CURRENT ISSUES IN RESOURCE ACCOUNTING [1]

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ABSTRACT

This article has two main purposes. The first is to discuss the theoreti basis for using a national product concept as an index of well-being, as well as show how a proper environmentally adjusted national product should be calculat. The authors stress at the outset that national income accounts serve other purpos they do not merely measure well-being. Still, a "green national product" should based on a conceptual basis that permits a welfare-theoretic interpretation of t measure. This is a point that the authors return to several times in this article. T second purpose is to review some of the major empirical studies on resour accounting.

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1. INTRODUCTION

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

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

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

This chapter has two main purposes. The first is to discuss the theoretical basis for using a national product concept as an index of well-being, as well as to show how a proper environmentally adjusted national product should be calculated. We stress at the outset that national income accounts serve other purposes, they do not merely measure well-being. Still, a "green national product" should be based on a conceptual basis that permits a welfare-theoretic interpretation of the measure. This is a point that we return to several times in this chapter. The second purpose is to review some of the major empirical studies on resource accounting.

The structure of the chapter is as follows. We begin in Section 2 discussing the national product as a welfare measure, illustrating the link between (changes of) the national product and cost-benefit rules. Section 3 presents a number of issues in

the construction of a welfare-measuring national product. These include l
(working time), transboundary pollution, discoveries of resource stocks and ca
flows. These issues are couched within a discussion of the proper treatmen
environmental stocks, and (damage) flows. We also link our findings
sustainability concerns and show that there is a close connection between a cor
NNP and sustainability. In Section 4 we present an accounting system tha
consistent with the welfare theory presented in Section 2 and 3. Section 5 detai
number of the most important empirical studies on resource accounting and Sect
6 concludes the chapter by some comments on the future of resource accounti
The appendix contains a sequence of models, where we develop the theory i
stringent way.

II. THE NATIONAL PRODUCT AS A WELFARE MEASURE.

Provided certain technical restrictions are met (see below for details), f
any conception of social well-being, and for any of technological, transactio
information, and ecological constraints, there exists a set of shadow (or accountin
prices of goods and services that can be used in the estimation of real net nation
product (NNP). The index in question has the following property: small investme
projects that improve the index are at once those that increase social well-being. W
may state the matter more generally: provided the set of accounting prices
unaffected, an improvement in the index owing to an alteration in economi
activities reflects and increase in social well-being. This is the sense in which re
net national product measures social well-being. Moreover, the sense persists n
matter what is the basis upon which social well-being is founded.[5]

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

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

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[5] It should be noted that national income accounts have other important uses; for example, as a tool for assessing the volume and composition of economic activities.

possibility would be to rely on local prices for the current period and optimal prices for future periods. And so on.

In order to illustrate these ideas, consider an economy consisting of two consumer goods and a single individual. In Figure 1 X and Y denote the two goods and the curve TT' denotes the production possibility frontier. Let W (X, Y) be the individual's well-being function and II' the indifference curve which is tangential to TT' (tangency is at the point A). In the figure we have assumed that the production possibility set is convex and that W (X,Y) is a concave function. The common tangent at A, which we have denoted as pp', defines the optimal prices, p_x and p_y. We may then define NNP at any production point, (X,Y), as $p_xX + p_yY$.

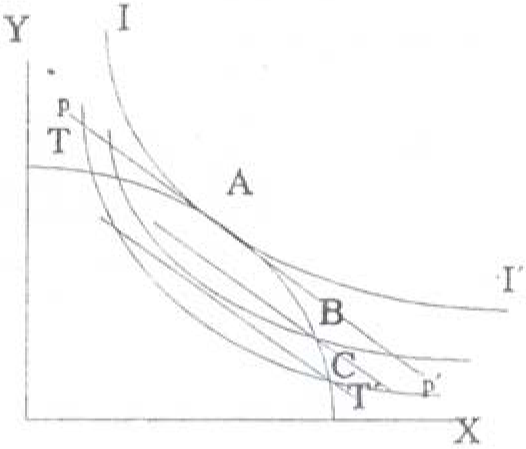

FIGURE 1

Let us assume that the economy is at C (a point on the production frontier). We wish to check if a move to B (also on the frontier), which is an improvement in the individual's well-being, records and increase in NNP defined as above. As Figure 1 shows, it does record an increase. Moreover, it can be confirmed that a move from C to any point on the frontier that records and improvement in NNP also reflects and improvement in the individual's well-being.

Thus far we have illustrated the use of optimal prices for measuring NNP. For points inside the production possibility set, these prices are inappropriate for the estimation of NNP. Instead, local prices ought to be used.[6] The idea is simple enough. Let (X, Y) be the current consumption point. Then the individual's well-being is W (X,Y). Consider now a small change in consumption (dX, dY). Then, to a first approximation, the resulting change in the individual's well-being is $W_x dX + W_y dY$, where W_x and W_y are the two partial derivatives of W at (X, Y). The change is desirable if $W_x dX + W_y dY > 0$; it is undesirable if $W_x dX + W_y dY < 0$.

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[6] Of course, local prices could be used also for points on the frontier.

This means that W_x and W_y could be used as the accounting prices. In other word NNP, evaluated on the basis of current marginal valuations, is an appropia measure of social well-being.

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

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

III. ISSUES IN THE CONSTRUCTION OF A GREEN NATIONAL PRODUCT.

We use an optimal growth model to study the most important characteristics of an accounting framework. This approach has many advantanges, one being that is provides insights into the nature of the shadow prices we need. The analysis depends heavily on Mäler (1991) and Dasgupta & Mäler(1991). We have collected the most important mathematical results in the appendix.

III.1. Labour

Imagine two countries, both with perfectly competitive markets, that differs only in the number of hours worked. If leisure-time is valued positively, should our welfare indicator record any difference between the countries?[7] Given that the two countries' national products are equal, the conventionally computed GNP suggests that welfare in both countries is also equal. Thus under the current accounting systems the answer would be no. In this section we show how such conclusions would be modified, if the purpose were to obtain a welfare indicator.

