CHAPTER III

MEASUREMENT ISSUES WHEN INCLUDING MORE INFORMATION ON NATURAL RESOURCES AND THE ENVIRONMENT IN THE NATIONAL ACCOUNTS

A substantial amount of conceptual work and data gathering will be necessary to incorporate more information on natural resources and the environment into the national accounts. And in order to revise the accounts to incorporate such "green" information, decisionmakers must ultimately address the practical issues of measurement.

Even apparently straightforward revisions can pose knotty problems. One important challenge will be to put a dollar value on natural resources and the environment where there are no reliable market data on prices and quantities. Reliable market data are lacking for many types of natural capital assets, because either the asset itself or the asset's service flows are not bought and sold as distinct commodities. It is likely that expanding the asset boundary to record degradation in environmental assets will be difficult because, with few exceptions, environmental services are not marketed.

It will be especially difficult to expand the production boundary to include the final services of natural capital because virtually none of these services are marketed. This will create more of a problem for some services than for others, depending on whether the services can be indirectly linked to market activities. For example, the use of the final services of nonmarketed recreation is tied to related market expenditures on food, transportation, and special clothing. Thus, a price for recreation services can be imputed indirectly from market data. Fewer techniques are available, however, for pricing such services as the benefits of biodiversity because they are remote from market activities. Nonuse benefits can only be measured by surveys designed to show the public's willingness to pay for the possible use of these services.

It is also likely to be difficult to identify the costs of reducing pollution risks because some items are purchased for multiple uses. Therefore, the market price indicates a value for the set of services that the purchased item provides. For example, when market data indicate the price of an air conditioner, information on the market price alone does not indicate how much of that price can be attributed to the service of cleaning the air as opposed to the service of cooling it.

Even when data are available for marketed service flows, it may be difficult to identify the net change in the stock of natural capital assets. The

task of determining asset value, depletion, or degradation also requires an assessment of how best to quantify changes in natural resources and the environment. Examples of physical measurements include board feet (forests); tons (iron ore); barrels (petroleum); and parts per million, deaths per thousand, and morbidity rates (environmental quality). For biological resources, it is important to account for regeneration of the physical stock; for nonrenewable natural resources, accounting for discoveries is an issue in evaluating reserves; and for the environment, the issue is accounting for natural regeneration and degradation.

QUANTIFYING ENVIRONMENTAL AND NATURAL RESOURCE ASSETS

Questions about the accuracy and precision of estimated changes in environmental quality and natural resource stocks raise doubts about the usefulness of incorporating such data in the national accounts. Environmental quality can be described in numerous ways--for example, by average pollutant concentrations, by frequency of violations of regulated standards, and by incidents that pose catastrophic risk to living organisms. In general these measures move together, but it is possible for improvements to be made in one area and not in another. Observations of biological populations are difficult, and hence, estimates for these resources are usually based on mathematical models. Estimates of existing supplies of economically exploitable reserves are constantly being revised (by adjusting estimates of the existing stock and adding discoveries) based on information gathered during production and exploration. Quantification of these natural capital stocks is subject to gross errors because of the uncertainty involved.

Measuring Environmental Quality

Environmental pollution is often described in terms of the quantity of toxins that are being released into the air, water, or land. Most environmental regulations are based on the same emissions metric. But any attempt physically to measure the quality of the environment on a national basis will be very difficult. Two important problems that have to be identified are risk assessment and aggregation.

The primary reason for restricting the release of toxins is the risk they pose to the health of humans and other living organisms. There is increasing interest, therefore, in developing a risk-based approach to environmental policy. This approach consists of estimating and ranking the probability of

actual exposure and harm that people or other living organisms will be subjected to during the life cycle of a pollutant. But it is difficult to determine how pollution affects organisms, especially when more than one toxin is present. In other words, it is not possible to assume a one-to-one relationship between any measure of emissions and environmental quality that is defined in terms of human health.

