Constructing a partially environmentally adjusted net domestic product for Sweden 1993 and 1997

- a presentation of the methodological steps and the empirical data -

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Abstract

An Environmentally adjusted net Domestic Product, EDP, should ideally value not only all "goods" produced during a year, but also all "bads". This paper is an empirical attempt to show how in practice one can construct an EDP according both to academic theory and the practical guidelines in the forthcoming UN handbook, in which a short version of the paper is included. An EDP, the first of its kind for an industrialised country, is calculated for Sweden for the years 1993 and 1997. Depletion of metal ores, loss of agricultural soils, and increments of stock pollutants, influencing environmental degradation as acidification and eutrophication, have been possible to evaluate monetarily. Current damage caused by pollution emitted the current year, having already affected current productivity and output, is accounted for separately. An accounting scheme following "the polluter pays principle" is used for this purpose, transferring value added between sectors, not affecting the aggregate figure.

Keywords: resource accounting, environmental valuation, System of Environmental and Economic Accounts (SEEA), green GDP, Environmentally adjusted GDP

1. Introduction

The interdependencies between the environment and the economy have been stressed in many academic studies, UN reports and political declarations during the last decade. How to bring in these interdependencies into modelling, accounting and production/welfare measuring frameworks is a major work task among environmental economists, employees at United Nations Statistical Office and its member countries' statistical offices around the world. Relevant environmental and economic data should be collected and systematised into an integrated interdisciplinary database, making it possible to construct an environmental and economic accounting system.

Currently, both the academic society (Heal and Kriström [2000]) and the network of statistical offices[1] are preparing handbooks in resource accounting. Some empirical attempts have already been made to adjust the System of National Accounts (SNA) production measures using estimates of the depletion of non-renewable natural resources in mines and wells and the degradation of the renewable natural resources in ecosystems.

The integrated economic and environmental information from the data base should allow for multipurpose applications, depending on the policy issue, as there is no one measure, which can answer all questions. If the purpose is to account for qualitative and quantitative changes in the natural capital, the point of departure could be NDP - *the net domestic product* -, where the depreciation of the real capital in a similar way has been subtracted from the GDP-measure (gross domestic product). Consequently, a (partially) environmentally adjusted net domestic product (EDP) would be the appropriate measure, in which one could take into account depletion of natural resources and the assimilation capacity of the environment.

Below, a partial EDP[2] will be constructed step by step, in accordance with the guidelines set up by academic theory (EDP-formulas derived from theoretical models) and the methodology to be presented in the forthcoming handbook of System of integrated Environmental and Economic Accounting (SEEA). Using Swedish data from the years 1993 and 1997, EDP:s are constructed, the first of its kind for an industrialised country, which make it possible to study the development between two points in time. This methodology could be used to answer

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[1]UN Statistical Office published a draft handbook: *System of Environmental and Economic Accounting (SEEA)* in 1993. A revised handbook will be published in 2001, and a draft of that can be found on: http://ww2.statcan.ca/citygrp/london/london.htm. See also BEA (1995) and other proceedings from the London Group meetings.

[2] In the UN handbook the term damage adjusted income (product) is used instead of the EDP. The terminology has not been settled once and for all, as resource accounting is a joint discipline, where academic theorists and people working empirically at statistical offices collaborate. Throughout this paper the EDP terminology is used.

questions about the annual production of goods and “bads”, i.e. present and forward looking negative external effects. Depletion of metal ores, loss of agricultural soils, and increment of stock pollutants, causing environmental degradation such as acidification and eutrophication, have been possible to evaluate in monetary terms. Other global environmental problems, e.g., biodiversity loss, climate change and ozone depletion, are not yet incorporated. Still, of the 15 official Swedish environmental quality objectives, ten are being evaluated, fully or partially, in the EDP-measures to be presented. Damage caused by pollution emitted the current year, having already affected current productivity and output, is calculated but accounted for separately to avoid double counting. An accounting scheme following “the polluter pays principle” is used for this purpose, transferring value added between sectors, not affecting the aggregate figure.

Theoretically, the development of EDP over time will indicate if the net investments in the total capital stock, including renewable and non-renewable natural capital, are positive, and if the national wealth is increasing. Future years’ production will be based on that national wealth, and under some rather strict assumptions, e.g. substitutability among different forms of capital, non-negative net investments, and a non-decreasing national wealth, a positive development of EDP over time will indicate a sustainable development. However, the results of the EDP-calculations will not be discussed in terms of sustainability, as the calculations are partial, only two years are studied, and it is hard to verify that all the assumptions behind the sustainability claims of a non-negative EDP development actually hold. Instead, the results of the calculations have their real merits in discussing orders of magnitude of different (adjustment) items and possible outcomes for different sectors, if policies according to “the polluter pays principle” would be introduced.

2. Background

2.1. Theoretically …

Fisher (1906), Lindahl (1933) and Hicks (1939) are said to be the fathers of the tradition of discussing income as the net return on the total capital stock. The System of National Accounts, which defines economic entities and organises economic data in a way that makes it possible to practically measure GDP, was outlined contemporaneously with Hicks’ work, but the first version was not completed until the 1950s. Revisions and extensions are still being made. The theoretical framework was further developed by Weitzman [1976], showing how a production measure, NDP, under certain conditions can be interpreted as a perpetual (sustainable) income. Hartwick [1979, 1990] and Mäler [1991], and Dasgupta and Mäler [1998] built further on these results to develop (theoretical) accounting schemes for adjusting NDP for environmental degradation and natural resource depletion. Although the theoretical literature on the issue has grown extensively in the 1990s, few papers deal with the question on how to make different types of production measure adjustment in general[3] or to calculate an EDP in practice in particular.

The model framework that lies behind the proposed adjustments is presented in Ahlroth [2000], which in turn uses results in Weitzman [1976], Hartwick [1979], Solow [1986], Mäler [1991], Dasgupta [1993, 1994, 1998, 1999], Aronsson and Löfgren [1995, 1996] and Heal and Kriström [1998]. Compared to Ahlroth (2000), which only contained emissions of sulphur and nitrogen for one year, the scope of the EDP-measures presented in this study is much broader.

The gross domestic product, GDP, is simply the gross return from all capital stocks available to an economy, and the net domestic product, NDP, takes into consideration all changes in all capital stocks, originating from the production and consumption activities in an economy during a given year. The EDP focuses on the changes in natural capital. However, science is not capable of explaining all changes in Nature, and hence in natural capital, in a way that makes it possible to quantify, or evaluate the changes in monetary terms. Thus, not all changes are, for different reasons, accounted for, which means that the measure presented in this paper is a *partially* environmentally adjusted net domestic product, as was explained in section 1.

2.2. … and empirically

Due to lack of data, very little empirical work on green accounting has been presented historically. However, in the 1960s, there was a growing recognition that economic growth could have detrimental effects on the environment and that many developing countries achieved their economic growth at the expense of depleting their natural resources. An

[3] See Eisner (1988)

interest emerged for adjusting the national accounts for externalities of economic activities (Nordhaus&Tobin [1973] and Daly&Cobb [1989]). A few empirical studies have been carried out, mostly in developing countries, foremost dealing with depletion issues (Repetto et.al. [1989]). The approach is generally very pragmatic and takes the data availability as a starting point, rather than the theoretically ideal EDP measure.

However, in the industrialised countries, the main environmental problem is usually not depletion of natural assets, but rather degradation of the environment, such as detrimental effects of pollutants on the functioning of ecosystems. These effects are usually described in physical terms. Evaluations of the costs or the foregone income that the detrimental effetcs incur are rarely done. Some countries, e.g. the Netherlands (Hueting [1989]), are trying to evaluate the costs of abatement measures, which hypothetically could have been carried out to counteract the degradation of ecosystems. The best known study on valuation of environmental degradation in economic accounts is perhaps Peskin and Angeles (1996), calculating an EDP for the Philippines. They used dose-response functions to estimate the damages, and valued the loss using market prices on closely related goods and services. Ahlroth (2000) reports the NDP adjustments made for sulphur dioxide and nitrous oxide emissions, to account for effects of acidification and eutrophication in Sweden.

3. Extending the SNA to account for changes in Swedish natural capital assets

To be able to partially environmentally adjust the Swedish NDP, we need to identify changes that take place in the environment and we need to decide how to register these events in the economic accounting system.

3.1. The state of the Swedish environment

To be able to measure the most important changes in the Swedish natural capital, defined according to the classifications of the SEEA, one has to analyze both economic and environmental data. The quantitative use of natural resources can usually be analyzed primarily from economic data, but the qualitative changes of land and water have to be analyzed according to some environmental standards. The Swedish Environmental Protection Agency and the Swedish Ministry of the Environment have set up 15 national environmental quality objectives. In short, they describe the present state of the Swedish environment in relation to some set of sustainability standards, based on considerations about the production of natural resources, the promotion of human health and recreation, and the protection of biological diversity (De facto 1998).

Ten of the targets are analyzed and evaluated in economic terms in this study, while for different reasons five have not been studied.[4] Furthermore, the EDP presented in the next section is partial in two other aspects. Not all affected geographical areas or all kinds of objects of the addressed targets and only certain economic aspects of the included areas and objects are evaluated. However, the areas and objects that have been analyzed are the ones that economists and natural scientists for methodological reasons have been able to study and for policy reasons have chosen to study, as being of economic and environmental importance.

The ten environmental targets that the economic analysis below will be based on, are:

- **Clean air –** Concentrations of some unwanted substances in urban air should decrease. Most effects can be traced to transportation, energy conversion and industrial processes. Some aspects of the high concentrations of nitrous oxides, sulphur dioxide and ozone are dealt with in sections 4.5 and 5.3.
- **High quality groundwater –** In southern Sweden, the nitrate level in wells is critical for approximately 100.000 households. In many parts of Sweden the alkalinity (protection against a decreasing pH-value) is low due to acidification. Both problems are dealt with in sections 4.4 and 4.6. Other pollutants and water scarcity (saltwater intrusion in coastal areas) will not be studied here.
- **Sustainable lakes and watercourses –** Acidification and eutrophication influence productivity and biodiversity in many waters. Out of 55 fish species almost half are diminishing. We look at the effects on fisheries, recreation (welfare) and real estate values in sections 4.4 and 4.6.
- **A balanced marine environment, sustainable coastal areas and archipelagos –** Overfishing, eutrophication and contamination affect biodiversity in some coastal

[4] The five environmental targets not studied here because of quantification problems are:
A safe radiation environment – aiming at keeping all forms of radiation within safe standards for humans and all other forms of life.
A protective ozone layer – aiming at halting ozone-depleting substances.
A limited influence on climate change – aiming at living up to the Kyoto protocol, which is set up to limit the emissions of greenhouse gases.
Flourishing wetlands – aiming at preserving the biodiversity in the wetlands.
A magnificient mountain landscape – aiming at preserving the quiet and sensitive (semi)alpine ecosystems.

areas. Effects on fisheries, recreation and real estate values are analysed in sections 4.3, 4.4, 4.6 and 5.3.