We assume, for the time being, that there is only one factor of production-labour. We also assume that there is a perfect market for labour that is in equilibrium at each point of time. If the supply of labour were completely inelastic we need not consider the issue of labor further. The individual works a given

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[7] The link between the national product as a welfare measure and the treatment of labour goes back at least to Pigou

amount of time and there is no leisure-labor choice. Instead assume that the labor supply is elastic. At the margin, the individual is indifferent between working one more hour or having one more hour for leisure. This being the case, and given the fact that we are only trying to evaluate marginal projects, wage income should not be part of our index. This may not be obvious, but the following example may clarify our point.

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

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

Our conclusion above is based on a number of implicit assumptions. The most questionable is that labor markets equilibrate. Though obviously this condition does not always hold, we can still construct an index, proceeding as if the labour markets are in equilibrium. Alternatively, we can use the local prices, i.e. the workers marginal reservation price for taking a job. Assume for simplicity that the reservation price is zero, i.e. the worker is willing to take a job as long as he gets something above zero. The accounting price for labour is then zero and the wage bill, evaluated as this price, would also be zero.[8]

This discussion has important implications for the discussion on how to treat "defensive expenditures". Such expenditures are dedicated to cleaning up damaged environments.[9] It has been suggested that conventional national income accounts would register an increase in GNP because of damage to the environment due to pollution. The reason is that companies (or the public sector) will hire labour to clean up the environment. This will show up as an increase in GNP. Therefore, it is argued, defensive expenditures should be deducted from GNP. This conclusion is clearly not correct. If the economy is in full employment, then hiring of people

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[8] We have explored the consequences of labor market disequilibrium in detail elsewhere.

[9] See also section III.2 for more on defensive expenditures.

in the clean-up industry will be offset by a reduction in production somewhere else in the economy. If the economy is not in full employment, then (assuming we are using the local prices) the wage bill should be zero, and there will be no increase in GNP.

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

III.2. Flows of goods and services.

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

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

The direct use of ecological services is not accounted for in SNA. There is a considerable confusion in the literature as how to include the direct services in an adjusted national product.[10] The confusion arises largely from problems of definition. One example illustrates this point. Assume that an individual is disturbed by noise from a nearby highway. An increase of the traffic-volume will raise the noise level and reduce the well-being of the individual. In response, the individual might invest in three-pane windows and increased insulation. Should these defensive expenditures be subtracted in order to obtain a more appropriate national product index? In order words, are the expenditures reasonable money measures of the utility loss?

The answer to these questions lies in the way we are measuring the environmental damage. Let N be the outdoor noiselevel. As a result of the increased traffic, the noise level increases from N^0 to N^1. Let the original indoor noiselevel be M^O and assume that the level is maintained through defensive expenditures. Let D (N) be the damage function (the willingness to pay for a quiet neighborhood). One correct way of adjusting the national product index is to subtract

$$D'(N^0)* (N^1 - N^0) = D(N^1) - D(N^0)$$

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

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

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

III.3. Valuation issues.

During the last twenty years or so, the techniques for estimating environmental damages in monetary terms have been extensively developed.[11] These techniques have been developed for use in particular situations where a cost-

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[11] See f.e. Freeman (1993) and the chapters by Mitchell & Carson, Hanemann & Ktiström and Harrison & Kriström in this book.

benefit analysis is needed for making a specific decision, and not for use in the production of national product estimates. If these rather sophisticated techniques were to be used, the cost for adjusting the national product measures would likely be prohibitive. Therefore, more simple, but still robust methods are needed.

The conventional way of including the public sector in SNA may give some clues as to how to find reasonably accurate and inexpensive valuation methods. Because the output from the public sector is, in general, no marketed there is no way of assessing the value of that output directly. SNA has solved the problem by looking at the cost of production in the public sector (mainly labour cost). This is a correct approach if the public output corresponds to the demand. In fact, if politicians are able to make correct decisions on the size and composition of the public sector, then the cost of production (including cost of capital) in the public sector would exactly correspond to the value of the output. Thus one possibility would be to use the same basic idea when approximating the value of environmental damage.

The use of a 'politically determined' willingness to pay would require that there are politically determined targets for environmental policies - ambient standards, emissions targets, etc. The situation is illustrated in Figure 2. Here MC is the marginal cost of abating emissions and MD is the marginal damage from the emissions. The total abatement and damage cost is minimized when marginal abatement cost equals marginal damage cost, i.e. at the point A.

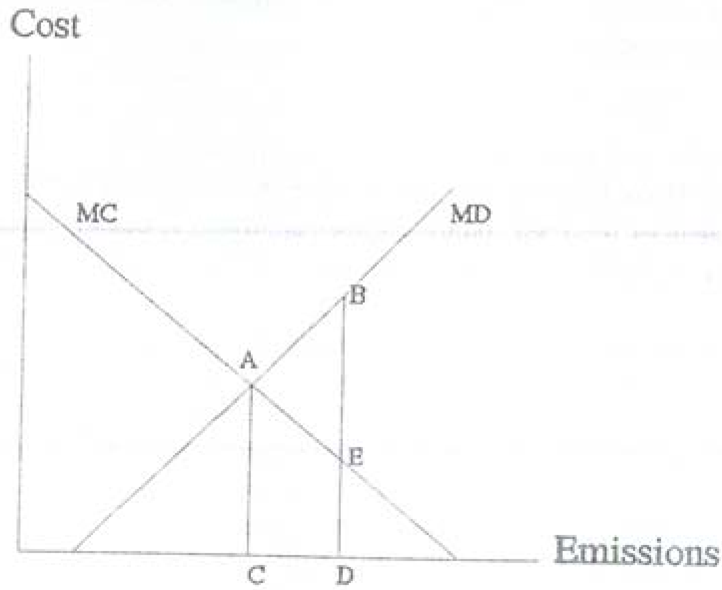

FIGURE 2

Assume that the current emissions are at D. It would the be desirable to reduce the emissions to C. The total cost of doing that is the area ACDE. The reduction in the environmental damages from such an emission reduction is ACDB. We inmediately see that these two areas are correlated. An increase in the environmental damages from an increase in the emissions will be accompanied by an increase in the abatemente costs necessary to achieve the optimum level of pollution. Therefore, the cost of achieving the target emission reduction is, although hardly perfect, an approximation of the environmental damage. If the political system has determined explicit targets for environmental policies, then one could use the cost of achieving these targets as approximations when adjusting the conventional national product concepts for the flow of environmental services. However, policitians very seldom determine specific targets in environmental policies, and the scope of this approach to evaluating environmental damage is therefore limited.