Physical measures such as the level of emissions by pollutant and region may also be poor indicators of pollution problems because they do not reveal information about the risk of exposure. For example, data on the total weight of oxide pollutants can disguise the fact that one ton of sulfur oxides poses a far greater risk to human health than a ton of carbon monoxide. Moreover, totaling physical measurements over several regions may result in misleading information. National statistics may not reveal severe problems with water quality in local streams or high levels of ozone in a particular area. For example, the implications would be different if the total amount of emissions into the atmosphere during a period were not released in various concentrations at the local level but were spread over the entire United States. Air quality as measured by total emissions would be the same but a wider area of dispersion could positively affect human health because both population and pollution tend to be concentrated in urban areas.

There are also measurement problems associated with specific media. Air quality in a region at any specific time depends on several conditions, including the rate at which pollutants are discharged in the region, the air temperature, wind conditions, humidity, cloud cover, and other weather conditions. Each of these factors can change markedly over time. For some pollutants such as smog, there are well-defined daily cycles that can be traced to peaks in auto traffic (a direct source of emissions) and the noonday sun. For other air pollutants, cycles are not pronounced and concentrations tend to vary as randomly as the weather.

Monitoring stations throughout the United States collect data on water quality. Although the monitoring stations are placed so as to gather a broad sampling of the nation's water quality, the collected data do not necessarily measure quality where it is most likely to affect people. The collection stations are further limited because they do not measure all pollutants (including potentially toxic organic chemicals) and may not measure low concentrations of pollutants that are nonetheless significant.

Available Data on Environmental Quality

Available data on air, water, and land quality has increased in both quantity and quality over the last two decades. Further improvements are probable.

Air Quality. Since 1970, efforts to control air pollution have been focused on limiting the emissions of six common pollutants: total suspended particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide, lead, and the organic compounds that contribute to the formation of ozone in the lowest layers of the atmosphere. The U.S. Environmental Protection Agency (EPA) has established national ambient air quality standards for these pollutants to be applied uniformly throughout the country. The idea behind ambient air quality standards is that they are to be based on scientific determinations of the levels of air pollution below which humans or the environment will not be affected adversely.

Statements about air quality, whether they pertain to individual communities or national averages, rely on monitors placed in a few locations. Unfortunately, the monitors collect data on only a limited number of places, and often the locations of the monitors do not indicate actual human exposure. Furthermore, data from monitors usually are not weighted by population concentrations to account for exposure.

Water Quality. The U.S. Geological Survey (USGS) provides trend information about specific water contaminants through its National Ambient Stream Quality Accounting Network (NASQAN). Ambient monitoring stations in river basins and sub-basins throughout the country have collected information on the same pollutants since 1974. Technicians adjust these data to reflect annual variations in stream flow and statistically analyze the results to observe trends in pollution concentration levels. Indicators of pollution include concentrations of dissolved oxygen, nutrients, metals, and toxic substances such as lead, arsenic, and cadmium. Surface waters have been monitored for decades for a number of conventional water quality parameters, but the USGS only began checking in the 1980s for toxic contaminants as a contribution to the EPA's Toxic Release Inventory data base.

Because NASQAN does not monitor estuarine waters, it cannot assess the quality of water affecting large coastal population centers. Information on groundwater quality is also very limited. Even the data that are collected are unsatisfactory for some purposes. They suffer from many of the same problems as those indicated for air quality data. They often come from widely separated, fixed stations and do not adequately represent water quality in the intervening reaches. The stations are often located without regard to human

or ecological exposure so that the data provide little information on how seriously the water quality affects people or ecosystems. Only a few conventional contaminants are commonly monitored, leaving substantial gaps in our knowledge of other pollutants that may present greater risks.

Another problem with data about water quality is that consistent indicators are simply not available nationally over contiguous time periods. The EPA has recently made available national data on loadings of biochemical oxygen demand (BOD) for selected years between 1950 and 1988. BOD measures the amount of oxygen-demanding wastes in a body of water. Dissolved oxygen is necessary to sustain fish and other aquatic life. Decomposition of organic pollutants, such as those in municipal sewage, or of chemicals, such as those in industrial wastes, depletes the natural oxygen level. Other common measures of water quality include fecal coliform--a bacteria that in large concentrations may harm humans; total suspended solids--a comprehensive measure of concentrations of particles including sand, silt, and other materials that cloud the waters and may have other effects; and nutrients--including nitrogen and phosphorus--that increase the growth of plants and require oxygen when they decompose, depleting the amount of oxygen available to sustain fish. These measures all gauge various aspects of water pollution, but BOD is a fairly comprehensive indicator and is the only measure available for several contiguous years.

