Accounting for Natural Resource Depletion and Degradation in Developing Countries

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ABSTRACT

An appropriate measure of sustainable income—consistent with the concept of income underlying most national income accounts—should include an estimate of environmental and natural resource depreciation.

This paper presents an approach for measuring this depreciation based on an application of conventional capital theory. The important distinction between physical depreciation and true economic or “value” depreciation is emphasized. Economic depreciation can be shown to equal physical depreciation plus real capital gains (which may be positive or negative). Only economic depreciation is appropriate for theoretically valid adjustments to gross income. As the paper shows, with respect to environmental assets, the two depreciation concepts can widely diverge over time.

The paper discusses the relationship between economic depreciation and the value of services generated by environmental and natural resource assets and the determinants of these service values. The theory suggests that as environmental assets are used, there may be both positive and negative services generated. Furthermore, the value of these services depend on the values placed on the services by potential as well as current users. Thus, for example, the value of a forest depends not only on its timber services but on all other services generated including potential uses of the land for agriculture.

The paper, accordingly, presents a modification to the conventional economic accounts that, in principle, is capable of displaying all uses of environmental and natural resource assets. This accounting framework leads to several alternative measures of aggregate income, all of which may be useful for policy purposes.

Finally, the depreciation concepts and accounting framework are illustrated with two empirical examples. The first is a modification to the national accounts of Tanzania to reflect both household production of fuelwood and the depreciation of fuelwood stocks. The second is an analysis by Robert Repetto of the depreciation of forests in Indonesia.
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ACCOUNTING FOR NATURAL RESOURCE DEPLETION AND DEGRADATION IN DEVELOPING COUNTRIES

Introduction: Resource accounting and income measurement

National economic accounting—the systematic accounting for all economic transactions in a country—is practiced, to some extent, in nearly every nation in the world. In principle, and often in practice, these accounts serve the economic policy objectives of these nations in three ways. They provide a framework within which economic statistics can be assembled in a consistent and coherent fashion; they provide a tool of analysis for better understanding of how the economy functions; and they provide indices that gauge the performance of the economy and therefore the success of failure of economic policy decisions.

It is this last function by which the national accounts are best known. Indeed, the accounts are often judged by their ability to provide “good” indicators of economic performance. If the indicators perform poorly, either because of an inherent inability to measure what people think is important or because of poor availability of data, official and public support for national accounting diminishes greatly.

Both these reasons perhaps explain why national accounting, as a tool of economic policy and planning, has been less used in developing nations than in the more industrialized world. The paucity of data is well-appreciated by anyone who has done research in these countries. But equally important is the conventional emphasis on market transactions. This almost exclusive focus on the market may seem largely irrelevant in poor countries where many, if not most, exchanges of goods and services take place in households or otherwise outside of well-organized markets.

A related deficiency of standard national accounting practice, which is of significance in developed countries as well, is the failure to accounting for the deterioration and depletion of natural resources and other environmental wealth. Thus, while we attempt to account for the deterioration of machines, we do not attempt to measure any deterioration in the stock of materials that might be processed by these machines. For reasons of symmetry

The deficiency is related to the problems caused by focusing on market transactions. Because capital consumption, deterioration, or depreciation is not directly observed as a market transaction, it is not recorded for many forms of wealth—not just environmental and natural resource wealth.
alone, we may wish to correct this particular deficiency. However, as Prof. Herman Daly has pointed out (in Ahmad, et. al., forthcoming) there is a more important and fundamental reason why an effort should be made to measure the deterioration in the stock of natural resources and environmental wealth.

The principal indicator of economic performance provided by the accounts is national income measured either as gross national product (GNP) or gross domestic product (GDP). Conventional national accounting practice is to define income in the sense recommended first by Alfred Marshall (1920) and later by Professor Hicks (1946): the maximum amount the nation could consume without running down its wealth. Thus, in the Marshallian-Hicksian sense, a country that can consume five units of rice and still maintain a stock of five units of rice is better off—has a higher income—than its neighbor who consumes five units while depleting the stock to zero. In conventional practice, the national accountant attempts to measure Hicksian income as the sum consumption plus investment goods (including net foreign investment—that is, exports less imports) less a measure of capital depreciation. To the extent that natural resource and environmental capital depreciation is excluded from this measure, true national income will be overstated.

For a developing country, this overstatement can have serious policy implications. Simply put, such overstated income is not sustainable income. Policies that successfully maximize such overstated income may produce short-run gains at the expense of long-run impoverishment. In contrast, policies that maximize true Hicksian income will have a far greater chance of generating an ever-increasing income path that leaves future generations as well off or better off than present generations.

Resource depreciation measurement: basic theory

First some definitions. Following Alfred Marshall and John Hicks, income (regardless of whether it originates from marketed capital such as machines or nonmarketed capital such as a natural forest) is defined as the sum of current and potential future additions to wellbeing. More specifically, we identify current additions to wellbeing as consumption and define gross income as consumption plus gross investment. Gross investment is the addition to capital that will allow for both future income and the maintenance of current income. Net income is simply consumption plus net investment, where net investment is gross investment less that portion of capital investment just necessary to maintain current levels of consumption. Finally, depreciation is defined

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2GDP, which excludes income generated abroad, is widely used in developing countries because it is a better measure of domestic production. GNP, however, is probably a better measure of social well-being. The distinction is not important for this paper.
conventionally as the difference between gross and net investment. However, as defined by
the economist, depreciation also equals the change in the value of the initial capital stock
over the accounting period. Although it is not conventional, I find it useful to distinguish
between this economic definition of depreciation, or *value* depreciation, and *physical*
depreciation.

It is apparent that one reason that depreciation exists is because of a reduction over time
in the physical ability of capital to generate consumable services. This loss in physical
ability—physical depreciation—may also lead to a loss in the value of the capital stock—
value depreciation. That is, value depreciation may be caused by physical depreciation.
However, value depreciation can also arise for other reasons. For example, the value of
capital can fall due to a change in tastes for those consumption items produced by the
capital or simply because of a change in interest rates. Thus, it is quite possible that an
asset that remains physically intact (or even grows) can “depreciate.”

The relationship between income and the change in value depreciation can be shown as
follows. A society’s capital has value presumably because it generates a stream of goods
and services, i.e., income. Let $V_0$ represent this value at the beginning of the year and,
$Q_1, Q_2, \ldots$, represent the services generated (that is, “gross income”) at the beginning
of the next and subsequent years. Thus, $Q_1$ is gross income in year 1.

The theory of investment relates $V_0$ to the $Q$'s as follows:

$$V_0 = \frac{Q_1}{(1+i)} + \frac{Q_2}{(1+i)^2} + \ldots + \frac{Q_n}{(1+i)^n} + \ldots, \quad (1)$$

where $i$ is the rate of interest. Since $V_1$, the value of $V_0$ at the end of year 1, is simply

$$\frac{Q_2}{(1+i)} + \frac{Q_3}{(1+i)^2} + \ldots + \frac{Q_{n+1}}{(1+i)^{n+1}} + \ldots,$$

equation (1) can also be written:

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3 I should add that while this depreciation concept is accepted by economists, it is not necessarily accepted
by accountants or tax authorities.
\[ V_0 = \frac{Q_1}{(1+i)} + \frac{V_1}{(1+i)} = \frac{Q_1 + V_1}{(1+i)}, \]  

(2)

from which it follows that

\[ Q_1 = iV_0 + (V_0 - V_1). \]

(3)

The term \((V_0 - V_1)\), representing the loss in value of the initial capital stock, is, by definition, *value* depreciation occurring in year one, or \(D_1\). As before, gross income, \(Q_1\), is defined as consumption plus gross investment. However, since, by definition, *net* income equals consumption plus *net* investment and net investment equals gross investment less (value) depreciation, net income also equals consumption plus gross investment less depreciation. Equivalently, net income equals gross income less depreciation. It follows from (3) that, since \(Q_1\) is gross income, the term \(iV_0\) can be identified with net income. Thus (3) can be rewritten as:

\[ Q_1 = C_1 + I_1 + D_1 \]

(4)

where \(C_1\) and \(I_1\) are consumption and net investment in year 1. In words,

Gross income = net income + (value) depreciation  
= consumption + net investment + (value) depreciation  
= consumption + gross investment.