Similarly, if the political bodies have determined emission taxes instead of quantity targets, these taxes could be interpreted as proxies for the social marginal damage from further pollution. In Sweden, the emission tax on sulphur is 30.000 SEK per ton. This reveals implicitly that society values the damage from one more ton as 30.000 SEK. Unfortunately, there are very few such emission taxes and in most countries there are no environmental taxes at all.

III.4. Transboundary pollution.

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

To construct a welfare index, and more generally a consistent accounting system, we need to return to the fundamental question; whose well-being should be considered? Should we consider the global population, or should we limit ourselves to the citizens of the own country? Either approach is equally valid, but they lead to different formulations of the indices as well as the accountns.

Begin by assuming that we are interested in a marginal cost-benefit rule for projects in one country.

Then we should deduct the environmental damage "our projects" give rise to abroad. Thus, export of pollution should be counted negatively. Furthermore, as the cost-benefit rule applies to domestic projects only, the import of pollution should not be accounted for. If the objetive is to create an index measuring the impact on global well-being from projects in one country, then environmentally damaging activities in other countries should not be included. If all countries based their accounts on this objetive, all accounts would be consistent, and could thus be summed. In fact, the global national product calculated in this way would give the same result as the result from a calculation in which we would have considered the whole globe as one country.

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

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

III.5. Environmental assets.

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

In SNA (before -93), changes in only two such assetss are included - man-made capital and human capital. In the gross national product, GNP, gross investments in real capital are included. If we are interested in a welfare index that includes future generations, it is clear that the net national product, NNP, is better index than GNP. What matters for future generations is the capital stock they inherit, and we should measure how much we add to this stock by focussing on net investments.

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

Changes in stocks of natural resources have typically not been included in

SNA. As many of these resources generate essential life supporting services, their exclusion may severely distort the net national product estimates. It should be of highest priority to try to include changes in the complete asset base in the accounts.

Exactly how changes in these assets should be included in the national accounts is still controversial, though it should not be. Once again, starting with the objetive of creating a marginal social cost-benefit rule, we have to determine the impact current projects have on welfare. To do this it will be necessary to make some assumptions on what the future will look like. In deriving the appropriate accounting prices, the simplest and most practical assumption is to assume that the economy will follow an optimal path from now on: recall the discussion involving Figure 1. There we concluded that we could use the optimal prices even if the economy is not at the optimum. The same is true in a dynamic setting. We use the optimal path as a vehicle to compute accounting prices which are then used to value the current changes in resource stocks. Basically, these prices will reflect the present value of the future welfare stream from one more unit of the resource today. Having computed these accounting prices, it follows that we should add the value of changes resource stocks at these prices to the conventional national product.

This conclusion has important implications. One implication is that we must include the price times the change in the resource stock. The change in the accounting price is not included. That is, we do not consider capital gains (or losses). Another implication involves exhaustible resources and the proper treatment of new disconveries. If discoveries are deterministic in that one can predict with some certainty that new reserves will be found, if investments are made in explorations, then the net stock may increase. On the other hand, if discoveries are completely random, then changes in the stock should be valued with accounting prices that take into account possible (but not certain) future discovery.[12]

Furthermore, the so called El Serafy[13] model for computing the depreciation charges for exhaustible resources is incorrect, due to the fact that it is based on an arbitrary prediction of the future - a prediction which is not self-consistent. El Serafy considers the case when a resource has a fixed lifespan and generates a constant revenue for each of the remaining years. He then transforms this revenue to a consumption charge that can go on forever. This enables him to compute the depreciation charge. However, as the assumptions are arbitrary, the computed depreciation charge will also be arbitrary.

For many of the resources included in the stock of natural capital, the same valuation problems arise as did with the flow of services discussed in the previous

[12] See Dasgupta & Mäler (1991).

[13] See Ahmad, El Serafy and Lutz (1989).

section. There are no market prices for these assets because they are not subject to transactions. Instead, one has to follow the same rather ad-hoc approaches as were discussed. However, there are important resources for which there are market prices. Most of the exhaustible resources are traded on markets, and the established market prices could be used as a first approximation to compute the appropriate depreciation charges.

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

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

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

III.6. Sustainable development and sustainable income.

It is possible to show that the net national product concept that was introduced in the previous section has some rather interesting properties:[14]

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

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

The NNP is a linear measure and if we are following an optimal path, it is

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[14] See Mäler (1991) and Dasgupta & Mäler (1991).

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

IV. AN ACCOUNTING SYSTEM

The theoretical arguments, put forward in the previous sections are obviously far different from the basic idea underlying the Standard National Accounts. Furthermore, they are also quite different from the ideas underlying System of Integrated Environmental and Economic Accounting (SEEA).[15] Obviously, the ideas expounded in this paper will be very difficut to implement, particularly because of the inherent difficulties of valuing environmental services.[16] However, it is possible to embed the arguments above in an accounting framework, similar to SNA. A brief presentation of such a framework is given in this section. The basic building block is a SAM - a Social Accounting Matrix- which can be used to summarize the accounting system in a compact way. The Table 1 does not take into account the fact that wages for raw labour should not be included. It does not include international relations and it does not include the input/output structure of the economy. Furthermore, it would be much desirable to include a finer classification of institutions, including the public sector, instead of only have households as the only institutions.