Land Quality. The disposal of solid wastes, which renders sites unsuitable for alternative uses, or the dumping of hazardous and toxic wastes, which results in soil contamination, pollutes the land. Some solid wastes, such as batteries, florescent bulbs, thermometers, mirrors, plastics, and tires, are also hazardous. These wastes are carcinogenic, corrosive, ignitable, toxic, or reactive. The Environmental Protection Agency regulates about 500 chemicals and substances that are subject to federal regulations. The list includes toxic chemicals, such as trichlorethylene, benzene, dioxin, and polychlorinated biphenyls (PCBs); heavy metals, such as cadmium and lead; industrial by-products, such as fuels, oils, solvents, paints, and sludge; and pesticides, explosives, and asbestos.

The large number of contaminants and the wide variety of soil conditions make it difficult to define a standard for land quality. Moreover, collecting data on the volume of waste generated is a formidable task. Most estimates of municipal solid waste are based on extrapolations from small samples or estimated from mathematical models. Estimates derived from these methods vary widely. Information on industrial, agricultural, and mining wastes is even less certain. In most cases these by-products are disposed of

on-site by the generator, who produces no data assessing the amount or characteristics of the wastes generated.

Measuring Natural Resource Stocks

The availability of the stock of natural resources is measured in terms of resources and reserves. A resource measurement is an estimate of the total stock in existence. Reserves are that part of any resource stock that is believed to be exploitable, given today's technology, prices, and costs. Most experts agree that some definition of reserves should serve as the basis of any estimate of the availability of a natural resource. The reasoning behind this position is that any estimate of an asset should be based on resources that might actually be used in current or future production.

A great deal of controversy exists, however, over an appropriate definition of reserves. Reserves are currently classified according to the degree of certainty attached to the estimates. The most conservative estimates are known as "proved" reserves. These estimates are assumed to be highly accurate, since they are based on the output of sources (forests, fields, mines, and so on) that are currently being exploited. Other known reserves that are less certain to be recovered at current prices and costs are classified as either "probable" or "possible." The broadest category, "economically recoverable undiscovered" reserves, includes both known and speculative quantities. Estimates of reserves based on more restrictive definitions, such as proved reserves, are more likely to be precise and less likely to fluctuate from one year to the next.

However reserves are defined as a basis for asset value, the way in which discoveries are to be handled remains at issue. A discovery of new reserves could be treated as gross capital formation, which increases both net and gross domestic product. Similarly, the sale of mineral rights on lands not included on the list of proved reserves could be treated as an increase in government receipts and wealth rather than the sale of assets. Other methods evaluate the net change in the stock (including use and additions) to determine asset changes over the period. This approach smooths some of the possible fluctuations in the NIPA accounts that could be caused by accounting for discoveries. This information could also be used to help reconcile value changes in the balance sheets.

Finally, the task of estimating the net change in the stock of renewable resources requires biological models in order to estimate the natural regenerative patterns of renewable resources. To obtain accurate estimates

of changes in stocks it is necessary to take into account special patterns of growth for the several varieties of timber and fish and other valuable renewable resources.

Available Data on Natural Resource Stocks

The stocks of natural resources are important economic assets. Information about each of these resources--including measurements of reserves and their value--is issued by agencies with responsibility for their management.

The Department of Agriculture (USDA) publishes a series of data on the market value of agricultural land resources.[1] Values in the series are based on actual purchase prices. USDA also provides data on assets and returns to farm assets.[2] The Forest Service (a part of USDA) collects data on the stock of timber, the amount of timber harvested and sold, the costs of the timber sale program, and the average price per unit of timber.[3] The Bureau of Mines and the Department of the Interior (DOI) publish estimates of the domestic and international demand for mineral resources and the quantities of identified supplies of these resources. Estimates of the ratio of identified stocks of resources to their expected demand are available through the year 2000. As an indicator of scarcity, this ratio measures the adequacy of known supplies and varies considerably among different resources.[4] Finally, both the DOI and the Department of Energy publish information on oil and gas reserves and royalties and bonuses paid for federal leases.[5]

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1. Department of Agriculture, Economic Research Service, *Agricultural Resources, Agricultural Land Values and Markets*, Situation and Outlook Report (June 1991). These data report land value, including value of buildings on the land. The Economic Research Service provides historical data on the market value of farm land.

