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Policy Applications of Environmental Accounting

Glenn-Marie Lange

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1 Introduction

The first environmental accounts (EA) were constructed by Norway in the 1970s and were only slowly adopted by other countries. In the early 1990's, the World Bank conducted a review of (EA), providing a compendium of which countries had compiled environmental accounts, the methods that had been used to construct EA, and the extent of coverage (Peskin and Lutz, 1990). Since that time, EA have increasingly been recognized as a useful economic tool, resulting in a great deal of activity in both developed and developing countries. Over the last decade, conceptual and technical aspects of construction EA have received a great deal of attention; however, much less is known about how EA are being used for policy.

The motivation for EA has been the adoption by governments, at least in principle, of the notion of sustainable development, coupled with the understanding that economic activities and appropriate economic incentives play a central role in determining whether development is sustainable or not. EA provide policy-makers a) with indicators and descriptive statistics to monitor of the interaction between the environment and the economy, and progress toward meeting environment goals; and b) with a database for strategic planning and policy analysis to identify more sustainable development paths, and the appropriate policy instruments for achieving these paths.

This report reviews the policy applications of EA in industrialized and developing countries, and also indicates potential applications, which may not be fully exploited at this time. The report is intended to serve as a guide for countries implementing EA by showing how EA can support policy decision-making. It may also assist EA practitioners and scholars by providing them with a better understanding of the needs of end-users of the accounts.

Table 1 identifies the major countries that are constructing EA on an on-going basis in their statistical offices or other government ministries. These countries have the most extensive experience with policy use of the EA and provide the core of this report. Most of the work is being done in Europe, Australia, and Canada and a relatively few developing countries. Of the developing countries, the Philippines, Botswana, and Namibia are particularly important because policy analysis was built into the EA project design. There are countless other one-time or academic studies; a few which are referred to in this report and are also listed in Table 1.

The second section of the report provides a brief review of the different approaches to EA, beginning with a discussion of the concepts of sustainability that underlie different EA methodologies. The methodologies are reviewed mainly as they relate to the System of Environmental and Economic Accounts (SEEA), the handbook for EA developed by the United Nations, Eurostat, OECD, World Bank, and other agencies (UN, 1993, currently under revision). The applications themselves are described in four subsequent chapters organized around the structure of the EA: asset accounts (section 3), flow accounts for materials and pollutants (section 4), environmental protection and resource management expenditures (section 5), and macroeconomic indicators (section 6). The final section provides concluding remarks about the use of EA for policy.

Table 1. Countries with environmental accounting programs

	Assets	*Flow accounts for pollutants & materials*		*Environmental protection & resource management expenditures*	*Macro aggregates*
		Physical	*Monetary*		
Industrialized countries					
Australia	X	X		X	
Canada	X	X		X	
Denmark	X	X		X	
Finland	X	X		X	
France	X	X		X	
Germany	X	X	X	X	X
Italy	X	X		X	
Japan	X	X	X	X	X
Norway	X	X			
Sweden	X	X	X	X	X
UK	X	X		X	
US	X			X	
Developing countries					
Botswana	X	X	X[a]		
Chile	X		X[a]	X	
Korea	X	X	X	X	X
Mexico	X	X	X	X	X
Moldova		X[a]			
Namibia	X	X	X[a]		
Philippines	X	X	X	X	X
Occasional studies					
Colombia		X	X	X	
Costa Rica				X	
Eu-15			X		
Indonesia	X				
South Africa	X	X	X[a]		

Notes: [a] accounts for water only.

Other European countries have also constructed environmental accounts but are not included here because of the limited policy analysis of the accounts.

2 Methodological Approaches to Environmental Accounting

Environmental and resource accounting evolved since the 1970s through the efforts of individual countries or practitioners, each developing their own frameworks and methodologies to represent their environmental priorities. Since the early 1990s, concerted efforts have been underway through the United Nations Statistics Division, the European Union, the OECD, the World Bank, country statistical offices, and other organizations to standardize the framework and methodologies. The United Nations published an interim handbook on environmental accounting in 1993 (UN 1993), which is currently under revision. The discussion below describes the different methodologies and how they are related to the revised SEEA.

Environmental accounts have four components:

- Natural resource asset accounts, which deal mainly with stocks of natural resources and focus on revising the Balance Sheets of the System of National Accounts (SNA)
- Pollutant and material (energy and resources) flow accounts, which provide information at the industry level about the use of energy and materials as inputs to production and final demand, and the generation of pollutants and solid waste. These accounts are linked to the Supply and Use Tables of the SNA, which are used to construct input-output (IO) tables.
- Environmental protection and resource management expenditures, which identifies expenditures in the conventional SNA incurred by industry, government and households to protect the environment or manage resources
- Environmentally-adjusted macroeconomic aggregates, which include indicators of sustainability such as environmentally-adjusted Net Domestic Product (eaNDP).

This section begins with a discussion of concepts of sustainability and the implications for approaches to measuring sustainability, then discusses each component of the environmental accounts.

2.1 Concepts of sustainability

While this report cannot review all the literature about sustainability (see Pezzey (1989, 1994) for such a review), a brief discussion of the topic is necessary in order to understand some of the issues underlying the different approaches to environmental accounting. The Brundtland Commission Report, *Our Common Future*, popularized the notion of sustainable development as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). This rather vague concept resonates with the economist's basic notion of sustainability, whose starting point has been the idea of income expressed by John Hicks "…income is the maximum amount an individual can consume during a period and remain as well off at the end of the period as at the beginning." (Hicks 1946). Hicks' statement has generally been interpreted as the amount of income that can be spent without depleting the wealth which generates the income.

Hence, sustainability requires non-decreasing levels of capital stock over time, or, at the level of the individual, non-decreasing per capita capital stock. Indicators of sustainability could be based on either the value of total assets every period, or by the change in wealth, consumption of capital (depreciation) in the conventional national accounts. For a proper measure of sustainability, all assets should be included in such an indicator: manufactured capital, natural capital and human capital. In the past, only manufactured capital was recorded in the SNA, but the recognition of the importance of natural capital has led to the expansion of the asset boundary to include this asset. (Human capital has not yet been included because there is no agreement about how to measure it and is not discussed further.)

Economic sustainability can be defined as strong or weak, reflecting controversy over the degree to which one form of capital can substitute for another. Weak sustainability requires only that the combined *value* of all assets remain constant, that is, it is possible to substitute one form of capital for another, so natural capital can be depleted or the environment degraded as long as there are compensating investments in other types of capital: manufactured, human, or other type of natural capital.

Strong sustainability is based on the concept that natural capital is a complement to manufactured capital, rather than a substitute. Renewable resources such as fish or forests, can be exploited only at the natural rate of net growth; the use of non-renewable resources should be minimized and, ideally, used only at the rate for which renewable substitutes are available; emissions of wastes should not exceed the assimilative capacity of the environment. The indicator of sustainability requires that all natural capital is measured in physical units. A less extreme version of strong sustainability accepts some degree of substitutability among assets, but recognizes that there are some "critical" assets which are irreplaceable. The corresponding measure of sustainability would be partly monetary (for those assets, manufactured and natural, which are not critical and for which substitution is allowed) and partly physical, for critical natural assets.

Das Gupta and Maler (2000) have argued that prices can fully reflect sustainability and the limits to substitution. Hamilton (2000) points out the highly restrictive and unlikely conditions that must be fulfilled in order for prices to provide a true measure of sustainability.

2.2 Asset accounts

Natural resource asset accounts follow the structure of the asset accounts of the SNA, with data for opening stocks, closing stocks, and changes during the year. The changes that occur during the period are divided into those that are due to economic activity (e.g., extraction of minerals or harvesting of forests), and those that are due to natural processes (e.g., growth, births, and deaths) or other factors. There is some controversy over how to treat new discoveries of minerals: as an economic change (the result of exploration activities), or as part of other volume changes. The monetary accounts for resources have an addition component, like manufactured capital, for revaluation.

Measurement of the physical stocks can present problems both in terms of what to measure as well as how to measure. In some earlier versions of subsoil (mineral) asset accounts, only economically proven stocks were included in the asset accounts. Some countries have modified this to include a portion of probable and possible stocks, based on the probability of these stocks becoming economically feasible to mine. Certain resources, like marine capture fisheries are not observed directly and require biological models to estimate stocks and changes in stocks.

Two methods have been used to value assets: net present value (NPV) and net price. The NPV method, that is, the discounted sum of its future income stream, is the theoretically correct method for asset valuation, and it has been recommended by the revised SEEA. The income stream is calculated as the net price, which is the price of an asset minus the marginal costs of extraction. In practice, net price is often calculated as price minus the average costs of extraction because information about marginal costs are unavailable, often leading to an upward bias in NPV.

It is best to calculate net rent from establishment data, but when the information is not available, aggregate data from the national accounts are used. Whatever the source of data, it is necessary to estimate two components of cost included in the operating surplus, or mixed income part of value-added. The first is the cost of capital, or so-called "normal profit," which is usually viewed as either the cost of borrowing capital or the opportunity cost of capital. The second component is the earnings of the self-employed. This is essentially a payment for labor which is not included in compensation of employees because, as the owners of business, the self-employed do not pay themselves an explicit wage.

The NPV method of valuation requires assumptions about future prices and costs of extraction, about the rate of extraction, and about the discount rate. It is often assumed that net price and level of extraction remain constant, although when information is known about planned extraction paths, or expected future prices, this information can be incorporated. A wide range of discount rates have been used by different countries.

In much of the early work on environmental accounting (e.g., Repetto and others 1987, Bartelmus and others 1992, Van Tongeren and others 1993, UN 1993), the net price method was used to value assets rather than NPV. The net price method simply applies the net price in a given year to the entire remaining stock. Based on an interpretation of Hoteling's Rule, it is equivalent to the NPV method under the restrictive assumption that the net price increases at the same rate as the discount rate. Although this assumption is unrealistic, the net price method was widely used because it appeared to avoid the need to project future net price or extraction paths. However, the method did not really avoid the need to make these projections, it simply made it unnecessary to make them explicit.

The revised SEEA recommends NPV, and this method has come to be more widely used than the net price method in more recent work. The only significant exception has been the work on forest assets by Eurostat (2000b), which used several methods, including variation of NPV and net price. NPC is used by Eurostat for valuation of subsoil assets (2000a).

Regardless of the method, most asset valuation has focused on the dominant commercial use of a resource. Some assets may have multiple uses. For example, forests, in addition to providing timber, may have a direct commercial use for the recreation industry, as well as other important but less direct uses, e.g., carbon sequestration, or watershed protection. In principle, all these values should also be included in the value of the forest; in practice, they may not be included.

Depletion and depreciation

One of the major motivations for the preparation of asset accounts has been to account for the depletion of natural capital. This is particularly important for resource-rich countries which may appear to perform well according to conventional economic indicators, but in fact are living off their (natural) capital in a manner that cannot be sustained indefinitely. The cost of depletion was initially measured as the value (net price) of extraction of non-renewable resources, and, for renewable resources, the value of the volume of harvest above sustainable yield.

It has since been recognized that this concept, derived from ecological concepts of sustainability, is not consistent with the economic concept of depreciation used for manufactured assets in the SNA. (For further discussion, see Davis and Moore (2000) or Vincent (1999)). El Serafy (1989) proposed one method of estimating depreciation, but it is not consistent with the economic definition of depreciation and has not been widely used. The revised SEEA proposes a measure of depletion cost more consistent with economic depreciation: the change in the asset value from one period to the next. However, several alternative ways to measure this cost have been proposed and no consensus has yet been reached (Ryan 2000). As a result of the uncertainty over measurement of depreciation of natural capital, most countries do not measure it.

2.3 Pollution and material flow accounts

Pollution and material (including energy and resource) flow accounts track the use of materials and energy and the generation of pollution by each industry and final demand sector. The flows are linked through the use of a common industrial and commodity classification to IO tables and Social Accounting Matrices (SAMs), as exemplified by the Dutch NAMEA framework, which has been adopted by Eurostat and the revised SEEA manual. Much of the work on environmental accounts has been pioneered by industrialized countries and reflects their major policy concerns.

Physical accounts

The most widely available accounts are for energy and air emissions, especially emissions linked to the use of fossil fuels. Energy accounts have been constructed by many countries since the dramatic oil price increases of the 1970s, and, since many air pollutants are linked to energy use, it is relatively simple to extend the accounts to include these pollutants. Transboundary flows of atmospheric pollutants that cause acid rain has been a major policy concern throughout Europe for more than two decades. More recently, the concern with climate change has made tracking greenhouse gas emissions a priority. Accounts are also constructed for other air pollutants, water pollutants, solid waste, and other forms of environmental degradation such as soil erosion. In a growing number of countries, especially water-scarce countries, water accounts are a high priority (Australia, France, Spain, Chile, Moldova, Namibia, and Botswana).

Some studies have attempted to fully account for all environmental services including such items as watershed protection provided by forests and open space, pollination of agricultural crops by wild bees, recreation, and aesthetic enjoyment of the environment (Nordhaus and Kokkelenberg 1999). This is very difficult and not commonly undertaken.

Monetary accounts for environmental degradation

In many countries, assigning an economic value to environmental benefits and damage may be considered the most effective way to influence policy, if not the most efficient way to design policy. However, there remains controversy over whether these monetary estimates are properly part of the environmental accounts or a separate analysis of the (physical) accounts. Most countries attempt some valuation, even if outside what they define as the environmental accounts, using one (or sometimes both, for comparison) of two different approaches to valuation:

- Maintenance, or avoidance, cost approach, which measures the cost of measures to reduce pollution to a given standard
- Damage cost approach, which measures the actual damage caused by pollution, in terms of, for example, reduced agricultural productivity due to soil erosion, increased corrosion of structures from acid rain, or damage to human health from water pollution.

In addition, the willingness-to-pay methodology can be applied to environmental degradation, although it is not widely used at this time.

Measuring maintenance cost requires setting a level of acceptable emissions (which may be zero) and calculating the cost of introducing technology to reduce current emissions to that level. It is often, though not always, assumed that the end-of-pipe, pollution abatement technology would be used, rather than a redesign of industrial processes to prevent pollution. For example, the avoidance cost of pollution from motor vehicles often assumes the use of catalytic converters added on to vehicles, rather than policies to reduce use of motor vehicles, such as subsidies for mass transit. The pollution abatement approach is attractive for several reasons: it is clearly consistent with the polluter pays principle; in the past, abatement technology dominated technological solutions; and in many instances, abatement cost is relatively easy to measure than other approaches. In the above example, it is much easier to estimate the cost of widespread use of catalytic converters than to estimate the necessary mass transit subsidies and the development of the corresponding mass transit infrastructure.

Industrialized countries have a relatively long experience with pollution abatement, so that they can estimate the costs of reducing pollution. Developing countries do not have such extensive experience and often “borrow” expenditure data from other countries (a method called benefits transfer) to calculate coefficients for expenditure on pollution control per unit of output. These are then used as a crude estimate of the expenditures that would be required in order to reduce pollution in the country in question.

Calculating damages caused by pollution is much more difficult. Damages include loss of agricultural productivity or productivity of other resources, accelerated corrosion to structures, and damages to human health. Although it is theoretically the best method, it has not been used as often as the maintenance cost approach.

Monetary accounts for non-marketed resources
Valuation issues discussed in the SEEA have largely focused on environmental degradation, but other non-market goods and services also need to be valued. The use of near-market goods like non-market firewood or wild food products are, in principle, included in the SNA, and many countries have included some estimate of these resources in the conventional national accounts. Water, on the other hand, is an example of an economically important resource that is often either unpriced, or priced in a way that is not related to its true economic value. Water valuation can be quite difficult and even in the revised SEEA little guidance has been offered.

2.4 Environmental protection and resource management accounts

This third component of the SEEA differs from the others in that it doesn’t add any new information to the national accounts but reorganizes expenditures in the conventional SNA that are closely related to environmental protection and resource management. The purpose is to make these expenditures more explicit, and thus, more useful for policy analysis. In this sense, they are similar to other satellite accounts, such as transportation or tourism accounts, which do not necessarily add new information, but reorganize existing information. This set of accounts has three quite distinct components:

- Expenditures for environmental protection and resource management, by public and private sectors
- The activities of industries that provide environmental protection services
- Eenvironmental and resource taxes/ subsidies.

The United States pioneered the collection of environmental protection expenditure (EPE) data in 1972, but has curtailed this data collection effort in the mid-1990's. The European Union (European System for Environmental Expenditure Information, or SERIEE) and the OECD (Pollution Abatement and Control Expenditure system, or PACE) have compiled environmental protection expenditure accounts throughout the 1990s. These data are generally obtained from industry surveys.

Expenditure for environmental protection represent part of society's effort to prevent or to reduce pressures on the environment. However, the interpretation of indicators from the EPE accounts can be ambiguous. The EPE concept works best for end-of-pipe, pollution abatement technologies in which an additional production cost is incurred to reduce pollution. However, the growing trend in pollution management stresses pollution prevention through redesign of industrial processes rather than end-of-pipe technology. New technology may be introduced, perhaps during the normal course of replacement and expansion of capacity or for some other reason, that reduces pollution. There is currently no way to estimate how much of the cost of this new technology, if any, should be attributed to environmental protection expenditures. In some instances, process-integrated measures that reduce pollution may reduce costs and pollution simultaneously. The EU is responding to this problem by beginning to collect data about the use of integrated-process technologies. Surveys of recycling are also included.

These problems make spending on EPE extremely hard to interpret and, therefore, of more limited policy use. An increasing or decreasing EPE cannot be interpreted unambiguously as either a positive or negative trend. If EPE accounts are constructed at the *firm* level and tied to physical flow accounts at the firm level, then one can one interpret the data, and even then, only with the help of additional information to determine whether additional measures not included in EPE accounts were also undertaken.

2.5 Macroeconomic indicators

The three sets of account described above each provide a range of indicators, but, with the exception of the asset accounts, these indicators do not directly affect the conventional macroeconomic indicators such as GDP and NDP. Many practitioners have searched for a way to measure sustainability by revising conventional macroeconomic indicators or by producing alternative macro indicators in physical units. Table 2 lists the major environmental macroeconomic indicators.