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

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[15] See below for a discussion of this system.

[16] This is true for any application of resource accounting involving valuation of environmental damages.

TABLE 1
A SOCIAL ACCOUNTING MATRIZ (SAM)

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

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

V. SURVEY OF APPLICATIONS

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

Japan was one of the first countries to adjust the national product in a welfare-oriented way. Uno, in 1973, followed by Nordhaus & Tobin (1972), proposed a measure of economic welfare by adjusting the national product in a number of ways.[17] The most interesting adjustment, in this context, was the way environmental damages was monetized. Uno suggested that the damages could be approximated by the cost for reaching an environmental goal. Thus, if the officially stated goal is to reduce sulphur-emissions by 30%, then one can approximate current sulphur-damages by the cost of reaching this goal. Uno's suggestion is interesting and theoretically quite appealing, as we discussed above.

The Statistical Bureau of the Netherlands is particularly active in promoting

[17] See Economic Council of Japan (1974) "Measuring Net National Welfare for Japan", Tokyo.

"green GDP" calculations. In the beginning of the seventies, the bureau made several attempts to correct the national income by taking into account environmental damages. The work has continued in the 1990's. see Hueting (1990) for an overview.

Denmark and Sweden have recently completed two studies on resource accounting, each reaching widely different conclusions (see Danish Bureau of Statistics (1990) and SOU (1991:37)). The Danish position is strongly negative towards monetary account, while the Swedish commission expressed cautious optimism. Currently, a number of Swedish governmental bodies are involved in developing resource accounting systems. The Swedish National Institute of Economic Research is responsible for developing monetary accounts, while Statistics Sweden (SCB) pursues the work on physical accounts. Also, the Swedish Environmental Protection Agency is involved in these efforts and is currently compiling 'environmental indeces'.

Work is currently under way in an number of other countries. In particular, Australia, Canada and Germany are active. Several international organizations, such as the OECD, the World Bank and the United Nations are actively supporting the development of resource accounting systems. A particularly significant publication is the forthcoming Handbook of Integrated Environmental and Economic accounts by the the UN statistical office. Finally, we note that the president of the United States has instructed the Bureau of Economic Analysis to develop a "green GDP".[18]

V.1. France

"Les Comptes du Patromonie Naturel" bring together three different types of accounts; resource accounts, geographical accounts and "economic accounts". The resource accounts are similar to those which were developed in Norway (see Table 2), while the geographical accounts pertain to certain geographical areas or ecosystems. The economic accounts are designed to integrate the economy and the environment. According to Theys (1989) there are six different levels of the French information system: level I includes a large number of heterogeneous data (environmental or socioeconomic); level II harbors data on water, land, noise in sectors; level III provides comprehensive studies on environmental expenditures. etc.; level IV details actual accounting studies, both in monetary and physical terms; level V comprise two computerized models that can be used to assess macroeconomic effects of environmental policy and environmental consequences of

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[18] There is also a "local" application of resource accounting, involving the Chesapeake Bay (USA), bordered by the states of Maryland, Pennsylvania and Virginia. See Peskin, H. (1989) "A Proposed Environmental Accounts Framework". In Ahmed, Y. J., El Serafy, S. & Lutz, E. Environmental Accounting for Sustainable Development. Washington, D.C., The World Bank.

various policy choices; finally, level VI is devoted to compilation of quality-of-life indicators. The French system is still in its development and it currently plays a minor, if any, role in the formation of environmental and resource policy in France.

V.2. Norway

The energy-crisis in the beginning of the 1970's sparked the demand for information systems which aided in the planning of energy policy in Norway. Gloomy predictions by the Club of Rome and an increasing awareness of the scarcity of environmental resources accentuated the need for such instruments. Questions regarding the future use of hydro-power, the management of the discovered oil and natural gas sources were also important in this development. Further, extensive fishing in the North Sea and questions about the proper degree of agricultural self-sufficiency provided additional impetus for developing natural resource accounts.

In selecting the coverage of the accounts, a number of criteria were used.

(i) Political and economic importance
(ii) Costs of acquiring the data
(iii) Sector- and commodity definition should adhere to the SNA-system.[19]

After several years of work within the government, a detailed resource accounting system was introduced in 1978. In this system, resources are classified as being either material or environmental. Material resources are subdivided into mineral, biotic, and inflowing resources (hydro power). The environmental accounts focus on the state of air and land-use. A material account typically include three pieces of information: the ingoing and outgoing resource base including adjustments other than gross extraction (discoveries, reappraisals, new technology etc.); an extraction and trade part, where extraction, import and export is recorded sector-wise; finally, a part of the system describes domestic use in a systematic fashion. The environmental accounts include emissions to air for e.g. sulphur dioxide, nitrogen oxides, carbon monoxide and lead. They also include land-use accounts, whose primary purpose is to detail availability of land and its changes in varios classes. See Table 2 for an illustration of a typical material account.

One of the purposes was to develop resource budgets that would detail planned use of each included resource. The budgets were considered to foster a better and more farsighted resource-use. Tangible evidence of the actual existence of such budgets is, however, lacking (see Lone (1987)). Alfsen et al (1987) find the closest resemblance of resource budgets in a 1985 governmental quadrennial Long-Term Program compiled by the Ministry of Finance. Even is this case, as they

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[19] See Alfsen et al for further details.

point out, the only non-historical numbers contained in the report were not budgets in terms of planned or optimal use.[20]

Seen in this light, the Norwegian resource accounting system does not appear successful. Still, the system has been used to determine catch-quotas in the North Sea and to fix the proper exploitation-rate of the oil reserves. In addition, cost-efficiency studies (nitrogen leaching) in agriculture and models for projection of emissions to air, have utilized data from the system.

