4.

Green accounting
– the environment and natural resources in national accounts

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4.1 Sustainability and national accounting

Assume that a small open economy seeks to lead a policy that ensures sustainable development. What rules for the management of man-made and natural capital will such an economy have to abide by? How is it possible to construct an indicator that will provide information on whether such rules are followed?

The concept 'sustainable development' has, since the report of the Brundtland commission (WCED, 1987), been interpreted in many ways. We shall here concentrate on what the concept means with respect to the obligations of a country's present generation towards the future generations of the same country. Hence, sustainability will be treated as a requirement for intergenerational equity in a national context. This assumption does not reflect the view that intragenerational equity within and between countries is of less importance.

Sustainability in a single country is an important topic especially since the present generation can undermine the quality of life of the country's future generations by causing long-lasting degradation of important environmental resources. If the country is well endowed with natural resources, excessive depletion can have a similar effect.

A perfect market economy ensures that any consumer (or firm) that purchases a good (or factor of production) must pay the seller an amount that reflects the value of the traded good. Such compensation makes the buyer responsible for the cost of the purchase and implies that the buyer makes the purchase only if his own value exceeds the value of the good in its best alternative use. This leads to the efficiency properties of a market system. A perfect market economy does not, however, ensure an equitable distribution of income; either within a generation or between generations. Thus, it will not necessarily ensure sustainable development.

In a real-life market economy, consumers and firms may gain by emitting polluting substances into the environment without being made responsible for the cost of the environmental degradation to which such pollution leads. Then the gain for the polluters will

The dilemma of national accounts

The collected value of all goods and services sold and bought in a nation is traditionally expressed as Gross National Product, GNP. GNP is sometimes used as a measure of wealth of the nation. The relevance of this may be seriously questioned. In particular, it is clear that GNP includes a number of economic transactions that are not necessarily understood as wealth such as costs of health services. In short, it is clear that the GNP is not a direct measure of citizens' well-being.

As explained in the chapter, wealth encompasses not only the consumption of the present population of a country but also the expected future consumption possibilities. These future possibilities are increased by investments and decreased by depleting the total capital available which includes natural resources.

In addition, in order to account for the entire wealth of a nation, one should also capture a number of collective goods that are not bought and sold in the market. Some of these collective values, such as the school system, may be included in a traditional GNP but others, such as the environment and natural resources, are not. If these are added, we arrive at what is usually called 'Green GNP' (Green Net National Products).

All people ascribe a considerable value to environmental assets, such as clean air to breathe or clean water. Activities that are added to the GNP, such as industrial production or car transport, may give rise to degradation of the environment and thus to a decrease in the Green GNP.

There are several methods to develop a Green GNP that more truly reflects the wealth of the nation. Environmental damage may be estimated in various ways and an 'environmental debt' may be subtracted from the GNP. The total value of natural resources, such as forests, fisheries, etc., is more difficult to estimate. Nevertheless, a reduction of these values may be more easily quantifiable. It is in general easier to estimate the change in Green GNP than its absolute value.

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not necessarily exceed the cost elsewhere in the economy and the resulting allocation need not be efficient. If the environmental degradation is long-lasting, the presence of such external effects will also affect the sustainability of the economy.

In the present chapter the principles for national accounting in a perfect market economy are discussed. Hence, external effects are assumed to be internalized, for example, by having polluters pay the environmental cost of their pollution. Since such a perfect market economy does not necessarily ensure sustainable development, it is still important to develop rules for sustainability as well as indicators that provide information on whether such rules are followed. The insights gained from such an exercise may in turn be useful when incorporating natural and environmental resources into the national accounts for an imperfect market economy.

It is assumed that the purpose of national accounting is to provide an indicator of sustainability. In particular, a measure of national income is sought such that if this measure exceeds consumption, then the economy manages its man-made and natural capital in a sustainable manner. Measures of national income may have alternative objectives, namely, to be a measure of the level of economy activity, a measure of welfare, a basis for comparisons of standard of living between countries and so on. Such objectives will not be discussed here.

The term 'consumption' will be considered an indicator of the quality of life. Hence, consumption includes everything that influences the situation in which people live; in particular, it includes much more than material consumption. It is intended to capture the importance of health, culture and nature. In a real economy, such an indicator would be hard to measure. In this respect the present discussion also abstracts from the practical complications that confront national accounting under real-life conditions.

