Magnus Lindmark

TOWARDS ENVIRONMENTAL HISTORICAL NATIONAL ACCOUNTS FOR SWEDEN

Methodological Considerations and Estimates for the 19th and 20th Centuries
Towards Environmental Historical National Accounts for Sweden
Methodological Considerations and Estimates for the 19th and 20th Centuries

Abstract

New questions in a changing economy demands development of both contemporary and historical national accounts. One such question concerns economic and environmental relationships. From a national accounting perspective this issue has been approached in terms of environmental accounting. The aim of this study is to investigate how proposals for integrated environmental and economic accounting can be used for an extension of the Historical National Accounts for Sweden and for examining the long-term relationship between economic growth and environmental degradation and resource depletion. This issue is approached through methodological considerations and estimates of iron ore and timber depletion and discharge of pollutants.

The conclusions are that it is possible to construct environmental historical national accounts, but that the lack of historical data and theoretical difficulties cause a high level of abstraction and other problems concerning the series.

The empirical investigations show that the 19th century can be considered a period of depletion intensive growth. Furthermore, there seems to be evidence of a correlation between changes in the natural resource net prices and previous periodizations of Swedish economic development. Concerning pollutants, the analyses shows an increase of the aggregated discharges until the late 1960s. However, the pollution intensity of growth has fallen throughout the period, possibly in a pattern of long trend periods.

Keywords: historical national accounts, environmental history, environmental accounting, historical environmental accounting, iron ore, standing timber, pollution, environmental Kuznets curve.
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ACKNOWLEDGEMENTS

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Magnus Lindmark
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I. ABBREVIATIONS, CLASSIFICATIONS ETC.

**List of abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td>Convergence Research (U.S.A.)</td>
</tr>
<tr>
<td>CV</td>
<td>Contingent valuation</td>
</tr>
<tr>
<td>CVRD</td>
<td>Companhia Vale do Rio Doce</td>
</tr>
<tr>
<td>EAW</td>
<td>Economic Aspects of Welfare</td>
</tr>
<tr>
<td>EDP</td>
<td>Environmentally adjusted net Domestic Product</td>
</tr>
<tr>
<td>EHNA</td>
<td>Environmental Historical National Accounts</td>
</tr>
<tr>
<td>GA</td>
<td>General Assessment</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>HNA</td>
<td>Historical National Accounts</td>
</tr>
<tr>
<td>HNS</td>
<td>Historical National accounts for Sweden</td>
</tr>
<tr>
<td>IG</td>
<td>Industry Group (in HNS)</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climatological Change</td>
</tr>
<tr>
<td>ISEW</td>
<td>Index of Sustainable Economic Welfare</td>
</tr>
<tr>
<td>ISIC</td>
<td>International Standard Industrial Classification of all Economic Activities</td>
</tr>
<tr>
<td>IVL</td>
<td>Institutet för Vatten och Luftvårdsforskning (The institute for water and air research)</td>
</tr>
<tr>
<td>KI</td>
<td>Konjunkturinstitutet (The institute for economic research)</td>
</tr>
<tr>
<td>LKAB</td>
<td>Luossavaara Kirunavaara AB</td>
</tr>
<tr>
<td>MEW</td>
<td>Measure of Economic Welfare</td>
</tr>
<tr>
<td>NA</td>
<td>National Accounts</td>
</tr>
<tr>
<td>NDP</td>
<td>Net Domestic Product</td>
</tr>
<tr>
<td>NI</td>
<td>National Income investigation</td>
</tr>
<tr>
<td>NNP</td>
<td>Net National Product</td>
</tr>
<tr>
<td>NNW</td>
<td>Net National welfare</td>
</tr>
<tr>
<td>PREDI</td>
<td>The Industrial Pollution Projections Project (the World Bank)</td>
</tr>
<tr>
<td>RST</td>
<td>Riksskogstaxeringen (The National Forest Survey)</td>
</tr>
<tr>
<td>SA</td>
<td>Special Assessment</td>
</tr>
<tr>
<td>SCB</td>
<td>Statistics Sweden</td>
</tr>
<tr>
<td>SEEA</td>
<td>System of integrated Environmental and Economic Accounting</td>
</tr>
<tr>
<td>SGU</td>
<td>Sveriges Geologiska Undersökning (Sweden’s Geological Survey)</td>
</tr>
<tr>
<td>SNA</td>
<td>System of National Accounts</td>
</tr>
<tr>
<td>SNV</td>
<td>Statens Naturvårdsverk (Environmental protection agency, Sweden)</td>
</tr>
<tr>
<td>TGO</td>
<td>Trafik AB Grängesberg-Oxelösund</td>
</tr>
<tr>
<td>WI</td>
<td>Welfare index</td>
</tr>
<tr>
<td>WTA</td>
<td>Willingness-To-Avoid</td>
</tr>
<tr>
<td>WTP</td>
<td>Willingness-To-Pay</td>
</tr>
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</table>
Classifications and Accounts in SNA used in the investigation

<table>
<thead>
<tr>
<th>Code</th>
<th>Name of account etc.</th>
</tr>
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<tbody>
<tr>
<td>P</td>
<td>Transactions in goods and services (products)</td>
</tr>
<tr>
<td>K</td>
<td>Other accumulation entries</td>
</tr>
<tr>
<td>AN</td>
<td>Non-financial assets</td>
</tr>
<tr>
<td>CC</td>
<td>Classification of columns used in SEEA</td>
</tr>
<tr>
<td>CR</td>
<td>Classification of rows used in SEEA</td>
</tr>
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</table>