Physical indicators

Macroeconomic indicators measured in physical units have been proposed either as an alternative to monetary indicators, or to be used in conjunction with monetary aggregates in assessing economic performance. Physical indicators reflect a strong sustainability approach. The two major sources of physical macroeconomic indicators are the NAMEA component of the SEEA flow accounts and Material Flow Accounts, which are closely related to environmental accounts (see section

Table 2. Environmental macroeconomic indicators, physical and monetary

A. Physical Aggregates

Aggregates	*Title*	*Basis*
Physical macroeconomic aggregates		
NAMEA Theme Indicators, No acronym	Theme indicators for greenhouse gas emissions, acidification, eutrophication, and solid waste	Derived from the NAMEA system, embedded in the SEEA flow accounts
TMR, DMI, NAS, TDO, DPO	Total Material Requirements, Direct Material Input, Net Additions to Stock, Total Domestic Output, Domestic Processed Output	Derived from Material Flow Accounts

B. Monetary Aggregates

Aggregates	*Title*	*Basis*
1. Measures that revise existing macroeconomic indicators		
daGDP, daNDP, daGNI, daNNI	Depletion adjusted product and income measures	Subtract depletion of natural capital assets from macroeconomic aggregates
eaNDP, eaNNI	"Environmentally adjusted" product and income	Subtract depletion of natural capital and environmental degradation based on maintenance cost from macroeconomic aggregates In some implementations, part of EPE are subtracted.
Genuine income (gY)	NNI less damage costs; (related to genuine savings, goods and services)	Subtract depletion of natural capital and environmental degradation based on damage cost from macroeconomic aggregates
Genuine Savings, no acronym	Genuine Savings	Revise conventional measure of Savings for net change in natural capital and human capital
2. Measures that estimate new, hypothetical macroeconomic aggregates		
Hueting's Sustainable national income (SNI)	Sustainable income measure preserving environmental services	Modeling of hypothetical GDP, GNI if economy was forced to meet environmental standards using currently available technology
geGDP, geNDP, geGNI, geNNI	"Greened economy" product and income measures,	Modeling of hypothetical GDP if hypothetical environmental protection costs were required
Other forms of sustainable GDP, NDP, GNI, NNI	No technical term	Modeling of hypothetical GDP from a range of either short- and medium-term options (e.g., carbon tax) to long term strategic analysis of alternatives for sustainable development

Source: Part B adapted from Table 1, Chapter VIII of the revised SEEA (UN and others 2000).

4.1.B for further discussion of MFA and the SEEA).

The NAMEA provides physical macroeconomic indicators for major environmental policy themes: climate change, acidification of the atmosphere, eutrophication of water bodies, and solid waste. These indicators are compiled by aggregating related emissions using some common measurement unit, such as carbon dioxide equivalents for greenhouse gases. The indicators are then compared to a national standard—such as the target level of greenhouse gas emissions—to assess sustainability. The NAMEA does not, however, provide a single-valued indicator which aggregates across all themes.

The Material Flow accounts (MFA) provide several macro indicators; the most widely known is total material requirements (TMR) (see Bartelmus and Vesper (2000), World Resources Institute (2000)). TMR sums all the material use in an economy by weight, including so-called "hidden flows," which consist of materials excavated or disturbed along with the desired material, but which do not themselves enter the economy. In contrast to NAMEA theme indicators, TMR provides a single-valued indicator for all material use. Sustainability is assessed in terms of "dematerialization" such as Factor 4 (halving resource use while doubling wealth (von Weisäcker and others 1997). However, TMR does not differentiate materials by their environmental impact—highly toxic materials are simply added to materials like timber or gravel that may be much less environmentally damaging. Consequently, the sustainability goals set under this framework appear rather vague to be used as guides to policy, and require more disaggregation, by material and by industry, to be interpreted correctly. See Cleveland and Ruth (1999) for a criticism of these physical indicators of dematerialization.

Monetary indicators

The purpose of most monetary environmental macroeconomic aggregates has been to provide a more accurate measure of sustainable income. The first approach revised conventional macroeconomic indicators by adding and subtracting the relevant environmental components from the SEEA, the depletion of natural capital (daNDP) and environmental degradation (eaNDP) (O'Connor 2000). The adjustment of NDP for asset depletion (daNDP) is accepted in principle by most economists and statisticians, even though there is not yet a consensus over the correct way to measure it. Environmentally-adjusted NDP has been criticized for combining actual transactions (conventional NDP) with hypothetical values (monetary value of environmental degradation). If the costs of environmental mitigation had actually been paid, relative prices throughout the economy would have changed, thereby affecting economic behavior and, ultimately, the level and structure of GDP and NDP.

A macro indicator related to eaNDP is Genuine Savings, reported in the World Bank's *World Development Indicators* (Kunte and others 1 98, Hamilton 2000, World Bank 1999). It attempt to measure changes in asset values rather than income. According to economic theory, (weak) sustainability requires that wealth is non-declining over time. Many countries do not have comprehensive balance sheets, so it is not yet feasible for them to monitor wealth. However, it is possible to measure savings more accurately, which indicates how wealth is changing, and whether the trend is sustainable or not. Genuine savings adjusts gross domestic savings for consumption of fixed capital, investment in human capital, changes in natural capital, and environmental damage.

The criticism of eaNDP led to the construction of a second approach to constructing indicators, which asked the question, what would GDP or

NDP have been is the economy were required to meet sustainability standards. These indicators of a hypothetical economy are derived through economic modeling. Two modeling approaches were developed:

- Hueting's Sustainable National Income (SNI) which estimates what the level of national income would be if the economy met all environmental standards using currently-available technology (Verbruggen and others 2000)
- geNDP which estimates how the economy would respond if the estimated maintenance costs were internalized in the economy.

Hueting's SNI is the maximum income that can be sustained without technological development (excluding the use of non-renewable resources). It is not meant to represent what the economy should look like, but rather, to show to policy-makers the distance between the current economy and a sustainable economy. The geNDP approach is a bit less restrictive, technological change is possible, depending on the time period for the transition. The purpose of this approach is to provide policy-makers with guidance about the environmental impacts of alternative development paths and the most efficient policy instruments for meeting environmental objectives.

Identifying a sustainable national income is a highly complex undertaking. It requires economic modeling that includes assumptions about the environmental standards to achieve, the technological means to achieve them, the response to policy instruments, and the usual range of assumptions for an economic model: income and price elasticities, impacts on trade, etc. Different combinations of these options and assumptions about the future will result in quite different levels of sustainable national income. Much depends on the period of time over which sustainable income would be achieved. Because of this complexity, no studies have produced indicators that are comparable across countries.

3 Asset Accounts

One of the fundamental indicators of a country's well being is the value of its wealth over time. The discussion of sustainability indicated that there are different views about how wealth should be measured, i.e., if all forms of wealth can be measured in monetary terms (weak sustainability) or if wealth must be measured in some combination of monetary and physical units (strong sustainability). Whether one chooses to aggregate different forms of wealth, and whether one interprets the aggregate figure as an indicator of sustainability or not, it is certainly necessary for a country to monitor its wealth over time. While non-declining national wealth does not guarantee sustainable development, declining national wealth almost certainly a cause for concern. Better, more comprehensive accounts for national wealth can only improve the ability of researchers and policy-makers to make informed decisions.

This section begins with a review of the way asset accounts contribute to more effective monitoring of national wealth, then discusses how the asset accounts can be used to improve management of natural capital. Some of the issues that are addressed include:

Monitoring national wealth
- *Physical stocks* of natural capital and the *total economic value* of produced and non-produced assets
- *Change* in per capita wealth over time
- *Depletion* of natural capital and the *economic cost* of depletion.

Analysis of the management of national wealth
- · Is the *resource rent being recovered* successfully by government through economic instruments
- Is rent used to promote a *sustainable economy*—e.g., rent from non-renewable resources reinvested in other activities that can take their place
- Is the *maximum rent* being generated by natural resource policies
- If not, are there *other socio-economic objectives* that are being met, such as support to rural economies, or employment creation, and what is the economic cost of meeting these other objectives.

3.1 Monitoring total wealth and changes in natural capital

The asset accounts provide fundamental indicators to monitor sustainability: the value of wealth and how it changes from one period to the next through depreciation or accumulation. Although total wealth and per capita wealth, expanded to include both manufactured and natural assets, are useful indicators, not many countries compile such figures yet. Instead, many countries have focused on compiling accounts for individual resources and sometimes estimating depletion of natural capital, which is used to compile a more comprehensive measure of depreciation than is found in the conventional national accounts. This section begins with a review of the use of the asset accounts to measure wealth, and then turns to measures of depletion and depreciation.

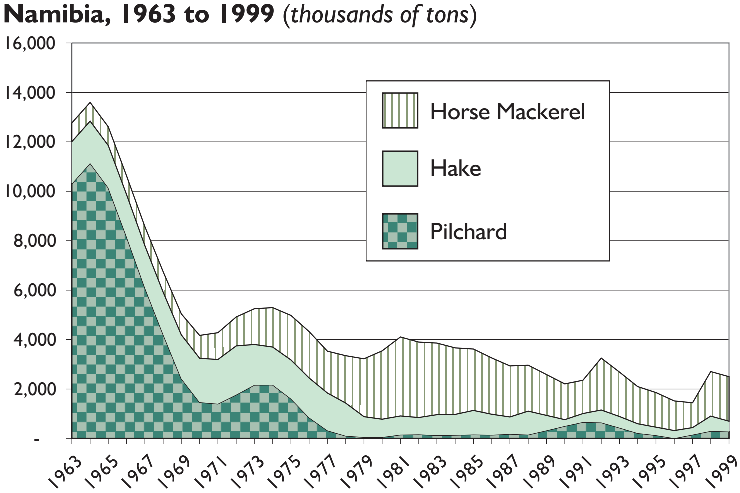
Physical Asset Accounts

The physical asset accounts provide indicators of ecological sustainability and detailed information for the management of resources. The volume of mineral reserves, for example, is needed to plan extraction paths and indicates how long a country can rely on its minerals. The volume of fish or forestry biomass, especially when disaggregated by age class, helps to determine sustainable yields and the harvesting policies appropriate to that yield.

The asset accounts track the changes in stock over time and indicate whether depletion is occurring. They can, thus, show the effects of resource policy on the stock and can be used to motivate a change in policy. For example, the biological depletion of Namibia's fish stocks since the 1960's has provided a very clear picture to policy-makers of the devastating impact of uncontrolled, open-access fishing (Figure 1). Similar accounts of depletion (or accumulation) have been constructed for forests in the Philippines, Brazil, Chile, Malaysia, Indonesia, Australia, Canada and much of the EU.

Physical accounts for land accounts track the use of land for different purposes, and its conversion from one use to another over time, which can be linked to the environmental and economic consequences of conversion, such as increased soil erosion or loss of watershed protection. For example, a major concern in developing as well as industrialized countries, concerns the conversion of high potential agricultural land to urban settlements, the loss or fragmentation of fragile ecosystems supporting unique biodiversity, or the clearing of forests for agriculture. Land accounts and indicators of environmental pressure related to economic activity have been constructed in a number of industrialized countries, such as Canada (1997, 2000), Germany (Rademacher 1998), and the UK (Stott and Haines-Young 1998) but have not been widely used in developing countries. Limited accounts were constructed for Korea. The Philippines constructed a model to assess the economic consequences of different patterns of land use (ENRAP 1998). Where land has been addressed, it is usually in relation to soil and, more particularly, degradation of soil through erosion or other factors.

Figure 1. Biomass of hake, pilchard, horse mackerel in Namibia, 1963 to 1999 (*thousands of tons*)



Source: Lange 2001.

Some environmental assets clearly yield economic benefits, which may not always be fully captured in monetary terms such as carbon sequestration, watershed protection, or provision of habitat to maintain biodiversity. For such assets, physical accounts often provide the best alternative for management. For example, physical accounts for stocks and flows of greenhouse gases (GHG) are required to address climate change. An important element in these accounts is the carbon storage capacity of natural assets, especially forests. Carbon binding is calculated as a given percentage of the estimated biomass of forests, and changes in carbon stocks are estimated on the basis of changes in forest biomass. Such accounts are constructed for Australia and Canada, and were constructed for South Africa's forests in a recent academic study (Hassan 2000).

International protocols for climate change which allow tradeoffs between carbon emissions and carbon sinks, such as forests, will make these accounts essential. Limited international trading in carbon sinks is already occurring. If this trend expands, it will be very useful for developing countries with large forest potential to compile forest and carbon accounts.

Monetary Asset Accounts

The physical accounts for individual assets can be used to monitor ecological sustainability. However, a more complete assessment of assets requires that the economic value of a resource also be known. The monetary value of different assets, produced and non-produced, can be combined to provide a figure for total national wealth. This figure can be analyzed to assess the diversity of wealth, its ownership distribution, and its volatility due to price fluctuations, an important feature for economies dependent on primary commodities. Diversity is important because, in general, the more diverse an economy is, the more resilient it will be to economic disturbances. Volatility is also important in planning for the future—lower volatility contributes to more stable economic development. The distribution of the ownership of assets—between public and private sector, the concentration among different groups in society, and between domestic and foreign—can have significant economic implications and can influence the sustainable management of resources.

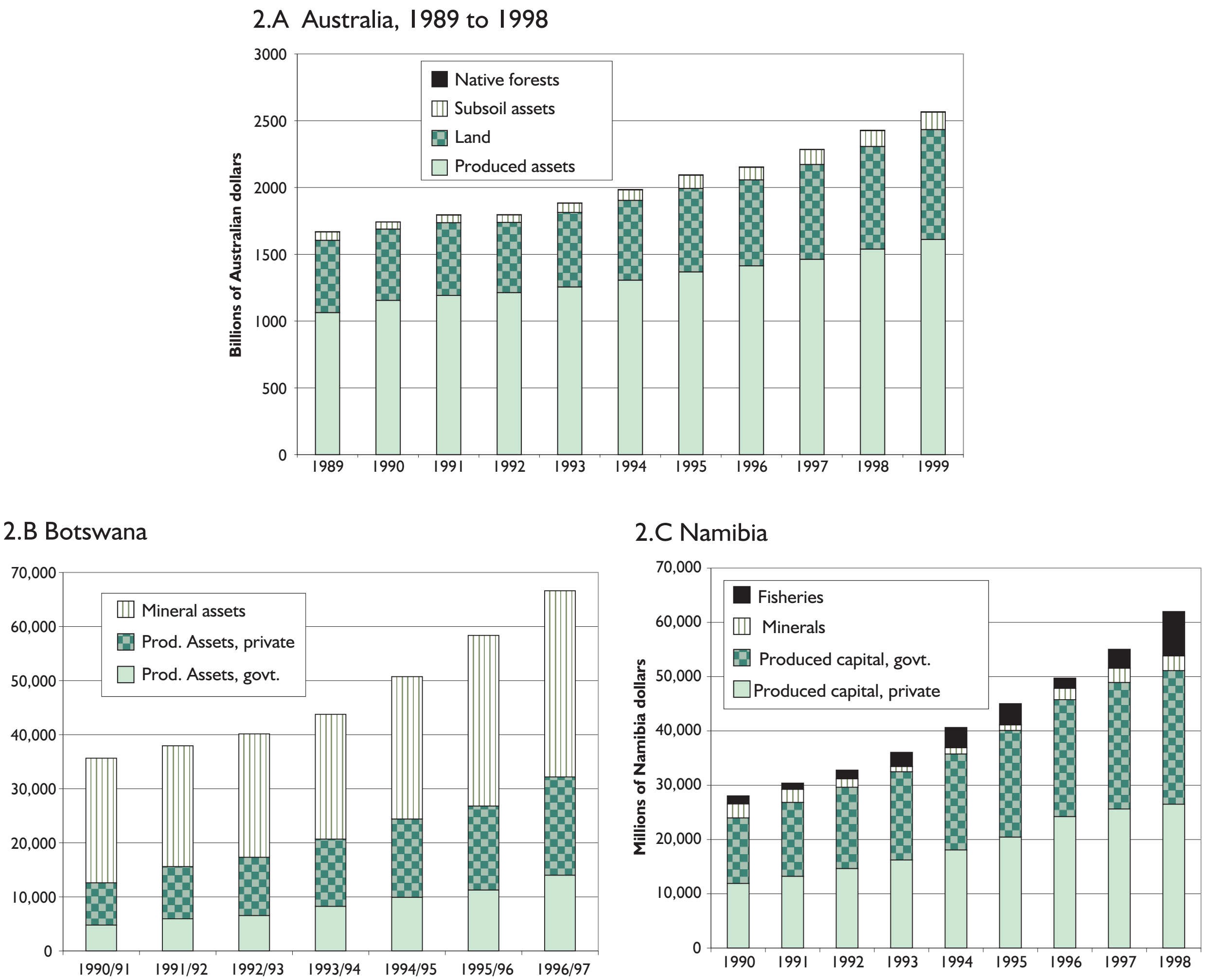
Most countries with asset accounts for natural capital have typically published the accounts separately for each resource and have not attempted to measure of total natural capital (the sum of all resources), or a measure of total national wealth (the sum of manufactured and natural capital). Among the developing countries, Botswana (Lange 2000a) and Namibia (Lange 2001) are doing so. Among the industrialized countries, Australia (ABS 1999) and Canada (Statistics Canada 2000) have integrated non-produced natural assets with produced assets in their Balance Sheets.

In some cases, this may simply reflect a relative lack of concern by policy-makers about wealth—most countries have traditionally been much more concerned with the income and product flow accounts of the SNA than with the asset accounts. Some developing countries, like the Philippines, may not have data about manufactured capital stock. In other cases, there may also be a reluctance to combine conventional measures of manufactured capital with what may be viewed as experimental calculations for natural capital, especially when there is controversy over the assumptions necessary for valuation (Ryan, 2000), or over the policy implications of the results, e.g., fisheries in Chile.

In the discussion that follows, the total wealth of three countries are compared—Australia, Botswana, and Namibia. Although accounts for natural capital are not comparable across these countries because of differences in methodology and coverage, international comparisons are nonetheless instructive, and provide the basis for improving the accounts.