2. Department of Agriculture, Economic Research Service, *Economic Indicators of the Farm Sector, National Financial Summary, 1990.*

3. Department of Agriculture, Forest Service, Timber Management, *Timber Sale Program Annual Report*, various years since 1987. These reports include data on the revenues and expenses of the timber sale program. The Forest Service also provides other unpublished data on the number of sales, value, price, and cost.

4. Department of the Interior and Bureau of Mines, *Minerals Yearbook*, vol. 1, *Metals and Minerals* (1989).

5. Department of the Interior, Minerals Management Service, Royalty Management Program, *Mineral Revenues 1990: Report on Receipts from Federal and Indian Leases*; Department of the Interior, U.S. Geological Survey, Minerals Management Service, *Estimates of Undiscovered Conventional Oil and Gas Resources in the United States--A Part of the Nation's Energy Endowment* (1989); Department of Energy, Energy Information Administration, *Annual Energy Review 1990* (May 1991).

MEASURING PRICES OF ASSET FLOWS AND STOCKS

Policymakers may be encouraged by statistics based on physical measurement to consider the impacts of policies on natural resources and the environment. But accounting for changes in natural capital on the basis of physical changes in stocks has at least two shortcomings: it does not lend itself to useful summation and it can disguise economic consequences. The act of totaling physical units of differing types or qualities can obscure wide differences in economic value--for example, physically adding up mineral reserves will not reveal vast differences in the values of different deposits, caused by variations in recovery costs and quality. Second, summaries expressed in physical units do not enable policymakers to understand the impact of economic policies on natural resources and the environment or the impact on the economy of standards based on physical measures.

If adjustments to the national accounts for changes in natural resources and the environment are to be accepted, credible techniques must be developed for pricing these assets and their service flows. The methods that are chosen should yield values that are consistent with national accounting measurements. Consistent techniques of pricing are necessary, whether the goal is to account for changes in natural capital assets within the current framework of the accounts, or the aim is to extend these totals to measure sustainable income.

The more remote a resource is from the market economy, the more uncertain is its monetary value. Generally, if all of the service flows of an asset are bought and sold in organized markets, the accounts value the services at those market prices. Other assets, such as groundwater, provide services that are rarely bought or sold, but the services of such assets are inputs to production. A price can be imputed for these services by using information about the production process and value of the marketed output. Other assets, such as noncommercial wild species, provide services that are not sold and do not contribute directly to production. Available methods used to assign value to these services are limited to information taken from consumer surveys on potential expenditures or willingness to pay.

Methods of Imputing a Price for Nonmarketed Goods and Services

The current prices of nonmarketed goods and services must be imputed because no market prices exist. The current price of services (actual or imputed) can be used with quantitative information on changes in stock to calculate depreciation of natural capital. The method of estimating prices for

nonmarketed services depends on whether these flows are (1) indirectly related to a market transaction or (2) not related in any way to market activity.

Methods Indirectly Based on Market Transactions

The *hedonic pricing method* is a statistical technique for dividing the price of a good into a series of prices for its constituent characteristics. The market price of the good is viewed as the sum of the values of all its characteristics. A house, for example, is a good whose price is determined by its many characteristics, such as the number of rooms, condition, location, and so on.

The price that people are willing to pay for an incremental improvement in air quality, for instance, can be estimated by examining housing prices in areas that have varying levels of air quality. This technique can be used, therefore, to price environmental and natural resources on the basis of market behavior, even though air quality is not bought and sold as a distinct commodity. Other market prices that have been used in hedonic studies include wages for a given occupation in different cities. The technique is limited because it requires a fairly large data set for goods with many characteristics in common and ignores institutional constraints in markets.