Industry groups of HNS and approximative corresponding ISIC

<table>
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<tr>
<th>Industry Group</th>
<th>Name in HNS</th>
<th>ISIC (2-digit level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metal and manufacturing</td>
<td>10-13, 27-35</td>
</tr>
<tr>
<td>2</td>
<td>Earth and stone industry</td>
<td>14, 26</td>
</tr>
<tr>
<td>3</td>
<td>Wood industry</td>
<td>20, 36</td>
</tr>
<tr>
<td>4</td>
<td>Paper and graphic industry</td>
<td>21-22</td>
</tr>
<tr>
<td>5</td>
<td>Food industry</td>
<td>15-16,</td>
</tr>
<tr>
<td>6</td>
<td>Textile industry</td>
<td>17-18 (part)</td>
</tr>
<tr>
<td>7</td>
<td>Leather, hair and rubber</td>
<td>18 (part), 19, 25 (part)</td>
</tr>
<tr>
<td>8</td>
<td>Electricity and water</td>
<td>40-41</td>
</tr>
</tbody>
</table>

Non-financial assets in EHNA, Classification of columns (CC)

Produced assets of industries (3.1.1)
Natural, living biota (3.1.1.2)
    Trees of timber tracts (1.2.2.2.2)

Non-produced natural assets (3.2)
Wild biota (3.2.1)
    Trees of uncultivated forests (3.2.1.1.4)
Subsoil assets (3.2.2)
    Iron ore (3.2.1.2.2.2), part of
    Water, air, soil (3.2.3) (3.2.4) (3.2.5.1)

Note: the classification follows the SEEA classification of rows
### HNS/NA/EHNA Overview

<table>
<thead>
<tr>
<th>CR/AN</th>
<th>Forestry</th>
<th>Iron ore mining</th>
<th>Production/Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1800-1980</td>
<td>1892-1988</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>ISIC 02</td>
<td>ISIC 13 (part)</td>
<td>1.1 and 2</td>
</tr>
<tr>
<td>3.1</td>
<td>1800-1925</td>
<td>1889-1988</td>
<td>Forestry+iron ore</td>
</tr>
<tr>
<td>3.1.1</td>
<td>part implicit</td>
<td>part implicit</td>
<td>part 1800-1990</td>
</tr>
<tr>
<td>3.1.3</td>
<td>no</td>
<td>1892-1988</td>
<td>NA 1952-1990</td>
</tr>
<tr>
<td>4</td>
<td>no</td>
<td>part 1892-1988</td>
<td>part 1800-1990</td>
</tr>
<tr>
<td>4.2.1</td>
<td>only depl. 1800-1925</td>
<td>only depl. 1892-1988</td>
<td>part 1800-1990</td>
</tr>
<tr>
<td>4.2.2</td>
<td>no</td>
<td>1892-1988</td>
<td>NA 1952-1990</td>
</tr>
<tr>
<td>4.2.3</td>
<td>HNS 1800-1990</td>
<td>1800-1988</td>
<td>HNS 1800-1990</td>
</tr>
<tr>
<td>6.1.1</td>
<td>not relevant</td>
<td>1892-1988</td>
<td>part 1892-1998</td>
</tr>
<tr>
<td>6.1.2</td>
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<td>1892-1988</td>
<td>part 1800-1998</td>
</tr>
<tr>
<td>6.2</td>
<td>1800-1925</td>
<td>not relevant</td>
<td>part 1800-1925</td>
</tr>
<tr>
<td>AN 1.2.2.1</td>
<td>1925-1980</td>
<td>not relevant</td>
<td></td>
</tr>
</tbody>
</table>

Note: 4.2.3 denotes value added (not explicit in SEEA)

3.1.3 part, implicit: some pollutants from ISIC 02 and 13 are internalised in production/consumption. They are accordingly not explicitly shown.

### Classification of rows used in EHNA

**Opening stocks (1)**

**Use of products of industries (2.1)**

**Use of non-produced natural assets (3.1)**

- Depletion of natural assets (3.1.1)
- Discharge of residuals (3.1.3)

**Use of produced fixed assets (3.3.1)**

**Eco Value Added/EDP (4)**

- Eco-margin (4.2.1)
- Net value added (4.2.2)
- Value added (4.2.3)

**Gross output of industries (5.1)**
Other volume changes (COVC) of non-produced natural assets due to economic decisions (6.1)

- Depletion of non-produced assets due to economic decisions (6.1.1.1)
- Imputed as (3.1.1)
- Discovery of new resources (6.1.2.1.1)
- Adjustments of volume (6.1.2.1.2)

Other volume changes of non-financial assets due to natural and multiple causes, n.e.c. (6.2)

- Net natural growth of non-produced natural assets (6.2.1)

Revaluation due to market price changes (7)

Closing stocks (8)

*Note:* the classification follows SEEA
1. AN INTRODUCTION TO ENVIRONMENTAL HISTORICAL NATIONAL ACCOUNTING

Introduction

In this thesis the concept of economic environmental historical accounting is introduced. There are two economic historical research traditions to which this concept relates. The first is historical national accounting and the second is environmental history. Both of these fields have their counterparts in contemporary research, namely, national accounting and various social scientific aspects of environmental science. The structure of the introductory chapter is based on these two economic historical fields of research. To some extent central themes in contemporary research are also touched upon. Of course, this introduction is in no way a complete survey. It is rather a choice of research works which can be considered to be of relevance for understanding the scientific context of environmental historical national accounting. After the initial orientation, the specific objectives of the thesis are presented. This section is followed by a presentation of some previously made attempts for environmental and welfare accounting. The focus is here on the most recent proposals for an environmental accounting system presented by the United Nations, the OECD, the IMF, the Commission of the European Communities and the World Bank.