- **No eutrophication** – The Baltic Proper and the western coasts of Sweden, as well as 1/6 of the lakes are eutrofied due to too high concentrations of nitrogen and phosphorous. Algae bloom and over-vegetation, which favour just one or a few species, too low concentration of oxygen and dead sea and lake beds are some of the consequences analysed in sections 4.3, 4.4, 4.6 and 5.3.
- **Natural acidification only** – Even without acid deposition, Swedish lakes and forest soils would slowly become more acidified. This will continue as long as bio-mass is removed at timber harvesting without compensation for the nutrients lost. The acidification is accelerated regionally because of deposition of acid rain, coming from emissions of sulphur dioxide, nitrogen oxides and ammonia. Liming can increase alkalinity and pH-values, but the long-term solution is naturally to cut emissions. The effects are analysed in sections 4.3, 4.4, 4.6 and 5.3
- **Sustainable forests** – Through more ecological silvicultural methods, the Swedish forest should be able to serve both as a sustainable producer of timber, berries, mushrooms and game, and as an area for sustained biodiversity. The accumulation of timber in the Swedish forests is studied in section 4.3, and the probable effect on productivity from acidification in section 4.2. Biodiversity and effects on non-timber values are not studied, except concerning welfare losses from acidification in section 4.6.
- **A varied agricultural landscape** – The loss of soil and a decrease in productivity, due to several factors, are analysed in section 4.2, but not the value of biodiversity.
- **A good urban environment** – Increased corrosion is analysed in section 4.5, but no other aspects are studied.
- **A non-toxic environment –** The concentrations of some heavy metals and persistent organic pollutants are included in the agricultural accounts in section 4.2, but not their effect on other ecosystems or on health.

In some cases, much of the deposition on Swedish ecosystems originate from foreign sources (acidification, eutrophication). Concerning other environmental problems (ozone, climate) Swedish emissions contribute to problems of global character. In the environmental targets, it is considered important that Sweden reduces its pressure on the local, regional and global environment. To solve the local environmental problems, national initiatives will often improve the situation, but in some cases the problems will not be solved if no other countries take sufficient measures as well. Thus, to give a full description of pressures affecting environmental quality objectives in an accounting system, it is necessary to account for emissions imported and exported between countries and to the global commons, i.e., the oceans and the atmosphere.

3.2. Classifications of capital assets in the SEEA system

To know under which economic accounting heading an environmental change should be registered, we have to briefly describe the capital assets in general and the natural capital assets in particular. The revised SEEA-handbook to be presented in 2001 classifies[5] not only traditional man-made assets, i.e. real capital as machinery, buildings and infrastructure, but also natural capital, which is divided into three categories: natural resources, land and surface water, and ecosystems.

The natural resources consist of:

- subsoil mineral and energy resources, which are exploited by the mining and energy industries (will be analysed in section 4.1)
- soil resources, which usually are seen as part of the land, belonging to the agricultural and forest landowners (will be analysed in section 4.2)
- water resources, measured as cubic meters of water, which are stored in artificial reservoirs by hydropower companies and water utilities. There are also natural storage for surface water, i.e. lakes and rivers and the subsoil groundwater, which can serve as water reservoirs for water utilities. Sweden has no fresh water shortage, but acidification, eutrophication and nitrification may threaten the water quality. This is analysed in section 4.4.
- biological resources, subdivided into timber, plants and crop, aquatic resources (fish) and cultivated (livestock) and uncultivated animals (game), i.e., all possibly marketable products. Environmental degradation, affecting biological resources is analysed in section 5.3.

[5] Commission of the European Communities, p 217.

All of these natural resources can be analysed in terms of the quantities that are material and energy inputs in the economy. The use of the natural resources usually means that one quantitatively, and in some cases also qualitatively, changes the remaining stock of the resource. Quantitative changes of fish stocks and forests are analysed in section 4.6.

The land and surface water categories consist of:

- exploited land for buildings and structures (corrosion and environmental degradation affecting real estate values are analysed in section 4.4.)
- agricultural land, in which soils are included for practical reasons (analysed in section 4.2.)
- forest land (analysed in section 4.2.)
- other land as tundra, prairie and other sparsely vegetated land
- major water bodies as lakes, rivers and wetlands, measured as water areas. All marine environmental effects are analysed under other headings; fish under biological resources in section 5.3.; all water pollution affecting real estate values in section 4.4.

All of these land and water areas can through land use changes move between categories. They can also lose or gain productivity for different reasons, changing the qualitative status and the value of the land or water areas.

The ecosystems consist of:

- Terrestrial ecosystems, subdivided into urban, agricultural, forest, tundra, dry lands, etc.
- Aquatic ecosystems, subdivided into marine, coastal, riverine, etc.
- The atmospheric system, concerning greenhouse gases and ozone.

The ecosystems produce the natural resources and maintain the quality and productivity of the land and waters described above. Furthermore, they serve all species with life supporting services making up the total biosphere with its immense biodiversity. The ecosystem services, especially the life support functions, are difficult to quantify and evaluate and no specific evaluation of ecosystem changes will appear in the calculations presented here. The quantitative and qualitative changes in the natural capital, to which all the references to different section were made above, involving changes in the use of land and natural resources, will be dealt with in the partially environmentally adjusted net domestic product below.

3.3. Extending the System of National Accounts

To environmentally adjust the SNA, the system boundaries have to be extended to include different forms of natural capital. Guidelines for how one might transform a standard GDP figure to a partially environmentally adjusted net national product through separate calculations will be presented below:

- First, capital depreciation will be subtracted from GDP to construct a NDP – the net domestic product. In the SNA-framework this is a standard procedure.
- Second, the resource rent, which is part of the value added in extractive sectors (mainly mining in Sweden), should, if exploited, be considered as depletion of natural capital and not be a part of the production value. This means that one makes a distinction between income and natural resource rent in the value added from primary sectors. This is done by applying Hartwick's rule (Hartwick 1979) in which one assumes that all resource rents from exploiting non-renewable resources are reinvested and all but the interest from the new investment is considered as depreciation (depletion of capital). In the SNA-framework the capital asset boundary is extended to include non-renewable natural capital, which will be depleted if mined.[6]
- Third, all changes in the natural capital stocks, originating from *external effects from this year's production and consumption, affecting production and consumption possibilities of future years* should, if practically possible, be quantified and valued. Pollutant accumulation (a negatively valued stock formation) can cause environmental damage directly or with a time lag, proportionally or disproportionally (after passing a threshold value). The deterioration of the ecosystems will continue until either environmental restoration measures are taken and/or emissions are reduced so that the critical loads will no longer be violated and the ecosystem can heal by itself. In the SNA-framework, this means extending the asset boundary to include living ecosystems, i.e., renewable natural resources, which feed the economy with inputs, while at the same time assimilate waste, which could otherwise cause damage.
- Fourth, the same reasoning about external effects affecting future productivity is applicable not only on natural capital, but on all other capital as well. Depreciation of real capital is accelerated by environmental factors. Acid rain causes metals and stone materials to corrode faster not only immediately, but also with a time lag. Real estates lose

[6] In Sweden, the SNA mining sector data do not at the present allow for the use of net price calculations. For

some amenity values as the surrounding ecosystems deteriorate, which might cause property prices to fall. In lake districts and in coastal areas, this might be driven by waters being affected by acidification or eutrophication. In the SNA-framework, this means that the real capital depreciation, which is set from a standard accounting scheme, is complemented by some environmentally driven (extra) depreciation of real capital (including real estate), *not captured elsewhere*.

- Fifth, all societal activities currently incorporated in the GDP as final use of produced goods and services, which primarily are aimed at maintaining or improving the natural capital (natural resources and environmental quality), should instead be valued according to the effects they have on the productivity of the natural capital. Their effects on output will be seen elsewhere, in the value added of other sectors or in changes in some capital stock, which would have been different if it had not been for the intermediate consumption. Thus, e.g., restoration costs should be considered as intermediate consumption and not as final use. An example is the (governmental) cost for liming acidified lakes, currently entering the GDP as public consumption. These governmental costs (outlays) should be deducted and instead, the effect the liming activity has on local fisheries (increased reproduction of fish) and amenities (tourism and property values) should be valued and added to the EDP. Acidification lowers the value of a lake. The liming raises the value again, at least partly. The cost of liming the lake should ideally not enter any adjusted production measure. However, any final change in the lake's acidification status and its effects on the economy, has the lake been limed or not, should enter the net product measure. In a SNA-framework this means a transposition of any items associated with environmental restoration from final use to intermediate consumption.
- Sixth, all damages on ecosystems, materials and human health, taking place this year (having affected GDP) due to negative external effects from this year's production and consumption, will be corrected for by "the polluter pays principle". This is done to illustrate the distributive effects of polluting activities. Consequently, the damage costs incurred will be subtracted from the causing sector, while the same sum is added to (compensate) the suffering sector, not changing the total sum of GDP. However, the different sectors' contributions to the total value added will be changed. In the SNA

countries with better data availability, Davis and Moore (1998) is recommended.

framework, this means moving value added between sectors within existing SNA boundaries.

The fact that many pollutants are transboundary creates accounting problems when the polluter pays principle is used as an accounting guideline. The polluter and the ecosystem, being affected, may be located in different countries. Rearranging value added means in that case that the effects cancel out on a global or even on a regional level, but not necessarily on a national level. Thus, the national GDP-figure could be affected by this exercise.