This relationship between income and depreciation was developed without any reference to the physical destruction of capital. It is true that as capital wears out physically, future \(Q\)'s may fall, explaining why \(V_0\) may exceed \(V_1\). However, future \(Q\)'s may fall for other reasons such as a fall in the demand for the capital's services. The \(Q\)'s may also decline because of an inability to employ the capital fully. That is, if capital is complementary to labor, a decline in labor services would also bring about a decline in future \(Q\)'s.
Moreover (in contrast to physical depreciation), value depreciation, $V_0 - V_1$, need not necessarily be positive, i.e., $V_1$ could in principle exceed $V_0$. It should be noted, however, that conventional practice is to define depreciation to be non-negative and to refer to the case where $V_1 > V_0$ as a “capital gain.” I shall not follow this practice since it implicitly assumes that the term “depreciation” can only mean physical depreciation. Rather, I shall decompose value depreciation into two components: the portion of the difference between $V_0$ and $V_1$ that is due to actual physical depreciation and the portion which is due to other causes. The latter, if positive, will be termed “capital gain” and, if negative, will be termed “capital loss.” Thus, if physical depreciation is $D_p$ and capital gain (or loss) is $G$, this decomposition of value depreciation requires that

$$V_1 - V_0 = D_p + G \quad (5)$$

or

Value depreciation = physical depreciation minus capital gain or plus capital loss.

Of course, the physical depreciation must be valued in order to make this computation possible. How the units of physical loss should be valued—using the original price of the capital, its current price, or some other price—is a matter of some controversy. As the choice affects the measure of physical depreciation, it has important implications for both corporate accounting (which is not our concern here) and for national accounting (which is our concern). However, if the focus is on value depreciation the implications of choosing among alternative capital prices can be avoided by estimating value depreciation by successive application of equation (1) one year apart rather than by applications of equation (5).

Sources of environmental asset depreciation

Like any other capital asset, the depreciation in value of an environmental asset such as a forest or other natural resource is due both to physical depreciation and capital loss (or gain). In order to illustrate these two sources of value depreciation, I shall consider two assets, one of which experiences only physical reduction. The value of the other depreciates solely because users of the services generated by the asset perceive a reduction in the quality of these services. The former asset might be a lake whose only service is to provide drinking water. I assume that as drinking water is withdrawn, neither man-made nor natural replenishment takes place so that the availability of drinking water is steadily
reduced.\textsuperscript{4} The latter asset might be a stretch of seashore of given length. I assume the only service provided by this asset is recreation and, further, as the demand for this service increases, the quality of service perceived by each demander diminishes.

Figure 1 is a schematic representation of the demand for the services of the first asset, drinking water, over time by two users. To clearly distinguish the two sources of value depreciation, I assume each user's demand is constant. Also, to keep matters very simple, I assume the demands to be identical and I hold the capital gain component in equation (5) to zero. The width of the triangle in Figure 1 represents the available physical asset (in this case, drinking water) at any time. The shaded areas under each demand curve represent welfare loss to each demander. I assume that each has a maximum demand of X. Further I assume that when capacity is reduced below 2X, the remaining asset is equally shared. Under the assumption that the demand functions are identical, such an even allocation is Pareto optimal—no other allocation can make one user better off, without making the other worse off.

\textsuperscript{4} Of course, in practice the availability of drinking water may be reduced for other reasons, notably by the poisoning from waste products. However, to keep the analysis simple, we are assuming that the lake provides only one service—drinking water—and not a waste disposal service.
The implication of Figure 1 for the lake's value over time is quite simple. For a period of time, since the availability of drinking water is more than adequate for both users, there is no value reduction and hence no value depreciation even though in real terms there is physical depreciation. However, the *value* of this physical depreciation is zero. Yet, as soon as the lake's capacity is reduced to $2X$ drinking water units, the value of the lake begins to decline and value depreciation increases. That is, the value of the physical depreciation becomes positive.

I now consider our second polar example represented by the seashore. I assume that there is an increasing number of identical individuals each demanding the same fixed length of seashore. In order to show the effect of this increasing demand in a two dimensional diagram, I group the individuals into two groups of equal size. Figure 2 shows the
summed demand curve for the two groups for three situations: (1) when the number of individuals is small enough that their maximum demand is less than the seashore capacity; (2) when the number of individuals is moderate so that their maximum demands just exceed seashore capacity; and (3) when the number of individuals is very large and their summed maximum demands greatly exceed seashore capacity. For the latter two cases I assume a Pareto optimal distribution: if capacity is $z$ and the number of individuals is $n$, each of the identical individuals is allotted $z/n$ of seashore.

The shaded area represents the disutility suffered by each group due to the fact that they share the seashore. For example, for the group represented by demand curve I, there is a loss due to sharing equal to area $EBA$ when the number of individuals is moderate and equal to area $E'B'A'$ when the number of individuals is large. However, even though the amount of external "damage" each user inflicts on the other increases as the number of individuals increases, the total utility for all individuals as a group increases. For those represented by curve I, this increase is shown by the increase in area from $ABCD$ to $A'B'C'D'$. 
Small number of individuals (n=P)

Moderate number of individuals (n=4P)

Large number of individuals (n=6P)

FIGURE 2: INCREASING DEMAND FOR NON-DETERIORATING ENVIRONMENTAL ASSET
Thus, the implications for the asset's value depreciation depicted in Figure 2 are more complicated than those illustrated in Figure 1. Algebraically, at the time when the number of individuals, \( n \), is moderate, the assumed utility of each individual (for a Pareto optimal distribution) is \( u = u(z/n) \). This utility decreases as \( n \) gets larger. However, total utility for all individuals is \( nu(z/n) \); and Figure 2 shows this utility increasing with increases in \( n \), although at a decreasing rate. In effect, previous seashore users are worse off as \( n \) increases, but because there are new users, total utility may increase even though average utility falls. On the other hand, total utility may also decrease depending on the relative magnitude of an individual's total and marginal utility with respect to \( n \). The theoretical change in total utility as \( n \) increases is \( u(z/n) - u'(z/n)/n \) and this can be either positive or negative.

In sum, it is not self-evident that the value of an asset, which does not deteriorate physically, declines as it becomes more heavily used. A recreational asset may experience a capital gain even though it becomes heavily congested and even though each user becomes less satisfied with the services provided. Whether the value depreciation of such an asset is positive or negative depends on a comparison between the declining utility of each user and the increasing number of users.

The situation is even more complicated for assets that both deteriorate (like the lake) and become increasingly more in demand (like the seashore) at the same time. A national forest area, which jointly provides timber and recreation services, is one example. For such mixed assets, it is almost impossible to infer anything about their value depreciation from observations about changes in their physical size or condition.