Background

Historical national accounting in Sweden

During the latter half of the 19th century an interest in measuring and studying economic change emerged. Its focus was not originally on income and output augmentation, but on the increase of the national wealth. From an environmental accounting perspective this is interesting since natural assets like iron ore deposits and forests were included among the items which constituted the national wealth. National wealth estimates had been done in the U.S. during the 1840’s, and historical estimates had been done for each decade since 1790.\(^1\) In a

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\(^1\) Bollfras, K.D. *Försök till uppskattning av den svenska nationalsförmögenheten*, Stockholm 1878, p. 11. The cited work is *Journal of the Statistical Society*, March 1878.
commission report from 1863 Swedish wealth estimates were furnished. Of primacy in the report was economic development. In 1878 K.D. Bollfras published an investigation of the national wealth. His investigation was followed by a comprehensive attempt to estimate the Swedish national wealth in 1885 by Pontus Fahlbeck. As had been possible in the U.S. subsequent estimates could be compared to the previous ones, thus giving an idea of the economic development. The most comprehensive of the early national wealth investigations wherein more advanced estimations methods were utilized was led by Isidor Flodström and was published in 1912. The next national wealth investigation for Sweden took place in the 50’s, when Karl Englund, a former colleague to Flodström, published an estimate for 1952. A few years earlier, Statistics Sweden (SCB) had started to publish the official Swedish national accounts (NA). Their general objective was to constitute a tool for economic policy planning. Not the least the Keynesian focus on management of the aggregated demand deserves to be mentioned in this context. The national accounts did not include estimates of the national wealth. However, from the 1980’s, there were suggestions in official reports that the long-term economic political goals should be expressed in terms of national wealth, including natural assets and human, fixed and financial capital. This would allow monitoring of resource consumption concerning natural environment, loss of human health and contribution of human capital, posts which are not included in either the GDP or NNP aggregates. Again, a focus on new issues related to long term conditions for growth, environment and welfare may be seen as initiating new demands on the organization of economic statistics.

Economic growth as a specific concept has been widely used since the 1950’s. It corresponds to growth of GDP per capita measured in fixed prices over a long period. In Sweden, the first growth study was made during the 1930’s, when Lindahl/Dahlgren/Kock investigated the development of the na-

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3 Bollfras (1878), and Bollfras, K.D. Svenska nationalförmögenheten vid 1880 års slut, Svensk trävarutidning, 1885:15, pp. 3-4.
4 Fahlbeck, P. E. Sveriges nationalförmögenhet, dess storlek och tillväxt, Stockholm 1899.
tional income 1861 - 1930. The national income project (NI) marked the emergence of a research tradition pertaining to historical national accounts (HNA) in Sweden. In the early 1950's Lindahl constructed GDP calculations for the period 1861-1951. These calculations, which also included volume estimates, were largely based on the NI series. The NI series were improved in 1967 when Östen Johansson constructed volume series based on separate deflators. This methodology was further refined by Olle Krantz and Carl-Axel Nilsson through the introduction of deflation periods of 15-20 years. This same methodology was later to be used in a project in Lund during the early 1980's. This project also involved the construction of completely new series based on the output-statistical method. In short, this meant that the production of industries was allocated to different uses such as inputs and final consumption. Thus, the reliability of the estimates could be checked in terms of balancing output and input. Of additional importance was that new analytical objectives with Swedish HNA evolved during this project. From a concentration on growth itself and the measurement of GDP, interest increasingly was focused on HNA as a tool for analyzing economic change. Functioning as inspiration to the project was a hypothesis of structural transformation in the Swedish economy which Krantz and Schön had developed on basis of HNA series. Recently, this hypothesis has been further refined by Schön.

long wave theories are obvious. Krantz has opposed the emphasis on long wave types of explanations and prefers to label the hypothesis a historical generalization.\textsuperscript{16} Research on structural transformation is also conducted in Umeå.\textsuperscript{17}

The most recent development of Swedish HNA research is a joint Nordic project with the objective of coordinating the construction of HNA in order to facilitate cross-country comparisons.\textsuperscript{18} The development of the society and the economy has meant that new objectives for the national accounts and HNA have evolved. The project therefore involves extensions of the traditional HNA into new fields, namely unpaid domestic work and environmental accounting. The need for a tool for studying the relation between structural transformation and the use of various natural resources is one motivating factor behind the environmental extension of HNA.\textsuperscript{19} The environmentally related question which most obviously relates to traditional HNA and to traditional economic history, concerns the contribution of natural resources to GDP. Is it possible to measure the role played by natural resources \textit{per se} in the development of the Swedish economy? In other words, have there been substantial windfall gains from natural resource use which may have affected the economy substantially? For instance, how large a part of the incomes during a certain historical period can be attributed to natural resource rents?

Another, even wider, question deals with the fundamentals of the industrialized society, namely the relationship between economic growth and the environmental degradation and depletion of natural resources. Economic growth has a close connection to the development of standards of living and GDP has literally been used as an instrument to measure national success. However, only a decade after the burst of interest in GDP assessment and national accounting in

the 1950's, the modern environmental discussion assumed a position of prominence in the public debate. Rachel Carson's book *Silent Spring*, which dealt with the dangers of biocides, is often seen as a pioneering work.²⁰ Gunnar Myrdal turned the environmental question to a problematization of growth itself.²¹ Economic growth was seen as the root of the environmental problem. This view was not entirely new. Already during the late 19th century, Stanley Jevons claimed that industrialization would come to a halt with the exhaustion of coal reserves.²² Basically, the same idea was put forward by Meadows et al. in the report *Limits to Growth* published in 1972.²³ The focus was on the consequences of exponential economic growth in a world with a finite supply of raw material and a biosphere with a limited capability for assimilating pollutants. Thus, it can be claimed that parts of the environmental movement suggested that growth provided an illusion of progress since growth undermined the prospects of further achievements due to environmental impact. This view was opposed by many economists. From a neo-classical point of view, substitution and technological development have been regarded as forces which counterbalance resource scarcity. Given suitable institutional arrangements, i.e. definitions and enforcement of environmental property rights, such as tradable emission quotas, the price signals will promote necessary technological change and substitution.²⁴ Not the least in the famous WCED report the importance of international institutional arrangements were put forward as a precondition for combining economic and social development and a healthy environment.²⁵ According to this position, there is no need to assume an unavoidable trade off between growth and the environment.²⁶