Another possibility to make all income losses for the suffering sectors visible is to construct a potential NDP. In the best of all worlds all sectors could maintain their highest possible production volumes without causing any damage to any other sector. In that world it would be possible to produce a potential, higher NDP. The otherwise suffering sectors would produce as if they had been unaffected, having a higher value added than normally, while nothing needs to be subtracted from the causing sectors, as they have not had any negative external effects. However, this would only be possible in a hypothetical world, where the necessary environmentally friendly technology could be delivered free of charge to the economy, not crowding out any productive use of the existing resources in the economy. The difference between the potential NDP and the regular NDP shows the value of the (static) environmental degradation, where the pollution causes damage the same year as it is emitted, i.e., the sum of all value added moving around according to "the polluter pays principle". To get hold of the (dynamic) environmental degradation, where the damage is lagged in relation to the emissions, one has to look at the difference between the regular NDP and the EDP. One can calculate the total (static + dynamic) environmental damage caused in a single year, affecting NDP that same year, and future years' NDP as well, by subtracting the EDP from the potential NDP.

- Finally, some items not included in the GDP, typically recreational values, are also affected negatively by economic activities. These negative external effects lead to welfare losses, even if the production accounts are not affected. These welfare changes could be quantified and compared to the GDP or the EDP values, even if it is problematic, as will be explained below. This adjustment can not be made within the SNA-framework for two reasons. The system boundary will have to be extended to include welfare aspects of life, affected by economic externalities. Furthermore, recreational values, contrary to all other SNA values, are usually free public goods and hence not derived from market transaction. As they include consumer surplus, contrary to market prices and most other derived values, they can not be compared on equal terms to the NDP-figure. Nor can they be subtracted as they have never been added, if they are not treated as negative capital changes.

4. Calculating the adjustments

The extensions to the SNA, i.e. the different possible adjustments describing changes in the quantity or quality of ecosystems, presented in section 3.3 have to be calculated from physical data and the best possible monetary valuations. The methodology, the physical data and the monetary valuation methods used are presented below for each adjustment in the Swedish EDP-calculations. All values are expressed in year-2000 US-dollars[7]. The valuation methods used are mainly market prices according to production losses calculated through dose-response relationships or actual defensive expenditures. In the welfare calculations presented in sections 4.6 and 5.2, willingness to pay studies have been used as well. The costs to society of natural resource use and environmental pressures consist of:

- the depletion of non-renewable resources (e.g. iron ore; in section 4.1)
- production losses in natural processes and economic activities, of which some have already occurred and influenced the GDP-level, and have to be handled separetaly (e.g. health effects, in section 5.3) and others will have consequences in the future (e.g. impaired timber growth; in section 4.2),
- depletion of (or additions to) renewable natural capital (e.g. fish stocks; in section 4.3)
- all losses which will force the communities to offset resources, which otherwise could have be consumed, to invest in structures that formerly were managed by ecosystem services (e.g. water purification; in section 4.4), or to mend natural capital (e.g. liming of lakes; in section 4.5)
- welfare effects in the form of lost recreational values (in section 4.6)

[7] The monetary values from the different studies have been transformed to Swedish year 2000-prices using the GDP-deflator and then converted to US-dollars (exchange rate SEK/$ 8.50).

4.1. Adjusting for the use of non-renewable resources

All sub-soil assets are non-renewable natural resources and they are classified as natural capital. When being used, they are depleted (fossil fuels) or at least depreciated (metal ores). Fossil fuels naturally lose all their value after they are burnt, and what remains has a negative shadow value, because it adversely affects both living and non-living systems. Used metals usually have a scrap value.

If a company owning non-renewable resources exploits them, its assets decrease. To use non-renewable resources (assets) leads to increased societal consumption, by using up capital. Thus, in a NDP-measure the depreciation, not only the revenue minus costs, from exploiting non-renewable resources, must be calculated. According to Hartwick's rule (Hartwick (1977)) the resource rents earned from a non-renewable resource will have to be invested in some other, preferably renewable, capital for the economy to be sustainable.[8] The contribution to society's production from exploitation of non-renewable natural capital will then be the rents from the new capital, in which the profits from the exploitation have been reinvested.

In Sweden the operating surplus from the mining industry, which now enters the GDP, will be subtracted as depletion. On the other hand a schematic return on that surplus, representing the real return on capital, approximately 3%[9], will be added, as that is (what hypothetically would have been) the return from reinvesting the natural resource rents exploited.

[8] Asheim (2000) discusses the sustainability claims of the Hartwick rule and shows that they fall short of being general. The usual prerequisites of constant technology and a closed economy are complemented by other necessary assumption, of which the substitutability between different forms of capital is acknowledged above in the sense that the investments preferably should be made in renewable capital. Kriström (2000) shows that effectively, the Hartwick rule, the net price (rent) method and the user cost method come up with the same depreciation rule, even if the El-Serafy (1999) user cost method's time dependency requires constant recalculations. In practice the Hartwick rule is easier to apply. The net price rule requires data on marginal costs. The user cost method requires, in addition, data on the size of the reserves or the ratio between the volume extracted and volume left in the ground (mine/well).

[9] The Swedish physical capital stock (national wealth calculations in SNA) was some $ 850 bill. in 1989, the last year Swedish wealth was accounted for. The net operating surplus, which equals the real return (net of depreciation) on that capital was $ 30 bill. Thus the net return on capital was approximately 3%.

Table 1: *Depletion of non-renewable natural resources in the Swedish mining sector in 1993 and 1997: all values expressed in millions of year 2000 dollars.*

	Extraction of iron and other metal ores and minerals	
	1993	*1997*
Net operating surplus deducted[10]	- 144	- 165
Returns from reinvestments added	4	5
Adjustment for non-renewable resource depletion	- 140	- 160

4.2. Adjustments for changes in the renewable natural capital stock

An ecosystem reacts to all influences with a time lag. This year's human activities might affect the future functioning and productivity of an ecosystem, influencing the future years', even generations', production possibilities and prerequisites for welfare. Some of these external effects are quantifiable with some certainty and affect goods and services we know how to value. The changes in renewable natural capital stocks caused by negative external effects are presented in this section. The deliberate management strategies leading to depletion of, or addition to, the renewable natural capital (overfishing, increasing the timber stock in the forest by letting the cutting fall short of the natural growth) will be discussed in section 4.3.

4.2.1. Consequences of agricultural land use

Major land use changes may transform an ecosystem, where photosynthesis can take place, to an urban type of ecosystem, where the exploited land is used for settlements, traffic or industrial purposes. Most building projects in Sweden concern densely populated areas, i.e. southern Sweden's mostly agricultural parts. That means that at least as much agricultural land as forest land is exploited, even if less than 10% of all Swedish land is agricultural, while some 60% is forested. Every year some 3500 hectares (ha) are converted from productive

[10] + Value added – compensation to workers (wages and social fees) – (real) capital depreciation. Extrapolated data have been used for the two last terms (have been stable for many years) as new data do not exist.

land, where photosynthesis would otherwise have occurred, into biologically sterile land.[11] These 3500 ha amount to approximately 1/1000 of all Swedish agricultural land. GDP is affected as some forestry and agricultural production is lost. Some more profitable economic activities will substitute for agriculture or forestry, creating value added that enters GDP. As the conversion of productive land usually entails the loss of photosynthesis for many decades or even centuries, this is a permanent opportunity cost to society. The solar driven production of renewable resources and energy are the only economic activities continuing without human participation. Self-regenerating capital is destroyed[12]. Land rents, the productive capacity of the land areas, are lost[13]. In this study the exploited hectares are valued at the average price of Swedish agricultural land, which is approximately $ 4,000/ha[14]. That value is a conservative estimate of the value of continued photosynthesis, as it only incorporates the private gains, while many other ecosystem values are involved, but they are hard to estimate. The discounted present value of the lost agricultural land is $ 14 mill.[15], i.e. society has in one year lost a self-generating production worth that much by transforming fertile land into infertile land.

The qualitative change of the Swedish agricultural ecosystem is not as visible as the quantitative land use change, but the monetary impact on the economy is much greater, because the area involved is much larger. Agriculture's own production techniques, such as using heavy machinery and pesticides on large open fields, without compensating the soils for the harvested bio-mass by anything but fertilisers, causes the soil capital to lose future production capacity. The change can be permanent (irreversible), i.e., it will decrease land productivity forever. Some changes, the semi-permanent ones, are possible to reverse and will be discussed below. The lost production capacity from these permanent and semi-permanent qualitative changes can be subdivided into soil packing, erosion, contamination and loss of topsoil, i.e. the soil loses its carbon content. As a result of these impacts Haasund (1986) forecasts a decrease in the production of Swedish agriculture by the equivalent of

[11] Statistics of land use in Sweden (1993).

[12] Heal and Chichilniski [1998]. In an example of the polluted Catskills watershed in upstate New York, Heal and Chichilnisky have calculated that the cost to restore the natural capacity to naturally supply purified water is much less than the capital and operating cost of a water purification and filtration plant. Thus, to let Nature keep up its capacity to do work through the eco-cycles has a value and to destroy that capacity has an alternative cost.

[13] The scarcity value of land for locational purposes might be high, but that does not add to resource generation. Biologically or ecologically, production is lost.

[14] Statistics Sweden (1992) – the latest National wealth and stocks of fixed assets published.

[15] The income foregone is around $ 0,45 million a year, but by summing up all future foregone incomes and discounting them; the value of the land lost this year was $ 14 mill. (3.500 hectares times $ 4.000/ha).

10,000 + 7,500 ha/year. The estimated losses of production capacity are reported in Tables 2 and 3:

Table 2: *Permanent damage of agricultural land, by cause*

Water erosion	500 ha/year
Wind erosion	1,500 ha/year
Losses due to oxidation	4,000 ha/year
Soil packing of subsoil	4,000 ha/year

All Swedish agricultural land, which amounts to 3 mill. ha, is valued at $ 12 bill. The lost value can then be calculated as $ (10,000/3,000,000)*12 bill./year) = $ 40 mill.