An important lesson that seems to emerge from the Norwegian system is the importance of making an early identification of the demand side. The risk of building impressive mountains of "sleeping" informatin to meet a vaguely defined demand-side is apparent here, particularly when there rarely exists any well-defined political goals for natural resource use. This may seem to be a mundane insight, but it is all the more important in the formative stage of resource accounting system.

TABLE 2
RESERVE ACCOUNT FOR ENERGY IN NORWAY 1985

	Coal	Crude-Oil	Nat. Gas	Hydropw	Biomass
	Mill.t	Mill. t.	Bill.t	TWh	Mill.m³
Non-dev. reserves 1/1	-	291	128	60.6	-
Revaluation	-	0	- 1	-	-
Planned dev.	-	65	6	-	-
Developed	-	-	-	-1.5	-
Non-dev. reserves 31/12	-	356	133	59.1	-
Des.reserves 1/1	30.0	359	271	99.7	5
Revaluation	-	56	9	-	-
New dev.	-	-	-	1.5	-
Extraction	- 0.5	- 38	- 27	-	-
Dev.reserves 31/12	29.5	376	254	101.2	5
Non-dev. & Dev.reserves 31/12	29.5	732	287	160.3	5

Source: Alfsen et al (1987)

Resource accounting in physical terms avoids the complexity of transforming resource use into monetary terms. It also focuses directly on the resource scarcity in physical terms. According to Lone (1987), the work of Ayres & Kneese (1969) on the mass balance principle provided an important intellectual

[20] The Norwegian Ministry of Finance has recently promoted the national wealth as an anchor for economy policy. By focusing on the national wealth they hope to encourage a sustainable resource management.

starting point for developing physical, rather than monetary, resource accounts. While there appears to be nothing that will change the current emphasis of accounting in physical terms in Norway, one may perhaps view the current interest in national wealth calculations as a step towards monetization.

V.3. Indonesia

The study of Indonesia by Repetto and his co-workers (1989) is perhaps the best-known application of resource accounting. Central to this work is the observation that in the SNA (before-93) depreciation of man-made capital is treated differently than depreciation of natural assets. Hence, while the cost of 'using up' a machine is reflected in the net national product through depreciation allowances, the cost of 'using up' a natural asset is not. Because both a machine and a forest provide for the welfare of current and future generations, they are productive assests. Thus, according to Repetto et al (1989), these assets should be treated symmetrically in the national accounts. Such a treatment is consistent with the theoretical consideration above.

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

As a first step, the authors' construct physical resource accounts. Specifically, they focus on three major assets: forests, oil, and soil. For each asset a physical and monetary account is constructed. A key issue is valuing the change, in monetary terms, of the asset stock. The basic approach to the economics of depreciation, outlined in 1925 by Harol Hotelling, is to analyze the present value of future services from a machine or a resource.[21] Repetto et al select to use the net rent method. The depreciation allowance is equal to price minus the costs of extraction.

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

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[21] Hotelling, H. (1925) "A General Mathem...

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

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

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

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

A summary of the findings is reported in Figure 3.

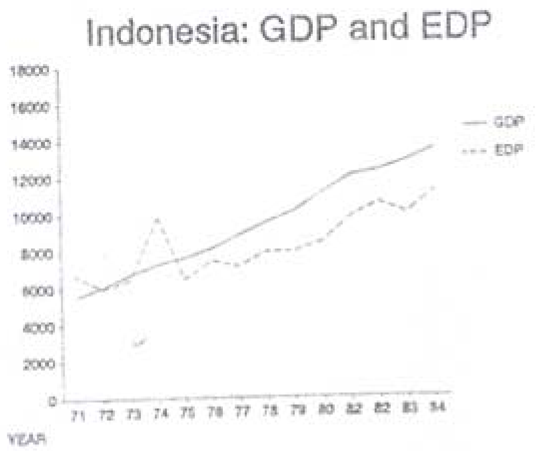

FIGURE 3

Critiques of the study have focused on both the valuation procedures and the choice of income measure. Clarke & Dragun (1989) argue that the net rent method is not an appropriate valuation method (in the case of a renewable resource) whence decreasing the stock may be part of a program to increase future growth of the forests; compare the use of cleanings and thinnings. El Serafy also contends that the net rent method is not a correct depreciation approach. He advocates the approach which we dismissed as arbitrary.

Clarke & Dragun's point about the forest calculations can be approached from a number of standpoints. The simplest is to separate final fellings from the investment-like cleanings and thinnings in the accounting procedure. It is difficult to assess how such reclassifications affect the final results calculated in Repetto et al's study.[22]

If we compare Repetto et al's EDP-concept with the welfare index we proposed in section III.5 there are a number of differences. The treatment of labor, human capital and environmental quality are main dissimilarities. It should also be pointed out that Repetto et al use gross rather than net investments in real capital.

While Repetto et al's study has been critized for various errors it remains the first important study to show how resource accounting can be used to shed light on particular resource allocation problems. Our review has concentrated on the 'EDP' concept presented in the report, which is only a part of the material compiled. The effort of Repetto et al to construct the Indonesian resource accounts paves the way for a wide variety of analyses pertaining to relationships between the economy and the environment. This is perhaps its most important contribution. A similar application is made for Costa Rica, see WRI (1991).

V.4. Malaysia.

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

[22] For additional critique of the Repetto et al study, see e.g. Peskin (1989.

sustainable.

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

Vincent's (1993) analysis can be seen as an attempt to check whether different part of Malaysia satisfies Hartwick's rule. This rule says that if production possibilities in a country with only non-renewable resources are such that it is feasible to sustain positive consumption, then the economy can enjoy the maximum constant consumption, if the resource rents are invested in reproducible capital. Given such an objective, much of Vincent's analysis is consistent with our discussions on how to value resource stocks. There is one difference, however. According to Vincent (1993, p.8), discoveries should not be included measures of net depletion of a nonrenewable resource. As we saw in section III.5 we should include the net change of the stock, if it can be predicted with some certainty that explorations lead to new discoveries. See the appendix for a formal treatment of this point.