²² Jevons, W.S. *The Coal Question: An Inquiry concerning the progress of the nation and the probable exhaustion of our coal mines*, London 1886.
²⁶ See also Kågesson, P. *Growth versus the Environment-Is There a Trade-off?* Department of Environmental and Energy Systems Studies, Lund University 1997.
The relation between the economy and the environment can be approached in several ways. Natural scientific approaches, or if that is preferred, social scientific approaches inspired by natural science, have in common that the environmental problem is given a predominantly objective definition. This is because the natural sciences do not deal with trade-offs, conflicting goals or value judgments. The environmental problem can be seen as the disturbance or destruction of an eco-system resulting from human activity.

An analysis of the relation between the economy and the environment can depart from what may be called the ecological model.27 The underlying principle is the second law of thermodynamics which was formulated by Rudolf Clausius in 1865. The second law or the entropy law says that in a closed system entropy will always increase when activity takes place. The concept of entropy might at first glance disagree somewhat with common sense. Low entropy is the 'good' and high entropy is the 'bad', in practice to be described as the difference between a useful natural resource and a worthless waste. From the natural scientific point of view the economic process, as well as any other process, involves the transformation of low entropy to high entropy. Basically, in the long run the main product is garbage. High entropy indicates a high degree of disorder which occurs when energy is equally distributed in a system. However, all activities utilize differences in energy levels. The entropy concept should therefore be understood in the following way: the activities which take place now will allow fewer options for future activities as a result of increasing entropy. This line of reasoning departures from the first law of thermodynamics which says that energy cannot be destroyed and thus not consumed. What is consumed – or destroyed – is instead the quality of energy, more precisely referred to as exergy.28

Thermodynamics was the single domain of natural sciences until the economist Georgescu-Roegen, almost 130 years after Clausius, took the entropy law as the point of departure for heavy criticism of standard economic theory.29 Traditionally, the economy is described as a circular flow of goods and money. On the contrary, the thermodynamic approach as interpreted by Georgescu-

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Roegen regards the entropy flows from nature to the economy and from the economy to nature as more fundamental. That is an input of low entropy and an output of high entropy. In this way Georgescu-Roegen has argued for a theory of an economy described as open towards nature. This is the cornerstone of environmental economics.

As stated above, the qualitative measure of energy and matter is called exergy and reflects the usefulness of the energy/matter. Exergy is a well defined measure, but in more general terms it can be thought of as order. In the ecological model, the economy is an open system. That implies that activity in the economy is maintained through a flow of exergy from the economy's surroundings, simply called the surrounding system. Consequently exergy decreases in the surrounding system. At the same time, the exergy level in the economy usually tends to increase. Taken together the society and the surrounding system form an eco-system.

Thus, the relation between society and the environment can be studied in terms of visualizing the flows between the economy and the surrounding system. Environmental accounting in physical terms, like Materials/Energy Balances (MEB) can be seen as an example.

It is possible to transform flows of matter, measured as for instance tons of iron ore or cubic meters of timber, to exergy or other energy related measures. Non-monetary environmental accounting approaches based on energy have been elaborated upon by several international researchers, Odum being perhaps the most well known. Such approaches reflect a biocentric view centering on the carrying capacity of an eco-system. Basically, sustainability is indicated if the use of exergy in the economy is equal to or less than the total inflow of energy to the surrounding system. This point of view has led to proposals for a steady-state economy, in which the optimum scale is seen in relation to the surrounding system.

From a social scientific and a historical point of view the environment and the notion of environmental crises are treated differently. From a social scientific point of view the environment is appraised according to human values, which in their turn reflect the social context and what could be described as the spirit of the age. Conflicting goals have to be dealt with since both natural re-

sources and eco-systems may have alternative uses. At the same time, the use of natural resources is a necessary means to meet various social ends. Therefore, an environmental crisis must be seen in relation to subjective societal preferences, such as the value attributed to production of goods and services, in other words, the relative values attributed to material welfare relative to environmental standards. Which eco-systems are worth to be sacrificed for material welfare and which eco-systems should be preserved? Also the relative value of present benefits versus future costs is relevant in this context. In the economy this trade-off, concerning resource allocation over time, is reflected in the interest rate, which has no counterpart in the natural scientific world.

An important dimension concerning sustainability is the political one. How should the costs for achieving sustainability be distributed? Should the market or other allocation instruments be used? Should sustainability also involve a dimension of solidarity, fairness and equality? Should solidarity concern future generations? Should the solidarity be global, aiming at a state where all people have Western standards of living? The last question refers to the so-called "factor 10 goal", according to which the material through-put should be cut by 90% in order to assure a sustainable and just world economy.\(^{33}\) Without stretching the discussion any further, it is clear that the concept of sustainability involves several dimensions which are dealt with within different social scientific disciplines. An economic approach is used in this work. This will allow an analysis which, in contrast to natural scientific approaches, includes value dimensions of the sustainability problem.