There is one additional, and perhaps disquieting, implication of Figure 1 that deserves mention. As noted below, it is conventional in national accounting to value the total quantity of a good or service according to the value of the "last" or marginal unit produced or consumed. If, however, such marginal valuations are used, our pristine lake would have no value until a point of congestion is reached—that is, the point where demand curves cross as shown in Figure 1.\(^5\)

Nevertheless, many would feel that the pristine lake has value even in the absence of option demand or any other source of demand. Even if everyone accepted this view, it would not violate the theoretical structure just presented. The key point to remember is that

\(^5\)It should be noted that actual physical congestion is not required. A demand can exist without actual use if the demand is in the form of a reservation for future use. The existence of such "option" demand may suffice to give value to the pristine lake.
we are attempting to account only for conditions that affect *economic* welfare. Valuations therefore, are confined only to economic valuations—not to valuations that may have purely religious, ethical, or philosophical foundations. Unlike other these other sources of value, the basis for economic valuation is the interaction of demand and supply, such as depicted in Figures 1 and 2.

**Determinants of the value of environmental assets**

As we have seen, for any asset, environmental or otherwise, the theoretically appropriate deduction from gross income to obtain net income is the change in the value of the asset during the accounting period or (value) depreciation. These values, in turn, depend on the \( Q_i \)'s, the “incomes” contributed by these assets over time.

If these assets generate marketable services, such as timber, market prices provide the basic information used to infer the values of these income streams. Indeed, for such assets, markets can often provide direct measures of the asset values.\(^6\) However, for most environmental and natural resource assets, appropriate values must be inferred. To understand the valuation principles involved, we rely on the following theoretical framework. This framework also provides further insights on how to include natural resource and environmental assets in a system of national accounts.

At the outset, it is important to recognize that an environmental asset provides a multitude of valuable services: raw materials, habitat, climatic balance, esthetic, recreational, and a location or medium where society can dispose of its wastes. Associated with these benefits of environmental asset use are two types of disbenefits. One is the familiar direct damage that waste disposal by one party can inflict on another. Air pollution’s effect on a person’s health is a clear example of this sort of direct effect. We can display *marginal* benefits and disbenefits due to the consumption of environmental asset services on the following diagram:

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\(^6\)The measures are not perfect due to market imperfections and the inability to forecast perfectly future income streams.
Net benefits are maximized at level X, where marginal benefits of pollution and marginal disbenefits are equal.

We should note that, assuming we can define a function relating asset use to pollution, Figure 3 could be redrawn with “units of asset service” rather than “pollution” on the horizontal axis.

The second type of disbenefit occurs when one’s use of the environmental asset service use serves to deny someone else use of the same or different service. For example, use of a lake for waste disposal may deny the use of the lake to someone else for swimming or fishing. I refer to this second type of disbenefit as an indirect disbenefit to distinguish it from the direct disbenefits associated with pollution. The key feature of this type of disbenefit is that it will exist only if there is a finite amount of available environmental asset service. However, a finite upper bound on available service is a necessary condition for the generation of these indirect disbenefits but it is not a sufficient condition. If the availability of asset services is finite but very large, there can be extensive use of the environmental services without the generation of any disbenefits. These propositions can be illustrated as follows:
For graphical exposition, I assume that there are only two users of an environmental asset, each desiring the same services, but not necessarily for the same purposes. For example, if the asset in question is a forest, one user might be a timber company and the other a household seeking a recreation experience. I also assume that at least the potential exists for these uses to mutually conflict: the greater or better the recreation experience, the less timber can be cut; the more timber that is cut, the poorer the recreation experience. Under these assumptions, we can construct a marginal benefit curve for each party with a shape similar to the marginal benefit and disbenefit curves shown in Figure 3.

![Figure 4: Competition for an Environmental Asset in Fixed Supply](image)

User 2's marginal benefit is measured from the right side of the figure while user 1's marginal benefit is measured from the left.

As shown there are \( A_0 \) units of asset-service available for both parties. Clearly, the attempt of both parties to maximize benefits will not be successful since the amount \( O_1A \) (user 1's maximizing level) plus the amount \( O_2B \) (user 2's maximizing level) exceeds \( A_0 \). To the extent that either party successfully manages to obtain an amount of service that exceeds the other party's maximizing level, a disbenefit will be created for the other party. For example, if user one manages to reach \( O_1A \) units, user 2 will be denied \( BA \) units, thereby generating a disbenefit to user 2. Since the marginal value of each unit of service denied to user 2 can be read off of line segment \( Ba \), the total disbenefit to user 2 would equal the area \( BaA \). Similarly, if user 2 managed to obtain its maximizing level of \( O_2B \)
units, user 1 would suffer a disbenefit equal to the area BbA.

It can thus be seen that Figure 4 is very analogous to Figure 3 even though the former depicts direct disbenefits while the latter depicts indirect disbenefits. From the point of view of user 1, user 2's marginal benefit curve could be viewed as a marginal disbenefit curve. Similarly, from user 2's point of view, user 1's marginal benefit curve is a marginal disbenefit curve.

As with Figure 3, there is an optimal level of environmental asset use indicated by point X in Figure 4. At this allocation of $A_0$, total benefits reach a maximum even though each party suffers some degree of disbenefit (BxX for user 2; XxA for user 1).

Figures 3 and 4 are central to the valuation and accounting framework. Several key elements are reflected in these diagrams. First, and most important, both figures illustrate that associated with any amount of resource or environmental asset use, there are both positive and negative benefits. Thus, a single accounting entry will, in general, not be adequate to capture the effects of environmental asset use. Secondly, with finite availability of environmental asset services, the identification of one party (e.g., industry) as the "polluter" and another party, e.g. households, as the injured party is not always appropriate. Both the value and accounting system should recognize that any actor in the economy may be using environmental asset services to the detriment of another actor.

A third element of the valuation framework reflected in these figures concerns the effect of the total availability of environmental asset services. If the availability is very great relative to the demands placed on the environment and depending on the method chosen to place values on these demands (see below), it may be appropriate to place a zero value on the asset service and to ignore this service in the accounting system. The life-sustaining service provided by the atmosphere may be an example.\footnote{To ignore this particular service does not mean that other services of the atmosphere, such as its waste-disposal service, should be left out of the accounting system.} To make this argument, I shall redraw Figure 4 as follows:
Assuming rational behavior, user 1 and user 2 would not consume more than $O_1A$ and $O_2B$ units of asset service respectively, leaving $AB$ units not consumed by either party. As indicated, the value of the marginal unit of asset service consumed by either party is zero. If all units consumed are valued the same as this marginal unit, then the total value of the consumed environmental service for either party would equal zero. Such consumption could thus be safely ignored in the expanded accounts.

Valuation concepts

This theoretical framework, reflected in Figures 3 and 4, suggests that users of an environmental asset may experience two types of costs. First, there are the costs that users may have already incurred if they have had to take measures to protect the resource. (Land restoration after strip mining might be an example.) Secondly, there are the costs faced by users, in terms of foregone benefits, due to the denial of further access to the resource. The former costs are, in principle, already accounted for in the conventional economic accounts. The latter costs are not currently accounted for. Yet the estimation of these costs is important since it provides an estimate of the value of services generated by the environment.
This important distinction between costs already incurred and those opportunity costs to the user were he or she denied access to the environment can be shown schematically in Figure 6. This figure is a "linear" redrawing of Figure 4.