V.5. Mexico

Van Tongeren et al (1991) present an integrated environmental and economic accounting system of Mexico.[23] The study followed the guidelines set forth in UNSO's draft handbook on environmental accounting. Oil depletion, deforestation, land use and environmental asset depletion (air & water pollution, soil erosion, ground water and solid waste) were focused upon. In the sense that physical accounts were established first and then later transformed into monetary accounts the general strategy followed closely that of the Indonesian study. Two environmentally adjusted domestic products(EDP) are calculated. The reason for presenting two types of EDPs is that EDP1 is based on market transactions, while EDP2 includes calculations involving less generally agreed upon principles (such as the avoidance cost method).

Valuation of changes in oil and timber stocks was carried out by using both the net rent method and El Serafy's approch. In the second case, one needs to calculate the discounted sum of depletion allowances necessary in keeping income constant. The study year (1985) gives different results for the two approaches; net rent is 1162 pesos/barrel, the depletion allowance is 160 pesos/barrel. Average stumpage values for forests were computed to be 21.5 and 1.6 pesos/m3 respectively.

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[23] The SEEA-system has been tested on New Papua Guinea (see below) and Thailand.

The Van Tongeren et al study also includes environmental quality changes. Besides valuing soil erosion and solid waste generation (by households), the authors also include surfur dioxide, Nitrogen Oxide, Carbon Monoxide and emissions of suspended particulates. Land erosion was valued at the cost of fertilizer to maintain the productivity of the land. Ground water loss was valued at the cost to maintain the productivity of the land. Ground water loss was valued at the cost of re-injecting water back into underground water reservoirs. Finally, water and air pollution were valued at the cost of reducing such pollution "to acceptable levels" (p.7)

The main findings of the monetary valuations are summarized in the Table 3:

TABLE 3
CONVENTIONAL AND ENVIRONMENTAL ACCOUNTS, MEXICO 1985.

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

Source : Van Tongeren et al (1991), p. 24
Figures are in Billion pesos.
C = Consumption
CAP = Net Capital Formation
EDP1(2)= Environmentally Adjusted Net Domestic Product(see text for details)
NDP= Net Domestic Product

EDP1 includes degration of natural capital. By subtracting these costs from NDP, one finds that the value of this degradation is about 6% of NDP. If additional environmental damages are taken into account, the adjusted Mexican income is about 13% less than the conventional NDP. It can also be seen that consumption is the major component in the studied income-measures. Computation of changes in the capital stock (net) gives different results, depending upon which measure is selected. The most comprehensive measure, EDP2, suggests a negative build-up of real capital in Mexico.

Both EDP1 and EDP2 differ substantially from our suggestion of how to adjust the national product. First, the wage-bill and the human capital stock is not given a correct treatment in this study. It is difficult to say, based on the data in the report, how a correct treatment would have changed the conclusions. Second, new finds of oil are not included in the net change of the oil stock. As in the Vincent (1993) study, this is not a correct treatment. Third, changes of the stock of forests are only accounted for if the harvests are larger than the maximum sustainable yield. No compelling arguments are presented to support that treatment. Several similar points can be made, but they all point in one direction, namely that the system is ad-hoc. The proposed concepts of adjusted national products may have some connections to a welfare index, but this is very difficult to know. One example of the generic problem in this study is the following quote (p.22): "It should furthermore be noted that in the derivation of Yn2 (EDP2), an additional deduction has been made for environmental services produced by the government in the form of sanitation services. They are treated as intermediate consumption of (domestic) household protection activities." Again, no compelling reasons are presented to support this argument.

V.6. Papua New Guinea

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

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

The main findings are summarized in Table 4.

TABLE 4
ADJUSTED NATIONAL PRODUCT FOR PAPUA NEW GUINEA
1986-1990.

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

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

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

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

V.7. Swedish forests

Hultkrantz (1991) made and attempt to adjust the sectoral forest accounts by including several non-priced services provided by forests. The Table 5 illustrates the components included in his analysis.

TABLE 5
COMPONENTS INCLUDED IN MODIFIED FOREST ACCOUNTS

Yield	Maintenance	Stock
Timber	Maintenance	Forest Inventory
Harvest of Berries		Berry-yielding Herbs
Mushroom		Mycclium
Meat(bag)	Game Protection	Game Population
Recreation	Various Activities	Various
Biodiversity	Fauna/Flora Protection	Survival Conditions
Effects on Hydrological flows	Measures that affect runoff	Forest Inventory, bare lands, ditches, etc.
Fixing of Carbon	Silviculture and Boarding (non-harvesting)	Carbon Pools
Buffering of Acid Rain, Tree Nutrition	Liming, Fertilization	Content of exchangeable base cations insoil and vegetation
Nitrogen Leaching	Construction of nitrogen sinks	Nitrogen-fixing capacity
Reindeer Forage		Lichen Stocks

Source: Hultkrantz (1991)

To the extent possible, Hultkrantz (1991) utilizes market prices to evaluate each component. Such data is available on timber, berries and mushrooms. The value of meat from hunting and recreational values, are obtained from a contingent valuation study. Biodiversity is valued by considering the area of protected land that must be set aside to protect biological diversity, and then computing the opportunity costs. The hydrological effects, e.g. forest absorbation of water that could have been used for power generation, are not valued explicitly. Carbon fixing is valued by using the effluent fee of carbon dioxide (c.f. our theoretical discussion above). Note that Hultkrantz (1991) counts the increase of growing forest stock twice. First, the timber value and then the value of carbon fixing. The annual depletion of exchangable actions in forest soils can be compensated by liming, and this cost is used as a proxy. For lack of data, nitrogen leaking is not considered explicitly. Forests (in the Norther of Sweden)also provide reindeer forage. Because changes in lichen stocks are not included in the current accounts, so Hultkrantz (1991) utilizes studies on opportunity costs to obtain a value of the change is stocks. His final results are reported in the Table 6.