Environmental history from an economic historical perspective

Environmental issues have a long tradition in economic history. However, they have more seldom been thought of in the context of eco-systems. Instead they have usually been approached in terms of aspects of industrial production processes and growth, for example raw materials, agricultural history, climatic factors and regulation and property rights problems, pertaining to, for instance, land or water. The most likely explanation is that in everyday language the environment and environmental problems are associated with a comparatively modern discussion of industrial pollutants. Many key themes in this debate concerning the use and regulation of naturally produced assets and the development of substitutes have several counterparts in history.

Property rights

On the social scientific scene, Hardin’s article on ‘the tragedy of the commons’ raised the question of the relationship between resource management and property rights. The ‘single ownership’ solution to the problem as well as the ‘true’ nature of the problem itself turned out to be a complicated matter, and criticism of Hardin’s standpoints inspired new research efforts and theoretical development. At that time, property rights had long been a central question in economic history. Not least of all enclosure in Britain and similar acts in other countries have been the object of numerous studies. Theoretical development concerning Institutions, Property Rights and Public Choice spurred during the 1980’s research in Swedish economic history focusing on natural resources. In economic history the main interest has been to study the importance of regulations and economic performance, while the discussion initiated by Hardin focuses more on ecological performance. One of the latest contributors in this field is Ellinor Ostrom. She has both promoted theoretical development concerning institutions, behavior and environmental performance, and made empirical operationalizations. In national accounting, property rights and other institutional arrangements are presupposed. Also for historical analysis, the institutional, the economic and the environmental perspectives should ideally be combined, since they are mutually dependent on elements from each other in order to provide a dynamic explanatory framework.

Malthusian and Boserupian approaches

Two principal traditions can be distinguished concerning growth and resources. The first one, which sometimes is called Malthusian after Robert Malthus, stresses the limits to growth that are imposed by natural resources. It may be claimed that the Malthusian standpoint emphasizes natural resources as given independently of social constructions. Thus, there is always a point in a devel-

opment path where further progress is constrained, not because of the socio-economic system itself, but due to natural resource factors beyond the control of the socio-economic system. Malthusian standpoints are infrequent in historical analyses, possibly because people still live on the earth. Easter island, however, constitutes a case which has been brought forward as an example of collapse due to natural resource scarcity. In addition the collapse of certain Indian cultures in Meso-America has been analyzed in Malthusian terms. However, the Malthusian analysis usually concerns the future rather than the past. Clive Ponting has therefore stressed the Malthusian trap as something of a ‘normal case’ in the history of mankind.

The other tradition, in which dynamic responses to resource scarcity are stressed, can be called Boserupian, after Esther Boserup, who argued against the Malthusian view on demographic development and resources. In her model, natural resources are not imposing a permanent limit to development, since new social constructions, through regulation or technical and/or scientific development, may increase or change natural assets qualitatively by defining new ‘natural items’ as resources, in other words as suitable for meeting human needs. The resource crisis has, however, a role to play in the Boserupian analysis since it is a catalyst for economic change. This view of economic change implies that a given natural resource may be redefined as a natural item, in other words, not as a resource. The blue whale, which no longer is hunted, is one example of such a process. Among historians and economic historians who have analyzed historical change in Boserupian terms, Wilkinson, Wrigley and in Denmark Kjærgaard could be mentioned. Wilkinson, for example, in an analysis based on works of Ashton and Nef, proposed that the British industrial revolution was the outcome of a Boserupian response to land and timber shortages. In Wilkinson's analysis, shortages were indicated, or signaled, by market prices changes. Other economic historians, such as Flinn and Hammersly, have argued against this standpoint. While Hammersly was

42 Flinn, M.W. Technical Change as an Escape from resource Scarcity. England in the seventeenth and eighteenth centuries, in Meczak, A./Parker, W.N. (eds.) Natural Resources
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stressing empirical evidence, Flinn focused on the innovative process for criticizing an over-simplified Boserupian interpretation of the industrial revolution. According to Flinn, past technological and scientific progress and chance, play significant roles in the prospective success of a technical response to a resource shortage crisis. The limits to innovative responses lie here in the nature of the unknown natural laws that must be understood in order to successfully solve a specific problem.

Thus, it is clear that natural resources possess a 'dual' nature from a social scientific and cultural perspective. To a certain extent they exist as 'natural items', independent of human needs and values. As such, a natural item is not a means for reaching some human-defined goal. Rather, natural items can be seen as structured matter and/or energy. However, the structure is given, not by human social construction, but by natural laws. When a natural item becomes a natural resource, it has been socially defined by man as a resource. Society relates in one way or another to the natural resource by using it for some kind of purpose. Thus, the natural resource produces a benefit to society. However, there must be alternative uses for the natural item, in order to provide a meaningful notion of the concept of resource. For example, the sun produces benefits to society, but it is not possible to choose not to benefit from the sun. All technology—and everything else—relates to natural laws, and, therefore, one can say that technology is utilization of natural laws for some socially defined end. For instance, a hydropower plant is utilizing gravity. Gravity is, however, not a resource, while the power plant is. The waterfall can in turn be seen as a naturally produced resource. While it is possible to choose not to build the waterpower plant, and thereby to be able to utilize the waterfall for tourism, one cannot choose to avoid gravity as a structuring principle for societies. Ultimately, the dynamics in environmental history lies in the obscure demarcation line between the naturally given and the socially constructed. One could say that the basic idea underlying this thesis is that society cannot be seen as separate from nature. All social constructions need to fit into what Mary Cathrine Bateson calls natural possibilities. Furthermore, the certain category of social constructions which are at focus here are economic relationships with the environment.