In the subsequent analysis, national accounting will be discussed within the context of a small open economy that trades freely and has access to international capital markets. It will explicitly deal with the effects of changing terms of trade. The assumption of access to international capital markets entails that the country can trade intertemporally; this is of particular importance for the foundation of national accounting that is presented here (see Section 4.3). Also the terms of intertemporal trade are allowed to change; this corresponds to changing interest rates. Throughout, the country's population is assumed to be constant.

4.2 Rules for the sustainable management of man-made and natural capital

This discussion is based on the following definition of sustainability: Our capital management is sustainable if the consumption that we ensure ourselves can potentially be shared by all future generations. If capital is a homogeneous stock, then it is straightforward to formulate a rule for sustainable capital management: let each generation bequeath to its successors a stock that is at least as large as the stock that the generation received as its inheritance.

If sustainable development is a stationary process, then it is reasonable to represent the stocks that are bequeathed from one generation to another as one homogeneous capital good even though it consists in reality of many different capital goods. If so, the requirement of sustain-ability faced by any generation will be, for each stock, to bequeath at least as much as was inherited. Such a requirement is often tied to the concept of 'strong sustainability' (see, for example, Daly 1992). Strong sustainability – as an extreme position – means that no generation will be able to exploit non-renewable resources even when stocks have no value if they remain unexploited and do not inflict environmental damage when they are exploited.

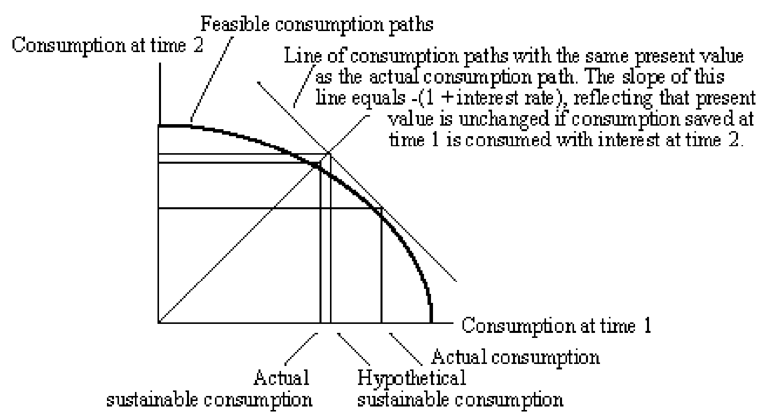
There are reasons to assume that sustainable development is not a stationary process. Human activity leads to depletion of natural resources and degradation of environmental resources. If a generation is to fulfil its obligations towards future generations, this decreased availability of natural capital must be compensated by investment in human capital (in particular, knowledge) and man-made capital. The requirement that any generation must compensate reduced natural capital by accumulation of human and man-made capital is often tied to the concept of 'weak sustainability' (see, for example, Pearce and Atkinson (1993), p. 104).

If weak sustainability is used as a rule, then it must be possible to evaluate whether the reduction of the stocks of natural capital is compensated by the accumulation of stocks of human and man-made capital. To do this, relative prices for various capital goods are needed. Let us assume that there exist market prices for all kinds of capital goods, including natural and environmental resources as well as knowledge capital. Let us also assume that polluters are made responsible for negative external effects. Under such assumptions, it is common (see, for example, Mäler (1991), p. 11 and Hultén (1992), p. 1; see also Solow (1993)) to argue the following: a generation's capital management is sustainable if, and only if, the increase in the stocks of human and man-made capital is in value at least as large as the decrease in the stocks of natural capital. In short: the claim is that capital management is sustainable if and only if the value of net investments is non-negative, where depletion of natural resources and degradation of environmental resources are included as negative investments.

There are important reasons why this result does not generally hold. The reasons – some of which are of special interest in open economies – will be explained in Section 4.3. Let us end this sec-

An expression for NNI, net national income

Weitzman (1976) associates Net National Income (NNI, earlier referred to as Net National Product) with the stationary equivalent of future consumption. Hence, NNI is the level of consumption that, if held constant, would yield the same present value as the path of consumption that the economy actually will follow. In a closed economy, this level of consumption is not actually sustainable; it is hypothetically sustainable if consumption at one time could be linearly transformed into consumption at some other time.



The figure illustrates this in a situation where there are only two points in time.

However, as argued by e.g. Brekke (1995), a small open economy with access to an international capital market can linearly transform consumption at one time into consumption at some other time. Consequently, for such an economy the Weitzman foundation yields a measure of actual sustainable consumption. Hence, NNI as a stationary equivalent is an exact indicator of sustainability in the context of the present chapter. When we subsequently refer to NNI it will be in the sense of a stationary equivalent.

