand and forestry land markets supplies a price-fixing reference to the recently developing stand market exchange and forestry land market exchange. Fifth, the total evaluation is helpful for the specification of meditating forest resources asset management.

In October 1994, the research report had been expounded and proved by tens of experts inside and outside the forestry system and some delegates from the synthetical management institutions in some countries invited by the Science and Technology Committee under the Ministry of Forestry. It had been expected that only 40 people would attend the meeting, but 70 people were present. This proves that it has great importance. The present experts admitted the significance of this project and the initial research achievement; moreover, some places which need further improvement had been pointed out. The present directors from some related administration institutions also expressed their support for this research work. After the meeting, the main news medium in Beijing reported it widely, which attracts further attention from the society on the project. At present, some institutions like Da Xing An Ling Forestry Administration Bureau, Beijing Forestry Bureau, Hainan Forestry Bureau and some other institutions in he Bei province, Yulin Prefecture in Gangxi Zhuang Autonomous Region have contacted us and are expected to cooperate in the next step of the research work. We are willing to fulfil their proposals as we can, on one side, carrying out a testing evaluation in the whole Hainan Province in 1995; on the other side cooperating with the above-mentioned other districts in forming some kind of research network so as to plan for the realization of the pioneering project and research objective from the angles of theory and practice during the 9th Five Years' Program according to the above research procedure.

References

Anthony, C.F. et al., 1987, Quasi-potion value: some misconceptions dispelled, Journal of Environmental Economics and Management, 14, 183–190.

Bateman, I., 1991, Recent developments in the evaluation of non-timber forest products: the extended CAB method, Quarterly Journal of Forestry, 85, 90–102.

Bateman, I., 1991, Placeing money values on the unpriced benefits of forest, Quarterly Journal of Forestry, 85, 152–165.

Bi, B., 1993, Land economics, Beijing: China People University Press.

China Forestry Yearbook, 1989, Beijing: China Forestry Press.

China Forestry Yearbook, 1990, Beijing: China Forestry Press.

Daniel, J.D. et al., 1986, Existence values and normative economics: implication for valuing water resources, Water Resources Research, 22, 1509–1518.

Daniel, K. et al., 1992, Valuing public goods: the purchase of moral satisfaction, Journal of Environmental Economics and Management, 22, 57–70.

David, S.B. et al., 1985, Forestry and benefit–cost analysis, Journal of World Forest Resources Management, 1, 189–198.

David, W.P. et al., 1990, Economics of Natural Resources and Environment.

Douglas, M.J. et al., 1992, Can non-use values be measured from observable behavior, American Journal of Agricultural Economics, 74, 1114–1120.

Dwyer, J.F. et al., 1985, Assessing the benefit and cost of the urban forest, Journal of Arboroculture, 8, 227–234.

Glenn, W.H., 1992, Valuing public goods with the contingent valuation method: a critique of Kahnement and Knetsch, Journal of Environmental Economics and Management, 23, 248–257.

Guillard, J., 1982, What is the Research Field and Object of the Forestry Economics, France: ENGREF.

He, Y. et al., 1988, Economic Cybernetics, Southwest Communication University Press.

Hou, Z. et al., 1990, Supply and Demand for the Timber in China, Beijing: China Scientific and Technical Press.

Kalle, S. et al., 1992, Willingness to pay for environmental goods in Norway: a contingent calculation study with real payment, Environmental Resource Economics, 2, 91–106.

Kerry, V.S., 1993, Non-marker valuation of environmental resource: an interpretive appraisal, Land Economics, 69, 1–26.

Kong, F. et al., 1998, Theoretical Method and Applying for Forestry Output Value, Beijing: China Forestry Press.

Li, Y. et al., 1991, Introduction to the Western Modern Micro-Economics, Beijing: Higher Education Press.

Liao, S., 1987, An Introduction to Forestry Economics, Beijing: China Forestry Press.

Lu, S.-C. et al., 1993, Quantitative analysis on agricultural productivity, Journal of Ecology, 12, 12–22.

Lu, S. et al., 1991, Grey Theory and its Apply, Zhengzhou: Henan University Press.

MOF, 1988, Forestry Resources Report in China (1984–1988), The Chinese Forestry Publishing House.

Mohan, M., 1992, Biodiversity protection policy: environmental valuation and distribution issues. AMBIO, 21, 227–236.

Nautigal, J.C. et al., 1985, Forestry and benefit–cost analysis, Journal of World Forest Resources Management, 1, 189–198.

Peyron, J.-L., 1992, Value Evaluation on Forest, France: ENGREF.

Wang, X., 1992, The Economic Problem of National Resources Exploitation, Beijing: Science and Technology Document Press.

Wu, C., 1992, Study on tour value of national forest park at Zhang Jia Jie in China, Forestry Science, 28, 423–430.

Yan, X. et al., 1993, Urban Land Property Evaluation, Beijing: China People University Press.

Zhai, Z. et al., 1993, Forestry Economic Geography in China, Beijing: China Forestry Press.

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