Economic environmental accounting can be seen as an attempt to capture parts of this dualism of natural resources by offering a synthesis of ecological and economic points of view. In a historical perspective, series may be

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constructed in order to show how natural items appear in the resource base and how they are used up for the purpose of creating economic values. The accounting system also shows how they may be redefined as non-resources in accordance with economic factors such as price changes. Thus, the economic accounting approach offers an opportunity to visualize both Malthusian and Boserupian effects in a long-term economic perspective.

Objectives of the thesis

Since historical national accounts in Sweden are internationally seen in an advanced state, extensions and broadening of the framework has been requested. Broadening HNA would correspond to the introduction of accounts to HNA which are part of the latest version of the System of National Accounts, SNA93, but not of HNA. One example is the distribution and use of income account. An extension of the framework corresponds to the introduction of historical satellite accounts. Such accounts are related to, but not part of, the core of SNA. These accounts include for instance, unpaid household work and the environment. As discussed above, the objective of environmental economic accounting is the monitoring of both economic and ecological perspectives on environmental problems. However, due to analytical reasons, compromises between economical and ecological concepts cannot be avoided. The economic concepts are basically those of SNA93 and SEEA, while the environment should be understood as all other species besides man, the atmosphere, the waters and seas and the earth’s surface. Nonetheless, since environmental accounting is compatible with SNA93, the treatment of environmental issues is in accordance with the treatment of other economic issues. In its turn, SNA93 can be seen as a method for operationalization of macro-economic theory. Environmental Historical National Accounts (EHNA) therefore offer an approach for studying economic values and economic/environmental relations in a non-arbitrary way.

Thus, the main purpose of this thesis is to extend the existing historical national accounts for Sweden by including environmental items. Swedish HNA cover the period 1800-1980. The ambition in this work is to cover the same period. It can, however, be foreseen that lack of historical data in some cases may make this impossible. In that case, shorter periods must be considered. Needless to say, it is impossible within the framework of this thesis to construct

45 Krantz / Lindmark (1995)
complete EHNA for Sweden. Instead some parts of the accounts—probably some of the most important—are dealt with.

In the extended HNA, environmental monetary values are linked to traditional economic values within a framework of Environmental Historical National Accounts. To determine how such a framework should be constructed with respect to data and credibility is one of the major problems which has to be solved before the main purpose of the thesis can be approached. Methodological development and the use of methods within environmental and resource economics for HNA purposes is therefore a central part of the work.

As to general areas of use, three important fields are recognized:

-First, the potentials offered by ordinary HNA are extended. The analysis of economic growth can be widened by the introduction of environmental capital as a production factor. Also, the study of structural change may be extended with the introduction of environmental accounts since the environmental accounts reveal the contribution of natural resources to value added. Further, structural change may in a system of extended HNA be analyzed in terms of changes in the capital stock.

-Secondly, EHNA may serve to deepen analyses based on contemporary environmental accounting by offering a historical perspective. Some of the issues that are to be analyzed within the framework of contemporary environmental accounting are likely to be of a long-term character. In these cases EHNA may be a supporting tool, even though it is likely to be more simplistic than contemporary environmental accounting systems.

-Thirdly, EHNA can serve as a reference frame for other fields of research within economic environmental history. One example is that of changing attitudes towards the environment and connections with patterns revealed in EHNA. Another related area of use is the macro-periodization that EHNA offers which may be used for guidance when relevant research periods in other kinds of studies are decided upon.

Given the main purpose of the thesis, a quantitative generalization of the historical development of environmental cost, estimated and treated in accordance with other economic values and costs are sought for. The specific questions which are dealt with are:

(1) How can depletion of natural assets be characterized from an economic historical point of view and how has it been correlated to economic growth?
(2) How can environmental degradation due to pollution be characterized from an economic historical point of view and how has it been correlated to economic growth?

Obviously, the two questions could have been formulated as a single question. However, since depletion and degradation represent different concepts in environmental accounting, the two-question option is considered more relevant.

The thesis is divided into five main sections including preliminary analyzes and a summary of the results. The first section concerns the accounting framework and addresses methodological issues of importance when integrating EHNA and HNA. Due to the formalized and complicated construction of the national accounting system and the environmental accounting framework, this section is in part very technical. This is necessary in order to show how the subsequently elaborated accounts fit into the accounting system.

The second section concerns iron ore extraction. From a historical perspective iron ore is Sweden’s most economically important non-renewable natural resource. It is therefore natural to include iron ore depletion in the study. The focus is on estimating physical stocks of economically extractable iron ore resources, calculating a relevant unit price for stock valuation, and establishing a broad HNA framework for the iron ore industry which allows a full integration of environmental accounts. This section also includes a discussion on how the results can be understood and interpreted in an economic historical perspective.

The third section concerns the standing timber volume. Also timber is natural to include since forest-related industries play, and have played, important roles in Swedish economic life. In this section, the historical development of the standing timber volume is reconstructed. Subsequently, the economic value of the stock is estimated. In comparison with the iron ore section, the discussion on how the results should be interpreted is here reduced. The reason for this is that the price data and estimation of stock values here are less subject to ambiguous estimates than they are in the case of iron ore. Both concerning iron ore and timber it is relevant to investigate, in relation to question one above, what the historical contributions of natural resources to value added have been in the Swedish economy. This question is examined in the fifth part.

The fourth section concerns pollution. Most environmental accounting systems pay attention to costs associated with different kinds of pollution. Likewise historical environmental accounting should include pollution in order to present a picture of the historical development of this type of environmental problem. In this section, emitted quantities of a number of hazardous substances are estimated. Subsequently, the economic cost which can be attributed to each type of emission is collected or estimated in order to create an aggregated pollution cost series.
An Introduction to environmental historical national accounting

In the fifth section, analyzes of the results are done basically in accordance with the questions raised above. In addition the limitations of the study are discussed. A periodization and a preliminary analysis is made for both the iron ore depletion series and the corresponding series for forestry. Also in the case of pollutants a periodization is made. Furthermore, the economic historical context of these findings is discussed and a structural interpretation of the long term relationship between growth and the environment is proposed. The thesis is closed with a summary.