Australia's accounts for natural capital include land, subsoil assets, and native forests in non-produced asset accounts, and commercial forests in produced assets (Figure 2.A). Botswana's accounts currently include only mineral assets (Figure 2.B), and Namibia's asset accounts include minerals and fisheries (Figure 2.C). Neither Botswana or Namibia have valued land yet because no market price exist for the very large portions of the land that are subject to traditional communal tenure regimes. Other

Figure 2. Value of produced and non-produced assets in Australia, Botswana and Namibia in current prices



Source: Australia—Australian Bureau of Statistics 2000, Botswana—Lange 2000, Namibia—Lange 2002.

significant missing assets include wildlife for both Botswana and Namibia, and water for all three countries. Figures are reported in current prices because there is not yet an agreed upon methodology for constant price calculations for natural capital.

The trend of national wealth over time indicates, at an aggregate level, whether capital is maintained, whether depreciation of natural capital, if it has occurred, has been compensated for by an increase in other forms of capital. In all three countries the value of total capital has increased over time. The value of Australia's total (non-financial) capital increased 43 percent, and roughly doubled in Botswana and Namibia during the 1990's, despite exploitation of non-renewable resources. Whatever depletion has occurred in these countries has been compensated for by a combination of factors: new discoveries, an increase in economically profitable reserves, and an increase in the economic value of reserves. In the case of Namibia's fisheries, improvements in fisheries management has also played a role in the increased value of the fish stock.

In addition to the volume of wealth, the composition of wealth is also an important indicator to monitor because, generally, a more diverse economy is a more resilient one. Many resource-rich developing countries have identified economic diversification as one of their development objectives. A comparison of the shares of produced and natural capital over time is one approach to monitoring this aspect of resilience and progress toward diversification.

Natural capital is quite important in all three countries (Table 3). Botswana is the only country where the share of natural capital, 52% in 1996, is greater than manufactured capital, 48%. This share is significantly lower than its 65% share in 1990, which indicates substitution of produced capital for mineral capital over time, and diversification of the economy. For an industrialized country, Australia has a relatively high dependence on natural capital—37% of its non-financial assets in 1998, but not much different from 1990. The share of natural capital is much smaller in Namibia, only 18% by 1998, but higher than its share in 1990 (14%). In the Australian accounts, land dominates natural capital, accounting for roughly three-quarters of the total value of non-produced assets. Neither Botswana or Namibia have included land in their asset accounts, probably resulting in serious underestimates of national wealth.

Australia's national wealth shows relatively low volatility, possibly because land is the largest component and land value is not subject to the large changes in price and demand faced by globally-traded resources like minerals and fish. Although Botswana has seen a dramatic change in the relative shares of produced and non-produced capital, the transition has been smooth, without major changes from year to year. By contrast, the natural assets of Namibia appear to be less stable, accounting for 14% of wealth in 1990, falling to a low of 8% in 1996, followed by a high of 18% in 1998. This trend that is more pronounced when its natural assets are examined individually.

Namibia's mineral assets consist primarily of diamonds, uranium and gold. The combined value of these assets (confidentiality concerns prevents reporting the value for each mineral) fell from N$2,575 million in 1990 to N$976 million in 1993, then recovered steadily to just over its 1990 value in 1998. Under a new management system since independence in 1990, Namibia's fisheries are recovering from a long period of over-exploitation, which makes the stock extremely vulnerable to disturbances of the marine environment. The value of the fish stock fell and recovered twice during the 1990's, rising dramatically by more than 100% between 1997 and 1998, due partly to fluctuations in the tock and partly to fluctuating economic conditions. Clearly, Namibia's wealth is much more volatile than the other two countries.

Table 3. Natural capital as percent of total non-financial assets in Namibia, Botswana, and Australia, 1990 to 1998 (*percent*)

	1990	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
Namibia	14	12	10	10	12	11	8	11	18
Botswana	65	59	57	53	52	54	52	na	na
Australia	34	34	32	33	34	35	34	36	37

Notes: Na: not available.
Figures for Australia include only non-produced assets, not types of natural capital which are included under produced capital.
Percentage shares calculated in current prices.

Source: Derived from: Australia—Australian Bureau of Statistics 2000, Botswana—Lange 2000. Namibia—Lange 2002.

In using national wealth to monitor economic sustainability, it is crucial to include all assets, or at least as many as possible (human capital is not yet included). Some natural assets are not yet included in the countries accounts, mainly because of valuation difficulties. Another important component of a country's asset portfolio is its net foreign financial assets. It is not uncommon for resource-rich developing countries, like some of the major oil-producing countries, to invest much of the income from resource exploitation in foreign assets, especially if the economy is small and opportunities for domestic investment are limited. For such countries, net financial assets form a significant share of national wealth. Indeed, for Botswana, foreign financial assets have grown increasingly important, from 13% of total net worth in 1990 to 21% in 1996. In the case of Australia, net foreign financial assets are negative and growing, reaching –16% of net worth in 1998 (Table 4). Figures are not yet available for Namibia.

So far, we have considered only trends in total wealth. However, in most countries, population is still increasing, so a constant level of wealth and income would result in a declining per capita level of wealth and income for future generations. Inter-generational equity requires that not just total wealth, but *per capita* national wealth is non-declining over time.

Figure 3 shows the index of per capita wealth in current prices from 1990 to 1998 (1996 for Botswana). For Botswana and Australia, the net worth figure including net foreign financial assets is used; for Namibia, only produced plus natural capital are available. Per capita wealth has grown the fastest for Botswana, by 80% from 1990 to 1996, and the slowest for Australia, only by 22%, which is not surprising for a mature industrialized economy. Per capita wealth also grew fast in Namibia, though not as fast as Botswana, though without information about foreign financial assets, it is not certain whether the figure reported understates or overstates asset growth. The trends for the three countries are not readily comparable because they are not in constant price terms.

Table 4. Financial, non-financial assets, and net worth in Botswana and Australia, 1990 to 1999

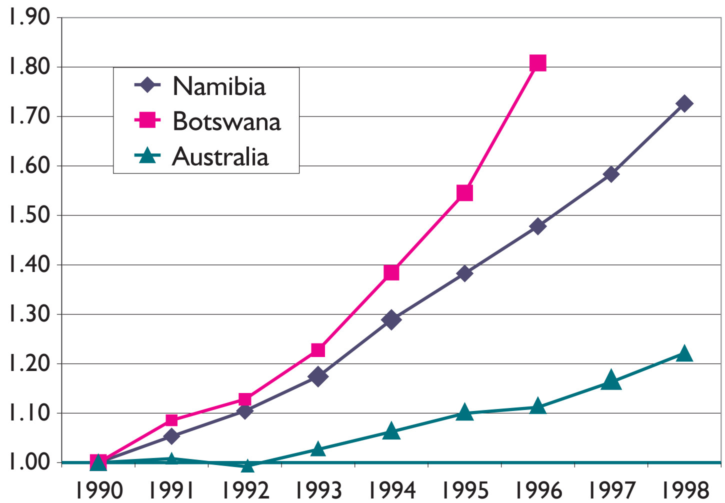
	1990	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
Botswana,millions of pula									
Produced + Non-produced assets	35,657	37,947	40,147	43,764	50,734	58,351	66,613	Na	Na
Net foreign financial assets	5,482	6,919	7,595	9,413	10,693	11,871	17,636	19,378	24,517
Net worth	41,139	44,866	47,742	53,177	61,427	70,222	84,249	Na	na
Australia, billions of A$									
Produced + Non-produced assets	1,742	1,796	1,797	1,885	1,984	2,095	2,154	2,285	2,428
Net foreign financial assets	-171	-192	-201	-217	-238	-263	-279	-303	-321
Net worth	1,572	1,604	1,596	1,668	1,746	1,832	1,875	1,982	2,107

Na: not available

Notes: Figures are in current prices. Figures for Namibia are not currently available.

Source: derived from: Australia: Australian Bureau of Statistics, 2000. Botswana: Lange, 2000.

Figure 3. Index of per capita national wealth in Australia, Botswana, and Namibia, 1990 to 1998 (*1990=1.00*)



Notes: Index calculated in current prices.
National wealth is net worth for Australia and Botswana. For Namibia, only produced + natural capital are included.

Source: derived from: Australia—Australian Bureau of Statistics 2000, Botswana—Lange 2000, Namibia—Lange 2001.

The public and private sectors may have different resource management objectives which affect the way resources are exploited. Consequently, monitoring the distribution of asset ownership between public and private sectors may be useful, not as a direct indicator of sustainability, but as an aid to resource management. The private sector is motivated largely by commercial concerns, which can favor economic efficiency, but also depletion of renewable resources under certain conditions. Government may or may not utilize resources in a sustainable, and it may use resources to achieve other socio-economic objectives, even if this lowers the economic return from a resource.

The response to the depletion of natural capital may also differ between the private and public sector. Where depletion occurs, sustainability requires reinvestment in other forms of capital. Private ownership may result in reinvestment in private sector activities, but foreign ownership may result in reinvestment elsewhere which does not benefit the country providing the wealth. In countries where the government owns the resource and recovers most of the resource rent, the government bears responsibility for reinvestment, often investing in public sector capital. There is disagreement over the extent to which growth in government assets is an effective substitute for other forms of capital. There is a tendency to assume that government is economically inefficient compared to the private sector, but it is also well documented that the private sector will under-invest in assets where social benefits exceed private benefits, like public infrastructure and human capital. In any case, it is useful to monitor the distribution of capital, as well as its level and composition.

In Botswana and Namibia, minerals and fisheries are owned by the state. Private sector manufactured capital has been growing faster than public sector manufactured capital in Namibia, while the opposite is true in Botswana (Figure 2). In Australia, non-produced assets, dominated by land, are mainly (70%) owned by the private sector.

Depletion and Depreciation or Accumulation of Natural Capital

In addition to a measure of overall wealth, asset accounts may provide a measure of annual depreciation of produced assets and natural capital. The depletion of natural capital reduces the wealth available to future generations, and reduces the income-generating capacity of the economy. If this loss is not reflected in the national accounts, policymakers may overestimate the level of sustainable national income.

Depletion accounts, mostly using the net price method rather than economic depreciation, were calculated in the early studies for Indonesia and Costa Rica by Repetto (1989), for Mexico (van Tongeren and Schweinfest 1991) and Papua-New Guinea (Bartelmus and others 1992) by the UN and World Bank, and in more recent work undertaken by the Philippines (forests, minerals, land, fish), Chile (forests), Indonesia (forests, minerals) and Brazil (forests). Indonesia reported that depletion accounted for 11% of GDP over the period 1993 to 1996 (Saleh 2000). Estimates of depletion or depreciation have been estimated in a number of one-time, or academic studies such as Malaysia (Vincent 1997).

Depletion estimates for the Philippines are dominated (90% or more) by the costs of deforestation, which was halted by a logging ban in 1992 (Table 5). Depletion for minerals is quite low, reflecting the slow-down in mining due to falling world mineral prices from 1991 to 1993. Depletion of land and fisheries have both been increasing, fisheries at a rather alarming rate.

Controversy over measurement has made it more difficult to provide policy-makers with a definite figure for depletion (See discussion in section 2) and many of the industrialized countries have not calculated it, or are conducting experimental calculations, not fully integrated into the national accounts. The recent publication by Eurostat of pilot accounts for subsoil assets (Eurostat 2000a) and for forests (Eurostat 2000b) did not attempt to measure the cost of depletion. Australia used several alternative methods for valuing the cost of depletion for sub-soil assets during the 1990's. Including this depletion with conventional measure of depreciation would reduce Net Domestic Product by less than 1%, which is not very significant (Ryan 2000, Tables 2, 8).

Of course, not all change in the stock of resources is negative. There has been a net increase in the volume of cultivated timber in South Africa. Using the change in asset value approach of Vincent (1999), Hassan (2000) found this would increase Net National Product by roughly 0.5% over the past decade. For countries like Botswana, if the cost of depletion is calculated using the old method—net price times the quantity extracted—then this cost will be quite high. However, if the economic method of depreciation, the change in asset value, is used, there is a net appreciation because of holding gains.

3.2 Managing resources—economic efficiency, sustainability, and other socio-economic objectives

In the early days of environmental accounting, resource rent was calculated in order to calculate the value of assets, but its usefulness as a resource management tool was not always recognized. More recent work by Norway

Table 5. Cost of depletion of natural capital in the Philippines, 1988 to 1993
(millions of pesos)

	1988	*1989*	*1990*	*1991*	*1992*	*1993*
Forests	24,529	14,852	10,404	11,766	542	300
Land	918	979	1,212	1,618	1,401	1,241
Fisheries	188	366	573	936	1,106	1,073
Minerals	381	296	81	1	0	0
Total	28,004	18,482	14,260	16,312	5,041	4,607

Note: depletion cost estimated using the net price method.
Source: NSCB.

(Sorenson and Hass 1998), Eurostat (2000a) for subsoil assets, in the Philippines (ENRAP 2000, Lange 2000b), Botswana (Lange 2000a), Namibia (Lange and Motinga 1997, Lange 2001b), and South Africa (Blignaut and others 2000) has included detailed analysis of resource rent. Rent has been used to assess resource management in terms of economic efficiency, sustainability, and achieving other socio-economic objectives, such as inter-generational equity.

In terms of economic efficiency, some of the issues addressed include:

- How much resource rent is being generated and is it being recovered by government or accruing to the private sector?
- Do payments to government by the private sector at least cover the cost to government of managing the industry?
- Do current management policies maximize the amount of rent that can be generated from the resource, or could rent be higher under an alternative management regime?

In terms of sustainability, issues include:

- Is rent from nonrenewable resources being reinvested?
- Do pricing policies for renewable resources promote sustainable management?

In terms of other socio-economic objectives, issues include:

- Do policies contribute to inter-generational equity?
- How are the benefits from resource exploitation shared among different groups in society?

3.2.A Economic efficiency

The value of an asset depends, in part, on how efficiently it is exploited. Norway provides a good example of how analysis of rent can be used to compare very different approaches to resource management that affect the value of three major natural assets—petroleum, uncultivated forests, and fisheries. Figures 4, 5,and 6 show the rent generated by each of these resources and the distribution of that rent between government and private sector. In many countries, resources belong, by law, to the state. As the owner of the resource, the government has a right to charge for the exploitation of the resource by private companies, and the responsibility to ensure proper use of the rent. Often, resource pricing does not recover the full rent, or even the full cost of managing the resource.

Significant amounts of rent have been generated by the oil and natural gas industry of Norway, but the rent has fluctuated a great deal, even becoming negative in 1988, meaning that, in that year, the industry did not even earn a normal return to the capital it had invested in the industry. To understand the high volatility better, one must distinguish between total rent and per unit rent (not shown) to determine how much of the rent fluctuation results from changes in the volume of extraction, and how much results form changes in market price or the cost of production. The figures for petroleum indicate that government appropriates most of this rent through taxes. In 1986 to 1988, the taxes collected by government actually exceeded rent.

Uncultivated forests are also managed in a way that generates substantial rents, but, rather than contributing this rent to government, the rent accrues to the private sector which receives, in addition, large subsidies (Figure 9). Fisheries (Figure 10) provide an example of yet a third management strategy. Fisheries (these figures include both capture fisheries and aquaculture) are managed in a way that generates no positive rent—rent from fisheries has been negative except in 1995, and, rather than collecting revenue, government has been providing the industry with considerable subsidies. The management regime promotes exploitation of

Figure 4. Resource rent and taxes from oil and gas mining in Norway, 1985 to 1996

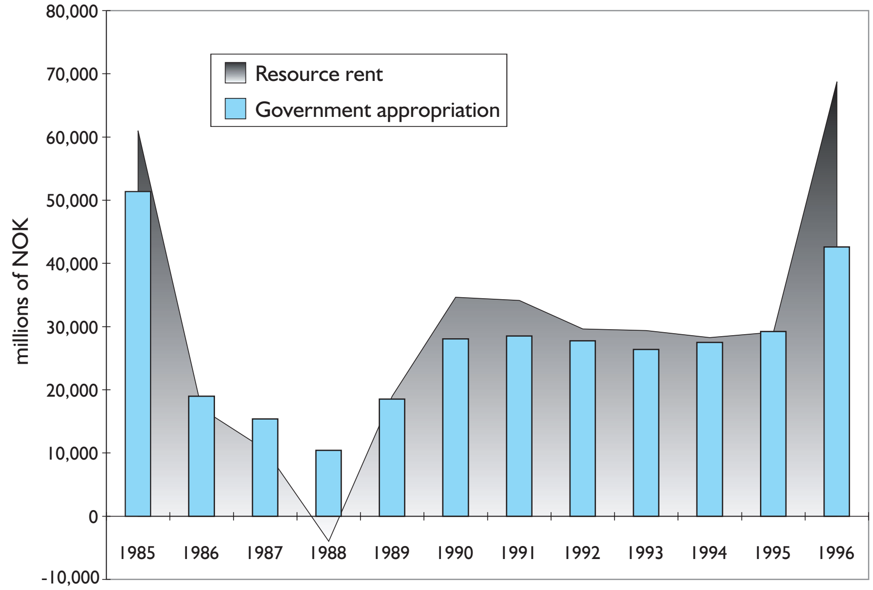


Figure 5. Resource rent and taxes from forestry in Norway, 1985 to 1995

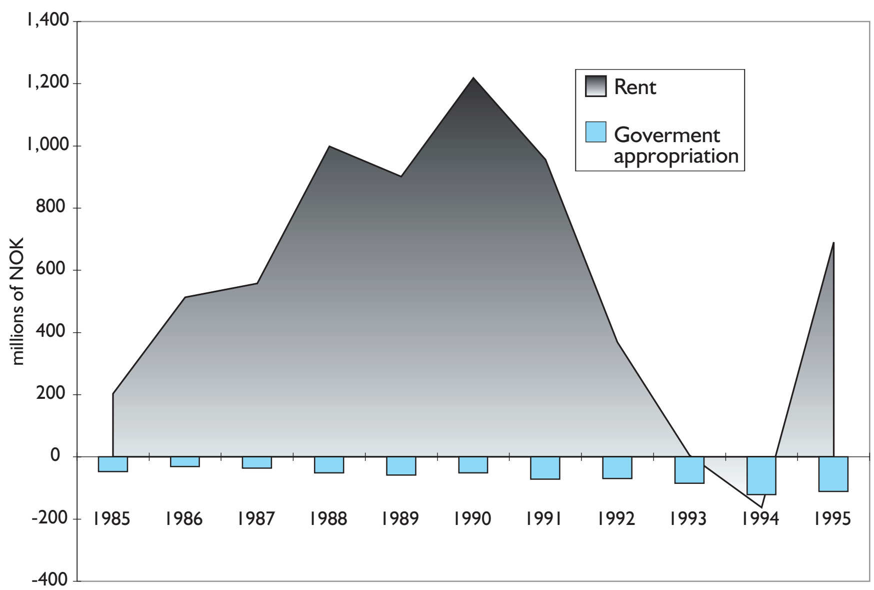
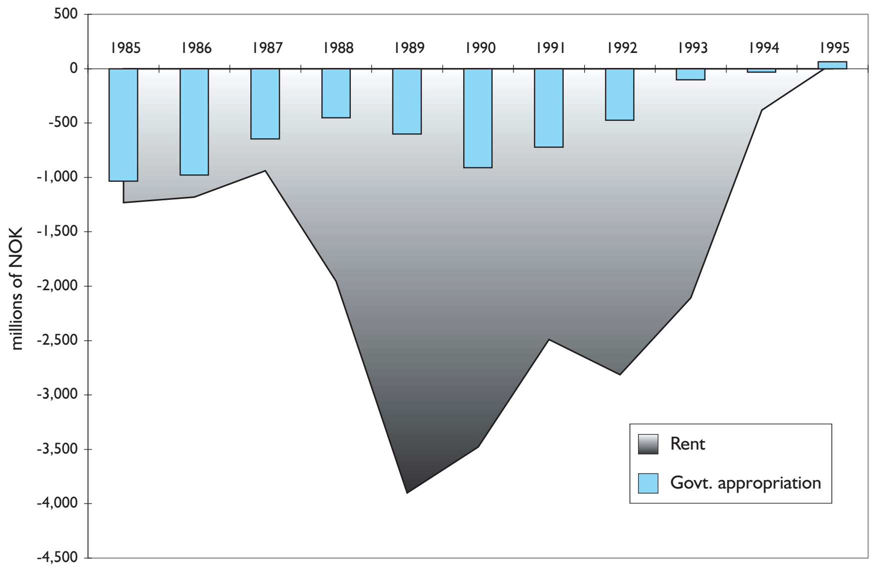