In Figure 6, MB is marginal benefit; MD, marginal disbenefits; and EA, environmental asset use.

I now suppose that a user of the resource, because of environmental regulations, is observed consuming environmental assets just to level V, rather than level A, the level likely to be observed in the absence of any constraints on the user's behavior. The actual costs to this user—in terms of direct environmental regulatory costs and any loss in profits—is just equal to the area of the triangle Vwa. In principle, these control costs are already accounted for in the standard national accounts, although their separate

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8 The proposition that area Vwa equals this cost is a logical consequence of the definition of the marginal benefit curve. If regulatory costs were greater than this area, then the benefit to the polluter by not having to reduce asset use to level V would be greater than area Vwa. But this result is a contradiction since, by definition, this benefit just equals area VwA. Similarly, if regulatory costs were less than area VwA, the benefits of moving from V to A would be less than VwA—again a contradiction.
identification as regulatory and pollution control costs is fairly recent. In the past, these costs have been merged with all other costs of doing business.

What has not been accounted for is the value to the user of being allowed access to the resource to level V. The total amount of this value is area OVwf. This amount could also be interpreted as a “cost”—in this case, the prospective cost to the user of being denied use of the environmental asset. This sort of cost has not been included in the conventional accounts. However, a complete accounting of all sources of economic income would include such costs since they measure the value of a nonmarketed, but valuable, factor input (the environmental asset service) just as, say, wages measure the value of marketed factor input (labor).

As environmental assets are used, there is, as we have seen, the “production” of disbenefit in terms if any pollution generated and in terms of a denying access to the resource by other potential users. This “negative” production that is also neglected in conventional accounting systems. At an environmental asset use equal to level V, the total value of this disbenefit equals the triangular area BzV.

The use of the areas OVwf to value the benefit of V to the user and BzV to value the direct damage or disbenefit to any injured party (e.g., another competing user) is consistent with the definition of the curves drawn in Figure 6. However, these valuations, which I shall term “total” valuations, are not entirely consistent with the valuation concept used for marketed goods in the conventional national accounts. The usual valuation for marketed goods is a price-times-quantity valuation, the price in question being that for the “last” or marginal unit sold. All other, so-called infra-marginal units are valued at this same price. If we wanted to adopt an analogous valuation for the benefits and disbenefits associated with level V of environmental asset use, we would use rectangle OVwa to value the polluter benefit and the rectangle OVzd to value the associated disbenefit or damages. I term these valuations “marginal” or “market” valuations.9

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9One important advantage of marginal valuations (besides the consistency argument) is that they provide a means of estimating whether observed environmental asset use is greater or less than the optimal use, level X, the use which maximizes net benefits. At level X, the marginal benefit and disbenefit valuations are exactly equal; at levels greater than X, the marginal valuation of disbenefit exceeds the marginal valuation of benefit; and at levels less than X, the marginal valuation of benefit exceeds the marginal valuation of disbenefit. We can interpret these latter situations as conditions for too much and too little use, respectively. However, while marginal valuations allow for making this interpretation, total valuations are usually easier to estimate.
I have, up to now, neglected the fact that the actions of two competing users have reciprocal effects: that is, they "damage" each other. To account for these effects, it is necessary to increase both the benefit and disbenefit estimates arrived at above. Thus, in addition to the total benefit to "party 1" of $OVwf$ (using "total" valuations), we must account for the fact that "party 2" enjoys a benefit from the remaining $A_0 - V$ units of environmental assets available. The total value of this benefit is $VzhA_0$. The total benefit value equals the sum of these two areas.

Similarly, the indirect damage party 1 causes for party 2 is, as above, $BzV$. To this value, however, must be added the damage party 2 causes party 1 due to denying party 1 $A_0 - V$ units of asset service. This damage equals the area $VwA$. Again, the estimate of total indirect disbenefit is the sum of these two triangular areas.\(^{10}\)

This theoretical analysis suggests one method that could be used to place a monetary value on nonmarket environmental and natural resource services. This technique attempts to measure the various areas under the curves in the above figures by analyzing the costs (or benefits) to competing parties were they allowed more or less access to the asset. The approach is similar to those that are commonly used in benefit-cost analysis and in the preparation of environmental impact assessments. Whether these techniques are always suitable for developing countries is addressed below.

There are also several other lessons to be learned about valuation of environmental and natural resource services from this theoretical analysis. In particular, there are two that I would like to emphasize:

- There is generally both a positive (benefit) and a negative (disbenefit) value associated with the use of environmental and natural resource services. In general, these values are not equal.

- The values to one user of environmental and natural resource services depend on the values other parties place on the same or other services that are being provided.

These two consequences of the theory are important because they point up the inadequacy of accounting for a particular service value and resulting environmental asset

\(^{10}\) Using marginal valuations, total benefit would equal $OVwa$ plus $VzrA_0$, while total indirect disbenefit would equal $OVzd$ plus the rectangle $VA_0uw$. As before, at the optimal level $X$, total valuations of benefits and disbenefits are equal.
value without looking at all competing uses of the asset. Thus, for example, the value of a forest has to be ascertained by looking at all existing and potential competing uses of the forest simultaneously. One benefit of a national accounting structure is that, in principle, it can picture these competing uses.

The accounting structure

The above theoretical discussion suggests both a framework for introducing the services of environmental assets into the conventional accounts and the principles for evaluating these services. Basically, the framework assumes that these services can be treated as unpaid inputs to either production or consumption activities. The adverse effects of consuming these services, either due to pollution or to the denial of environmental services to other users, can be treated as negative output or damages. A balancing term is required to assure that the conventional equality between total inputs and outputs is maintained.

The following set of accounts is rather similar to the conventional input-output structure underlying most national economic accounting systems including the United Nations System of National Accounts. We can illustrate the system by dividing the economy into four sectors and showing the input-output accounts for each. The four sectors are: Industries, Governments, Households, and the environment (Nature).

Industrial sector

The typical industry account is shown in Figure 7. The entries shown in capital letters represent the sum of the numbered entries above it.

Below the conventional industry output measures ("GROSS INDUSTRY SECTOR INPUT" and "GROSS INDUSTRY SECTOR OUTPUT") are three new entries that would ordinarily be absent from a conventional account of the industry's inputs and outputs. Item 10 is an accounting of the environmental services and item 15 is an accounting of damages. Environmental services, because they are "free," are treated as if they were a subsidy to the industry. Therefore, they are entered as a negative input. Item 11 is the arithmetic difference between items 15 and 10. It assures that the modified accounts balance. Since it is defined as the difference between the service benefit of the environment and the "disbenefit" of environmental damage, it has been given the name "net environmental benefit." The modified industry account input and output totals equal the conventional input and output totals less the absolute value of environmental damage.
Figure 7: Industry Product Account (Typical Sector)