Environmental accounting in perspective

In the early seventies, the GDP measure came under increasing criticism for its shortcomings as a welfare indicator. National accounting had been used in the developed countries since the 1950's. Even though the national accounting system had been designed as a tool for economic analysis and as an aid for conducting economic policy, it was at the time –and still is– frequently used as an instrument to measure welfare. In a more general sense GDP has almost literally been seen as a measure of national success. Obviously a welfare related drawback of the GDP aggregate is ignorance about income distribution. But also negative effects on the environment caused by economic activity is given high priority for integration in the national accounts.

Among researchers, resource managers and politicians the concept of sustainability became very common during the 1980's. In the report by the World Commission on Environment and Development called Our Common Future, sustainable development was presented as a key concept. It was defined as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". Researchers have struggled ever since to devise more precise definitions which can be used for the development of environmental policy instruments.

Since sustainable development often has been seen as a concept which involves both a social and an environmental dimension, many of the attempts to

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47 GDP has also been criticized for its shortcomings as a measure of economic activity, see for instance Daly, H.E./Cobb, J.B. For the Common Good. Green Print, London 1990. The discussion is however not considered in this work.
integrate the environment into economic accounting have been accomplished in conjunction with adjustments for non-environmental welfare factors.

An often used principle governing welfare accounting is the subtraction of so-called defensive measures or ‘social maintenance costs’ from the national income. Defensive measures are then seen as intermediate consumption rather than final consumption.\textsuperscript{51} The defensive measures may, for instance, include military defense expenditures or commuting costs, but also items which are not included in the national accounts like environmental damages.

In welfare accounting, environmental problems are treated as defensive measures falling into two categories. First, there are defensive measures that are already included within the production boundary of the national accounts, like garbage collection, and then there are defensive measures which from an environmental point of view ought to be included, but have not been so in reality. This includes measures that should be taken in order to avoid environmental degradation.

Ever since the 1970’s a number of attempts to adjust the national accounts have been the cause of strife among researchers as to what should be included and how it should be measured.\textsuperscript{52} The definitions of a welfare measure are always arbitrary. This is because welfare accounting seeks to establish a national welfare function, in other words, the relationship between economic values measured in the national accounts (NA) and the experienced welfare. To do this, all individual welfare preferences must be known. Since this is impossible, the researcher’s welfare preferences must be used as a substitute. Welfare accounting is however worth closer examination since it is here that environmental issues have traditionally been dealt with.

The first ones to suggest and estimate a welfare adjusted version of the national accounting system were Nordhaus and Tobin.\textsuperscript{53} However, their measure MEW (measure of economic welfare) did not include environmental aspects. Nordhaus’ and Tobin’s methods of welfare adjustments became the point of departure when the economic council of Japan in 1973 introduced a measure called NNW (Net National Welfare). This version of the MEW also included some adjustments for environmental costs.

In 1981 Zolotas estimated an Index of the Economic Aspects of Welfare (EAW) which included defensive costs for some pollutants and mineral re-

\textsuperscript{52} A critique of economic environmental accounting and a proposal for a non-monetary statistical system for measuring sustainable development is found in Lintott, J. Environmental Accounting: useful to whom and for what?, Ecological Economics 1996:16, pp. 179-190.
source depletion.\textsuperscript{54} Defensive costs for garbage control and water cleaning were also included in the EAW. The estimates were made for the U.S. for the period 1950 to 1977.

Daly and Cobb attempted in the early 1990's to construct a measure called ISEW (Index of Sustainable Economic Welfare).\textsuperscript{55} It was based on modified national accounting aggregates. In addition to adding more items than had been included in previous welfare accounting approaches it also included costs for some pollution and resource depletion. The ISEW was estimated for the U.S.A. between 1950 and 1986 and actually showed some divergence from the GDP growth. This, however, was not caused by the environmental adjustments. Jackson and Marks have attempted to estimate the ISEW for the U.K. during the same period\textsuperscript{56}. The most striking result from their investigation, as compared with other attempts including Daly and Cobb, was that the ISEW for Britain showed a dramatic divergence from the GDP development. This included a substantial drop of the ISEW from ca 1974 back to the level of the 1950's. In the British case the environmental costs clearly reinforced this downward trend. After this, a series of ISEW investigations, among them one concerning Sweden, have been published.\textsuperscript{57} All of these investigations showed a negative development of the ISEW since the 1970's.\textsuperscript{58}

In 1995, Rörmos-Jensen and Möllgaard estimated a welfare index (WI) for Denmark which as regards environmental costs included emissions of SO$_2$, NO$_x$, agricultural pollution, lead and effluents.\textsuperscript{59} Also in the Danish investigation the defensive costs have been treated as a mix of actual and potential avoidance costs. The welfare index revealed a development which strongly resembled the ordinary GDP development. When the WI study and the ISEW studies are compared, it is apparent that the construction of the index and the methods used for the obtaining the environmental costs may have a great influence on the result.