Table 3: *Semi-permanent damage of agricultural land, by cause*

Loss of top soil (carbon)	1,500 ha/year
Soil packing of topsoil	6,000 ha/year

The semi-permanent changes in Table 3 take decades to reverse naturally, but by ploughing down bio-residues, farmers can increase the carbon content of the soils. A changed management regime aimed at increasing the carbon content will in the first few years result in foregone income, as the soils can not be cultivated and harvested as usual. However, unless this is done, and as long as the present trend continues, natural capital and future production capacity are lost. The lost value can be calculated as (7,500/3,000,000)*12 bill./year =) $ 30 mill.

Acid rain and bio-mass removal[16] cause acidification of agricultural soils. Acidified soils can be treated by increased liming, but it is rarely done. The acidification makes the soil less suitable for some crops. Thus, flexibility in the choice of crops is decreased. Furthermore, the increased acidification makes the cadmium in the ground more accessible to the plants. This could be critical in soils high in (natural) mineral cadmium or if the cadmium content is high because of heavy fertilising. If the crops have too high a cadmium content, they should be classified as inedible. The loss of soils, due to cadmium contamination, or other forms of contamination is calculated to be 1000 ha/year, but can potentially be much higher. This

[16] More bio-mass is removed from a field when harvesting than is returned in the form of fertilisers, ploughing

represents a cost, in the form of foregone income, of some $ 4 mill. To lime all soils, to compensate for the acid rain and the loss of nutrients in the harvest would cost approximately the same amount on an annual basis.

The total cost of this environmental degradation, or depreciation of the agricultural natural capital, sums up to $ 88 mill. annually.[17]

4.2.2. Consequences of forest soil acidification

In the Swedish forests, the acidification of the soil might in some areas affect timber productivity. The natural scientists do not fully agree on when and how (much) acidification might affect timber productivity, nor do they agree on what other factors may cause the damage seen on trees today[18]. Here, a simulation model based on soil chemistry data (Sverdrup and Warfvinge [1994]) has been used for monetary valuation of acidification of forests (Skånberg [1994]). According to the simulations, the Swedish forest owners will lose $ 15 bill. during the 21:st century, due to soil acidification, even if the international agreements on reducing acidifying emissions are implemented. The costs from a lower productivity in acidified areas will rise from low figures in the 1990s to a maximum of $ 300 mill. a year during the next decades.

The deposition in Swedish forests was at its highest in the 1970s. A large part (80-90%) of the acid substances deposited in Sweden are emitted abroad. Ideally the division of the total cost caused by acidification should therefore be shared between emission importing and exporting countries[19]. However, for data availability reasons the transboundary problems are neglected, i.e., all deposition is treated as being emitted in Sweden. Approximately 0,8% of the total costs caused by acidification of Swedish forest soils, in the form of foregone income, will fall on each year of the 1990s.[20] The total future productivity loss, i.e. a decreased

down straw and other residues. The resulting loss of nutrients causes acidification of the soil.

[17] 14+40+30+4=88. i.e., the income lost because of exploitation (3.500 ha), permanent (10.000 ha) and semipermanent (7.500 ha) changes and cadmium contamination (1.000 ha) of agricultural land. All agricultural data are from Haasund [1986]. As the calculations are based on long term trends, which are hypothetically subdivided into yearly changes, the same value is used for 1993 and 1997. Specific data for a single year do not exist.

[18] The view that soil chemistry and the pH-value of the water in the forest soils are more or less unrelated to timber productivity is presented in Binkley and Högberg (1997).

[19] On the other hand, Sweden is exporting acid rain, causing losses abroad twice as large as the ones caused at home, given the assumption that our neighbour countries' forests are as sensitive as ours.

[20] Of the total acid deposition above critical loads in the time span of the Skånberg (1994) model describing the acidification process in forest soils between the year 1900-2200, a little more than 0,8 was emitted in 1993 and a

production of timber, in Swedish forests, which can be tracked to the deposition of acid rain and to a lack of recirculation of nutrients in the forestry sector, is valued at $ 112 mill. due to the acid emissions produced in 1993 and at $ 102 mill. due to the somewhat lower emissions produced in 1997.

4.2.3. Consequences of changes in water quality

In the water ecosystems, environmental problems related to polluting emissions, such as acids, nutrients, oil or chemicals, may cause production losses in the same year the pollutants are emitted (see section 5.3). In most cases, however, the effects show up later and they may persist for many years. The high concentrations of chemicals and heavy metals that still might be detected in the aquatic food webs are mostly the effect of past emissions. The correct way to perform the accounting is to register external effects in the accounts for the years when the pollutants were emitted, not when the problems were detected. If both the emissions and the detectable effects stay on a constant level for a long period of time, as is the case with eutrophicating substances and the sea eutrophication status of Swedish waters in the mid 1990s, it is possible to think about the effects as a one-year problem. As there are no good ecological models describing the dynamics between fish stocks and the sea eutrophication process, and as the final valuation result is not affected by the assumption that eutrophication is a one-year problem, this accounting simplification is used here. Consequently, the only environmental effects of eutrophication of 1993 and 1997 in this study are the income losses for fisheries calculated in section 5.3, as the water quality has neither deteriorated, nor improved noticeably in 1993 or in 1997, according to the Swedish Environmental Protection Agency. Thus, no future changes in the production prospects of Swedish fisheries are assumed to be explained as external effects of the total economy's production in 1993 or 1997. The lake fisheries in Sweden are so small that the environmental effects are hardly detectable in national production measures. However, the effects on recreational fishing are substantial both in the sea and the inland waters. These welfare effects are described in section 4.6. All changes in renewable natural capital stocks are summed up in Table 4.

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little less than 0,8% was emitted in 1997. Therefore these two years are responsible for some 0,8% of the total cost for the impaired timber productivity.

Table 4: *Changes in the renewable natural capital stock in Sweden in 1993 and 1997, due to qualitative changes in soils and water: all values expressed in millions of year 2000 dollars.*

	1993	1997
Depreciation of agricultural land	- 88	- 88
Depreciation of forest soil	- 112	- 102

4.3. Adjustments for depletion of (or additions to) renewable natural capital stocks

In this section, the species living off the land and waters will be discussed. In the former section only the qualitative status of the soils and the waters was analysed. All income losses caused by changes in the chemical conditions of the soils and waters were registered in section 4.2. Here, all changes in stocks of living species caused by the manager of the resources will be registered.

An accumulation of pollutants or abusive land management can decrease the reproductive capacity of plants and animals further up in the foodweb. Most agricultural crops are harvested annually. However, fishes do not even reproduce the first few years, and trees can live for centuries. Thus, management decisions today can influence the size and the value of the stock of fish populations and timber for many years ahead. Consequently, it does not suffice to account for the degradation of ecosystems, but also depletion and/or additions to natural capital stocks have to be accounted for. This is a typical example of the reasoning behind Hicksian income; if one harvests more than the annual return, this will erode the capital stock producing the return.

In the Swedish primary sectors, two management patterns emerge, one for fisheries, the other for forestry. In the short term, the fisheries tend to overfish some fish stocks[21], thereby keeping the long term catches on levels lower than otherwise would have been possible. This suboptimization, i.e., that the income received from the overfishing comes at a cost in terms of a much larger depreciation of the value of fish stock in the ocean, is equivalent to the agricultural case of foregone photosynthesis (section 4.2.1, Heal&Chichilniski [1998]). For example, the overfishing of cod has resulted in catches that are only 50% of their potential.[22]

[21] Most fisheries are governed by international settlements, which partly are based on biological considerations, but experts still consider many catch quotas to be too high. Statistics also indicate that catches are lower than what would be possible for many fish species.
[22] Sture Hansson, Department of marine biology, Stockholm University. Personal communication.

This loss in potential fish catches, lost water rents, due to the present management of fisheries, which keep the fish stocks at too low a level, is valued at $ 15 mill./year.[23]

The 17th century charcoal-related clear-cutting of large forest areas in central Sweden and the early 20th century cutting of dimension logs are examples of periods of a decreasing Swedish timber stock. During the last three decades, the Swedish timber stock has increased by 30 mill. cubic meters annually; the total timber stock is approaching 3.000 mill. cubic meters. Only 70-80% of the natural growth has been harvested for the last decades. The forested areas increase, too, but rather marginally. The annual timber growth, not harvested, is multiplied by the market price of standing timber, i.e. stumpage prices.[24] Since 1993, the changes in the timber stock are part of the traditional SNA. Thus, the numbers are put within parentheses below as they will not be part of any correction of the NDP-figure.

Table 5: *Changes in the renewable natural capital stocks in Sweden 1993 and 1997, due to management decisions: all values expressed in millions of year 2000 dollars.*

	1993	1997
Overfishing	- 15	- 15
(Increasing timber stock	+ 825	+ 750)[25]

4.4. Adjustments for degradation of the capital stocks due to environmental pressures

If the pH –value falls too low, because of increased acidification, or if the nitrate concentration gets too high, mostly due to agricultural mismanagement, present water purification facilities in houses with private wells will lose their sanitary effect and new investments are needed to secure the availability of drinkable water. The number of private wells affected has been identified through geographical information systems, comparing real estate statistics with maps showing nitrate concentrations and acidification status.

23 Larger fish stocks would mean that more fish could be caught with the same (economic) effort, which means that the extra revenue would be entered as value added in the fisheries sector if the (potential) water rent, possible fish catches, would not have been eroded by overfishing. Cod catches, at present levels, at 50% of their potential, are worth $ 15 mill. This indicates that the eroded water rents from the continuing overfishing can be valued at $ 15mill./year.

24 This rather crude multiplication of price and quantity can be improved on by taking the ageing of the forests into consideration, which can have an impact on the value, especially if the size of the cohorts vary (Vincent, 1999).

25 Changes in the timber stock are already part of NDP according to the revisions presented in SNA 1993; therefore these numbers will not appear in the corrections in section 5.1.

Usually, the water cycle purifies the water by letting rainwater be transported through soils into the groundwater or surface water reservoirs. Too much pollution in waters and soils result in a degraded water quality, as the water cycle is not able to produce drinkable water. Well-owners will live either with the acidification or nitrate problem or, at a cost, they will have to install filters or transport water from unpolluted areas.