Another method of imputing prices uses information derived from equations that characterize the physical relationship between inputs and output. Prices of inputs can be imputed from the incremental value of output that results from adding one additional unit of input. A statistical estimate of the production equation can be derived from data about the output that is associated with various combinations of inputs. But such information is not universally available, although preliminary estimates for certain commodities such as irrigation water and agricultural soil are available.

Estimates of the incremental costs of abating pollution--called marginal abatement costs--can also be used to assign a value to the services of environmental waste disposal. The incremental cost of abating pollution represents the cost of spending money on reducing pollution versus other productive uses. Thus, it may be possible to use an estimate of marginal abatement costs as a proxy of the value of environmental waste disposal services. But abatement costs show the value of these disposal services as an input to production and do not necessarily reveal the value to society of the benefits (or damages) of using the environment. It is only when abatement activity is at a socially efficient level that marginal abatement costs will equal the marginal benefit (and hence, price) to society.

Another approach involves estimating the potential costs of either maintaining the level of environmental quality at the beginning of the accounting period or achieving a level specified by regulated environmental standards. The approach estimates the potential costs of abatement. These are the costs required to achieve either a certain level of environmental quality at the beginning of the accounting period or a level specified by environmental regulation. The Bureau of Economic Analysis (BEA) collects data on abatement expenditures. Researchers could use data about physical emissions to estimate levels of environmental quality combined with estimates of abatement costs to determine how much it would cost to maintain a certain level of environmental quality. The reliability of the results depends on how accurately the methods show interactions between expenditures, emissions, and quality; that is, how well potential abatement costs and physical degradation are measured. That kind of pricing does not necessarily reflect damage to households or the environment.

Pricing Methods with No Relation to Market Transactions

Information from interviews and questionnaires is often used to place a value on the final services of natural resources and the environment. The value of a good or service can be estimated by posing questions to ascertain the maximum that people are willing to pay for some improvement in the service flow (or minimum acceptable compensation for suffering a loss). This approach avoids the pricing problems associated with market structure, externalities, and the inability to exclude nonpayers. This technique, which is widely known as *contingent valuation*, is an acceptable method of assigning value to goods under the Comprehensive Environmental Response, Compensation, and Liability Act and the Oil Pollution Control Act.

Nonmarket measures can be inaccurate, however, because they are based on what buyers or sellers claim they are willing to do rather than on actual behavior. Distortions can occur, for example, because respondents do not reveal their true sentiments or are not used to the idea of paying for such goods as hiking and clean air. In addition, researchers have serious doubts about whether values that apply to one site can be used at others and whether values are additive. Further research must address these questions satisfactorily before values obtained from nonmarket measures can be used in the national accounts.

CONCLUSIONS

The principal problems of measurement are (1) identifying the most appropriate way of measuring physical changes in environmental quality and natural resource reserves and (2) identifying reliable and consistent methods of pricing the nonmarket services of these assets.

It is difficult to place a value on the depletion or degradation of natural capital because many of its goods and services are not sold in markets, a problem that is especially troublesome in determining the costs of service flows associated with the health effects of changes in environmental quality. Problems can also arise when estimating natural resource depletion. In particular, the measurement of the change in stock must allow for regeneration and discoveries of additional reserves.

The United Nations and the Bureau of Economic Analysis have addressed the conceptual issues and problems of data availability and quality associated with assigning value to nonmarketed service flows. First, they recommend maintaining satellite accounts to record the value of natural capital, its depletion, and flow of services while measurement issues are being addressed. These measurements could be integrated later into the main components of the accounts if problems are resolved.

Second, the initial efforts of the U.N. and BEA, which are meant to improve their understanding of how best to incorporate natural resources and the environment into the accounts, have relied to a large extent on market data. As a result, their current activities have concentrated on expanding the asset boundary. The aim is to record values and depletion or degradation of natural resources with marketed flows and identify the costs of avoiding the damages of pollution. The assets being considered include land, national forests, and oil and gas reserves. In addition to these assets, the U.N. has also estimated values for the degradation of environmental quality by monitoring the costs of abatement.