Figure 6. Resource rent and subsidies to fisheries in Norway, 1985 to 1995



Source: Norwegian Central Bureau of Statistics 2000.

fish stocks by relatively small inefficient vessels in order to support Norway's regional economies. The economic value of fish under this management regime is zero.

A pilot study by Eurostat for oil and natural gas found that in the Netherlands, government appropriated between 82% and 97% of the rent between 1990 and 1998. The figures were generally lower for the UK; after the industry began to earn a positive rent in 1993, government's share ranged from 45% to 99% (Eurostat 2000a). Rent recovery in the Philippines was generally quite low for all resources except minerals. The studies of Namibia, Botswana, and South Africa (sub-soil assets and, in Namibia, fisheries) showed mixed results: rent recovery from sub-soil assets was quite high for Botswana and Namibia, but low for Namibian fisheries. Rent recovery in South Africa was mixed: high from gold mining but low from coal.

These figures can provide a basis for setting resource pricing policy. The figures for Namibia were one of several factors prompting a review of quota fees for fisheries. In the Philippines, the rent for grasslands was used in negotiations between government and ranchers to revise grazing fees (Batcagan 2000).

In assessing the contribution of the resource to the economy, it is also useful to calculate the contribution of rent taxes to total government revenues, and the share of resource management costs incurred by government that are recovered through taxes on rent. These uses of SEEA for resource management are fairly recent recommendations in the SEEA and have not been carried out routinely by all countries compiling asset accounts.

Government's reliance on tax revenues from its resources may be quite significant in some small, resource-dependent economies. For example, the government of Botswana receives about 50% of its revenue from taxes on mining. Even in Norway, the petroleum industry makes a significant contribution to government revenue, 7–8% in recent years (Central Bureau of Statistics, unpublished data 2000). A comparison of rent and resource management costs has been carried out by some European countries, as well as Chile, Costa Rica, and Namibia.

Economic Efficiency — Potential vs. Actual Value of Assets

Resource management can be evaluated from the point of view of economic efficiency to determine if alternative policies might increase the income generated and, hence, the economic value of a resource. While it is unlikely that any industry is perfectly efficient, the fisheries industry in Norway represents an extreme case of economic inefficiency where the economic value of its fish stocks is zero.

Analysis of micro-survey data of Norway's herring fishery found significant differences in rent-earning capacity between large and small fishing vessels. Generally, the large-scale operations were more efficient and generated rent. Assuming that most of the fishery could potentially be managed in a such an efficient manner, one study of Norway's herring fishery estimated the potential resource rent of 1,000 million Norwegian kroner (Flam 1993 quoted in Sorensen and Hass 1998). A similar observation was made of Namibia's hake fishery, where the rent generated by the three most profitable fishing companies earned rents more than double the industry average. The data were not sufficient to support calculation of potential rents, but large differences in efficiency exist, mostly attributable to the differences between large, experienced operators with good international connections, and the smaller Namibian newcomers to the industry (Lange 2001b).

Efficiency with Multiple Uses of a Resource

The values for assets discussed so far have been based on a single use; Norwegian forest assets, for example, consider only the timber value. The full economic value of an asset and the efficient management of the asset must be based on an accounting of the full range of environmental services which the asset can provide. Forests may provide multiple benefits, such as timber, recreational benefits, carbon sequestration, and the provision of traditional medicines and foods, which can be important for rural populations in developing countries. In practice, comprehensive valuation of the may be difficult to achieve.

Although the non-timber benefits are more difficult to value, it is increasingly important to do so. The carbon sequestration value of forests will be increasingly important as progress is made on an international agreement to address climate change. Physical accounts for carbon storage by forests were discussed earlier, but values for carbon storage have not been systematically included in forest accounts. Carbon sequestration rights of tropical forests have already been purchased or rented by some electric utility companies in North America to offset the companies' carbon emissions. If a condition of this purchase or rental is that timber not be cut, or that logging occurs on a much reduced basis, then valuing such a forest at timber value alone may underestimate its true economic value.

Similarly, forests in Alaska have provided substantial economic benefits to the logging, recreation, and fishing industries. Economic efficiency requires assessing the optimal mix of these competing uses. Valuation of forests based on timber alone would underestimate the real economic value of the forests.

3.2.B Sustainability

Economic sustainability requires that a portion of the rents from non-renewable resources (or from unsustainable exploitation of renewable resources) be re-invested in other assets or economic activities. In this way, exploitation of the resource can be *economically* sustainable—because it creates a permanent source of income—even though non-renewable resources are, by definition, not *biologically* sustainable. For renewable resources, like forests or fisheries, one of the economic instruments for management includes resource pricing or user fees. To encourage sustainability, fees should be set high enough to recover the rent generated at the most profitable, sustainable level of production, so that it becomes unprofitable for companies to harvest at levels that deplete the resource stock.

Policymakers have sought indicators of the share of rent from non-renewable resources that should be reinvested to maintain sustainability. Hartwick's rule seemed to provide some guidance, stating that all net returns from exhaustible resources should be reinvested (Hartwick 1997), but this now appears to be more a descriptive rule than a prescriptive one (Asheim and Buchholz 2000). El Serafy provides another approach. The SEEA does not provide guidance on this issue and no countries have so far integrated this concept into the sustainability indicators they compile, with, perhaps, the exception of Botswana.

Botswana, whose economy is highly dependent on mineral revenues (roughly 35% of GDP), has developed the Sustainable Budget Index (SBI) to indicate how much of the mineral revenues are used for capital expenditures including spending for human capital on education and health (Ministry of Finance and Development Planning 1997, Wright 1997). Although there are no strict rules for policy based on the SBI, government has adopted an informal fiscal guideline that no revenues from mining should be used for recurrent expenditures. In effect, this is a very strict interpretation of Hartwick's rule where all revenues from mining are reinvested. While spending under government's capital budget does not ensure that all investment is productive, the SBI represents one type of indicator, based on information that can be provided by the SEEA, that can help to monitor sustainability.

3.2.C Other socio-economic objectives

Countries may choose to sacrifice economic efficiency in order to achieve other important socio-economic objectives. Norway has chosen to support small-scale fisheries as a component of its strategy to promote regional development. Fisheries are a mechanism to create employment and generate income in parts of the country that have few options for employment. Norway is willing to sacrifice economic efficiency and the greater income this would generate in order to achieve this goal (Sorenson and Hass 1998).

Resource rent may be used to achieve a more equitable distribution of benefits from the use of resources, especially for economies that rely heavily on extractive industries. Within the current generation, the resource rent can be used to support economic development that betters the lives of all citizens, not only the minority who may own companies. To ensure inter-generational equity, countries need to resist the pressure to consume all the income. At least some portion of the rent must be re-invested to contribute to increased well-being for future generations, as discussed above.

An analysis of access to resources and the beneficiaries of the resource rent (the portion that does not accrue to government) is another important aspect of resource management (Manning 2000). The terms of access by foreign operators to a country's resources may have important implications for domestic employment and income. Monitoring this situation requires estimating the share of rent that accrues to domestic operators, to government through taxes, and to foreign operators. Where there are joint ventures between domestic and foreign companies, it may be exceedingly difficult to determine these shares.

Evaluating Trade-offs Among Alternative Policy Objectives

When the pursuit of socio-economic goals conflicts with economic efficiency, there is a cost, and policy is more effective when this cost is known. The costs of a policy which distributes access to resources more widely in society, for example, but results in less efficient exploitation, can be measured as the resource rent that has been sacrificed, and the corresponding, lower value of national wealth, i.e., as the difference between the potential rent and rent actually generated. An initial, static analysis of the trade-off might measure this loss of rent based simply on information from micro data sets of individual companies under an existing resource management regime, such as the study of Norway's herring fishery. More sophisticated modeling of an industry would be required to determine the long-term economic effects of alternative management strategies on the value of a resource, and the benefits obtained from achieving other goals. Economy-wide modeling would be necessary to take into account all the changes that would result from alternative resource management policies.

Developing a Consistent Policy for Resource Management

As the case of Norway shows, resource management may be motivated by different objectives and result in very different outcomes in terms of efficiency, sustainability, and equity. Countries may well use different resources to achieve a range of socio-economic objectives—some resources managed purely commercially and others not. However, in some instances, policies for managing resources may have been determined independently for each resource without the benefit of an economy-wide review which would establish a comprehensive policy for all resources. This may have occurred in the past because there was no comparable framework for measuring and analyzing all resources. It is particularly important for certain resources, such as forests, which have multiple uses cutting across different economic activities. Thus, comparing the management of all resources in the common framework of the SEEA provides a valuable tool for more rational resource management.

4 Physical Flow Accounts for Pollution and Material Use

In the national accounts, the flow accounts are used much more extensively than the asset accounts for economic analysis, and the same has been true of the SEEA flow accounts for pollution and materials (including energy). The flow accounts provide indicators of sustainability as well as more detailed information to support economic analysis of sources of environmental pressure and options for change that can be used to improve the aggregate indicators of sustainability.

The SEEA flow accounts have two components: the physical accounts and the monetary accounts, which are constructed by valuation of the physical accounts. The physical accounts help set priorities for policy based on the *volume* of pollution, while the monetary accounts identify the relative *costs and benefits* of reducing pollution. The flow accounts are also used in economic models to evaluate options for dealing with the problems: long-term strategies for addressing environmental problems and the policies for implementing a given strategy, such as green taxes. This section describes applications for deriving indicators as well as for analysis first of the physical flow accounts, then of the monetary accounts.

4.1 Physical flow accounts

4.1.A Indicators and descriptive statistics

Data from the physical flow accounts are used to assess pressure on the environment and to evaluate alternative options for reducing pressure on the environment. At their most simple, the flow accounts monitor the time trend of resource use, pollution emissions, and environmental degradation, both total and by industry. A rising level of emissions, for example, would be a clear warning sign of environmental problems.

The overview of environmental trends helps assess whether national goals, typically set in terms of total figures for emissions or material use, are being achieved. A great deal of work has been done throughout the industrialized world to construct time series of pollution emissions and energy use. Similar work has been done for water accounts by a number of countries, including Chile, France, Spain, Moldova, South Africa, Botswana, Namibia, and the Philippines. The example for Botswana shows declining per capita water use, and declining water intensity of the economy (measured by the GDP per cubic meter of water used); the volume of water has still increased because population and GDP growth outweigh the gains in efficiency (Table 6).

The aggregate indicators provide an overview of the relationship between economic development and the environment; the more detailed accounts help explain the overview. The construction and analysis of detailed statistics are required to determine the roles of different factors in causing environmental problems and to design effective strategies to address them. Levels of pollution, material use, and waste are determined not only by the size of an economy, but by other factors as well,

Table 6. Index of water use, GDP growth and population growth in Botswana, 1993 to 1998 (*1993 = 1.00*)

	1993/94	*1994/95*	*1995/96*	*1996/97*	*1997/98*	*1998/99*
Volume of water used	1.00	1.01	1.03	0.99	1.04	1.05
Per capita water use	1.00	0.99	0.98	0.92	0.94	0.93
GDP per m3 water used	1.00	1.02	1.06	1.18	1.22	1.26

Source: Lange and others 2000.

including economic structure and technology. The more extensive the range of environmental problems and the sources of pollution, the more important it is to develop detailed statistics.

The construction of environmental-economic profiles, or "eco-efficiency" indicators has become a common way of monitoring and ranking industries in terms of their environmental performance. There are many versions of environmental-economic profiles, each showing some aspect of the environmental burden imposed by a sector relative to the economic contribution it makes. Most commonly, the environmental burden is represented by a sector's share of pollution generated and economic contribution by its share of value-added, employment, and sometimes export earnings.

In the Netherlands, the profile revealed a very unequal sectoral distribution of economic benefits and environmental burdens (See Table 7). The economic contribution for economic activities is represented by value-added (GDP at factor cost), and for final consumers, as total consumption expenditure. Reading across the first few rows of Table 5, it is clear that industrial activity accounts for most pollution (73–97%). Among industries, a large share of pollution is produced by a relatively few industries, not at all in proportion to their economic contribution. For example, three industries account for 55% of greenhouse gas emissions: agriculture (15%), chemicals (14%), and public utilities (26%), but their combined contribution to GDP is only 7%. Agriculture alone accounts for 47% of acidification and 91% of eutrophication emissions, but only 3% of GDP. The striking environmental burden imposed by agriculture compared to its relatively low economic contribution made the headlines in Dutch newspapers and elsewhere.

These profiles have been constructed by all industrialized countries with environmental flow accounts (many were presented in a special issue of SCED 1999), who have a longer history of environmental monitoring. Economic-economic profiles for air pollution are used in Norway for "benchmarking" industry performance, both for national environmental policy as well as environmental management at the company level (Hass and Sorenson 1998). The environmental performance of companies or industries is compared to cleaner, more efficient companies or industries in the same country or in other countries. The performance of an industry over time is also monitored. Developing countries, perhaps because monitoring and benchmarking are relatively new, have been slower to introduce this indicator, with the exception of Chile, Botswana, Namibia, and South Africa for water, and the Philippines and Korea for pollution.

While the environmental economic profile described above is useful for cross-sectoral comparisons, it is cumbersome for comparison of performance over time or across countries. For such comparisons, a different indicator, the pollution or material intensity of a sector, may

Table 7. Net contribution of consumption and production to GDP and to six environmental themes in the Netherlands, 1993

	Economy	*Environment*				
		Greenhouse effect	*Ozone-layer depletion*	*Acidifica-tion*	*Eutrophica-tion*	*Solid waste*
TOTAL, %		100	100	100	100	100
Consumption		19	2	15	9	3
Industry		79	97	85	91	66
Capital and other sources		2	1	-	-	31
HOUSEHOLD CONSUMPTION, % of spending and residuals	100	100	100	100	100	100
Own transport	8	38	-	88	21	1
Other consumption	92	62	100	12	79	99
INDUSTRY, % *of GDP and residuals*	100	100	100	100	100	100
Agriculture, hunting, forestry, fishing	3	15	2	47	91	7
Mining and quarrying	3	2	-	1	-	1
Manufacturing						
Petroleum industry	1	7	-	11	-	
Chemical industry	2	14	27	6	2	16
Metal products and machinery industry	3	2	9	1	-	2
Other manufacturing	12	12	20	7	6	25
Public utilities	2	26	-	9	1	2
Transport and storage	6	8	6	12	1	5
Other services	68	14	36	6	-1	42

Source: Statistics Netherlands (EPIS-report).

be used. This is calculated as the quantity of sectoral emissions per unit of sectoral output or value-added. Such indicators for pollution have been used widely within industrialized countries to assess performance over time, although there have been no formal cross-country comparisons.

Table 8 shows the comparative economic contribution of water use in three neighboring, water-scarce countries: Botswana, Namibia and South Africa, which all share international waters. While the striking differences cannot be fully explained here, agricultural policy is a major factor: Botswana has relatively little agriculture, while Namibia and South Africa have, until recently, subsidized low value, irrigated agriculture. These profiles, on a more disaggregated sectoral level, have been used both for internal policy analysis and in on-going

Table 8. National income per cubic meter of water by sector in Botswana, Namibia, and South Africa, 1996
(*Botswana pula per cubic meter of water used*)

	Botswana	*Namibia*	*South Africa*
Agriculture	9	6	2
Mining	420	54	44
Manufacturing	437	189	98
Trade, Services, Government	724	542	302
GDP per m^3 of water input	124	45	20

Note: Calculated as water input divided by sectoral value-added.

Source: Lange and others 2000.

negotiations over regional allocations of shared water. Identifying the economic contribution of water in agriculture relative to other sectors has provided policymakers in southern Africa with a more sound basis on which to discuss future policy for agriculture as well as other sectors.