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Purchases from other industrial sectors</td>
<td>12. Sales to private sector (current account)</td>
</tr>
<tr>
<td>2. Compensation of employees and proprietors (incl. rental income)</td>
<td>a. To other industries b. To households c. Exports</td>
</tr>
<tr>
<td>3. Profits after inventory valuation and capital consumption adjustment</td>
<td>13. Sales to government</td>
</tr>
<tr>
<td>5. Imports</td>
<td></td>
</tr>
<tr>
<td>6. Transfer payments</td>
<td></td>
</tr>
<tr>
<td>7. Indirect taxes</td>
<td></td>
</tr>
<tr>
<td>8. Subsidies received (-)</td>
<td></td>
</tr>
<tr>
<td>9. Capital consumption allowances</td>
<td></td>
</tr>
<tr>
<td>GROSS INDUSTRY SECTOR INPUT</td>
<td>GROSS INDUSTRY SECTOR OUTPUT</td>
</tr>
<tr>
<td>10. Environmental services (-)</td>
<td>15. Environmental damages (-)</td>
</tr>
<tr>
<td>a. Air</td>
<td>a. Air</td>
</tr>
<tr>
<td>b. Water</td>
<td>b. Water</td>
</tr>
<tr>
<td>c. Land</td>
<td>c. Land</td>
</tr>
<tr>
<td>11. Net environmental benefit</td>
<td></td>
</tr>
<tr>
<td>(I.15 - I.10)*</td>
<td></td>
</tr>
<tr>
<td>MODIFIED GROSS INDUSTRY INPUT</td>
<td>MODIFIED GROSS INDUSTRY OUTPUT</td>
</tr>
</tbody>
</table>

*I.15, I.10, etc., means item 15, item 10, etc., account I.

Governments

The government's account is similar to the industrial account. As with industries, it displays entries that account for the government's use of the environment and the resulting damage from this use. Also shown, is the necessary balancing entry.
The major difference between the industry and the government accounts in that environmental depreciation is shown as a governmental entry. This is a somewhat arbitrary decision based on the assumption that environmental and natural resource assets are "owned" by governments.

Figure 8: II. Governmental Product Account

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Purchases from industry (I.13)</td>
<td>7. Governmental goods and services</td>
</tr>
<tr>
<td>2. Compensation of employees</td>
<td></td>
</tr>
<tr>
<td>3. Imports</td>
<td></td>
</tr>
<tr>
<td>4. Environmental depreciation</td>
<td></td>
</tr>
<tr>
<td>5. Environmental services (-)</td>
<td>8. Environmental damages (-)</td>
</tr>
<tr>
<td>a. Air</td>
<td>a. Air</td>
</tr>
<tr>
<td>b. Water</td>
<td>b. Water</td>
</tr>
<tr>
<td>c. Land</td>
<td>c. Land</td>
</tr>
<tr>
<td>6. Net environmental benefit (II. 8 - II.5)</td>
<td></td>
</tr>
</tbody>
</table>

Households

The conventional national accounts assume that very little production takes place in households (primarily accounted for by nonprofit institutions and the services of domestics). The focus of the conventional accounts on activities that reflect market transactions precludes consideration of the "outputs" related to keeping up a house, preparing meals, raising children, and do-it-yourself projects.

Households are far more important in these modified accounts. Households, in their disposal and recreational activities, are major consumers of the services of water and, as a result, are major contributors to water pollution. Households, through their use of automobiles and though the burning of fuels for heating and cooking, also account for a

11However, to the extent that household sanitary wastes are sewered, the resulting disposal services and pollution are more properly credited to the governmental account.
substantial portion of environmental damage and the associated use of the air for disposal services.

Figure 8: III. Household Product Account

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Purchases of intermediate goods from industry (I.12.b)</td>
<td>8. Services to households</td>
</tr>
<tr>
<td>2. Compensation of employees and proprietors</td>
<td>a. Nonprofit institutions</td>
</tr>
<tr>
<td>3. Imports</td>
<td>b. Domestics</td>
</tr>
<tr>
<td>4. Surplus of nonprofit institutions</td>
<td></td>
</tr>
<tr>
<td>5. Capital consumption allowances</td>
<td></td>
</tr>
<tr>
<td>GROSS HOUSEHOLD INPUT</td>
<td>GROSS HOUSEHOLD OUTPUT</td>
</tr>
<tr>
<td>a. Air</td>
<td>a. Air</td>
</tr>
<tr>
<td>b. Water</td>
<td>b. Water</td>
</tr>
<tr>
<td>c. Land</td>
<td>c. Land</td>
</tr>
<tr>
<td>7. Net environmental benefit (III.9 - III.6)</td>
<td></td>
</tr>
<tr>
<td>MODIFIED GROSS HOUSEHOLD INPUT</td>
<td>MODIFIED GROSS HOUSEHOLD OUTPUT</td>
</tr>
</tbody>
</table>

Households are unique among the producing sectors in that most of the environmental damage caused by households (as a result of their consumption of environmental services) are inflicted within the household sector itself. In contrast, industries and governments tend to inflict damage outside their own sectors.

Nature

This modified national accounting system differs most markedly from the conventional system with its inclusion of Nature as a producing sector. Nature is shown as the primary source of all environmental asset services and as the final "consumer" of environmental damages. Nature also must be included because it generates a substantial portion of
environmental damage. For example, a large portion of both dissolved solids suspended sediment in water have a natural origin and, on average, naturally-generated particulates and nitrogen oxides (other than $\text{NO}_2$) greatly exceed the man-made production of these air pollutants.

While some may have a philosophical objection to the idea of Nature as a "polluter," the concept is required for practical reasons. Available estimates of damages due to air and water pollutants cannot distinguish between damages from those offensive residuals that have a human origin and damages from residuals with a natural origin. Rather than attribute all the damage to non-natural causes, it is more accurate to prorate the damage total between the two sources.

Figure 9: IV. Natural Account

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Environmental damages</td>
<td>2. Environmental services</td>
</tr>
<tr>
<td>(Including those naturally generated)</td>
<td></td>
</tr>
<tr>
<td>a. Air</td>
<td>3. Net environmental benefit</td>
</tr>
<tr>
<td>b. Water</td>
<td>(IV.1 - IV.2)</td>
</tr>
<tr>
<td>c. Land</td>
<td></td>
</tr>
</tbody>
</table>

NATURAL SECTOR INPUT              NATURAL SECTOR OUTPUT

Consolidated gross product account

The above modified accounts can be consolidated into a modified gross product account as shown in Figure 10. All intra-sector flows have been eliminated. Households and Nature are not included in the consolidation. While nature is viewed as the source of environmental services and the consumer of environmental damages, the proposed accounting framework does not view nature as undertaking production activities. Following conventional national accounting practice, Households are also excluded from the consolidation because they are also viewed as not undertaking production activities.

The unconventional environmental entries are shown in such a way as to preserve the conventional account entries, enabling those who may not be interested in the modifications to simply ignore them. Thus, for example, while the modified accounts show environmental depreciation as a negative adjustment (item 9.) to Net National Product, it is added back (item 11.) in order to leave the conventional measure of Gross National Product unchanged. By arranging the entries in this way, I have tried to alleviate
the fears of those who object to modifying the conventional accounts on the grounds that such modifications destroy the “integrity” of the existing system.

Inspection of the modified consolidated account indicates that modified GNP equals conventional GNP less environmental damage. Actually this relationship is an identity: it is necessarily true because of the way we chose to arrange the entries in our accounting structure. However, a number of other arrangements are possible, each leading to its own formula relating the conventional GNP to a “modified” GNP.