TABLE 6
MODIFIED NNP ACCOUNTS FOR INCOME FROM SWEDISH FORESTS, 1987.

Market value of Timber	18.63
Inputs from other sectors	-3.14
Stock growth	3.8
Silviculture	-1.55
Subtotal 1	*17.75*
Berries	0.5
Mushrooms	0.55
Meat from game	0.47
Subtotal 2	*1.52*
Biodiversity	-0.6
Carbon Pools	3.8
Exchangable cations in soil	-0.6
Lichen Stocks	-0.02
Subtotal 3	*2.58*
TOTAL NET INCOME	21.85

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

The SEEA

We end this section by commenting on the System of integrated Environmental & Economic Accounting, which has been developed by the UNSTAT, the Statistical Division of the United Nations. This system complements the current SNA in two important respects: (i) Depletion of natural resources in both production and final demand and (ii) changes in environmental quality. The SEEA also includes a broader concept of capital, this includes not only man-made capital but also natural capital.

The SEEA contains both physical and monetary accounts. The physical accounts have a structure which is similar to the Norwegian accounts we presented in section V.2.[24] The asset-boundary is very general and includes, in principle, all assets (Handbook (1993, p.8)). It is acknowledged that an application of the SEEA probably needs to restrict the number of assets included. In any case, the asset boundary is much wider compared to the ordinary SNA.

In transforming the physical data to monetary units, the Handbook discusses three different approaches: (i) Market valuation, (ii) Direct Methods (e.g. Contingent Valuation) and (iii) Indirect Methods (e.g."environmental protection costs").[25] The most important of these in the SEEA are the indirect methods, in particular the "maintenance cost concept". While the exact definition of this concept is unclear, it it stated that "The (hypothetical) maintenance costs are -- mainly prevention costs that would have been necessary to prevent negative impacts of economic activities on the environment and/or to meet given sustainability standards -- "(Handbook(1993, p.19).

As illustrated in the studies of Mexico and Papua New Guinea above, the SEEA also suggests an Environmentally adjusted Domestic Product (EDP). It is defined (Bartelmus(1993, p. 67)) as:
ECP = Final Consumption + Net Capital Formation + Net Exports of goods and services + Net Exports of residuals.[26]

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

1. Opening Stocks (produced and non-produced).
2. Use/Value added tables (GDP, NDP, EDP).
3. Supply tables (Goods and Services, Imports of residuals).
4. Revaluation and other volume changes.
5. Closing stocks.

Defensive expenditures are identified and classified in a number of ways.

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[24] The differences between material/energy balances and the French and Norwegian systems are, according to the Handbook (1993 (p.75), e.g. less detailed spatial description of transformation processes (c.f. the French system) and a more comprehensive description of economic activities and their use and production of residuals.

[25] The terminology used in the Handbook for different valuation methods is somewhat unusual, in that Hedonic pricing and travel cost methods are called "Direct Methods" (Handbook (1993, p.17). In the literature, these are typically called "indirect", because the value of the environmental resource is revealed indirectly form associated market goods.

[26] In the Handbook of SEEA, considerable doubt is expressed regarding the possibilities of calculing net exports of residuals.

The argument for not deducting them from EDP is, according to Bartelmus (1993, p. 59), bases on reductio ad absurdum-- food could, for example, be considered a defensive expenditure against starvation and "in the limit" the adjusted national product is zero.

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

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

6. CONCLUDING REMARKS.

This chapter has explored the consequences of basing resource accounting on firm theoretical grounds. We found that if certain technical restrictions are met, for any conception of social well-being, and for any set of technological, transaction, information, and ecological constraints, there exists a set of shadow (or accounting) prices of goods and services that can be used in the estimation of real net national product (NNP). This holds no matter what is the basis upon which social well-being is founded. We also showed how an accounting system can be constructed using conventional tools of welfare economics.

Our scrutiny of existing applications showed that our approach is different from the ones currently used. This should not be surprising, given the fact that resource accounting is still in its formative stage. Nevertheless, it is important to begin with the fundamental question: what is it that we want to measure? If we want to measure well-being, then our suggestions follows naturally from received welfare economics. Our fundamental point is that measurement without theory is as dangerous in resource accounting as elsewhere. We agree whole-heartedly with Erik Lindahl, who made exactly the same point, when he developed his accounting system in the 1930s.[27] Without supporting theory we run the risk of developing accounting systems that are inherently useless when it comes to increasing our understanding of the proper husbandy of our environment and natural resources.

APPENDIX

In this appendix we present a number of very simple models to illustrate how an accounting system could and should be developed. Even if the models may seem too simple, they do give insights on how different items should be included in the accounting system.

A. Flow of services.

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

$$L_1 + L_2 = L$$

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

$$pC = wL_1 + R$$

As in the main text, we will neglect income distribution. Let.

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

be the utility function of the representative individual.

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

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

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

[27] Lindahl's contributions to national accounting are described in Kriström (1994)

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

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

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

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

$$\Delta NNP = R^1 - R^0 + q(Q^1 - Q^0).$$

Thus, (the change in) NNP case corresponds to the change in "other" incomes and the value of the change of the flow of environmental services. This proves the proposition in the main text that return on raw labour should not be included in NNP.