The cost of installing and maintaining the purifying technology is here used to evaluate the environmental degradation resulting in the ecosystems' inability to, by themselves, purify water to drinking standards. As the acidification and nitrate accumulation have been caused by decades of environmental pressures and as the pressures will decrease, but still influence the acidification and nitrate situation for some decades, the cost of the cleaning equipment is in the calculation spread evenly across 40 years. Furthermore, there are annual costs related to the regular use of the additional equipment. The cleaning technology also takes away several other pollutants, so that only half of the sum[26] is ascribed to nitrate in the agricultural areas and to acidification in the acidified areas. The costs of this year's contribution to the problem amount to $ 7 mill. for nitrate both in 1993[27] and 1997 and $ 11 mill. for acidification in 1993[28] and $ 7 mill. in 1997, due to the slowly decreasing emissions and deposition of acid substances[29]. The costs to provide Swedish households with high quality fresh water, so as to avoid health risks, are assumed to approximate, or to be lower than, the damage that acidification and nitrate in ground water do to the functioning of water ecosystem services, in this case the provision of healthy drinking water. Thus, the defensive expenditures, the costs to install cleansing equipment, can be used as a (lower bound) valuation of the actual damage.

Most metals corrode faster if the atmosphere and the water, which they come in contact with, are acid. Especially sulphur accelerates corrosion. An analysis of the metals used in an average Swedish construction and the number of buildings and constructions of different types showed that every year the sulphur concentrations in the Swedish air causes additional corrosion amounting to $ 300 mill. in 1991.[30] The corrosion is proportional to the deposition of sulphur and its concentration in the air, and the stock of real estate was relatively constant during the period of study because of the recession. Hence, the cost estimates can be imputed

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26 Larsson (1996) after communication with the water cleaning technology industry

27 Larsson (1996)

28 Andersson (1994)

29 Sulphur deposition was reduced by 50% and nitrogen deposition by 25 %, while the forest management regimes concerning recirculation of nutrients were unchanged between 1993 and 1997, according to Statistics Sweden (2000). Each component is responsible for 1/3 of the total of the acidification process with local variation, according to Sverdrup and Warvfinge (1994), which means that the negative external effect is 25% lower in 1997 than in 1993.

from sulphur deposition and concentration data. Sulphur data for 1993 and 1997, respectively, suggest that the corrosion costs were $ 240 mill. and $ 180 mill. These costs occur as extra maintenance and shorter life expectancy of constructions. Hence, the damage caused by emissions and deposition in one year is characterised by increased depreciation and reinvestment costs in the future.

Real estate prices will be affected if the surrounding areas are environmentally degraded. Locations with a scenic environment, e.g., close to water, generally command high prices, indicating that a premium is paid for the environmental services of scenery and recreation opportunities[31].

A geographical information system has been used to combine Swedish real estate locations and valuations with maps of the lake districts and coastal areas, environmentally degraded by eutrophication and acidification. The Swedish real estate taxation rules have been used to price the environmental degradation under the assumption that a degraded area loses half of its previous location advantage. For example, according to the taxation authorities there is a premium of 10%, if the house is located near the waterfront. Having a waterfront location that is affected by eutrophication or acidification, would cut the premium to 5%. As Swedish waters partly have been, and will be, acidified and eutrophied for some decades, the calculated capital loss, $ 60 and 420 mill. respectively, (depreciation of the real estate value according ti the tax authories) will be divided evenly across 40 years. The contribution to acidification would then cost real estate owners $ 1,5 mill. in 1993 and $ 1,2 mill. in 1997, as the acid deposition decreased between 1993 and 1997. The contribution to eutrophication $ 10 mill. in 1993 as well as in 1997 since eutrophicating emissions were stable between 1993 and 1997.[32]

Table 6: *Real capital depreciation due to environmental degradation in Sweden 1993 and 1997: all values expressed in millions of year 2000 dollars.*

	1993	1997
Drinking water quality decline	- 18	- 14
Corrosion	- 240	- 180
Real estate devaluation	- 12	- 11

30 Andersson B, “Costs of corrosion caused by sulphur emissions”, in Swedish, NIER, 1994

31 Wilhelmson (2000) shows that noise depreciates real estate values by up to 30%.

4.5. Adjustments for items classified as final use that should be registered as "intermediate consumption"

When private and public expenditures are spent on protecting natural or other capital that otherwise would have been degraded, these costs should not be seen as final use of goods or services. Instead, they should be classified as intermediate consumption, aiming at maintaining capital intact. Such defensive expenditure should, if and only if the changes in the (natural) capital that gets positively affected is accounted for, be deducted from NDP. If the defensive expenditures are not deducted, the improvements are accounted for twice, a double counting entry. The liming of lakes to neutralise acidification is an example that cost the Swedish government $ 25 mill. both in 1993 and in 1997. Hospital attendance and use of pharmaceuticals, due to the high nitrous oxide concentrations in urban air (same concentration in 1993 and 1997) costing $ 105 mill./year, is another example.[33] The valuation is based on the idea that human capital would have depreciated if no medical care or medication had been given to the people exposed to too high concentrations of nitrous oxides.

Waste water processing and waste management improve the quality of water and land ecosystems, as, e.g., all polluted water would otherwise have ended up in the water systems downstream. The costs of treating waste and waste water were $ 1210 mill. in 1993 and $ 1200 mill. in 1997[34].

All the liming, health care and wastewater and waste management costs described above are public expenditures, which show up in the GDP-figure as public consumption.

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[32] All calculations/figures from NIER 1998:9.

[33] Several other health care expenses should probably also qualify, but the only environmentally related health care costs which have been analysed so far are the asthmatic effects caused by nitrous oxides. One should be aware of the difficulties one runs into, when trying to make a distinction between which consumption and investment expenditures can be categorised as defensive expenditures, having an impact measured in a capital stock elsewhere, or a consumption cause in itself. In these partially environmentally adjusted accounts the three examples above are chosen, because they have been analysed in the ongoing environmental accounting project. They are also clear cut defensive expenditures, where the effects on the related (improved) capital stock are measured.

Table 7: *Reclassification of goods for final use to intermediate consumption in Sweden 1993 and 1997: all values expressed in millions of year 2000 dollars.*

	1993	1997
Liming of lakes	- 25	- 25
Health care costs due to N-emissions	- 105	- 105
Waste and water management	- 1 210	- 1 200

4.6. Possible adjustment for welfare losses from environmental degradation, not generally accounted for in the traditional SNA

Some of the economic activities in the Swedish GDP are affected by the environmental degradation, but what people usually react to is the impact on the ecosystems that they experience during their leisure time. These welfare losses do not normally enter the GDP-figure[35]. However, it is possible through willingness to pay studies to evaluate the welfare losses, e.g., worsening conditions for recreation, due to a deteriorated environment, and to compare the result with the GDP/NDP figures.

Swedish recreational fish catches amount to half of the professional fishing trawlers' catches, if one only studies the most valuable species. The welfare loss to the recreational fishermen from increased acidification in lakes and streams and eutrophication in the ocean was valued at $ 65 and $ 55 mill./year respectively in a willingness to pay (WTP) study[36]. The other welfare losses of the acidification of the Swedish lakes and streams were valued at $ 600 mill./year in a WTP-questionnaire (NIER, 1998:9). This study incorporated eutrophication and nitrate in ground water and forest acidification. The WTP to avoid eutrophication in lakes and streams was $ 300 mill./year and $ 300 mill./year to avoid eutrophication in the ocean. The WTP to avoid forest acidification was $ 360 mill./year, of which 2/3 is attributable to recreational values, i.e. a welfare loss, not a loss of income (NIER, 1998:9).[37] Nitrate in private wells was considered the least serious of the five pollution items

[34] Statistics Sweden [2000], diagram page 223.

[35] The tourist industry could locally suffer from a degraded environment and labour productivity might also be affected if the recreation activities, which promote health and high spirits, lose their attraction, due to environmental degradation.

[36] The results of Silvander (1991) were divided into a loss of fish meat and a loss of consumer surplus for the fishing experience as such (welfare loss due to worsening conditions for recreation) in Ahner&Brann, NIER, 1996)

[37] The forest owners loose $ 120 mill. and these owners should be represented among the persons stating their willingness to pay, so that the remaining $ 240 mill. are ascribed to recreation. For comparison, the total

investigated and to avoid concentrations above the health recommendations, the Swedish people stated that they were willing to pay $ 225 mill./year (NIER, 1998:9). Adding up all welfare losses of environmental degradation gives the following table:

Table 8: *Loss of welfare (recreational values), due to environmental degradation in Sweden in 1995: all values expressed in millions of year 2000 dollars.*

Loss of recreational fishing	- 120
Water acidification	- 600
Forest acidification	- 240
Fresh water eutrophication	- 300
Ocean eutrophication	- 300
Nitrate in wells	- 225
Total	- 1 785

Note that the stated WTP-sums in many ways differ from the damage costs presented earlier. This affects the way one can use them for adjustments of, e.g., a NDP-figure. In section 5.2, the appropriateness of using these WTP-sums for such adjustments is further discussed.

5. A stepwise transformation of Swedish GDP to EDP-figures for 1993 and 1997

Within the SNA-framework, formulas for different production measures such as GDP (and NDP) are constructed by adding and subtracting items: consumption + investments + exports - imports (and capital depreciation). The EDP formulation proposed below starts with the usual GDP-formulation and elaborates it[38]:

+ consumption
+ the trade balance

recreational value of the Swedish forests has been estimated at $ 3 bill./year (Jämttjärn). The same reasoning has been used to separate between the fishermen´s willingness to pay and the sums stated to avoid all problems related to acidification and eutrophication.

[38] For a mathematical formulation, see Ahlroth (2000), in which a model specifically for the purpose of calculating a Swedish EDP from the studies presented in section 4, is formulated and implemented on emissions of sulphur and nitrogen in Sweden 1993. For a more general model formulations, from which EDP:s could be derived, look at Weitzman (1976), Mäler (1991), or any of the other references given in section 2.1.

+ the volume changes of *all* capital stocks valued at any given year's price vector

and deduct any final consumption expenses that rather should be regarded as intermediate consumption to improve or keep status quo in a capital stock. Note that the changes in the value of the capital stock, resulting from the intermediate consumption, is already incorporated in the item above (all stock changes).

Possible further extensions to the SNA include:

- rearrange the sectors' value added according to the polluter pays principle
- calculate the potential NDP (without negative environmental external effects)
- account for welfare effects (i.e. recreational values), not ordinarily included in production measures

All data are either collected from the Swedish National Accounts publications[39] or from the Swedish Environmental and Economic Accounting publications[40]. All items are valued in millions of year 2000 US-dollars.