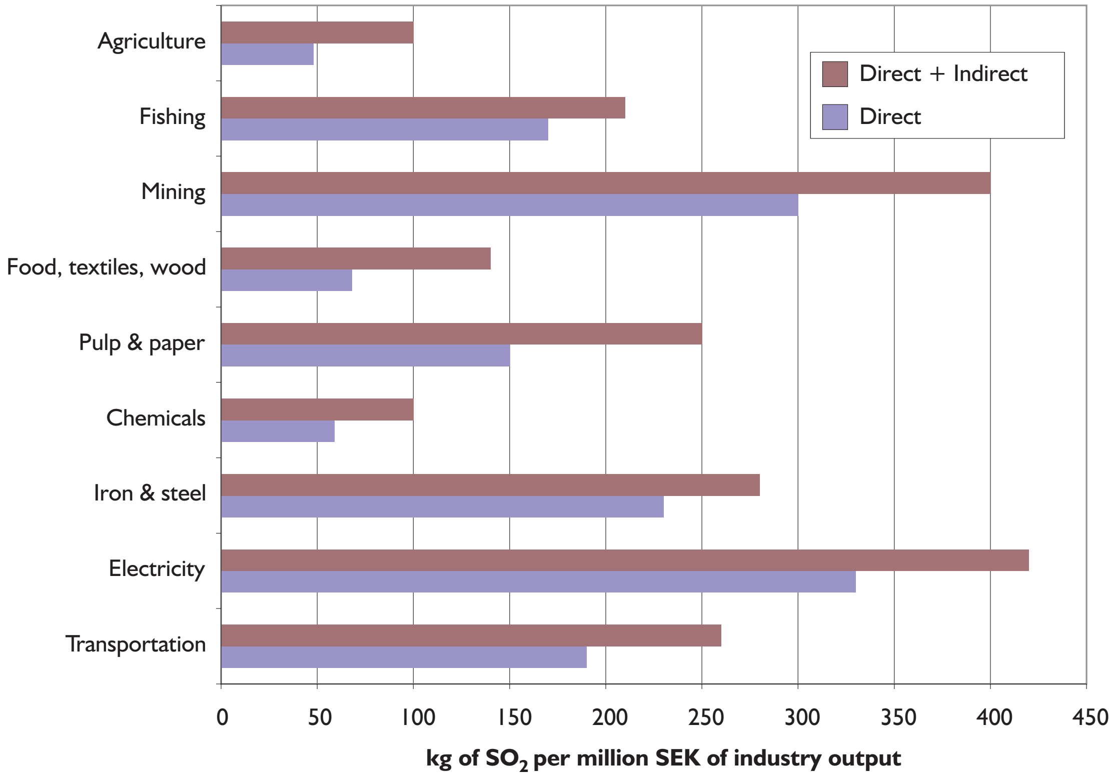
The level of pollution from a given sector depends on two factors: pollution intensity (determined by its technology) and level of output. Reducing pollution can be achieved by addressing either or both of these factors. While the eco-efficiency profile shown above reports the *direct* generation of pollution associated with production, it is important for policy makers to understand the *driving forces* that cause such levels of pollution. In the Dutch example, a relatively small proportion of total residuals is generated by final consumers; most pollution results from industrial production. However, production takes place in order to supply other industries with inputs they need and, ultimately, to supply final users with products they want.

Input-output (IO) analysis is used to calculate the total (direct + indirect) impact of delivering a unit of a sector's output to final users. In effect, this analysis redistributes emissions from industry to the driving force (final user) for which this production took place. Long experience with environmental input-output analysis has shown that the total impact is often much larger than the direct impact (Førsund 1985, Miller and Blair 1985, Pearson 1989).

Figure 7 provides a comparison of the direct and total emissions of sulfur dioxide for each product delivered to final users in Sweden. For every one million kroner purchase of agricultural output by final users 50 kg of SO2 are generated directly by the agricultural industry, and an additional 50 kg of SO2 (for a total of 100 kg) is generated indirectly. Similar statistics have been constructed for other industrialized countries with environmental accounts, but, again, this aspect of the flow accounts has been underutilized by most developing countries.

The ability to measure total pollution and use of materials—direct plus indirect—associated with given products, industrial processes, or consumption patterns makes possible far more effective strategies for reducing the use, and managing the disposal, of materials than could be devised on the basis of direct use only. For example, Table 7 showed that public utilities, mainly electricity production, was responsible for 24% of greenhouse gas emissions and 9% of acidification emissions in the Netherlands. In attempting to reduce these emissions, policy incentives can be designed to bring about technological change in the electric power industry to reduce its direct emission coefficient, but policy can also attempt to change the behavior of those who purchase electricity. It is often necessary to design policy for both groups—the direct source of pollution as well as the users of products, whose demand drives the level of production and associated pollution.

Figure 7. Direct and total emissions of sulfur dioxide per unit of industrial output delivered to final users in Sweden, 1991



Source: Hellsten and others 1999.

The calculation of total emissions is particularly useful for understanding how the structure of an economy affects the levels of pollution emissions and resource use. Final use can be disaggregated into its components—household consumption, government consumption, investment, exports and imports—to determine how much of the total pollution generated in the economy occurs in order to meet the demands of each of these components. Because household consumption accounts for the greatest share of final demand, researchers have increasingly focused on the composition of household consumption as a critical component for sustainable development. Strategies for sustainable development have examined the impact of alternative household consumption patterns, particularly in the wealthy industrialized countries where the need to identify "sustainable lifestyles" has received a lot of attention.

Over time, levels of emissions can change considerably, and policy makers need to know how much of this might be the result of environmental policies or other factors. Policies affect the choice of technology (direct and indirect emission intensities) and the level and composition of final demand (driving forces), and it is not immediately evident how much of the change in emissions is attributable to each factor. Structural decomposition analysis is a formal technique developed to distinguish the different sources of change in the economy over time, including a) effects originating from changes in the structure of final demand versus changes in intermediate input coefficients, and b) further decomposition to distinguish between effects of relative prices (substitution) and technological change. This analysis is carried out by decomposing differences in the total (direct plus indirect) requirements matrices derived from the IO tables.

Decomposition analysis using the NAMEA for the Netherlands, was carried out for the period 1987 to 1998 to address changes in the levels of greenhouse gas emissions, acidification emissions, and solid waste. The results for CO_2 show that economic growth (the volume of production, +35%) outweighed the impact of improved efficiency (-11.5) and structural change (the changing composition of final demand, -3.2%) for greenhouse gas emissions, resulting in a 20.3% increase in CO_2 emissions over the period (Table 9).

4.1.B Policy analysis and strategic planning

So far, the discussion has focused on analysis of the interaction between the existing environment and economy, but policy-makers also need to anticipate the future and design effective instruments for environmental policy. These concerns are typically addressed in a multi-sectoral, economy-wide modeling framework. The use of the SEEA flow accounts for environmental-economic modeling is discussed here. Some modeling is undertaken primarily to derive environmentally-adjusted macroeconomic indicators, such as Hueting's SNI. These modeling applications are discussed in section 6 along with other macroeconomic indicators.

Table 9. Decomposition of the percent change in CO2 between 1987 and 1998, the Netherlands
(*percentage change from 1987 to 1998*)

Volume	*Structure*	*Efficiency*	*Total*
35.0	-3.2	-11.5	20.3

Source: De Haan (undated paper).

The process of analysis has two major components: strategic analysis in order to design a more desirable future and policy analysis in order to implement such strategies. Countries typically identify the broad environmental objectives they wish to achieve in the future, such as more sustainable development or more sustainable lifestyles. Under these objectives, specific problems, such as air quality, would be identified and more detailed strategies to address these problems are examined in a modeling framework. This analysis is often based on long-term models to explore alternative scenarios about paths of economic development, including quite bold, speculative alternatives.

Once the overall strategies are determined, the best policy measures to implement the strategies need to be identified. This analysis considers different instruments policy makers might take (usually a modest range of actions over a relatively short period of time, such as different values for a carbon tax), and provides policy makers with the most likely outcome of these actions. Policy models can be used to examine the economic implications of various environmental policy instruments—such as taxes, tradable permits, or emission standards—as well as macroeconomic policies, such as trade policy and its impact on the environment.

Strategic Analysis

Strategic planning addresses alternative development paths over a relatively long-term time horizon (10–25 years or more) and the fundamental changes in the structure of the economy that might be necessary to achieve society's environmental objectives. Thee models are used to project levels of emissions, or material requirements and the long-term economic impact of environmental policies. It considers new technologies that might be introduced over a long period and the changes in final demand, especially private consumption. Strategic planning often emphasizes dynamic modeling instead of the static analysis commonly used for policy analysis. Dynamic analysis is important because it informs policymakers about the transition path—the process of adjustment—to a new economy.

Examples of strategic planning include the Netherlands Environmental Policy Plan, a long-term plan for sustainable development. Norway's Ministry of Finance has long used a strategic macroeconomic planning model, the Multi-Sector Growth Model, which has integrated environmental components (energy and pollution accounts) from the SEEA. A great deal of work has been done with global models to project different global trajectories for greenhouse gas emissions. A few one-time studies have been carried out using environmental accounts in developing countries but are not yet fully integrated in their planning processes. For example, a multi-sector, dynamic IO model was used to assess the environmental implications of Indonesia's Second Long Term Development Plan for the Ministry of Planning (Lange 1997).

Policy Analysis

The flow accounts are widely used for policy analysis, for example, to assess the impact of environmental tax reform, to design economic instruments to reduce pollution emissions, and to assess competitiveness under new, more restrictive environmental policies. The EU has been the largest user of the accounts and has used them mainly to address two priorities: greenhouse gas emissions and acid rain.

Norway has used the flow accounts for energy and greenhouse gas emissions to assess a policy that many countries are considering: changing the structure of taxes to increase taxes on emissions and/or resource use, while simultaneously reducing other taxes by an equal amount in order to remain fiscally neutral, the so-called "double dividend" (Bye 1997, summarized in Natural Resources and the Environment 1998). Norway used its multi-sector general equilibrium model to look specifically at increasing the carbon tax to NOK 700 per ton of CO_2 with a compensating decrease in its payroll tax. Policymakers in Norway wanted to know what effects this tax reform would have on economic welfare.

Using a multi-sector, general equilibrium model of the economy, Norway initially found that employment and economic welfare would increase while carbon emissions declined. However, closer analysis of the results indicated that the tax reform would result in significant structural change in the economy—certain energy-intensive industries in the metal, chemical and oil refining industries were particularly hard hit by the tax, and would reduce output and employment considerably. Furthermore, these industries were disproportionately located in small towns where an industry might be the only major employer. It is reasonable to assume that, at least in the short term, people would be reluctant to move to new towns in search of new jobs. By including this element of labor immobility, the model showed that although emissions would still decline, the economic improvement disappeared and economic welfare actually declined slightly.

In considering environmental taxes, another issue policymakers must consider is the impact such taxes might have on the international competitiveness of their domestic industries. This is an especially important issue for very open economies like the Netherlands. A study addressing this issue for the Netherlands was undertaken using the flow accounts for energy as well as for carbon emissions, other greenhouse gas emissions, acidification and eutrophication emissions (Komen and Peerlings 1999). The study quantified the relative sensitivity of the different industries to changes in environmental taxes.

In another example, Swedish researchers were able to show policymakers that policies to reduce carbon emissions may generate additional unintended (or ancillary) benefits that should be taken into account when considering the advantages and disadvantages of different environmental policy reforms (Nilsson and Huhtala 2000). The study analyzed the advantages of utilizing a system of carbon trading permits in order to meet Sweden's carbon target under the Kyoto Protocol as an alternative to implementing measures to reduce domestic levels of carbon emissions. When only the benefits of reduced carbon emissions were considered, the purchase of low-cost carbon emission permits was the more cost-effective means of meeting Sweden's targets. However, measures to reduce domestic emissions of carbon also resulted in lower emissions of sulfur and nitrogen at no extra cost. When this ancillary benefit was taken into account, the purchase of carbon emission permits was not as advantageous as measures to reduce domestic carbon emissions. Many other countries have undertaken similar studies to the three described here.

In other countries, environmental priorities may be quite different, but similar modeling techniques can be applied. For example, in parts of Australia, the United States, and southern Africa, water scarcity is as critical an issue as water quality. The flow accounts for water were used in a CGE model to address new water pricing policies in South Africa (Hassan 1998). In the past, water prices were very low, with little regard for cost or scarcity, especially for agricultural use. The proposed new pricing policy includes full-cost recovery tariffs with a guaranteed "lifeline" amount of water supplied to all households, as well as innovative pricing policies such as a user charge for the reduction of rainfall runoff caused by commercial plantations of exotic forest species.

A broad range of policy studies was undertaken in the Philippines, including an assessment of the environmental implications of rice self-sufficiency (land, water, and pollution), a study of trade and environment linkages, and a study of the environmental implications of alternative land use patterns (ENRAP 1998).

Other applications of the physical flow accounts include life-cycle analysis (LCA). Traditionally, LCA is a bottom-up process analysis, based on linking the specific processes in a supply chain to trace the environmental impacts from "cradle to grave" of specific products, or production processes. The advantage of this extremely detailed approach is its capacity to represent environmental impacts precisely. However, a major limitation of process-based LCA is the likelihood that important parts of the product systems are left out of the analysis, simply because it is a very difficult task to follow the entire supply chain in such detail.

In some instances, practitioners have attempted to address this problem through the use of so-called hybrid life-cycle analysis in which the detailed, partial LCA is combined with economy-wide IO-analysis. Physical flow accounts for inputs of natural resources and outputs of residuals are combined with input-output analysis as a supplement to traditional process-oriented LCA.

A recent workshop sponsored by the Danish Ministry of Environment and Energy presented studies from a number of countries (Nielsen and Weidema 2001). This method was used, for example, to calculate the total CO_2 impact from Danish household consumption of 72 different commodities (Munksgaard 2001). This method has also been applied to examine the environmental implications of introducing fuel cell electric vehicles in the United States (Gloria 2001). The combination of traditional LCA with IO has been used in the UK to explore aspects of climate change policies, such as the development of a model for carbon emissions trading and an analysis to identify the industries that would gain and lose the most from carbon taxes (Ecotec 1999).

Material Flow Accounts

MFA were developed by the Wuppertal Institute (Spangenberg and others 1999) to address sustainability based on the ecological concept of de-materialization, or de-linking economic growth from material use. MFA are similar to the SEEA's physical flow accounts in that they record the use of materials and the generation of residuals, but MFA are not always fully disaggregated by industry. The SEEA can improve MFA by providing information about much of the material use disaggregated by industry. However, MFA also include the "hidden flows," which consist of materials excavated or disturbed along with the desired material, but which do not themselves enter the economy. Examples of hidden flows include mine tailings or soil excavated during construction. MFA also distinguish between dissipative use flows and flows which are embodied in products. Dissipative flows are materials which are shed from products during the normal course of use, such as fertilizer, or rubber worn from motor vehicle tires.

MFA have been constructed by a number of countries. An ambitious project by the World Resources Institute has made a substantial improvement by compiling roughly comparable MFA for five industrialized countries: Austria, Germany, Japan, the Netherlands, and the United States (Matthew and others 2000). In addition to compiling macro-level indicators, the study analyzed the flows to investigate issues such as the impact of e-commerce and the shift from heavy industry in the five countries to knowledge-based and service industries. The study found that despite these changes and the increasing efficiency of material use, the use of materials and the volume of waste generated continues to increase. The authors attribute this to economic growth and consumer choices that favor energy- and material-intensive lifestyles.

Extension from National to Regional Analysis

A country trying to design a more sustainable economy with its own environmental accounts can face two problems. First, even if it reduces domestic emissions, it may still suffer environmental damage because of transboundary flows of emissions from other countries. This is the case for regional issues such as acidification of air and eutrophication of water, as well as global issues such as climate change and ozone depletion. Construction of national accounts may need to include the international transfers of residuals. This has been proposed in the SEEA, but will not be easy to implement. Europe has a good system for monitoring transboundary flows, but many other parts of the world do not.

Secondly, world trade has led to a dissociation of consumption patterns that cause environmental degradation from the source of production where the degradation occurs. Open economies typically import a great deal, and the pollutants associated with the production of these imports in their countries of origin might be quite high. Attempts to take imports into account when assessing a country's total environmental impact have been hampered by lack of information about the emission characteristics of trading partners. Some studies have simply assumed that the imports have the same pollution and energy coefficients per unit of output as domestically produced products. The construction of flow accounts by many countries will make it possible to substitute real information for this highly unlikely assumption. This would greatly improve the estimates of the true environmental burden of a country's consumption patterns.

To estimate the importance of using country-specific emission characteristics, Sweden compared the emissions embodied in their imports under three alternative assumptions: 1) assuming Swedish industry-level emission coefficients for imports; 2) assuming national average emission intensity for all imports from each country based on emissions data for all EU countries plus other major trading partners (USA, Japan, Norway, and Switzerland); and 3) assuming industry-specific emissions coefficients for each country, derived from their environmental accounts.

The results for CO2, SO2, and NOx emissions embodied in imports were extremely sensitive to the method used (Table 10)[1]. The lowest estimate of CO2 and SO2 emissions was obtained when Swedish emission coefficients were used: emissions using the other two methods were at least 50% higher. The reverse occurred for NOx: Swedish emission coefficients resulted in the highest level of NOx emissions, although not much higher than the other two methods. The results reveal significant differences among countries in emission intensities. While there are a number of methodological and data improvements needed, this pilot study indicates the importance of obtaining environmental accounts for all major trading partners in order to evaluate correctly the emissions embodied in imports.

Table 10. Emissions embodied in Swedish imports under alternative assumptions about emission intensities of imports, 1995

	CO_2	SO_2	NO_x
Method 1: Swedish emission coefficients	20,800	43	128
Method 2: National average emission coefficients from exporting country	32,900	121	119
Method 3: Industry-specific emission coefficients from exporting country	36,300	128	109

Note: Method 3 used data from 1993 and so is not directly comparable to the other two methods.

Source: NIER 2000a.