It is straightforward to show that NNI is equal to the interest rate multiplied by the present value of future consumption. The present value of future consumption corresponds to current wealth. Therefore, we obtain that

(1) NNI = (interest rate) • (current wealth)

where the interest rate, if changing over time, corresponds to a long-term interest rate. This is not an expression that national accountants find useful, since current wealth (= the present value of future consumption) is not easily measured (see, for example, Usher (1994), see Section 4.4.

To translate expression (1) into a form that can more easily be calculated, it is useful to note that NNI has the following attractive feature: NNI increases if, and only if, NNI exceeds actual consumption:

(2) dNNI/dt = (interest rate) • (NNI – consumption).

Hence, if consumption is less than the stationary equivalent, then the stationary equivalent increases. This means that the difference between NNI and consumption can be interpreted as saving. Combining expressions (1) and (2) yields

NNI = consumption + (dNNI/dt)/(interest rate)
= consumption + d(current wealth)/dt +
(rate of change of interest rate) • (current wealth).

Moreover the term d(current wealth)/dt can be split into value of net investments (that is, value of the changes in the stocks) and capital gains (that is, changes in the value of the stocks). Thus, as is developed in greater detail in Asheim (1996b) the following expression is obtained:

(3) NNI = consumption + (value of net investments) + (capital gains) + (rate of change of interest rate) • (current wealth).

If (3) can be evaluated using current prices and quantities only, it can potentially be an operational measure of NNI.

Weitzman (1976) makes two simplifying assumptions. He assumes that

- all technological progress is reflected by augmented stocks of knowledge capital; this will be referred to as an assumption of no exogenous technological progress. and
- the interest rate is constant.

How can these assumptions be used to simplify expression (3)? The latter of these assumptions clearly means that the term (rate of change of interest rate) • (current wealth) in (3) vanishes. Furthermore, both assumptions jointly can be shown to imply that there are no capital gains (see Asheim (1996a)). Hence, Weitzman (1976) arrives at the following conclusion:

(4) NNI = consumption + (value of net investments)

This expression is of the same form as the conventional measure of NNI (or NNP).

tion by considering a case where this result does hold for a closed economy. Assume that all technological progress is reflected by augmented stocks of knowledge capital. Then the economy follows a completely egalitarian path (so that each generation ensures itself the maximum sustainable level of consumption) if and only if it holds for any generation that the increase in the stocks of human and man-made capital is in value equal to the decrease in the stocks of natural capital. This result is called Hartwick's rule (Hartwick, 1977; Dixit, Hammond and Hoel, 1980). Rather than being a prescriptive rule for sustainable capital management, Hartwick's rule is a result that characterizes an egalitarian path.

Of course, if the economy follows an egalitarian path, then the problem of achieving sustainability has already been solved: At any time consumption is equal to the maximum level of sustainable consumption. On the other hand, if an egalitarian path is not followed, then an indicator of the level of sustainable consumption is needed in order to determine whether capital management is sustainable. The next section investigates a foundation for a concept of national income designed to serve this purpose.

4.3 Measures of Net National Income

The derivation of an exact expression of NNI where 'NNI = consumption + value of net investments' is given in the box. The expression is of the same form as the conventional measure of NNI (or NNP). It is therefore important to note that the value of net investments is here assumed to incorporate depletion of natural resources and degradation of environmental resources. Such depletion and degradation, evaluated at market prices (which are assumed to exist!), is subtracted in the measure of NNI. Hence, this measure corresponds to what is usually called Green NNP. Furthermore, if stocks of knowledge capital are augmented, then the value of such accumulation is also included.

When Weitzman (1995) evaluated his result nearly two decades later, he wrote: "The force of this result is perhaps not sufficiently appreciated. Any 'sustainability crisis' looming over the horizon should manifest itself *now*. Sustainability, which is a measure of *future* consumption, is exactly reflected in *current* Green NNP.

As noted in the box, Weitzman's (1976) foundation yields an exact indicator of sustainability in a small open economy. Two conditions are assumed to be valid: *no exogenous technological progress* and *constant interest rate*. If these hold then the rule for sustainability discussed (capital management is sustainable if, and only if, the value of net investments is non-negative) has been shown to be valid. It is therefore of interest to discuss how strong these assumptions are in the context of a small open economy.