5.1. From GDP to NDP

Deducting the depreciation of the man-made capital from GDP yields NDP. The calculations in Tables 9 and 10 are standard SNA procedures.

Table 9: *Swedish GDP in 1993 and 1997: all values expressed in millions of year 2000 dollars.*

	1993	*1997*	*change*
Private consumption	110 400	117 200	+ 6%
Government consumption	59 250	57 000	- 4%
Investments	31 050	35 130	+ 13%
Trade balance (Exports – Imports)	10 300	21 370	+ 108%

[39] Statistics Sweden, series N XX, Statistiska meddelanden (Statistical Bulletin), year-month, i.e. N for economic data, XX is the code for the kind of data published, an official publication of Swedish statistics.
[40] Swedish National Institute for Economic Research (NIER) and/or Statistics Sweden (SS), Series of Environmental and Economic Accounting (miljöräkenskapsserien) year: serial number.

GDP	210 000	230 600	+ 10%

Table 10: *Swedish NDP in 1993 and 1997: all values expressed in millions of year 2000 dollars.*

	1993	*1997*	*change*
GDP	210 000	230 600	+ 10%
Depreciaton of man-made capital	- 29 450	- 28 130	- 5%
NDP	180 550	202 470	+ 13%

The explanation to the decreasing depreciation between 1993 and 1997 is the recession during 1991-1993 and the weak rate of investment during these and the following years. The level of investments was so low that the (value of the) stock of man-made capital actually decreased. The depreciation is a bookkeeping term, a percentage of the total capital stock, usually taken from the taxation write-offs of the firms.[41]

5.2. A Swedish (partly) environmentally adjusted net domestic product

Using data from sections 5.1 and 4 (except 4.6) yields a partially adjusted EDP.

Table 11: *A partially environmentally adjusted NDP for Sweden 1993 and 1997: all values expressed in millions of year 2000 dollars.*

	1993		1997	
NDP	180 550		202 470	
Total adjustments	- 1 960		- 1 900	
Depletion of metal ores		- 135		- 160
Depreciation of ecosystems		- 200		- 190
Exploitation of living resources		- 15		- 15
Increased depreciation of real capital		- 270		- 205
Expenditures aiming at maintaining natural capital		-1 340		-1 330

41 In the SNA the accounting routines never reveal how much capital is really put aside as obsolete, or how much productivity goes down because of wear and tear. The only occasions when real depreciation values are truly estimated are at extraordinary events, such as natural catastrophes like thunderstorms, which force insurance companies to evaluate actual damages.

EDP	178 587	200 568

The difference between the correction terms for 1993 and for 1997 amount to approximately $ 60 mill. The adjustment terms seem to be slowly decreasing, which fits the picture that many industrial processes become cleaner. The relative environmental pressure from an economic activity decreases, while the growing economy in some cases offsets this trend. An example of that is the increasing depletion of metal ores, but that is the only increasing adjustment term in the calculations above. The main difference between the two years is actually that the deposition of sulphur dioxide has decreased, which proves economically important as corrosion of metals thereby slows down. The adjustments absorb 1,02% of NDP in 1993 and 0,87% of NDP in 1997. As NDP grows rather quickly, the economic importance of the adjustment term decreases much faster relative to the economy (-13%), than it does in absolute terms (-4%).

If one looks at the environmental status, instead of just at the environmental pressures, the picture changes somewhat for two reasons. First, the environment reacts with a time lag to environmental pressures. Acidification appears decades after the acid substances are emitted. Climate change appears in full force more than a century after the greenhouse gases are emitted. Consequently, for many environmental problems, it takes time before the effect of the reduced emissions will be fully apparent as improved environmental quality. Second, not all environmental problems have been discussed in this paper, for different reasons, which will be further discussed below.

In this study the *production perspective* has been used, which means that the focus is on a certain year's production of goods and negative external effects of that production. It is not the environmental quality of that year which is being evaluated, but the environmental pressures produced that year and the effects they may have in the future. If one wants to evaluate the effects that the deteriorated environmental quality has on the production potential in a certain year, and how this affects welfare, another perspective, the *consumption perspective*, has to be applied. In that case, it is the present environmental health status, not the present environmental pressure that is evaluated. Preliminary calculations, based on the *consumption perspective*, which measure the present environmental status, irrespective of from what year any environmental changes originate, have shown that the environmental state in the Swedish ecosystems is rather stable. The improvement between 1993 and 1997 that was shown by the *production perspective* can not be discerned if the *consumption perspective* is used (Swedish Ministry of Finance [1999]).

The items evaluated in the EDP above do not cover all the environmental impacts caused by economic activities. First, there must be a scientific consensus about causes and effects, which can be quantified with dose-response functions[42]. Second, there must be a valuation method to translate the physical measures given by the dose-response functions into a money measure. For many of the most serious environmental threats the time frames are too long and the possible effects or the probability distribution of different outcomes too diffuse to make it advisable to come up with economic estimates (expected value) of their consequences. These include among others:

- climate change,
- depletion of the ozone layer,
- loss of biodiversity,
- accumulation of radioactive waste.

Note that not all countries will be able to do, or will want to do, the same adjustments, or restrict the number of adjustments to the ones discussed here. The environmental problems a country faces, the data that are available and the purpose or use of the measure to be constructed are all crucial factors to be taken into account when designing environmental macro-aggregates. Developing countries would probably focus more on resource depletion and loss of soils (land use changes) than on effects of emissions, as the economic impact of those adjustments would probably be greater. In Sweden the (right to) common access to other people's land makes the environmental quality of ecosystems not only a question for the owner, but for the general public. Thus, welfare aspects of a deteriorated environment are important to measure. Below, the Swedish EDP for 1993 is complemented by welfare effects in the form of loss of recreational values (from section 4.6).

Table 12: *A partially environmentally and welfare adjusted NDP for Sweden 1993, welfare effects measured as lost recreational values (from 1995): all values expressed in billions of year 2000 dollars.*

	1993
NDP	180,5
All environmental changes	- 2,0
Welfare losses (loss of recreational value)	- 1,8
EDP-welfare	176,7

[42] Relationships between concentrations (dose) of a pollutant in air, water or soil, and the effect (response) it has on an physical object such as timber, fish or human health.

The welfare loss inherent in the loss of recreational values due to environmental degradation naturally increases the adjustment. If welfare losses are included, the adjustment amounts to slightly more than 2% of NDP. Usually, values associated with recreation (welfare) are not included in GDP/NDP measures. In contrast to other items they contain consumer surpluses. Hence, it is questionable to treat them as any other priced good in the accounts. Furthermore, it is also questionable to deduct them from an aggregate, in which they were not included, in the first place. Another argument not to make use of the welfare losses in the adjustment is that the WTP-sums relate to hypothetical changes that can hardly be described as marginal. In adjusting a NDP-figure, all changes studied have to be small enough not to affect prices, as price changes will undermine the possible welfare interpretation of the results. On the other hand it is interesting to study the orders of magnitude of the different adjustments terms, even if they are calculated differently. One may also want to study all costs generated by environmental pressures, no matter if they appear as production or as welfare losses. To shed light on the total environmental situation, the welfare effects have to be illustrated somewhere, even if the currency they are measured in is not fully convertible, as it contains consumer surpluses and possibly other value uncertainty factors inherent in the contingent valuation method.

5.3. Rearranging value added between sectors according to "the polluter pays principle"

Some sectors pollute the environment and others, such as the primary sectors, live from the same environment. Consequently, the primary sectors' value added will be lower than it would have been in a non-polluted world. The value added should be distributed across the sectors according to the "polluter pays principle", i.e., the sector that pollutes should also pay the costs it causes, and ideally compensate the sectors that lose. One's gain is the other's loss in this (re)distribution exercise[43], the effects cancelling out, not affecting the total level of EDP. In Table 13 the affected and polluting sectors, and the values involved are presented. In Table 14 the effects on the sectors' value added are presented, implementing the PPP (re)distribution.

[43] An accounting exercise, which makes it a zero-sum game. If the polluter pays principle would actually be implemented the outcome would probably more economically efficient, as the polluter would have the incentive to cut cheap-to-avoid emissions.

In the real world, not only a single year's emissions, but the accumulated environmental pressure from previous years affect this year's production. The distribution across sectors will actually not cancel out every year as environmental effects persist over decades and even centuries. The same problem appears when it comes to transboundary pollution. The rearranging of value added affect two (or many) countries. The rearranged terms cancel out regionally, or at least globally, but not necessarily nationally. If one wants to make sure that all terms cancel out, one has to extend the accounting system both in time and in space, and construct a global centennial production measure[44].

In this exercise we will first assume that Swedish firms can only affect other Swedish firms and that no deposition of pollutants originates from abroad. We will also assume that all environmental effects registered this year are due to this year's emissions and that all emissions affecting the Swedish economy have Swedish origin. Since many pollutants causing damage in one country (or to the global commons), originate from other (many) countries, this exercise should ideally also involve all nations. Due to a lack of data it is rarely possible to do this in any depth and is usually only discussed in theoretical terms.

Table 13: *Economic losses in 1993 and 1997 from negative external effects in that year, respectively: all values expressed in millions of year 2000 dollars.*

Affected sector	*1993*	*1997*	*Polluting sector*
Forestry (acidification)[45]		- 1	Transport, Energy, Industry
Agriculture (ozone)	- 165	- 165	Transport, Energy, Industry
Fisheries (eutrophication)	- 15	- 15	Transport, Energy, Industry
All industry, due to nitrogen-related illnesses	- 60	- 60	Transport, Energy, Industry
Total compensation	240	241	

[44] Historical accounts, dating back to the first year a country is affecting its own, or any other country's future production prospects, for each and every country, which through emissions affect any other country or which is affected by any other country, would also take care of all interconnections in time and space.

[45] The total losses from impaired timber growth were in the model estimated at $ 75 mill. in 1997, but of those $ 74 mill. originate from earlier years' emissions (negative external effects).