To show this, I first define the following notation:

<table>
<thead>
<tr>
<th>VA:</th>
<th>Charges against conventional GNP or value added</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP:</td>
<td>Conventional GNP</td>
</tr>
<tr>
<td>GNP\text{i}:</td>
<td>Modified GNP, definition i (i = 1, 2, 3, and 4)</td>
</tr>
<tr>
<td>ES:</td>
<td>Environmental services</td>
</tr>
<tr>
<td>NEB:</td>
<td>Net environmental benefit</td>
</tr>
<tr>
<td>ED:</td>
<td>Environmental damage</td>
</tr>
</tbody>
</table>

Since the left hand side and the right hand side of the consolidated accounts must balance, the following identity holds:

\[ VA - ES + NEB = GNP - ED \]  \hspace{1cm} (6)

As noted, this identity implies the following “definition” of modified GNP:

\[ GNP_1 = GNP - ED \]  \hspace{1cm} (7) \hspace{1cm} (Definition 1)

However, accounting arrangements are somewhat arbitrary and other arrangements are possible as long as the accounts balance. For example, by adding ES, and ED to both sides of (6) and noting that NEB = ES - ED, we find that a new identity can be formed.

\[ VA + ES = GNP + ES \]  \hspace{1cm} (8)

which leads to a new definition:

\[ GNP_2 = GNP + ES \]  \hspace{1cm} (9) \hspace{1cm} (Definition 2)

Similarly, by adding ES and ED to both sides of (6) and again noting that NEB = ES - ED, we can find a third definition of modified GNP:

\[ GNP_3 = GNP + NEB \]  \hspace{1cm} (10) \hspace{1cm} (Definition 3)
Figure 10: V. Consolidated National Income and Product Account

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Compensation of employees and proprietors (incl. rental income) (I.2 + II.2 + III.2)</td>
<td>14. Personal consumption (I.12.b + III.8)</td>
</tr>
<tr>
<td>2. Profits after inventory valuation and capital consumption adjustment (I.3)</td>
<td>15. Gross private domestic investment (I.14)</td>
</tr>
<tr>
<td>4. Transfer payments (I.6)</td>
<td>17. Imports (-) (I.5 + II.3 + III.3)</td>
</tr>
<tr>
<td>5. Indirect Taxes (I.7)</td>
<td>18. Governmental goods and services (II.7)</td>
</tr>
<tr>
<td>6. Subsidies (-) (I.8)</td>
<td></td>
</tr>
<tr>
<td>7. Statistical discrepancy</td>
<td></td>
</tr>
<tr>
<td>8. National income</td>
<td></td>
</tr>
<tr>
<td>9. Net national product</td>
<td></td>
</tr>
<tr>
<td>10. Capital consumption (I.9 + III.5)</td>
<td></td>
</tr>
<tr>
<td>11. Environmental depreciation (+)</td>
<td></td>
</tr>
<tr>
<td>CHARGES AGAINST GROSS NATIONAL PRODUCT</td>
<td></td>
</tr>
<tr>
<td>12. Environmental services (-)</td>
<td>19. Environmental damages (-) (I.15 + II.8 + III.9 + IV.1)</td>
</tr>
<tr>
<td>(I.10 + II.5+ III.6)</td>
<td></td>
</tr>
<tr>
<td>a. Air</td>
<td>a. Air</td>
</tr>
<tr>
<td>b. Water</td>
<td>b. Water</td>
</tr>
<tr>
<td>c. Land</td>
<td>c. Land</td>
</tr>
<tr>
<td>13. Net Environmental Benefit</td>
<td></td>
</tr>
<tr>
<td>(V.19 - V.12)</td>
<td></td>
</tr>
<tr>
<td>CHARGES AGAINST MODIFIED GROSS NATIONAL PRODUCT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MODIFIED GROSS NATIONAL PRODUCT</td>
</tr>
</tbody>
</table>
Finally, by first adding ES to both sides of (6) and then subtracting NEB from both sides, we can find a fourth definition:

\[
\text{GNP}_4 = \text{GNP}
\]  \hspace{1cm} (11) \hspace{1cm} (Definition 4)

Thus modified GNP can be defined alternatively as conventional GNP less environmental damage, conventional GNP plus environmental services, conventional GNP plus net environmental benefit, or simply as equal to conventional GNP. These definitions are by no means equivalent but they are all consistent with the above modified accounting structure. The pros and cons of these alternatives will be discussed in the next section.

Relationship between the conventional and the modified accounts

I shall discuss the relationship between the modified accounts and the environment in terms of the modified GNP concepts defined in the previous section. However, since the fourth definition of modified GNP is exactly the same as conventional GNP, the discussion need only be confined to the first three.

Definition 1: \( \text{GNP}_1 = \text{GNP} - ED \)

One argument against conventional national account aggregates is that they do not always respond to changes in environmental quality in a manner that would make these aggregates acceptable indicators of well-being. Conventional GNP often increases with environmental deterioration. Furthermore, efforts to improve the environment are often reflected by reductions in GNP, particularly if these efforts were undertaken by reallocation of business current account inputs or through shifts in investment.

Clearly, the above definition of modified GNP seems to perform much better as an indicator of well-being. \( \text{GNP}_1 \) appears to move "correctly" with respect to changes in ordinary GNP and to changes in environmental quality. It is perhaps for this reason that this modification to conventional GNP was recommended by Olson (1977).

Yet, this first definition only covers part of the environmental relationship. Definition 2 covers another part.

Definition 2: \( \text{GNP}_2 = \text{GNP} + ES \)

The theoretical analysis behind the suggested modified accounting framework demonstrated that there was a beneficial environmental service associated with any
observed environmental damage. This service, being "unpriced" and apparently "free," does not show up directly in conventional GNP.

The second definition directly accounts for this unpriced input. Its use as an index of well-being would have interesting and perhaps controversial implications. For example, a nonindustrialized, "less-developed" country may be consuming the environmental services typically provided by a tropical climate: e.g., warmth and a long growing season. An industrialized society, located in a cold climate requiring a highly sophisticated agriculture, may be denied these services. Under Definition 2, the differences in GNP between these countries might be far less than would be the case with conventional GNP. (The difference might also be less under Definition 1 if the industrialized society were also the more polluted.)

However, GNP\textsubscript{2} is prone to possible double counting of environmental services consumed by business. While these services may not be accounted for directly, they may be reflected in profits, which are captured by ordinary GNP. For example, a business that can dispose of its wastes in the ocean has a distinct advantage over a competing business that must treat its wastes. The opportunity to use the ocean's disposal service may show up as an increased profit rate for the business. For the national accountant to add in an amount equalling the value of the ocean service would, in this example, be superfluous.\textsuperscript{12}

Some may feel that because of the potential for double counting, GNP\textsubscript{2} is a less desirable indicator of well-being than GNP\textsubscript{1}. However, its focus on the benefits of ES is a strong point in its favor.