4.2 Monetary flow accounts for environmental degradation and resource use

Effective environmental management is based not only on an understanding of the *volume* of pollution and material use, but also an understanding of the *economic* implications. Policy makers need to know what the welfare loss of pollution is (damage costs) and where limited financial resources will be most effective in reducing environmental pressure, i.e., the relative benefits and costs of reducing different forms of environmental degradation from different sources.

Two different conceptual approaches to valuing environmental degradation are commonly used: the maintenance cost approach and the damage cost approach. The former shows policymakers the *cost* of certain actions to prevent or remediate degradation, and the latter shows the *benefit* of policy actions, that is, the value of the damages that will be prevented. In the absence of efficient markets, these measures are likely to be quite different. The damage cost is the theoretically correct approach for measuring changes in economic well-being and adjusting macroeconomic aggregates, but both measures provide useful information for environmental management.

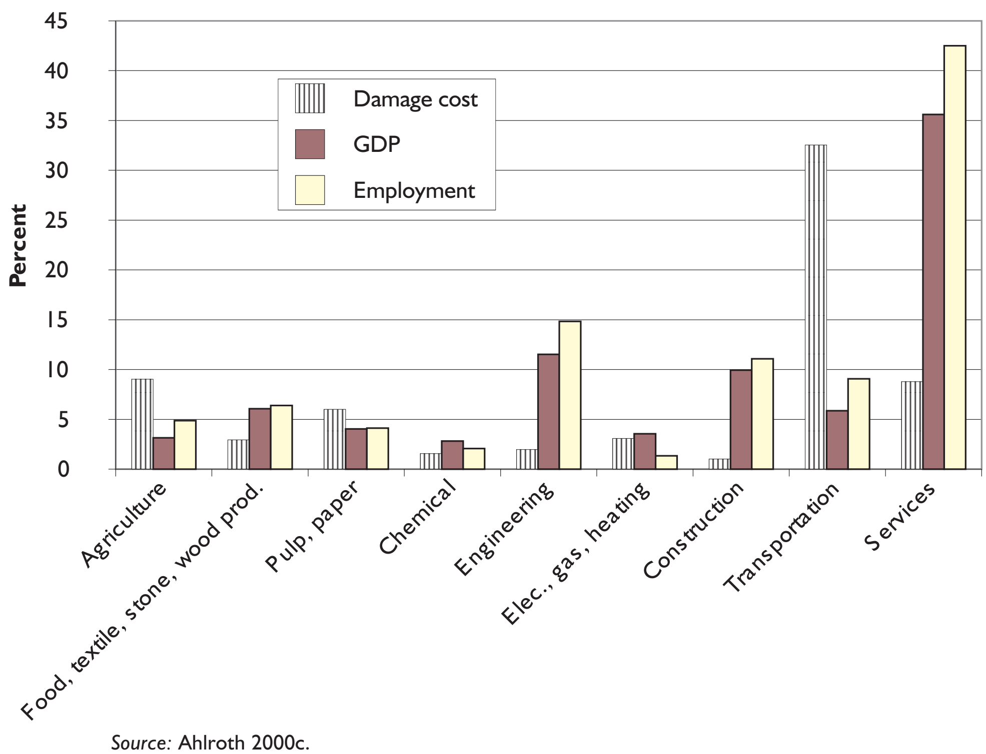
4.2.A Indicators and descriptive statistics

Many of the indicators and descriptive statistics developed for the physical accounts can be used for the monetary accounts. Trends in aggregate monetary figures can be monitored as well as measures of pollution intensity by economic activity. Various environmental-economic profiles can be constructed, and the monetary accounts can be analyzed to determine direct and indirect sectoral emissions, and how these may have changed over time. An advantage of the monetary accounts is that the environmental-economic profiles can aggregate different kinds of environmental problems into a single figure to represent the total environmental burden from each sector.

Figure 8 provides a snapshot for Sweden of the overall economic contribution and environmental burden posed by the most polluting industries in 1991. The environmental burden is represented by sectoral shares of damages caused by domestic emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), volatile organic compounds (VOC), nitrogen to water, and ammonia (NH3). The economic contribution is represented by sectoral shares of GDP and employment. The highest burden is imposed by Transportation (33%), followed by Services (9%), Pulp and paper (7%), and Agriculture (7%). However, the Service industry's economic contribution (36% of GDP and 43% of employment is) much higher than its share of the environmental burden. The reverse is true for Transportation whose economic contribution is only 6% of national income and 9%.

Information about relative economic contributions and environmental burdens is essential for policymakers when identifying industries that will play a key role in economic development. In the absence of such information, incentives to promote growth of a specific industry, such as subsidies to Pulp and paper or Agriculture, may result in levels of environmental damage that far outweigh apparent economic gains.

Figure 8. Economic contribution and environmental burden from domestic pollution by selected industries in Sweden, 1991



Source: Ahlroth 2000c.

In cases where environmental policy takes the form of setting emission standards without regard for balancing economic costs and benefits, the policy challenge is to find the most cost-effective opportunities for pollution reduction, represented by the maintenance cost approach. This approach was used in the Philippines and in Korea.

Korea was one of the first developing countries to construct environmental accounts and was hampered by a lack of data. Monetary accounts were constructed assuming the same pollution abatement method and unit cost for all industries, except for a few adjustments for mobile sources of air pollution (Korea Environment Institute 1998). Consequently, the pattern of damage costs by industry roughly parallels the pattern of physical emissions and the accounts does not provide policy-makers with any additional information for environmental management.

The Philippines constructed environmental degradation accounts for a range of pollutants to air and water from selected industries, as well as nutrient loss in agriculture and soil loss in forestry (NSCB 1998, 2000). Some results from the accounts for biological oxygen demand (BOD) are shown in Table 11. The results are instructive: although aquaculture is responsible for 64% of total BOD emissions, the cost of pollution abatement in that industry is extremely small—less than 1% of total costs. By contrast, the hog industry produces 34% of BOD but accounts for nearly 80% of the maintenance costs. The sugar industry contributes a tiny share of total BOD emissions, only 0.4%, but it would be quite costly to reduce these emissions: its share of environmental damage costs is 13%.

Comparison of valuation approaches

To compare the differences among valuation techniques, Sweden applied three techniques to the NOX: the damage cost approach, the avoidance cost approach (another term for maintenance cost), and willingness-to-pay (Table 12). The damage cost approach yields the lowest value, at just over 2,000 million SEK; the avoidance cost approach is higher, but not that dissimilar, at around 2,800 million SEK. At 7,300 million SEK, WTP yields a value more than three times the damage cost estimate.

While estimates of both damage and maintenance cost are available for some European countries (see discussion of GARP project below), few developing countries have implemented the damage cost approach, except in some cases for the Philippines (see ENRAP (1998)). The primary reason seems to be data availability. To estimate maintenance cost, many countries can use the benefits transfer method, i.e.,

Table 11. Emissions of BOD and environmental damage by selected industries in the Philippines, 1993

	Percent of emissions	*Percent of environmental damage*	*Ratio of cost shares to emission shares*
Aquaculture	63.7	0.7	0.01
Hog industry	34.2	79.7	2.33
Tuna canning	0.1	0.3	2.86
Textile industry	1.4	5.8	4.02
Leather tanning	0.1	0.3	5.03
Sugar industry	0.4	13.2	31.09
Total	100.0	100.0	na
Level of emissions (MT) and total costs (thousands of pesos)	1,303,452	2,053,000	

Na: not applicable

Notes: Environmental damage estimated using the maintenance cost approach.
Emissions of BOD were not calculated for all industries.

Source: National Statistical Coordination Board 2000.

Table 12. Cost of NO_x emissions using different valuation methods in Sweden, 1991 *(millions of SEK)*

Damage cost	*Avoidance cost*	*Willingness-to-pay*
2,020	2,792	7,301

Source: Ahlroth 2000c.

using estimates developed by other countries. A large databank for the cost of different pollution abatement technologies, which can be applied in virtually any country, is readily available. Environmental damage, however, is less amenable to benefits transfer because it is often a country-specific matter, both in terms of the relationship between level of emissions and amount of damage, and the local cost of this damage. Until more easily usable, or internationally transferable estimates of value are available, it will be difficult for many developing countries to implement the damage cost approach.

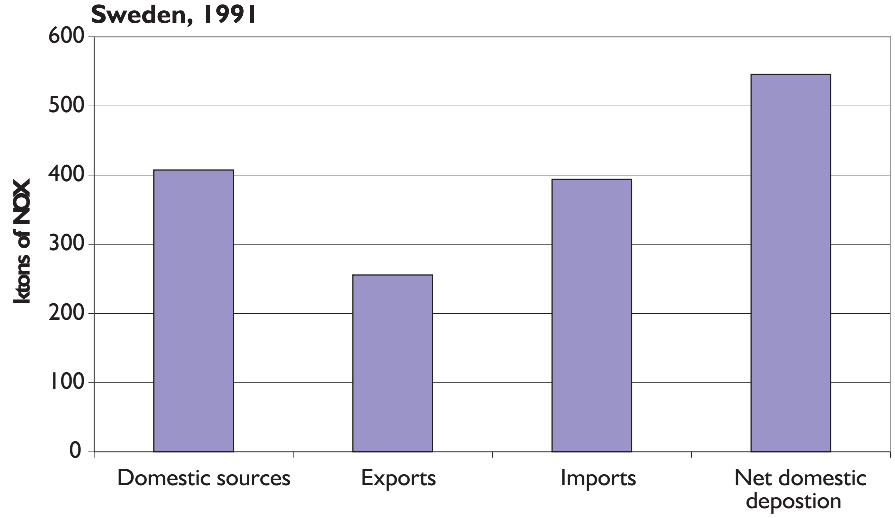
Transboundary Pollution

Ideally, the two valuation methods would provide a crude indication of the relative benefits and costs of reducing emissions (this limitations to this comparison are discussed in the revised SEEA). However, there is not a simple correspondence between domestic damage and domestic maintenance costs, in part, because of the large role played by transboundary pollution. Like many countries, Sweden imports and exports a great deal of pollution—more than 60% of its domestic production of NOX is exported, and imported NOX accounts for 72% of its net domestic deposition (Figure 9).

The very high share of imported emissions indicates that Sweden will need to cooperate with neighboring countries, who are sources of its imported NOX, in order to improve Sweden's domestic environment. The crude evidence from these accounts of the relative costs and benefits of reducing domestic emissions in Sweden lends further support to that approach. However, given Sweden's considerable exports of NOX, an efficient strategy for reducing emissions must take into account all countries involved, in order to identify in a regional context where the greatest benefits at lowest cost are to be found.

An ambitious study to map the costs of transboundary pollution among 15 EU countries was undertaken by the GARP project. Table 13 shows the distribution of these costs: the damage due to domestically generated residuals, the damage due to imports, and the damage that is exported. The first row, labeled EU, shows a total damage cost of 128.8 billion euros per year. Germany, France, UK, and Italy are the source of most of this pollution, and

Figure 9. Domestic emissions, exports and imports of NOX in Sweden, 1991



Source: Ahlroth 2000c.

these four countries also bear most of the cost. For many countries, domestic emissions are responsible for less than half the total domestic damages. Smaller countries with many neighbors tend to incur a high share of damages from imports, while larger countries suffer damages mainly from domestic residuals.

4.2.B Policy analysis with monetary accounts

As with the physical flow accounts, the monetary accounts can have many applications. They were used in the Philippines for partial equilibrium cost-benefit analyses of the use of economic instruments for addressing air pollution. One cost-benefit analysis considered two alternative policies to reduce atmospheric lead: a tax on leaded gasoline vs. a complete phase-out of leaded gasoline over a three-year period (Manasan et al. 1998). The accounts provided the physical lead emissions, data about the value of benefits (improved human health due to lower emissions) and costs (measures to reduce emissions) were obtained from other studies and used to construct monetary accounts. The results found that the present value of the phase-out was close to three times that of the tax differential approach, primarily because of its much greater and faster impact on health. For this reason, the authors conclude that the phase-out is a more appropriate policy than using economic incentives to reduce lead emissions.

The monetary accounts could potentially be used for more comprehensive policy analysis. For example, the abatement costs could provide the input into models such as the one used to calculate Hueting's Sustainable National Income, or models evaluating green taxes where the measures industries take in response to taxes would be included. In practice, the data required by these models is not obtained from monetary flow accounts because entire

Table 13. Pollution damage by source country and receptor country in the European Union

	Receptor Countries																
	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK	EU	Non EU
	Damage Costs caused by the Source Countries within the Receptor Countries [billion ECU/a]																
EU	**2.8**	**4.5**	**40.9**	**2.3**	**8.9**	**0.4**	**21.4**	**2.0**	**0.4**	**15.3**	**0.1**	**7.0**	**1.2**	**2.1**	**19.4**	**128.8**	**34.9**
	Percentage of Damage Costs Caused in the Receptor Countries [%]															[bn ECU/a]	
AT	**12.2**	0.2	0.9	0.6	0.2	0.9	0.2	0.9	0.1	2.2	0.3	0.2	0.0	0.8	0.1	**1.2**	**1.8**
BE	1.1	**12.3**	3.7	3.8	1.2	1.4	3.7	0.0	1.4	0.7	4.8	13.0	0.4	2.6	1.1	**4.4**	**0.4**
DE	47.0	14.2	**53.8**	43.7	4.8	38.7	13.4	2.0	6.9	15.6	33.3	15.6	0.9	49.6	6.7	**34.4**	**17.0**
DK	0.6	1.0	0.9	**9.2**	0.1	4.6	0.5	0.0	0.6	0.1	0.8	1.0	0.0	8.9	0.8	**1.2**	**0.4**
ES	1.7	8.6	3.8	1.8	**51.8**	0.0	16.3	0.0	16.1	5.6	8.9	6.1	50.4	1.0	7.3	**13.5**	**0.4**
FI	0.1	0.1	0.1	0.4	0.0	**29.5**	0.0	0.0	0.1	0.0	0.0	0.1	0.0	1.9	0.1	**0.3**	**0.1**
FR	8.7	33.5	15.3	7.2	16.8	2.1	**36.2**	0.1	11.2	10.3	31.9	23.8	5.9	5.4	11.4	**23.2**	**2.0**
GR	1.1	0.0	0.1	0.2	0.1	0.0	0.1	**78.0**	0.1	2.3	0.1	0.0	0.0	0.2	0.0	**2.1**	**3.7**
IE	0.0	0.3	0.2	0.5	0.4	0.1	0.4	0.0	**18.8**	0.0	0.2	0.4	0.3	0.2	2.1	**0.7**	**0.0**
IT	23.3	3.0	6.9	2.5	8.8	1.6	5.9	18.9	2.8	**60.1**	4.1	2.4	2.6	2.8	1.2	**15.8**	**6.8**
LU	0.2	0.3	0.4	0.2	0.1	0.1	0.2	0.0	0.1	0.1	**1.6**	0.4	0.0	0.1	0.0	**0.3**	**0.0**
NL	1.2	8.0	4.6	7.1	1.0	2.3	3.8	0.0	1.4	0.6	5.6	**13.8**	0.3	5.0	1.8	**4.9**	**0.5**
PT	0.0	0.6	0.2	0.1	6.8	0.0	1.1	0.0	2.4	0.1	0.6	0.4	**36.0**	0.0	0.7	**1.6**	**0.0**
SE	0.2	0.3	0.4	1.5	0.0	11.7	0.1	0.0	0.2	0.0	0.2	0.3	0.0	**8.1**	0.3	**0.5**	**0.3**
UK	2.6	17.5	8.6	21.2	8.0	7.0	18.1	0.0	37.8	2.0	7.7	22.4	3.3	13.4	**66.5**	**24.7**	**1.2**

Source: Markandya and others 2000.

abatement curves need to be estimated. The monetary accounts provide only a summary figure, although if the summary figures are derived from abatement cost curves, this underlying data may be useful in policy models.

Valuation issues discussed in environmental accounts, and in the SEEA chapter on valuation, have largely focused on environmental degradation, but policymakers can use this approach to address another challenge: pricing non-market goods and environmental services. Two examples of particular importance for developing countries have been water and recreational services from nature-based protected areas. In many countries, the price charged for these resources does not reflect the true financial cost, let alone the full economic cost. Where the costs are subsidized, as is water is in many countries, there is little incentive for resource conservation.

When tourists visit magnificent national parks and protected areas, they may not be charged an entrance or user fee that equals the full value of the benefits they receive. As a result, the recreational services and the unique ecosystems on which they depend, are undervalued. Given the apparently low economic value for this form of land use, countries often face pressure to convert protected areas to other uses. This problem can be especially severe for developing countries, e.g., the clearing of protected area forest for agriculture in many tropical countries, but is by no means limited to developing countries, e.g., the controversy over the conversion of Alaska’s Arctic wilderness to oil mining.

There is an extensive literature on the economic value of both protected areas and water, but relatively little has found its way into the environmental accounts yet. Where water rights are traded in reasonably competitive markets, as in parts of Australia, the value of water is reflected in the price of these rights. However, water is often not traded in competitive markets and its value can be difficult to measure, requiring a great deal of information that is not always readily available. Case studies of the value of water for agriculture were carried out in the environmental accounting framework for Namibia (Lange and others 2000), and found a very low value for water, though one that varied enormously by crop.

Even without estimating the economic value of water, there is monetary information about costs and tariffs that is very useful to policymakers. Flow accounts can be compiled for the cost of providing water to each sector, the tariffs charged, and, from this information, the subsidy by sector can be calculated. Monitoring subsidies is clearly important both for sustainable management of resources as well as for equity by identifying which groups in society receive the greatest subsidy. This work has been done, at least partly, in Chile, France, Botswana, and Namibia.

These calculations are not only important for domestic environmental policy, but also for issues that are regional or global. For example, Namibia’s water subsidies to commercial agriculture have declined considerably since the early 1990s when a policy of gradually introducing full-cost recovery was adopted. A comparison of water subsidies for Namibia and South Africa in 1996 (Lange and Hassan 1999) showed that commercial agriculture in Namibia continued to receive significant water subsidies, though much lower than the subsidies to commercial agriculture in South Africa. Quantifying the value of the subsidy has been particularly useful both in domestic discussions about water and agricultural policy, and also in the negotiations over future allocation of shared river water between Namibia and South Africa.