No exogenous technological progress.

This appears to be a very strong and empirically invalid assumption since

- history would suggest that technological progress has been important for the development of economies and
- technological progress is not normally thought to be reflected in augmented stocks of knowledge capital.

Special considerations arise for open economies. The 'technology' of an open economy must include its trade opportunities. Therefore, the assumption of no exogenous technological progress will be violated if its terms of trade are changing. If resource prices tend to increase, then a resource-exporting country will enjoy improving terms of trade, which within the present context corresponds to positive exogenous technological progress.

Constant interest rate.

For an open economy, a constant interest rate corresponds to unchanging terms of inter-temporal trade. It seems too strong to assume that the interest rate will be constant at all future times. Theoretical models that include natural resources often predict that the interest rate will fall over time; this is the case if capital management is sustainable in the model of man-made capital accumulation and resource depletion according to Dasgupta and Heal (1974) and Solow (1974).

When these assumptions are not reasonable, one might want to attempt to estimate the corrective terms in the full expression of NNI (see formula (3) in the Box): NNI = consumption + (value of net investments) + (capital gains) + (rate of change of interest rate) x (current wealth).

It is doubtful whether operational procedures will be developed for such an estimation. Under the assumption of a constant interest rate, Weitzman (1995) derives a semi-operation formula that corrects NNI as specified in the simpler expression (see formula (4) in the Box) for future exogenous technological progress. However, this correction requires that there is information on the pace of future technological progress.

Likewise, a resource-rich country may calculate the effect of improving terms of trade as capital gains on its stocks of unexploited reserves. However, such a calculation requires information on the development of future resource prices. Finally, the full expression establishes how – in principle – adjustments can be made for non-constant interest rates. However, this requires information on the path of future interest rates. It seems fair to argue that there is no reliable information on future technological progress, on future resource prices or on future interest rates.

4.4 The real calculation will be difficult

Since at best only unreliable estimates of the corrective terms of the full expression (3) can be made, one may be forced to adopt the simpler expression (4) as the concept of NNI that incorporates natural and environmental resources. This latter expression creates challenges of its own,

in particular associated with calculating prices for the natural resources that are depleted and for environmental resources that are degraded. Also, to measure consumption as an indicator of the quality of life is a difficult task. Furthermore, one must have in mind that, even if these challenging problems can be solved, one arrives at a measure which only imperfectly indicates the sustain-ability of the economy. Comparison of the two expressions gives information about the direction of the bias under different circumstances:

1. if there is technological progress, expression (4) is likely to underestimate the sustainability of the economy; Nordhaus (1995) and Weitzman (1995) argue that this bias is potentially large;
2. if the open economy has relatively large stocks of unexploited natural resources, then the expression (4) will underestimate the sustainability of such an economy due to improving terms of trade which manifest themselves as capital gains on these stocks;
3. if interest rates are decreasing, then the interest rate term in (3) entails that expression (4) will overestimate the sustainability of the economy.

The discussion in this chapter has sought to argue that it is a very demanding task to construct a measure of NNI that can be a reliable indicator of the sustainability of an economy. Even though, in theory, such a task can be accomplished, in practice it seems to require information that is not readily available.

Environmental accounts in Sweden

Work on developing environmental accounts is currently under way in most countries in the West, as well as internationally within the framework of fora such as the UN, the OECD and the EU. In Sweden the task to establish such accounts was commissioned by the government in 1992 to Statistics Sweden, the National Institute for Economic Research and the Environmental Protection Agency. Below follows a short description of some of the results as of January 1997, as extracted from reports.

WHAT ARE ENVIRONMENTAL ACCOUNTS?

The term 'accounts' refers to the compilation of statistics in an organized form, under a number of headings, in which credit items are balanced against debit items. The national accounts give an overall picture of the economic flows in society.

For environmental accounts, environmental statistics are prepared and presented alongside economic statistics. The purpose is to develop a system in which it is possible to deal with the use of natural resources and the environment in the same way as all other resources in national accounts.

The data are prepared in two steps. Firstly, environmental data are given in physical terms such as tonnes of a given emission; in the second step monetary accounts are drawn up on this basis by linking figures on emissions and waste with a set price on the impact it causes.

The main objective of the work is to produce a complete system of measures that illustrates the impact of different types of economic activity on environmental and natural resources and vice versa. In the short term it will not be possible to produce a 'green GNP' but it should be possible to achieve a 'greening of GNP'.