Affected sectors: Acidification of forest soils may lower timber productivity if the pH-value and the ratio between base cations and aluminium sinks to too low a value. Research indicates that acid rain and acidification are stressing forests, even if the nitrogen in the short term may act as a fertiliser[46]. Opinions differ on exactly what the threshold value is, how much productivity will be affected if thresholds are passed and what other factors there are that might influence timber growth.[47] The acidification process spans over centuries, which makes it necessary to use a model to answer questions about how much each year's emissions might affect the final outcome. A modelling approach also allows for assumptions on future actions to reduce emissions. Such a modelling exercise, based on results from soil chemistry research (Sverdrup and Warfvinge [1994])[48], has been performed at the Swedish National Institute of Economic Research (Skånberg [1994]). The results indicate that acidification reduces the productivity in the forests, i.e. the timber grows more slowly, and that this phenomenon started to appear in the Swedish forests in the early nineties. The loss of income to the forest owners was calculated to be negligible in 1993 and $ 75 mill. in 1997. However, $ 74 mill. come from earlier years' emissions and should, consequently, not enter the production account for 1997. By the end of the next decade, the loss of income is expected to increase to $ 300 mill./year, of which some 0,7 percent ($ 2 mill.), decreasing for every year according to the emission forecasts in the model, is related to the negative external effects from the same year's production.

Tropospheric ozone, a corrosive gas, which develops from oxygen in the presence of nitrogen oxides and volatile organic compounds, especially during sunny days, reduce agricultural crops. Some crops, as potatoes, lose ten percent of their productivity if tropospheric ozone concentrations are high. In Sweden it has been estimated that the ozone concentrations have reduced agricultural production by $ 165 mill. annually during the 1990s.[49]

Eutrophication of the Baltic Proper and the waters off the Swedish West Coast affects regeneration of some fish species, which are dependent on certain environmental conditions to reproduce, grow and prosper. E.g. the cod needs a high enough oxygen and salinity concentration in the Baltic Sea to reproduce. Eutrophication leads to an increased

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[46] Sverdrup and Warfvinge [1994].

[47] Källa 42, a report from the Swedish Council of Planning and Coordination of Research (FRN), "Does the Swedish forests need intensive health care?" ("Behöver skogen intensivvård?"), 1993.

[48] Sverdrup & Warfvinge [1994]

[49] Haasund et al. (1990). The ground level ozone concentrations have been rather stable during the 1990s, as has the Swedish agricultural crop production.

decomposition of dead bio-mass in parts of the Baltic Sea. This consumes oxygen resulting in a dead sea bed. The cod population is difficult to quantify, but from catches one can estimate how many individuals of each cohort there are in each species. Some 10% of the Baltic and Nordic waters are so affected by eutrophication that fish reproduction is threatened. If one assumes that fish and catches are identically distributed geographically, the eutrophication will lead to a productivity loss of 10% of the fish populations and an estimated 10% loss in catches, the value of which is $ 15 mill. annually for the Swedish fisheries (Ahner and Brann [1996]).

High nitrous oxide concentrations in the air lead to respiratory diseases, especially in urban areas. Other elements and particles in the air can also be damaging to human health, but in Sweden only the damages due to nitrogen oxides have yet been studied and valued in monetary terms. The costs (or rather income losses) arise from sickness leave (production losses). A dose-response function has been estimated and the concentrations of nitrous oxides causing sickness leave in 1993 were valued at $ 60 mill. (Hahn [1996]). Medication and hospitalisation cost estimates were presented in section 4.5. Those costs do not lower the GDP-level, in contrast to the sickness leave.

Pollution sources: Acidification, ozone and nitrogen concentrations are in approximately equal shares caused by energy transformation, transport and process industries. In the combustion processes, sulphur from the fuel and nitrogen from the air are converted into sulphur dioxide and nitrous oxides respectively. Ozone is a molecule, which is created as nitrous oxides and hydro-carbons react in the presence of sunlight. Eutrophication in the ocean is mostly generated by increased nitrogen run-off. It is approximately in equal shares caused by excess fertilising in the agricultural sector and by the remainders from the sewage system, after it, in most cases, has passed through a sewage treatment plant. The input to sewage treatment plants comes from private consumption and all industrial sectors, i.e. everything leaving the households or industries through the sewage system. Health problems from nitrous oxide and ozone affect all sectors, the most labour intensive ones the most.

Table 14: *Value added compared to the magnitudes of the negative external effects in 1993 for the sectors which should be receiving compensation for the damage suffered (in dollar terms and as a percentage change): all values expressed in millions of year 2000 dollars.*

Affected sector	*Value added 1993*	*Compensation*	*Change*
Agriculture	1 800	+ 165	+ 9%
Fisheries	70	+ 15	+21%
All sectors (health)	210 000	+ 60	very small
Total compensation received		+ 240	

Table 15: *Value added compared to the magnitudes of the negative external effects in 1993 for the sectors which should be paying compensation for the damage they caused (in dollar terms and as a percentage change): all values expressed in millions of year 2000 dollars.*

Causing sector	*Value added 1993*	*Compensation*	*Change*
Transport	8 000	- 75	- 1%
Energy	5 000	- 75	- 1,5 %
Industry	38 000	- 75	- 0,2%
Agriculture	18 000	- 7,5	- 0,4%
Private Cons. (sewage)	110 000	- 7,5	- very small
Total compensation paid out		- 240	

The total effect is 0,1% of GDP. Raising the GDP-level by a tenth of a percentage point will hardly be noticeable in aggregate terms. However, for industries like fisheries or agriculture, solving the eutrophication problem and lowering the ozone concentrations, respectively, or finding a compensation scheme, would be very important, as can be seen from the percentage change of these sectors' value added. As the causing sectors' value added would only decrease by approximately one percent, they could probably afford the compensation.

However, the fact that a large portion of the emissions crosses national borders complicates matters. International agreements will be necessary to sort out responsibilities and payments[50].

5.4. Potential NDP

The figures calculated in section 5.3 can also be used for constructing another hypothetical macro aggregate – a potential NDP. Assume that all polluting emissions could be costlessly stopped. Then production would increase in all sectors that are negatively affected by pollutants and none of the environmental effects described in Table 14 would have taken place. Thus, the NDP could potentially be higher than today if, somehow, through increased resource efficiency, cleaner technology, substitution of "dirty" fuels and materials for "cleaner" ones, an economy could produce the same basket of goods in an environmentally cleaner way. The best possible outcome would be the potential NDP.

Table 16: *A potential NDP 1997; data from Table 10 and 14: all values expressed in millions of year 2000 dollars.*

NDP (1997)	+	damages registered during 1997	=	potential NDP	
202 470	+	241	=	202 711	+ 0,12%

The reason for not achieving a potential NDP is that new technology does not develop costlessly, but comes through investments. These investments include research and development, investment in new real capital and education in schools and at the work place. All of these investments take time, material resources, labour and capital from other parts of the economy, therefore crowding out other production. Still, implementing all cost-efficient projects, i.e., all projects having a benefit to cost ratio above one, would mean somewhat closing the gap to the potential NDP. If the benefits are higher than the costs, taking the costs would mean crowding out other consumption or investments, but as the pay back is higher than the cost, the end result is that NDP would increase.

The costs of implementing potential environmental projects can be expressed in avoidance cost curves, describing, the marginal cost of reduced pollution. The cost to achieve a given reduction is presented on the vertical axis in, e.g., dollars/(reduced kilogram pollutant). The

50 The Swedish sulphur tax raises some $ 30 mill./year from the point source emitters, i.e. industry and energy, which would approximately cover all the costs presented here (corrosion, long-term forest damages and depreciation of real estate values) caused by sulphur, originating from Sweden and being deposited in Sweden. The Swedish emitters should ideally also cover the costs they cause abroad, as foreign emitters should cover a

horizontal axis measures, e.g., kilograms of reduction. The cheapest method to reduce pollutants appears to the left in the diagram. The further to the right one goes the more expensive it gets to reduce the pollutant with yet another kilogram. By combining this cost curve with the possible benefits the economy will get from a better environment, e.g., the marginal damage curve, cost benefit ratios can be calculated. Ideally the calculations should be based on a macro-model, as it is important to take into account all the substitution possibilities in the entire economy.

6. Conclusions and suggestions for further research

One single measure can not possibly cover all aspects of the interdependencies in the global system, containing the economy and all geobiochemical (eco)cycles, recirculating nutrients and water in complex ecological systems. The production approach used in this study discusses only the production taking place during a calendar year, with all the goods and services delivered by the economic activities and the negative external effects that are generated by the production and consumption. Some of these negative effects occur in the same year, holding back the production below potential. Others have an impact years, decades or even centuries afterwards. The future effects of environmental problems that can be forecasted with acceptable precision have been incorporated in the Swedish EDP-calculations.

The calculations show that the economic effects of the negative external effects (pollution, resource depletion and degrading land use) are rather small in comparison to the economic production, but still significant in absolute numbers, almost $ 2 bill. The adjustment terms amount to 1% of NDP without the welfare effects (loss of recreational services) and to 2%, or roughly $ 3,7 bill., if the welfare effects are included. Even if the economic burden of the negative external effects is not large compared to the whole economy, some sectoral effects are substantial, because in many cases it is the rather small primary sectors – agriculture, forestry and fisheries – that are affected. In developing economies, which depend more heavily on their primary sectors, the economic burden could be much larger. The redistributional exercise in section 5.3, where “the polluter pays principle” was used to hypothetically transfer money from the affecting sectors to affected ones, shows how green accounts can be used for policy planning.

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large part of the costs burdening Sweden. At the present, no such compensation exists.

The negative adjustment items declined by 4% in absolute terms between 1997 and 1993, which means that they declined even more (13%), relative to the growing economy. The major cause behind the declining pressure on the environment, and hence the lower (negative) environmental adjustment, was the decreasing concentration of sulphur dioxide in air, which slowed down the corrosion process. However, many more observations (years studied) are needed to be able to detect a certain trend regarding the damage and economic losses (costs) caused by pollution, resource depletion and degrading land use.

It is important to remember that not all environmental problems were covered in the study and that the monetary valuation methods used can not capture all different values of the negative external effects studied. Consequently, it is crucial to intensify research, both in the environmental natural sciences and in (environmental) economics. In the future, it should be possible to include environmental problems missing in this study (e.g. climate change), and the aspects of damage studied, which have not been valued, due to the lack of suitable valuation methods (biodiversity aspects of e.g. acidification).