5 Environmental Protection and Resource Management Accounts

Environmental regulation has been highly controversial in most countries and the environmental protection and resource management accounts were designed to help address some of the important questions surrounding regulation. For example, has the money spent on pollution abatement been effective in reducing pollution, and how has environmental regulation affected productivity and international competitiveness? This set of accounts has several quite distinct components including:

1. Expenditures for environmental protection and resource management, by public and private sectors
2. The activities of industries that provide environmental protection services
3. Environmental and resource taxes/ subsidies.

Section 2 discussed a range of problems in constructing and interpreting the EPE component of the accounts that make it difficult to use them for policy. For example, a decreasing EPE cannot be interpreted unambiguously as a trend toward a more or less sustainable economy. With more information to clarify some of the ambiguities if the EPE, practitioners can analyze some of the following issues:

- The cost of environmental regulation over time
- How effective environmental protection expenditures and eco-taxes have been in reducing pollution
- The economic impact of environmental expenditures and taxes, for example, the impact of carbon taxes on prices, productivity and international competitiveness.

The first part of this section addresses the construction of indicators and descriptive statistics from these accounts to use for monitoring environmental protection and resource management activities. The second section discusses the use of the accounts for analysis and policy modelling.

5.1 Indicators and descriptive statistics

Of the three components of this part of the accounts, environmental protection expenditure (EPE) accounts have been the most widely constructed, mainly in the United States, Canada, the EU, Japan, and Australia. Some developing countries have also constructed EPE accounts, notably the Philippines, Korea, Colombia, and Chile.

Environmental protection expenditure accounts

Eurostat has published a handbook with a detailed list of indicators that can be obtained from the EPE accounts, from the most general (e.g., time trend of EPE by sector and domain) to detailed (e.g., spending within industries by domain). EPE accounts for the United States, for example, show that, as a percentage of GDP, expenditures have remained constant at between 1.7 and 1.8 percent. Spending by domain (air, water, solid waste) was dominated by spending for water pollution from 1972 to 1994, but that spending for solid waste treatment was growing fast. Most of the spending for pollution abatement and control is undertaken by the private sector. A large amount of expenditures is undertaken by government for water treatment and solid waste management.

Of the four developing countries that have compiled EPE, coverage differs from country to country. Only Colombia and the Korea cover EPE by all sectors. Costa Rica and the Philippines have compiled only EPE by government. Figures for Chile have not yet been published. The indicators compiled from their accounts are shown in Table 14. It is not clear that anything has been done with these figures.

A more detailed breakdown of expenditures by industry can be used to identify which economic activities bear the greatest burden of environmental regulation. Canada's EPE accounts show that five industries account for nearly 80% of all EPE: Mining, Pulp and paper, Primary metals, Petroleum refining, and Energy utilities. Canada also provides a breakdown by province. The industrial and geographic disaggregation allows policy makers to identify the industries and communities that would be most affected by new environmental policies, and to design measures to assist them if necessary.

There has been some criticism that the EPE accounts focus too much on the expenditure side which emphasizes the extra costs imposed by environmental regulation. Possibilities for revenue and cost savings through implementation of process-integrated environmental measures have not received the same degree of attention. A Swedish EPE survey included questions about cost savings and found a large share of companies were engaged in cost-reducing or revenue-enhancing measures that were not covered by the standard EPE survey instrument (Johansson 1998). As companies are adopting process-integrated, pollution prevention instead of pollution abatement approaches, the conventional EPE accounts are less useful in analyzing the

Table 14. Summary indicators of environmental protection expenditures in 1992

	Philippines[1]	*Republic of Korea*[2]	*Costa Rica*[1]	*Colombia*
Total EPE/GDP	na	1.72	na	1.08
Government EPE/GDP	0.37	0.79	0.39	0.37
Capital EPE/Total EPE	61	49.7	50	72.7
Current EPE/Total EPE	39	50.3	50	27.3
EPE by environmental media/Total EPE				
Forest and non-forest ecosystems	na	na	28	2.7
Air	Na	18.3		2.4
Water and soil	Na	46.9	14	30
Waste	Na	30.1	36	19.4

Na: Not available.

1. Includes only government environmental protection expenditures.
2. Figures for Korea are for 1995.

Source: Table adapted from Alfieri 1998.

economic impact of environmental regulation, or the likely response to changes in regulation.

Resource management expenditures

This component of the accounts includes spending on resource management. The use of this account for improving resource management was discussed in section 3, the asset accounts. At present, these accounts have been constructed by a few European countries, Chile and Costa Rica.

Environmental protection industry

While EPE have imposed substantial costs, they have also created opportunities: entirely new industries have arisen to fill the need for environmental services. The second part of these accounts provide a clear description of this industry: its contribution to GDP, to employment, and to exports. For some countries, the environmental services industry has become an important exporter, while other countries are large importers of these services. For example, in France, the environmental services industry accounted for 2.3% of GDP and 1.4% of employment on 1997. More than half the employment was in solid waste and waste water management (Desaulty and Templé 1999).

Environmental and resource taxes

The third part of the accounts includes taxes and other fees collected by government for pollution emissions and for resource use, such as levies on minerals, forestry or fisheries. Environmental taxes and subsidies are important policy instruments for achieving sustainability. Many European countries are exploring the possibility of substituting green taxes for other forms of taxes to achieve a "double dividend" (revenues + a cleaner environment). The tax component of the EPE account can be very useful in assessing whether the tax regime provides incentives or disincentives for sustainable development, and whether taxes truly reflect the polluter pays principle that has been adopted by many countries. Taxes on specific natural resources, and their use in resource management were discussed in the section on asset accounts.

Eurostat has compiled a time series of environmental taxes for its 15 member countries (Steurer and others 2000). As a share of total tax revenue, environmental taxes constitute a small but increasingly significant tax, growing from 6.7% of total tax revenue in 1980 to 7.6% in 1997. Among the different environmental taxes—taxes on energy, transport, pollution, and resources—energy taxes dominate and presently account for about three-quarters of environmental taxes.

The use of environmental taxes has been increasing, yet there may be subsidies to some industries established for other policy purposes (e.g., competitiveness, regional development, employment) that conflict with the intent of the green taxes and sustainable development. To determine whether environmental taxes have been successful in implementing the polluter pays principle, further analysis of the EPE tax accounts is needed. The Swedish Environmental Protection Agency undertook such a study. Environmental taxes rose from 49.7 billion SEK in 1993 to 61.6 billion SEK in 1998, and are dominated by energy taxes, which include carbon taxes (Table 15).

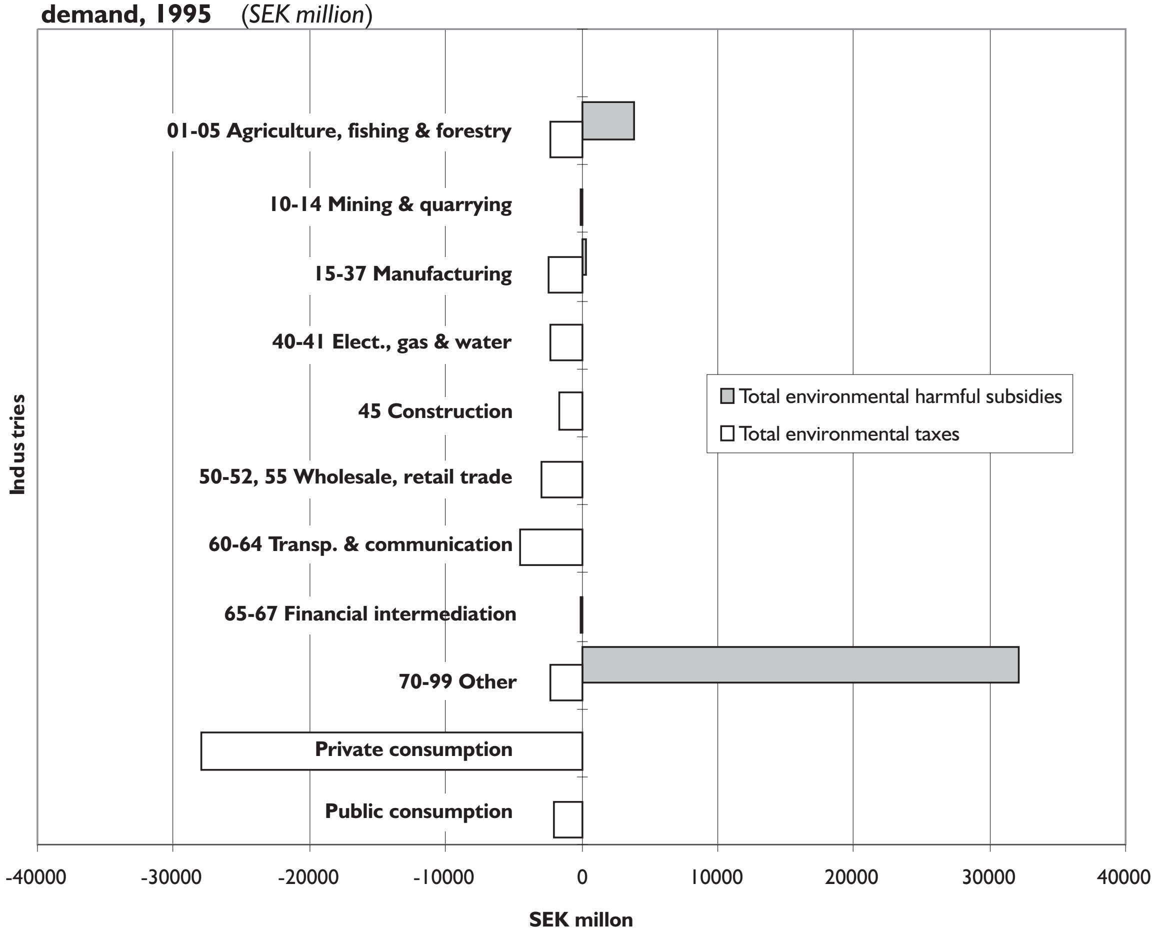
The study defined subsidies to include both direct subsidies as well as tax subsidies. Potentially harmful direct subsidies include, for example, support to home building, agriculture, forest road building, fisheries, and reindeer husbandry. Tax subsidies include lower than normal taxes on carbon and energy for industries such as Transportation, electricity and gas works, and mining. Linked with the physical accounts for energy, the tax accounts show the extent to which the "polluter pays" principle is being followed.

Table 15. Environmental taxes in Sweden, 1993–98
(millions of SEK in current prices)

Taxes on:	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
Energy	39,017	42,043	44,161	49,733	49,352	52,652
Pollution	582	566	682	753	551	508
Transport	8,119	5,852	5,798	6,721	6,451	6,336
Resources	-	-	-	70	131	142
Total	*49,711*	*50,455*	*52,636*	*59,273*	*58,482*	*61,636*

A summary of all the taxes and environmentally harmful subsidies by industry is shown in Figure 10. In some industries, the environmentally harmful subsidies received outweigh the environmental taxes paid. The largest environmentally harmful subsidies go to real estate, mainly interest rate subsidies for housing construction. Agriculture, forestry and

Figure 10. Total environmental taxes and total direct subsidies, by industries and final demand, 1995 *(SEK million)*



Source: Taken from Table 11 of Sjölin, M. and A. Wadeskog 2000.

fishing also receive more harmful subsidies than the environmental taxes they pay. Apparent conflicts between environmental taxes and environmentally harmful subsidies reflect different policy objectives. The accounts make clear what this relationship is and can provide a basis for discussion with industry about how best to achieve environmental objectives

5.2 Policy analysis

There are a number of areas where the environmental protection and resource management accounts could be used for policy analysis, such as:

- Economic impact of environmental regulation
- Economic impact of environmental taxes
- Assessment of the costs of regulation relative to their benefits
- Impact of recycling and reuse of materials.

No developing countries have yet used their EPE accounts for policy analysis. Some analysis has been done in industrialized countries, like the United States and the Netherlands, but given the problems of interpretation of EPE data, additional information is often required.

6 Economy-Wide Indicators of Sustainable Development

Many practitioners have searched for a way to measure sustainability either by revising conventional macro indicators or by producing new ones in physical units (listed in Table 2, section 2.6). Aggregate environmental theme indicators measured in physical units are derived from the NAMEA component of the SEEA. The physical indicators are meant to be used in conjunction with conventional economic indicators to assess environmental health and economic progress. A number of different revised environmental monetary aggregates have been calculated by different countries; all are discussed in the revised SEEA. At this time, there is no consensus over which indicators to use. Rather, since each indicator serves a somewhat different policy purpose, the choice of indicator depends on the policy question.

Two rather different questions can be posed by policy-makers: first, is the current level of national income sustainable? Second, what level of income would be sustainable? This section briefly reviews the experience with economy-wide physical indicators, then discusses the environmentally-adjusted macroeconomic indicators.

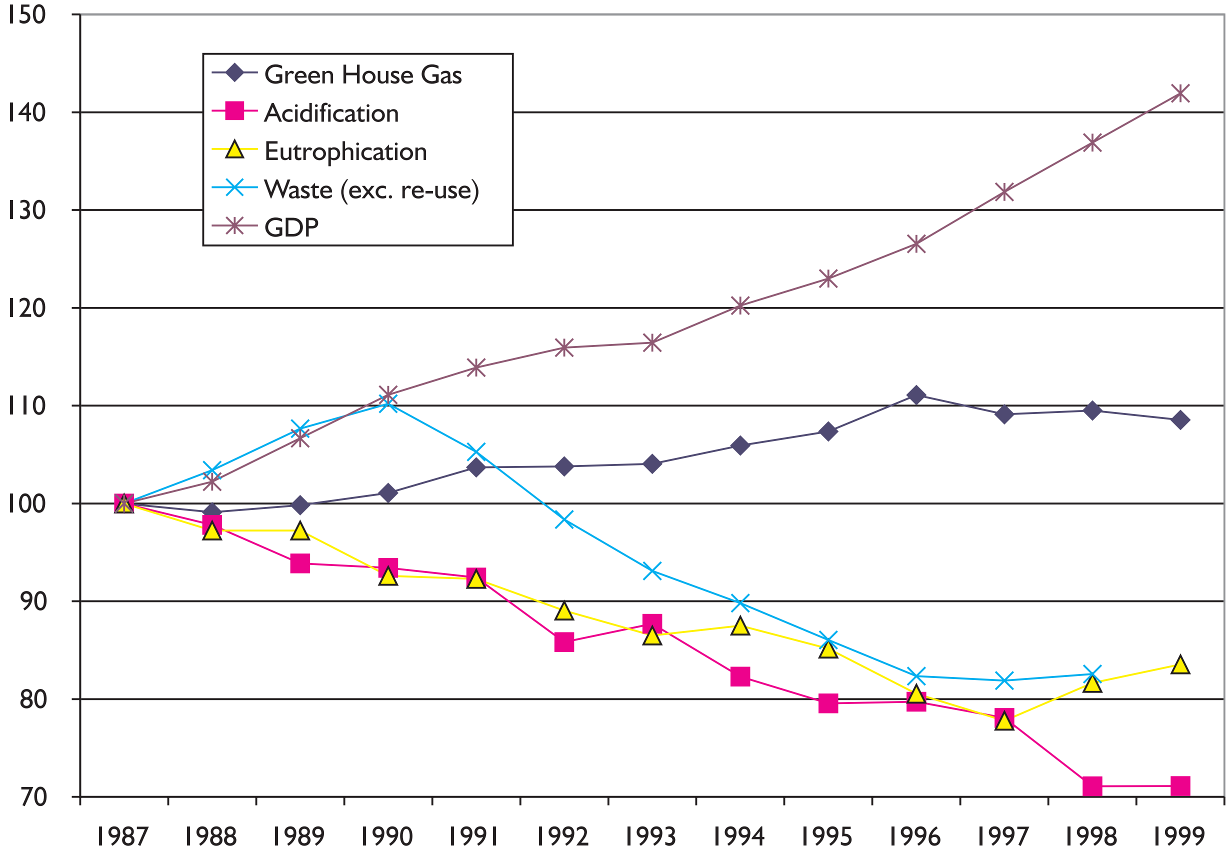
6.1 Physical indicators of macro-level performance

Section 2 discussed the use of macroeconomic indicators measured in physical units either as an alternative to monetary indicators (for assessing ecological, or strong, concepts of sustainability), or to be used in conjunction with monetary aggregates, providing environmental information that the monetary aggregates may not be able to capture fully. The NAMEA provides physical macroeconomic indicators for major environmental policy themes: climate change, acidification of the atmosphere, eutrophication of water bodies, and solid waste. The trend of these indicators for the Netherlands are shown in Figure 11.

The indicators can be compared to a national standard—such as the target level of greenhouse gas emissions—to assess sustainability. A national standard for greenhouse gas emissions, set for example, in terms of a country's target under the Kyoto Protocol can be useful. It may not be easy to assess some themes, such as eutrophication which may have a more local impact, in terms of a national standard. The NAMEA does not provide a single-valued indicator which aggregates across all themes.

The Material Flow accounts (MFA) provide another set of physical macroeconomic indicators, of which the most widely known is total material requirements (TMR). TMR sums all the material use in an economy by weight; its purpose, like the monetary aggregates, is to provide a single-valued indicator to measure dematerialization, the decoupling of economic growth from material use, a concept popularized by the Factor 4 movement. The World Resources Institute study of MFA for five industrialized countries shows significant de-coupling: since 1975, the material intensity of GDP in all five countries has declined by 20-

Figure 11. Index of macro-indicators for economic and environmental performance, Netherlands, 1987 to 1998 (*1987 = 1.00*)



Source: Statistics Netherlands, unpublished data.