THE SWEDISH SYSTEM

The Swedish system for environmental accounts is called SWEEA. A matrix has been developed for entering environmental data in the system called METRIS. The system has currently been adapted for data on

- energy use
- emissions of SO_2, CO_2, NO_x, VOC and organochlorine compounds
- flows of nitrogen and phosphorus
- environmental protection statistics
- solid waste
- material flows for wood, iron and steel

The material is provided for 16 different sectors of trade and industry, as well as the public sector and for private consumption.

The data have been aggregated in so-called economic environment indicators. These are key ratios representing the links between the different sectors of society and environmental impact. The indicators may for example provide information on marginal emissions quota, reflecting how emissions change in pace with changes in production volumes.

The so-called environmental economic profiles calculated from the accounts show how the different sectors contribute to the economy, to employment, their energy use and emissions of pollutants.

A STUDY OF SULPHUR EMISSIONS

Results are available for nitrogen and sulphur emissions. Below follow some results from the pilot case, used to test the design of environmental accounts, that was carried out on the 1991 data for the impact of sulphur emissions. The valuation covered four different types of area: forests, agricultural land, fresh water, and built-up areas. The price tag of society was estimated on the basis of lost output, valued at market price, or the cost of restoring the damage.

The approach taken was one of studying the cycle of sulphur, production use and deposition and the

Table 1. Endangered value/type of natural assets. The categories calculated in the sulphur study are marked by *.

	Health	*Biodiversity*	*Resource management*	*Natural and cultural landscape*
Forests			*	
Cultivated landscape		*		
Freshwater			*	
Urban areas			*	*
Natural land				

damage. In order to make correct calculations it is necessary to have information about the cause-effect relationships between emissions and environmental impact. The real difficulty was to identify these relationships. Emission data provide the cause-related information, but not the effect, while the environmental data describe the state of the environment, that is, the effect, but do not tell us anything about the cause.

The purpose was to provide an idea of the external costs incurred by the environmental impact of Swedish economic activities during the course of one year, 1991, broken down according to sectors. Again, even if we have environmental data, it may be difficult to determine which impact is due to activities in the previous year. In the long run, stress indicators may be developed. For the time being, various research results were used, though the effects of progressive acidification were difficult to estimate.

The matrix used for the calculations is shown in Table 1. Four types of impact in five different sectors were considered. As calculation methods for forests, future loss of timber was used. For agriculture and fresh water, liming costs were the basis, while for urban areas, corrosion costs were estimated.

The total costs of SO_2 deposition in 1991 in Sweden was estimated at SEK 2,570 million. Corrosion represented by far the largest part of this sum. This might be the result of the fact that by far the best data exist for this effect and also, because tangible capital is destroyed, there is a high market price.

PRICES, TRADE AND SECTORAL COSTS AND IMPACT

The total cost of SEK 2,570 million can be allocated to the agents generating it. Since the total sulphur deposition in 1991 amounted to 379,000 tonnes, the cost for emitting one tonne is SEK 6,525.

Sulphur, like many pollutants, does not respect national boundaries. Therefore a ‘trade balance’ of pollution costs may be calculated. The Swedish emissions exported are assumed to have the same impact abroad as imported emissions have

Table 2. Valuation of sulphur-related damages (Million SEK)

Sector	*Value of damage*
Forest	550
Agricultural land	5
freshwater	130
Corrosion	1885
Biodiversity	?
Total	**2.570**

in Sweden. The large majority come from abroad, about 75 per cent. So Sweden has a negative sulphur trade!

When considering different sectors, it appears that forestry only gives rise to about 1 MSEK but bears costs of MSEK 550. An acidification model, used to calculate lost timber output, could be used to simulate the effects of various economic policies in terms of sulphur emissions. Based on that, if the European target for reduction of emissions were set higher, that is, 3 per cent instead of the present goal of 1.5 per cent annually, total loss of income of timber output in Sweden during the next 100 years would be SEK 35,000 million instead of SEK 100,000 million.

VALUE OF NATURAL RESOURCES – FORESTRY ACCOUNT

A first result was also obtained for ‘forestry accounts’, that is, a more comprehensive total account of forestry output than in traditional accounts.

In addition to the production of timber, they include production of funghi, berries, game and lichen. Quality adjustment for changes in biodiversity, acidification of the soil and production capacity for lichen are also made.

The total net output from forest was calculated to be approximately SEK 6,000 - 7,000 million above the net output of timber, the value of which is around SEK 20,000 million.