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

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

The utility function is (we now neglect labour income)

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

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

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

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

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

This shows that the defensive expenditures should not be substracted from the NNP measure. The confusion that can be found in the litterature stems from the fact that we can also write ΔNNP as

$$\Delta NNP = (C^1 - C^0) + p_Z(Z^1 - Z^0).$$

where p_z is marginal willingness to pay for the "transformed" environment Z. Th one has to be careful about how one defines the flow of environmental services. most cases, it seems most appropriate to use the "external" environment, e.g. t noiselevel outside a building, the pollution before a cleanup etc. This wou correspond to the use of the Q-variable. In some cases, it is possible to estimate from estimates of the defensive expenditures, $p_y\ (Y^1 - Y^0)$. However, that is n always the case.[28]

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

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

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

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

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

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

$$(M^{S1} - M^S0) + \alpha_{sF}(M^{F1} - M^{F0}))$$

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

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

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

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

B. Human capital

Let us now introduce one stock- human capital. Total production is given by the production function.

$$Y = F(TL).$$

where T is the stock of human capital and L is the number of hours worked. Total production is allocated to investment E in human capital and the consumption C.[29] Let us assume that the dynamics of the stock can be written.

$$dT/dt = \mu ET$$

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

$$Max \int_0^\infty U(C,\ L)e^{-\delta t}dt$$

subject to

$$C = F(TL) - E$$

$$dT/dt = \mu ET$$

It is important to note that δ is a utility discount factor, which need not be equal to a market discount rate.[30]

The current value Hamiltonian for this optimal control problem is

$$H = u(F(TL) - E,L) + p_T\mu ET$$

with p_T denoting a multiplier. The optimality conditions are

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[29] The analysis is easily extended to cover other types of human capital models. We focus on the simplest one here.

[30] See Dasgupta / Mäler (1991) for a detailed discussion of the implications of this fact.

$$U_C TF(TL) = - U_L U_C = \mu p_T T.$$

The accounting price on T is determined by

$$dp_T/dt = \delta p_T - LF_T(TL) - \mu p_T E$$

The Hamiltonian now plays the same role as the utility function played in the previous section. It incorporates both the flow of current services and the value in the future from the current addition to the stock by investments. Thus, the Hamiltonian is the correct non-linear welfare measure. In order to get a linear measure, we linearize it. Using consumption as the numeraire and dividing by the marginal utility of consumption we have,

$$NNP = C - wL + (p_T/U_C)dT/dt$$

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

C. Stocks of environmental resources

Let S be a vector of stocks of resources. These resources are harvested at the rate X. Let the dynamics of the resources be represented by the growth function $\theta(S)$. Thus

$$dS/dt = \theta(S) - X$$

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

$$Max \int_0^\infty u(C_m)\exp(-\delta t)dt$$

$$dS/dt = - X$$

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

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

$$\lim_{Cm \to 0} \partial U(C_m)/\partial C_m = \infty$$

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

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

where γ and ζ are multipliers. The first-order conditions are;

$$\partial U/\partial C_m = \zeta q_m$$

$$\gamma = \zeta p_x$$

$$\zeta >= 0 \; (= 0 \text{ if } p_x X - q_m C_m > 0)$$

$$(d\gamma/dt)/\gamma a = r$$

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

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

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

Sometimes it is possible to discover more of a resource. Assume that this process is deterministic, i.e. that one knows with certainty that following a certain amount of investments in exploration, the stocks will increase in a deterministic fashion.[31] This idea can be incorporated by including Y used in exploration

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[31] When discoveries are stochatic the analysis needs to be modified as shown in Dasgupta & Mäler

activities in the growth function. For some resources, Y can also he interpreted as expenditures on maintenance, fertilizers, etc. Thus let us write

$$dS/dt = \theta(S, Y) - X$$

The production in society is described by the production function

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

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

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

$$W = C + I + Y$$

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

$$Max \int_0^\infty U(C,\ S)e^{-\delta t}dt$$

subject to the conditions above. The current value Hamiltonian is

$$H = U(C, S) + p_K dK/dt + p_s dS/dt$$

The accounting prices follow the differential equations

$$dK/dt = \delta t - \partial H/\partial K$$
$$dS_i/dt = \delta S_i - \partial H/\partial S_i$$

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

$$NNP = C + (U_s/U_c)S + (p_K/U_c)\ dK/dt + (p_s/U_c)dS/dt.$$

The net national product is again equal to the value of the consumption plus the value of the net change in the stocks of all resources and the "flow" value of the stocks S. This last value occurs because we have assumed that the individual has

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(1991). See also the main text for a verbal description of this case.

preference for the stock of some resources, such as biodiversity, such as the population of blue whales etc.

Note that the NNP equals the current utility value plus *the value of the change in the resource stock* and not the change of the value of the stock. Thus capital gains should not be included.

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

$$dB/dt = rB + p_x X - q_m C_m$$

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

$$\lim_{t\to\infty} B_t \exp(-rt) = \lim_{T\to\infty} \int_0^T (p_x R - q_m C_m) \exp(-rt)dt = 0$$

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

D. NNP and sustainable development

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

$$H = U(C,S) + p_K dK/dt + p_S dS/dt$$

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

$$dH/dt = (\partial H/\partial K)dK/dt + (\partial H/\partial p_k)dp_k/dt + (\partial H/\partial S)dS/dt + (\partial H/\partial p_s)$$
$$dp_s/dt + (\partial H/\partial u)du/dt$$

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

$$dH/dt = (-dp_k/dt + \delta p_k)dK/dt + dK/dt\,dp_k/dt + (\delta p_s - dp_s/dt)dS/dt + dS/dt\,dp_s/dt$$
$$= \delta(p_k dK/dt + p_s dS/dt) = \delta(H^* - U)$$

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

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

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

$$H^* = \delta K^*$$

where H* is the maximum value of the Hamiltonian. Thus, if we are at an optimal trajectory (and if the time-span is short enough (constant prices)), then the value of the Hamiltonian can be interpreted as the return on the aggregate capital stock[32]. This interpretation is not possible if the economy is far from the optimal trajectory. If the economy is at an optimal trajectory then it follows from the above that so that H^* is the maximum constant stream of utility the economy can have.

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

[32] See Aasheim (1993) for detailed investigations of this interpretation.

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