The international aspects of environmental problems, e.g. exports and imports of pollution, which have been assumed absent in this study, have also to be included in future calculations of environmentally adjusted macro aggregates. As the green accounting work accumulates around the world, the exports and imports of pollution will be easier to handle. One day, green accounting will also cover longer time periods, especially if one also constructs historical green accounts for past years. That will make it easier to build macro aggregates from the forward looking production perspective for past years, explaining the impact a certain year's production had on the following years' production and welfare outcomes. It will also make it easier to compile macro aggregates from the backward looking consumption perspective, which explains how present production and welfare were shaped by earlier activities.

References

Ahlroth, Sofia, [2000], Correcting net domestic product for sulphur dioxide and nitrogen oxide emissions: implementation of a theoretical model in practice, Swedish National Institute of Economic Research (KI), working paper No 73. (or report 121 from the Swedish University of Agricultural Sciences, department of forest economics)

Andersson, Björn, [1994], Korrosionskostnaden orsakad av SO2-emissioner (The corrosion costs caused by SO_2 emissions), NIER (in Swedish only) .

Aronsson, Thomas, and Löfgren, Karl-Gustav, [1995], National Product Related Welfare Measurement in the Presence of Technological Change, Externalities and Uncertainty. Environmental and Resource Economics **5**, pp.321-332.

Aronsson, Thomas, and Löfgren, Karl-Gustav, [1996], An almost practical step towards green accounting?, Umeå Economic Studies no.425, Umeå University.

Asheim, G B, [2000], "The Hartwick rule: Myths and facts", from the proceedings of the Ulvön conference 2000, www.sekon.slu.se/~bkr/ulv00.htm

Brann, Karin, and Ahnér, Elisabeth, [1996], Fisk - en miljöhotad naturresurs (Fish - an environmentally threatened natural resource), NIER (in Swedish only).

Binkley, D, and Högberg, P, [1997], "Does athmospheric deposition of nitrogen threaten Swedish forests?", Forest Ecology and Management, 92, 119-152.

Bureau of Economic Analysis, [1995], "Second Meeting of the London Group on Natural Resource and Environmental Accounting: Conference Papers, Washington, D.C., United States, March 1995", Washington, D.C.

Chichilnisky, Graciela and Heal, Geoffrey, [1998], "Economic Returns from the Biosphere", Nature, Feb 1998.

Commission of the European Communities et. al. [1993], System of National Accounts 1993.

Dasgupta, Partha, [1993], "Optimal development and the idea of net national product". In I Goldin and L.A. Winters eds., Approaches to Sustainable Economic Development, pp.111-143. Paris: Cambridge University Press for the OECD.

Dasgupta, Partha, and Mäler, Karl-Göran, [1998], Decentralization Schemes, Cost-Benefit Analysis and Net National Product as a Measure of Social Well-being, Beijer Discussion Paper Series no.116, The Royal Swedish Academy of Sciences.

Dasgupta, Partha, and Mäler, Karl-Göran, [1999], "Net National Product and Social Well-Being", Beijer Discussion Paper Series no.125, The Royal Swedish Academy of Sciences.

Dasgupta, Partha, Kriström, Bengt, and Mäler, Karl-Göran, [1994], Current Issues in Resource Accounting, Beijer Discussion Paper Series no.47, The Royal Swedish Academy of Sciences.

Davis, G A, Moore D J, [1998], "Valuing mineral reserves when capacity constraints production", Economic Letters 60 (1998) 121-125

De facto 1998. A report from the Swedish Ministry of Environment

Eisner, Robert, [1988], "Extended Accounts for National Income and Product", Journal of Economic Literature, vol. XXVI no.4, pp.1611-1684.

Eliasson, Peter, [1994], Miljöjusterade nationalräkenskaper för den svenska skogen åren 1987 till 1991 (Environmentally adjusted national accounts for the Swedish forest the years 1987-1991), NIER (in Swedish only).

El Serafy, S, [1999], "Natural Resource Accounting" in Handbook of Environmental and Resource Economics, edited by J.C.J.M van den Bergh, Edward Elgar, Cheltenham, UK.

Fisher, I, [1906], The Nature of Capital and Income, MacMillan New York

Haasund, K P, [1986], Arable land resource economics (in Swedish), Swedish University of Agricultural Sciences.

Haasund, K. P., Hedvåg, L. & Pleijel, H. (1990). Swedish EPA report 3862 (Naturvårdsverket, rapport 3862). In Swedish: English translation: "Economic consequences of the influence of tropospheric ozone on agricultural crops"

Hahn, Gunnela, [1996], Samhällsekonomisk värdering av kväveoxidrelaterade hälsoeffekter (Socio-economic valuation of nitrogen-oxide-related health effects), NIER (in Swedish only).

Hartwick, John M., [1977], "Intergenerational Equity and the Investing of Rents from Exhaustible Resources", American Economic Review 66.

Hartwick, John M., [1990], "Natural Resources, National Accounting and Economic Depreciation", Journal of Public Economics 43, pp.291-304, North-Holland.

Hartwick, John M., [1994], "National Wealth and Net National Product", Scandinavian Journal of Economics, 96(2), pp.253-56.

Heal, G, Kriström, B, [1998], "National Income and the Environment", Department of Forest Economics, Umeå, Sweden. Also published as a working paper at Columbia University [1999].

Heal, G, Kriström, B, [2000], "Resource Accounting", forthcoming, Handbook of Environmental economics, Mäler & Vincent (eds), North-Holland

Heuting, R, [1989], "Correcting national income for environmental losses: towards a practical solution", In Ahmad et al., Environmental accounting for sustainable development, The World Bank, Washington D.C.

Hicks, John R., [1939], Value and Capital, 2nd edition, New York: Oxford University Press.

Johansson, Ulf, [1996], Koppling mellan ekonomiska och fysiska data: Miljöskyddskostnader för svavel och kväve (Linking of economic and physical data: Environmental protection costs for sulfur and nitrogen), PM M/MI 1996:14, Statistics Sweden (in Swedish only).

Jämttjärn, Joachim, [1996], Svenska skogens rekreationsvärde (The Swedish forest's recreational value), NIER (in Swedish only).

Kriström, B, [2000], "A note on the general theory of depreciation", Department of Forest Economics, Umeå, Sweden.

Källa 42, a report from the Swedish council of planning and coordination of research (FRN) (in Swedish) – English translation of title “Does the Swedish forests need intensive health care?”

Larsson, Markus, [1996], Nitrogen and Groundwater, NIER (in Swedish only).

Lindahl, Erik, [1933], “The concept of income”, in G Bagge, ed, Economic essays in honour of Gustaf Cassel, London: George Allen and Unwin.

Mäler, Karl-Göran, [1991], “National Accounts and Environmental resources”, Environmental and Resource Economics **1**, pp 1-15.

NIER and Statistics Sweden, [1998], SWEEA - Swedish environmental and economic accounts: Svenska miljöräkenskaper En lägesrapport från Konjunkturinstitutet och Statistiska Centralbyrån, Miljöräkenskapsserien 1998:1. (Reprint from 1994) English version: SWEEA - Swedish environmental and economic accounts, Miljöräkenskapsserien 1998:2.

NIER, [1998], Svenska miljöräkenskaper för svavel och kväve och Sveriges kostnader för kväveutsläpp (Swedish environmental accounts for sulfur and nitrogen and the costs for nitrogen emission in Sweden), Miljöräkenskapsserien 1998:9.

Nordhaus, William, and Tobin, James, [1973], “Is growth obsolete?”, Review of Income and Wealth, vol.38, New York,: National Bureau of Economic Research.

Peskin, Henry M., and Delos Angeles, Marian, [1996], “Environmental Accounting as Instrument of Policy: The Philippine Experience”, Papers of IARIW [1996], International Symposium on Integrated Environmental and Economic Accounting in Theory and Practice, IARIW, Economic Research Institute, Economic Planning Agency and Government of Japan, Tokyo.

Repetto, R., McGrath, W., Wells, M., Beer, C., and Rossini, F., [1989], Wasting Assets: Natural resources in the national income accounts, World Resources Institute, Washington D.C.

Silvander, Ulf, [1991], Betalningsvillighetsstudier för sportfiske och grundvatten i Sverige (Studies on willingness to pay for angling and groundwater), Sveriges lantbruksuniversitet (the Swedish Agricultural University), Uppsala.

Skånberg, Kristian, [1994], En beräkning av skogsförsurningens skadekostnader (A calculation of the costs of damage due to forest acidification), NIER (in Swedish only).

Solow, Robert M., [1986], “On the Intergenerational Allocation of Natural Resources”, Scandinavian Journal of Economics, **88** (1), 141-149.

Statistics Sweden [1992], “National wealth and stocks of fixed assets”, SCB

Statistics Sweden [1993], Markanvändningen i Sverige (Land use in Sweden), SCB

Statistics Sweden, [1996a], Fysiska miljöräkenskaper, Na 53 SM 9601, SCB.

Statistics Sweden [1996b], Naturmiljön i siffror (The natural environment in figures), SCB.

Statistics Sweden, [1996c], "Third Meeting of the London Group on Natural Resource and Environmental Accounting: Proceedings Volume, Stockholm, Sweden, May 1996", Stockholm.

Statistics Sweden, [1997], Miljöräkenskaper - Samband mellan miljö och ekonomi, Miljöräkenskapsserien 1998:6.

Statistics Sweden [2000], "The Natural Environment in Figures 2000", SCB

Swedish Ministry of Finance [1999], Long term survey 1999 (LU 1999), Appendix 7 – What is a sustainable development?, chapter 7.

Sverdrup, Harald and Warfvinge, Per, [1994], "Critical load of acidity for Swedish forests", Lunds Tekniska Högskola.

UN, [1993], Integrated Environmental and Economic Accounting, Interim version, ST/ESA/STAT, series F, no 61.

Weitzman, Martin L., [1976], "On the welfare significance of national product in a dynamic economy", Quarterly Journal of Economics 90, 156-162.

Wilhelmsson, M, [2000], "Traffic Noise and Property values", dissertation, Stockholm Royal Institute of Technlogy

Vincent, Jeffrey, [1999], "Net accumulation of timber reserves", The Review of Income and Wealth 45, 251-262