Definition 3: \[ \text{GNP}_3 = \text{GNP} + \text{NEB} = \text{GNP} + \text{ES} - \text{ED} \]

This definition of modified GNP appears to be a compromise between GNP\textsubscript{1} and GNP\textsubscript{2}, sharing the strengths and weaknesses of both measures. As an indicator of well-being it appears to move in the "correct" direction: increases in ES and decreases in ED imply increases in GNP\textsubscript{3}. Yet there are some circumstances under which GNP\textsubscript{3} has difficulty in moving in any direction. In the absence of technological change, decreases in

\textsuperscript{12}One interesting aspect of GNP\textsubscript{2} concerns its behavior with respect to pollution-control expenditures. As noted, conventional GNP either is unaltered or declines depending on whether the expenditure is by business on capital or on current account and on whether pollution-control capital outlays divert capital from more "productive" uses. On the other hand, assuming full employment, GNP\textsubscript{2} will always decline as pollution-control expenditures increase. According to the theory behind our framework, pollution-control expenditures mean that marketed goods and services are being substituted for environmental services. Thus, since ES will decline, GNP\textsubscript{2} will also decline.
environmental damage by business, ED, must invariably be accompanied by decreases in environmental services to business, ES. Thus, under policies of pollution control and natural resource protection, NEB may remain essentially unchanged. For this reason, it may not be very effective as an indicator of well-being after all. However, if ED and ES are valued using "marginal" valuations (see above, p. 17), GNP\textsubscript{3} can convey important information beyond that of the other two measures of modified GNP. Referring to Figure 6, if the marginal valuations of ES (equal to MB in the figure) and ED (equal to MD in the figure) are the same (neglecting the minus signs), the allocation of the services of environmental capital is "optimal" in the sense that any other allocation is economically less efficient. Any move to the right of point X in Figure 6 means that the benefits of more ED are exceeded by the disbenefits of more ED. Any move to the left of X means that the benefits of less ED are exceeded by the disbenefits of less ES.

Thus, if marginal valuations are used (and if we can neglect environmental depreciation), an optimum allocation occurs when ES = ED or equivalently, when NEB equals zero or when GNP\textsubscript{3} = (conventional) GNP. If NEB were negative or GNP\textsubscript{3} < GNP, well-being would improve if ED were decreased. Such a policy recommendation to reduce environmental damage would not be very controversial. However, the analysis also indicates that if NEB were positive, or GNP\textsubscript{3} > GNP, then there may be "too little" environmental damage for social optimality.

The concept of "too little" environmental damage is perhaps much more controversial but it is a natural consequence of the fact that environmental asset services make a contribution to well-being just as the reduction in environmental damages makes a contribution to well-being. GNP\textsubscript{3} explicitly recognizes this duality and the fact that the benefits of pollution reduction are rarely gained costlessly: some portion of the benefits of environmental services usually have to be foregone.

As noted from Figure 10, environmental depreciation modifies only Net National Product and not GNP. For this reason environmental depreciation was neglected in the foregoing discussion of modified GNP concepts. However, recognizing that many prefer NNP to GNP as an aggregate measure of economic performance, it is possible to recast all the previous discussion in terms of NNP.

By simply subtracting capital consumption allowances and environmental depreciation (items 10 and 11 in Figure 10) from both sides of equations (6) through (11), all the conclusions can be restated for NNP. Thus, for example, NNP\textsubscript{1} = NNP - ED, NNP\textsubscript{2} = NNP + ES, etc. The above inequalities hold as well.
Difficulties with the above framework

The United Nations Environment Programme and the World Bank have expressed interest in developing accounting frameworks similar to the one discussed here. However, outside of a few research efforts, I do not know of any country that has attempted to add to their national accounts official estimates of the monetary value of environmental or natural resource services and the depreciation of environmental and natural resource capital. Nor do I know of any country that has adopted the above accounting framework although there are a number of active research efforts in certain countries, notably France (Archambault and Bernard, 1988) and Canada (Friend, 1986).

This failure to implement a program of environmental and resource accounting, in spite of strong interest, reflects a number of problems that have yet to be solved. Four are particularly troublesome.

1. Disagreement as to appropriate units of measurement

The above system assumes that all entities—values of environmental services and depreciation—will be measured in money terms. This approach has been attacked as unrealistic and arbitrary by those who question the validity of the recommended benefit-cost valuation techniques and the ability to implement those techniques in countries with very poor data bases. Instead, they recommend that all environmental entities be measured in physical units, recognizing that full integration with the economic accounts will not be possible.

However, before such a position is adopted, it is important to understand what is lost by not making the effort to measure everything in money terms. In the first place, it makes it impossible to obtain an objective measure of the importance of environmental services relative to ordinary marketed goods and services. Thus, analysis of policies that may require a trade-off between the development of marketed capital at the expense of environmental capital become very difficult. In the second place, a lack of a common monetary measure makes it impossible to adjust conventional GNP for reductions in environmental quality and conventional NNP for environmental degradation.

There is a third, more practical problem of measuring environmental assets and services in physical units: it is not clear what those units should be. Proponents of the physical approach seem to believe that there is a single natural physical unit for any environmental asset—perhaps, cubic meters for water, metric tons for minerals, hectares for forests, etc. However, as mentioned above, most environmental assets generate a number of very

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13 These are cited by Repetto, et. al. (1987).
different services and no single physical unit of measure seems appropriate for all these services. While the number of hectares may describe something about a forest, it says little about its ability to generate timber, to provide a wilderness experience, to protect endangered species.

One possible solution to this problem, other than opting for a monetary measure, would be to re-define environmental assets according to the services provided. Thus, instead of thinking in terms of lakes and forests, with their generation of heterogeneous services, we think in terms of timber capital, recreation capital, ecological capital, etc.—“pseudo-capital” categories that generate, by definition, homogeneous services.

While this approach may solve part of the problems raised by using physical rather than monetary units, it still does not address the problems of measuring trade-offs or of adjusting conventional GNP.

2. Disagreements over the appropriateness of discounting

As was discussed earlier, one way to measure the monetary value of an environmental asset is by first estimating the monetary value of the future “income” stream generated by the asset and then discounting this stream using an appropriate rate of interest. It is not clear, however, what interest rate, if any, is “appropriate.”

There is a vast literature on this subject, much of which has been aptly summarized by Robert Lind (see Lind, et. al., 1982), and it is not my intent to cover it here. However, it seems to me that the crucial issue for measuring the value of environmental assets in developing countries is not so much the appropriate rate of interest but rather the discounting process itself. One crucial implication of the procedure discussed above is that environmental asset values are being determined according to the preferences of today’s generation and not future generations. As Page (1977) and others have shown, it is quite possible that a society could choose for itself an “optimal” allocation of capital that, under certain circumstances, could bring the economy to a halt in the future. That is, the “optimal” growth path, from the point of view of the present generation, may not be sustainable.

The “certain circumstances,” under which this result occurs, depends on such factors as the degree of capital substitutability and the techniques of production. Thus, discounting is not necessarily inappropriate for all countries. However, for certain countries, some other (non-present value) methods might have to be found for valuing the stock of environmental and natural resource capital.
3. Over-dependence on the classical economic model

The theoretical structure and accounting framework presented in this paper is consistent with the neo-classical economic model commonly taught in most Western universities. It is not self-evident that this model is acceptable to or relevant for all societies.

For example, the individualistic aspect of the theory may be suspect. We spoke of competing users of environmental assets and how the value of the asset services depended on the values as perceived by these users. Nowhere did we speak of the possible independent value society might place on the same asset, since in the Western model, society's valuation is the consolidation of the valuation of each member of the society. We did not speak, for example, of separate religious or cultural valuations since, if such values exist, they are, in the Western economic model, dependent on the cultural and religious preferences of each member. Furthermore, as values in the neo-classical model are all preference-determined, we did not speak of an inherent value of labor or of "the environment" as such.

These Western economic concepts, which also underlie the benefit-cost techniques recommended for obtaining monetary valuation, may not be acceptable to countries with very different cultural traditions. If so, some other evaluation and accounting scheme might have to be found.14

4. Unacceptable demands on the availability of data and skills

Finally, the implementing the theoretical and accounting framework presented here may make unrealistic demands on the available data and analytical skills commonly available in developing countries.