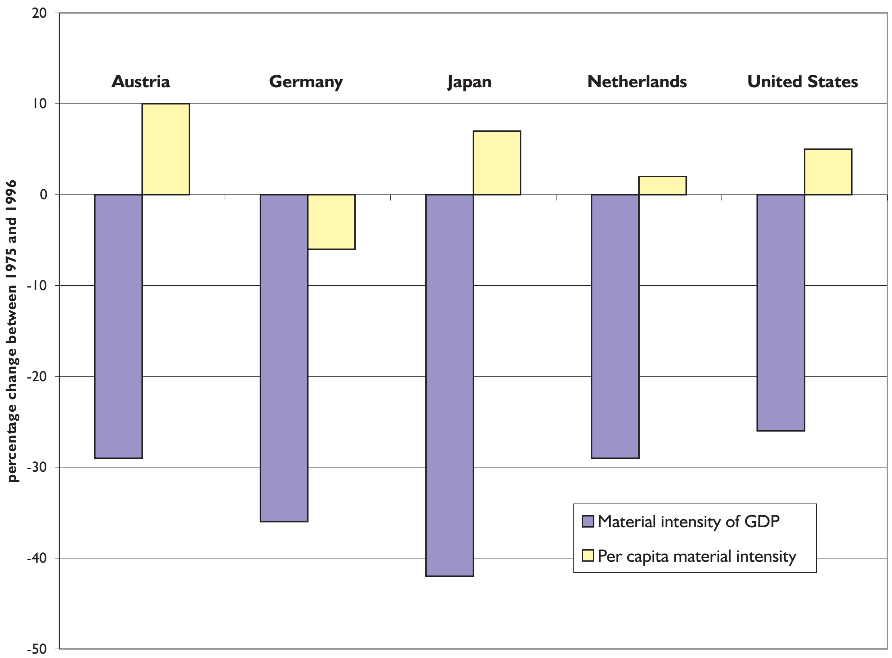
40% (Figure 12). This has been the result of efforts to reduce the volume of solid waste, and the shift away from energy- and material-intensive industries toward knowledge-based and service industries. Per capita material intensity has not declined in most countries over this time period; only Germany showed a decline (6%).

The limitations of these indicators of dematerialization, discussed in section 2, restricts their use for assessing sustainability. Indicators created for certain categories of materials whose environmental impacts are more similar may be more useful, such as the NAMEA theme indicators. Nevertheless, the relation between these indicators and total output, or trends over time can provide insight into whether countries are working towards overall goals of reducing their impact on the environment.

6.2 Environmentally-adjusted NDP and related indicators

The most well-known indicator in this category is the environmentally-adjusted NDP, eaNDP (sometimes GDP has been used instead). This indicator was calculated in early work on environmental accounting by Repetto and his colleagues as a way of focusing the attention of policy-makers on the importance of environmental degradation and depletion of

Figure 12. Percentage change in material use in five industrialized countries, 1975 to 1996



Notes: Material intensity calculated as Domestic Processed Output/GDP.
Per capita material intensity calculated as Domestic Processed Output/Population.
Domestic Processed Output = Domestic extraction + Imports – Net additions to stock – Exports.

Source: Based on (WRI 2000, Table 2, page 20).

natural capital. Repetto's work in Indonesia (on petroleum, forests, land degradation) and Costa Rica (on forests, fisheries, land degradation) was followed by similar pilot studies in Papua-New Guinea, and Mexico sponsored by the UN and the World Bank.

More recently, partially adjusted eaNDPs have been calculated for a number of countries, including Japan, Korea, the Philippines, Sweden, and Germany. The results are summarized in Table 16. The great differences among countries in terms of the types of coverage and how the maintenance cost approach was implemented make it impossible to directly compare results across countries. Korea, for example, assumed the same abatement costs in all industries, whereas the other countries estimated industry-specific abatement costs.

Sweden's eaNDP, called Genuine Income, shows the least change from conventional NDP, only 0.6%. One reason for this very low figure, despite subtracting some environmental protection expenditures which other countries did not do, is that it measures only environmental degradation from sulfur and nitrogen. Sweden also excluded degradation not already included in conventional measures of NDP, whereas other studies, notably the Korean and Philippine, did not explicitly address the issue of potential double-counting. The adjustment for Japan and Germany are rather large, mainly because they include the estimated cost of reducing carbon emissions (and, for Japan, CFCs). The other studies did not address these global pollutants.

While Sweden and Germany have calculated these measures, they have not become part of the official statistics of these countries because of the problems with this measure discussed in section 2. The United States has expressed an interest in measuring some form of eaNDP, but based on the damage-cost approach and incorporating estimates of the benefits of environmental services not currently included in the accounts (Nordhaus and Kokkelenberg 1999). However, the US has not been able to proceed due to lack of funding.

Table 16. eaNDP as percentage of NDP in selected countries

Country and time period	*Affect on macroeconomic aggregates*	*Coverage*	*Valuation method*
Japan, 1990	NDP reduced 2.4%	Depletion of minerals	Net price method
		Degradation of land, air, water, including CO2 and CFCs	Maintenance cost
Korea, 1985-1992	NDP reduced 4.1-2.6%	Depletion of minerals	Net price method
		Degradation of land, air, water	Maintenance cost
Philippines, 1988 to 1996		Depletion of forests, fish, minerals	Net price method
		Degradation of land, air, water	Maintenance cost
Germany	NDP reduced 3%	Depletion of minerals	Net price method
		Degradation of land, air, water including CO2	Maintenance cost
Sweden, 1993 and 1997	NDP reduced 0.6%	Depletion of minerals	Economic depreciation
		Environmental damage due to SOX, NOX only	Damage cost
		Environmental protection expenditures	Market cost

Note: See text for a more detailed description of coverage and valuation methods.

Source: Japan—(Oda and others 1998), Korea—(Korea Environment Institute and others 1998), Philippines—(NSCB, 1998, 2000), Germany—(Bartelmus and Vesper 2000), Sweden—(Skanberg 2000).

Genuine savings

Genuine Savings, which adjusts measures of wealth (actually, changes in wealth) rather than income has been calculated for many countries. A comparison of gross domestic savings to genuine savings for different regions of the world in 1997 is given in Table 17, based on estimates for human capital represented by expenditures on education, depletion of three major resources—energy, minerals, and forests—and environmental damage represented by carbon dioxide emissions. Crude assumptions were made in order to calculate this indicator for all countries. In all instances, genuine savings is less than gross domestic savings, but there is great variation among regions. In the Middle-East and North Africa, genuine savings are actually negative. As the author notes, a negative figure for any one year does not indicate that development is unsustainable—only if the negative trend persists over time does this become unsustainable.

6.3 Modeling approaches to macro-economic indicators

Environmentally-adjusted NDP has been criticized for combining actual transactions

Table 17. Genuine saving as percent of GDP, 1997

	Gross domestic savings	*Consumption of fixed capital*	*Net domestic savings*	*Education expenditure*	*Energy depletion*	*Mineral depletion*	*Net forest depletion*	*Carbon dioxide damage*	*Genuine domestic savings*
World	22.2	11.7	10.5	5.0	1.2	0.1	0.1	0.4	13.6
Low income	17.0	8.0	9.1	3.4	4.2	0.6	1.8	1.2	4.8
Middle income	26.2	9.2	17.0	3.5	3.8	0.5	0.2	1.1	15.0
High income	21.4	12.4	9.0	5.3	0.5	0.0	0.0	0.3	13.5
East Asia & Pacific	38.3	6.9	31.4	2.1	0.9	0.5	0.7	1.7	29.7
Europe & Central Asia	21.4	13.7	7.9	4.2	4.9	0.1	0.0	1.6	5.6
Latin America & Carib.	20.5	8.3	12.2	3.6	2.7	0.7	0.0	0.3	12.1
Middle East & N. Africa	24.1	8.8	15.3	5.2	19.7	0.1	0.0	0.9	-0.3
South Asia	18.2	9.1	9.1	3.8	2.1	0.4	2.0	1.3	7.1
Sub-Saharan Africa	16.8	9.1	7.8	4.5	5.9	1.4	0.5	0.9	3.4

Source: Adapted from World Development Indicators (World Bank 1999), quoted in (Hamilton 2000, table 6.1)

(conventional GDP and NDP) with hypothetical values (monetary value of environmental degradation). The response to this criticism led to the construction of a new set of indicators that seek to estimate what sustainable national income would be if the economy had to change to meet the environmental constraints. Two major approaches were developed Hueting's SNI and the geNDP.

Hueting's SNI is described in section 2 as the maximum income that can be sustained without technological development (excluding the use of non-renewable resources). Using a static, applied general equilibrium model, SNI has been calculated for the Netherlands in 1990 (Verbruggen and others 2000). The authors found that enormous changes would have to occur in order to fulfill the sustainability standards in the short term: SNI is 56% lower than national income in the base year (Table 18). Household consumption declines by 49%, government consumption by 69% and net investment by 79%. Both exports and imports fall by nearly two-thirds. Production in all industries falls. Revenues from pollution taxes are so high that they replace all other taxes. Taxes exceed government consumption and are redistributed as lump sum payments to households to pay for consumption. The purpose of the SNI is not to provide policy-makers with a goal for national income as such, but to indicate the difference between current income and sustainable income. If this exercise were updated, with new technologies introduced into the model as they become available, Hueting's SNI would indicate whether the economy is becoming more or less sustainable over time.

An alternative approach, the geNDP, estimates national income looking into a hypothetical future in which economic development must meet certain environmental standards. The impact on the economy is estimated by internalizing the costs of reducing environmental degradation. The purpose of this approach is to provide policy-makers with guidance about the likely impacts of alternative development paths and the instruments for

Table 18. Hueting's Sustainable National Income (*Billions of guilders*)

	Base 1990	*SNI*	*Change (%)*
National Income	*457*	*201*	*-56*
Private households consumption	314	159	-49
Government consumption	75	23	-69
Net investments	51	11	-79
Trade balance	16	8	-53
Exports	229	80	-65
Imports	-213	-72	-66
National Product	*457*	*201*	*-56*
Agricultural production	15	4	-76
Industrial production	113	19	-83
Services production	242	37	-85
Taxes on production	88	0	-100
Pollution rights	0	165	
Double counting	0	-24	

Note: SNI Variant 2b: constant trade shares; new equilibrium prices.

Source: Based on Table 7.5 of Verbruggen and others 2000.

achieving them. In these models, technology and other model parameters are not always restricted to what is currently available. Estimates for the Netherlands were carried out by (De Boer and others 1994). A similar study was carried out by the Swedish National Institute of Economic Research (NIER, 2000) focusing specifically on CO2 emissions.

NIER carried out simulations in order to inform the Climate Committee of Sweden about the likely macroeconomic impacts of achieving different levels of reduction of CO2 emissions. Three scenarios were constructed, specifying different percentage reductions for CO2. Under the Kyoto Protocol, Sweden agreed to stabilize CO_2 emissions at a level 4 percent higher than its emissions in 1990. However, there is also a widespread view in Sweden that CO_2 emissions should be reduced even further, so the alternative scenarios included two more restrictive target levels: 2 and 8 percent lower than the emissions in 1990; the last one being the same as the commitment for EU as a whole.

For these simulations, a static general equilibrium model was used with 18 production sectors including public sector, one household sector, and 6 types of energy inputs (from the energy accounts). The model had four mechanisms to reduce CO_2 emissions in the model: enhance energy efficiency, change to less use of coal fuels, lower production in coal-intensive industries (and expansion of industries which are less coal intensive) and, finally, to cut down on production (and consumption).

The baseline scenario outlines a "business-as-usual," probable growth path for the economy up to 2010 with no restrictions on CO_2 emissions. In this case, the emissions would rise to approximately 65 Mton, which is about 17 percent higher than level in 1990 (56 Mton). To keep emissions within 4 percent of emissions in 1990 thus requires a large increase of the CO_2 emission tax. The tax rate 1997 was (with exceptions for energy intensive export sectors[2])

Table 19. Macroeconomic effects of measures to reduce CO2 in Sweden

	Percent change compared to baseline scenario, 2010		
	+4% Scenario	-2% Scenario	-8% Scenario
GNP	-0,3	-0,4	-0,6
Private consumption	0,0	-0,1	-0,2
Public consumption	0,0	0,0	0,0
Investment	-0,4	-0,7	-1,1
Exports	-0,6	-1,0	-1,3
Imports	-0,5	-0,7	-0,9
Real income	-0,2	-0,4	-0,5

Source: S. Ahlroth 2000. "geGDP simulations in Sweden: Simulations of tax policy for CO_2 reductions." Unpublished paper of Swedish National Institute of Economic Research.

370 SEK per ton CO_2. In the +4 scenario representing the Kyoto Protocol, the tax would have to be increased to 820 SEK per ton CO_2. The changes in the economy would reduce GDP slightly, by 0.3% under the +4 scenario, and by 0.4% and 0.6% under the –2% and –8% scenarios, respectively (Table 19). Consumption is not much affected except by the –8% scenario. All other macroeconomic variables are affected—investment, trade and real income.

As a result of this study, the Climate Committee recommended that the emissions of greenhouse gases should, as a mean value for the period 2003 o 2012, be 2 % lower than emissions in 1990, counted as tons of carbon dioxide equivalent. The committee also suggested as a long-term objective to reduce greenhouse gases to 50 % of 1990 levels by 2050, but no political decision has yet been taken.

The models used to estimate a sustainable economy, whether Hueting's SNI or geNDP, vary not only in terms of the issues they address and the assumptions they make, but also in terms of the type of model used. Many of the SNI exercises have used general equilibrium models, but these models are typically static, that is, they do not describe the dynamic path an economy would follow to achieve the transition from the present economy to a sustainable one. Meyer and Ewerhart (1998) addressed the greenhouse gas issue for the German economy with a dynamic econometric input-output model. The model is more disaggregated by industry and uses the sale of carbon emission permits as a means to achieve the target levels of emission reduction by 2005 (from 5% to 30% lower than Germany's emissions in 1990). A 5% reduction of CO2 emissions resulted in virtually no change in GDP, relative to the baseline scenario, but a 30% reduction would reduce GDP by 3%, which is still rather small. The dynamic adjustment of the economy over time (1996 to 2005) is not smooth, suggesting that such a model provides important information to policy-makers.

Because of the many assumptions that practitioners must make in constructing these indicators, the wide range of environmental factors which practitioners may choose to include or ignore, and the different methodologies which have been used, no studies have produced indicators that are comparable across countries.

7 Concluding Comments

Much of the use of environmental accounts has been in industrialized countries, especially Europe, Australia, and Canada. The asset accounts are compiled by most countries, but not used very much in assessing sustainability. The flow accounts are widely used, both for the construction of indicators and as inputs to policy modeling. The construction of monetary environmental macro indicators is quite limited, and it is not clear that these indicators have been much used.

There are, in addition, four main observations regarding how useful environmental accounts are for policy:

1. Although some countries are using the environmental accounts quite actively, the accounts are still underutilized, especially in developing countries
2. No country has truly comprehensive environmental accounts
3. International comparisons are important, but not yet possible because of differences in methodology, coverage, environmental standards, and other factors
4. For a country to fully assess its environmental impact, it must have
   - Accounts for the transboundary movement into and out of the country of pollutants via air and water
   - Accounts for its major trading partners to calculate the pollution and material content of products that it imports.

Underutilization of accounts

The asset accounts have been used to monitor sustainability in various ways, but many countries have not exploited their full potential to monitor characteristics of wealth and changes in wealth over time. This may be due to the lack of emphasis on conventional asset accounts and measures of wealth. The lack of a consensus in the revised SEEA about a method for measuring the cost of depletion is also a deterrent. The asset accounts could also be more widely used to assist in resource management. Even simple analysis, such as comparison of rent to the taxes on rent and the costs of resource management is not routinely carried out in countries that compile asset accounts for natural capital.

The flow accounts are more widely used, both for the construction of indicators, environmental profiles, and analysis. There is considerable overlap between the SEEA and the sustainability indicators proposed by the United Nations, OECD, and other organizations. Tighter links among these different approaches could be useful.

Comprehensive environmental accounts

Sustainability can only be measured if all assets are included. Including natural capital as part of a country's wealth is an important step toward better measure of sustainability. However, most countries do not include all environmental capital, or all the environmental goods and services that natural capital provides. For example, asset values most often reflect only the value of the major commercial product, e.g., timber value of forests.

International comparability

International comparisons are extremely useful for countries in assessing their resource management. The comparison of water accounts in southern Africa or the environmental damage costs in Europe, for example, are extremely helpful for policy. So far, the comparison of accounts and of the resulting indicators across countries is not generally possible because of the wide range of definitions, coverage and methodologies used by different countries. Monetary accounts may diverge even more than physical accounts because of the range of different valuation methodologies that could be used, environmental standards, and other assumptions necessary for valuation. With the exception of the Genuine Savings indicator, it has not been possible to compare monetary environmental macro indicators across countries.

Full assessment of environmental impact

Several studies in Europe have shown that the quantities of pollution exported and imported via air and water are very large; without accurate information about these quantities, the use of environmental accounts for policy will be limited. Similarly, substantial pollution and resources are embodied in international trade. The Swedish study showed that environmental coefficients can diverge substantially among countries, and that a proper assessment of the environmental impact of a country's imports can only be made with information about the environmental coefficients of one's trading partner, from the partner's environmental accounts.

In addition, management of global or regional environmental problems, whether climate change or acidification, require comparable environmental accounts for each country.

Progress toward international comparability

Regional organizations and projects provide a good forum for developing comparable environmental accounts. The European Union has led several efforts, compiling oil and natural gas accounts for five member countries, and forest accounts for three countries. It has supported the GREENSTAMP (GREENed National STAtistical and Modeling Procedures) Project to work on developing environmental accounts and studying their potential applications in the EU. Eurostat has also supported the Green Accounting Research Project (GARP) which attempts to compile comparable monetary accounts based on the damage cost approach, including transboundary transport, across 15 EU countries.

A regional program to develop environmental accounts began in the late 1990's in southern Africa, focusing on Namibia, Botswana, and South Africa with support from international donors. As a regional undertaking, the project has emphasized coming to an agreement about common methods in order to construct comparable accounts among the countries. The formation of the Manila Forum, a group of southeast Asian countries promoting development of environmental accounts, also provides a good opportunity for building comparable environmental accounts in this region.

Notes

1. Data for the first two methods were obtained for 1995; data for the third method were only available for 1993, so the results are not directly comparable with results from the other two methods.

2. The manufacturing industry (= pulp and paper, chemical, refineries, iron and steel, engineering, and other manufacturing industries in the Excel figures) pays 50% of the CO_2 tax, i.e., 0.185 SEK/kg CO_2.

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