I would, however, caution against the view that the level of data availability and skills is always inadequate in developing countries. Depending on the country, even poor data, analyzed with rudimentary skills, can provide estimates of natural resource and environmental degradation that, while crude, are nevertheless quite valuable for policy decisions.

Questions of data and skill adequacy are ultimately empirical matters. As I have argued elsewhere (Peskin, 1988), they can only be addressed through experimental case studies.

14As Barber(1963) pointed out some time ago, standard national income accounting, with its foundation in Keynesian economics, may be equally unacceptable in many societies for similar reasons.
Indeed, all four problem areas identified above need to be addressed through a program of research and experiment.

Examples of resource accounting

As I note above, to my knowledge, no country has adopted these accounting methods on any official basis. Therefore, it is hard to find good “case studies” to illustrate their implementation. However, there are a few “unofficial” examples provided by scattered research efforts. I will briefly discuss two that focus on the accounting of forest resources.

1. Tanzanian example

The purpose of this example is to illustrate what a modified set of accounts might look like. The data, drawn from a project to investigate the implications of plantation forestry on fuelwood production in the Dodoma region of Tanzania, were developed by Julia Allen (1983a) and extrapolated by Allen to the country as a whole (Allen, 1983b).

For 1980, the Tanzanian National Accounts looked somewhat like the following:

Figure 11: CONVENTIONAL TANZANIAN ACCOUNTS (1980)
(in millions of Tanzanian Shillings)

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee compensation</td>
<td>Government purchases</td>
</tr>
<tr>
<td>Profits and proprietors income</td>
<td>Private consumption</td>
</tr>
<tr>
<td>NATIONAL INCOME</td>
<td>Investment</td>
</tr>
<tr>
<td>Indirect taxes</td>
<td>Exports</td>
</tr>
<tr>
<td>Subsidies</td>
<td>Imports</td>
</tr>
<tr>
<td>NET NATIONAL PRODUCT</td>
<td>EXPENDITURE ON GDP</td>
</tr>
<tr>
<td>Capital consumption</td>
<td>38760</td>
</tr>
<tr>
<td>GROSS DOMESTIC PRODUCT</td>
<td>40426</td>
</tr>
</tbody>
</table>

For purposes of the project, we had to make two adjustments to this conventional structure. First, we modified the Employee compensation figure to account for the imputed value of household labor used for the cutting, gathering, and transport of fuelwood from natural forests.
The Tanzanian accounts already includes about 11533 million shillings as the imputed value of household production of agricultural, hunting, fishing, and forestry products. Of this total, about 207 million shillings represents household fuelwood production. We felt that this estimate was suspect since it was based on very unrepresentative market data on commercial fuelwood production. Using Allen’s data, an alternative estimate was obtained by multiplying as estimated 137 million person days per year spent in household fuelwood production times the Tanzanian minimum wage of 20 shillings per day. This calculation yields a much larger estimate of 2746 million shillings as opposed to the official estimate of 207 million.

Using this new figure, the National Income was increased by 2539 million shillings (= 2746 - 207). On the Output side of the account, this increase was balanced by increasing Private consumption by the same amount.

The second modification to the standard accounts was to depreciate the forests due to the fuelwood consumption. A very rough estimate of the net depreciation was obtained by setting the value equal to the imputed value of the fuelwood cutting (=2746 million shillings) less the value of regeneration. According to Allen, in 1980 about 18.7 million cubic meters of fuelwood were consumed and about 5.7 million cubic meters regenerated. Thus, of the total consumption of 2746 million shillings, about 31 percent (5.7/18.7) or 840 million shillings represents the regenerated value of the cut wood. This figure implies that net depreciation is about 1906 million shillings (2746-840).

Note that we have implicitly assumed for this example that the only use of the forest is for fuelwood. We have also equated physical depreciation with value depreciation, which is equivalent to assuming that capital gains and losses were zero.

These modifications altered the conventional accounts as follows:
Modifying the Tanzanian accounts to cover the full value of household fuelwood production (and consumption) and natural forest depreciation due to this production had the effect in 1980 of increasing the GDP by about six percent and the NNP by about 2 percent. The most significant change was in Employee compensation. By not accounting for the value of household labor services devoted to fuelwood production, the conventional accounts underestimated the value of Tanzanian labor by about 24 percent.
Note that, consistent the accounting structure shown in Figure 10, natural forest depreciation has no effect on GDP. However, by itself, it would have lowered NNP by about five percent.

2. Indonesian example

A far more sophisticated estimate of forest depreciation was made for Indonesia by Robert Repetto and his colleagues at the World Resources Institute (Repetto, et. al., 1987). Repetto’s data, which also include estimates of petroleum reserve depreciation, cover the period 1970 to 1982.

As Repetto notes, the only asset “service” being accounted for is the production of timber. Other marketed services, such as the production of rattan, honey, silk, etc., are not accounted for. Nor are any nonmarket services, such as specie habitat or CO₂ absorption, accounted for.

Essentially, Repetto uses the value-of-“physical”- depreciation approach. That is, he does not estimate the discounted value of future income streams but rather relies on formula (5) above. The physical depreciation is valued at average “net prices” of cut timber, where net prices are essentially unit revenues less unit costs and where the average is computed over one year. Capital gains (or losses) are determined by multiplying remaining end-of-year physical stocks by end-of-year net prices. However, these capital gains were not added to the value of physical depreciation (as shown in formula (5)) but instead were reported separately.

The reason for excluding capital gains from the depreciation estimate is, apparently, because they are very volatile, being highly influenced by short-term price fluctuations. This volatility is easily shown by comparing the following two graphs. The first, drawn from Repetto’s paper compares Indonesian GDP with Indonesian Net Domestic Product after adjusting for both forest and petroleum depreciation—neglecting capital gains and losses.
The second graph re-adjusts Repetto's adjustment by adding his estimates of capital gains to his estimates of depreciation.
The volatility is clearly seen. Indeed, in two of the 12 years shown, "re-adjusted" NDP becomes negative.

These unacceptable and peculiar results, as Repetto points out, are due to the volatility in timber prices. It is not clear, however, whether these results are a valid argument for excluding the capital gain term from the depreciation calculations. After all, including this term, as our earlier discussion has shown, has strong theoretical justification. Rather, the peculiar results may be an argument against using formula (5) to estimate depreciation rather than the discounting approach. While formula (5) is correct, using it for estimating depreciation requires one to value physical depreciation and capital gains separately. Apparently, using a single year's set of prices for a single year's valuation of these two terms is, as Repetto's results suggest, questionable.

Repetto's accounting framework understandably differs from the one discussed in this paper in that it does not cover all economic activities. Such a complete coverage would have placed an impossible burden on Repetto and his colleagues. Nevertheless, his partial approach may lead to an overstatement of the effect of natural resource degradation on GDP. In particular, as our theoretical discussion indicated, the value of environmental asset services (and its depreciation) depends on the values placed on the asset by all competing users. Thus, as forests degrade through deforestation, there is the possibility that capital values increase elsewhere in the economy. In particular, in Indonesia, most of the forest clearing supports increases in agricultural land. Much of this increase in agricultural assets escapes the Indonesian accounts and Repetto's data.

Even within these limitations, Repetto's work has very important implications for GDP measurement in developing countries in general and for Indonesian GDP measurement in particular. This research is currently undergoing revision and is eagerly awaited by those of us interested in improved national accounting in developing countries.
References


Integrated Environmental-Economic Accounts,” unpublished draft prepared for the World Bank (October 20).