There have also been environmental accounting attempts from outside the welfare accounting tradition. In 1989, Rapetto et al. presented an investigation on economic growth adjusted for resource depletion in Indonesia between 1971

\textsuperscript{54} Zolotas (1981)
\textsuperscript{55} Daly./Cobb (1990)
\textsuperscript{58} Jackson/Stymne (1996) The countries include USA, UK, Germany, Austria, Netherlands and Sweden.
to 1984.\textsuperscript{60} The estimated costs for net depletion of petroleum reserves, forests and soil erosion were here deducted from the ordinary GDP aggregate. Thus a 'natural resource NDP' was elaborated. This version of the NDP showed a considerably lower annual rate of growth than the GDP. It should be observed that Rapetto's NDP only includes natural resource depreciation which also means that natural resources are the only items in the capital stock of this investigation. A probably unintended but logical consequence is that depletion costs equal the gross operating surplus for the specific extractive economic sector.

Also outside the domain of social accounting is Arne Jernelöv's measure called the \textit{environmental debt}, which he calculated for Sweden in 1992 and 1993.\textsuperscript{61} The environmental debt was defined as the costs for restoring previous environmental damage to an acceptable level, provided that the damage was repairable. In economic terms, it can be seen as the replacement cost for the part of the damaged environmental capital which is possible to recreate. Jernelöv did however not deal with resource depletion. Furthermore, Jernelöv's estimates included more items than many previously made environmental accounting exercises.

\section*{The System of Integrated Environmental and Economic Accounting}

In 1993, a proposal for a new satellite system of integrated environmental and economic accounting (SEEA) was presented together with changes in the System of National Accounts (SNA).\textsuperscript{62} The environmental accounting system is based on SNA93 and shows how different sectors interact with the environment by using environmental goods and emitting residual waste.\textsuperscript{63} SEEA is constructed as a satellite accounting system, suggesting that it does not disrupt or alter the information within the ordinary SNA accounts.

The main accounting idea is that the environment should be regarded as capital. Environmental damage is thus an analogue to capital depreciation. In

\begin{itemize}
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short the SEEA is a combination of input-output tables, and accounts of non-financial assets. This makes it basically an extension of the asset boundaries used in SNA-based calculations of national wealth and stocks of fixed assets. The input-output tables show flows of environmental goods to the economy, and flows of residuals (pollutants and similar products like garbage) to the environment. The system elaborates both physical and monetary accounts.

The matrix of non-financial assets shows how the stocks of environmental capital are changing due to i.a. exploitation of mineral reserves (quantitative use) and degradation of environmental qualities (qualitative use). Compared with the non-financial assets in the national wealth accounts, the classification of assets is slightly different in the SEEA. The SEEA shows whether the asset is naturally produced or manmade or if the asset is produced by man with the help of nature. Another difference is that the SEEA includes more non-financial assets, e.g. water and air. In the basic versions physical and monetary units are used without changing any of the established macro aggregates in the SNA.

In the more sophisticated versions a new aggregate, EDP (Environmentally Adjusted Net Domestic Product), is estimated. It is the NDP (Net Domestic Product) from which environmental costs (the Eco-margin) have been subtracted. Thus environmental changes may be recorded both in the production accounts, affecting value added, and in the asset accounts as stock changes. An increasing environmental capital stock is, for instance, not recorded in the flow accounts but only in the stock accounts. Thus, the discovery of a huge oil deposit can not lead to a higher EDP than GDP. In conclusion the following macro identity is used in the SEEA

\[ \text{EDP} = \text{NNP} - \text{EC} \]

where EC is the eco-margin (environmental depletion and degradation costs). Estimations of the EDP demands the use of imputed environmental costs. These may be estimated as so-called contingent costs, avoidance costs, maintenance costs and damage costs based on market prices. Costs measured by different methods should not be mixed since each method is related to different aspects, and, therefore, definitions of the environmental problem. In EHNA there probably exists a need for compromise, whereby different methods may be used for different environmental issues.

**Comments and conclusions**

When a society is transformed the issues on the public and scientific agenda also change. Lately, new issues related to long term conditions for growth, environment and welfare have initiated new demands on the organization of
economic statistics. Concerning Historical National Accounts (HNA), an extension of the accounting framework for studying the relationships between growth, structural transformation and environmental changes is motivated. Such an extension is in this thesis put forward as Environmental Historical National Accounts (EHNA). EHNA should be seen as a method for representing economic and environmental relationships, by describing how environmental items —other species, the atmosphere, water and the earth— appears or disappears as economic assets, through changing valuation, new discoveries and qualitative and quantitative use.

The research context of this work is a long tradition of HNA research in Sweden, an economic historical interest in natural resource related issues, modern environmental science and contemporary environmental accounting.

Concerning contemporary environmental accounting the environmental accounting system, System of Integrated Environmental and Economic Accounting (SEEA), proposed by the United Nations, the OECD, the IMF, the Commission of the European Communities and the World Bank is worth special attention.

The SEEA is the only approach to environmental accounting which has a straightforward linking to the SNA. It therefore appears as the first choice for an accounting framework in order to extend the HNA with environmental aspects. Welfare accounting approaches are conceptually more difficult to use. Usually they are partly based on the national accounts, and thus standard economic theory. However, usually the welfare indices are not compatible with SNA. Thus, it should be observed that different issues are investigated with different methods. Economic environmental accounting is intended for examining the relation between society and environment from an economic perspective. Welfare accounting is then, quite obviously, a method for treating the same issue from a welfare perspective. It is appropriate that investigations of the historical relation between macro economic and environmental changes should start with establishing a system which is an extension of or a satellite to HNA. Thereafter, non-monetary and monetary data should be collected. Finally, the data can be subject to analyses, which certainly may involve other analytical dimensions than economic ones. However, a closer examination of the SEEA is necessary in order to construct EHNA.
2. SEEA AS AN ACCOUNTING FRAMEWORK FOR EHNA

Introduction

In order to establish historical environmental accounts it is necessary to provide a thorough presentation of the SEEA. The objective of this chapter is to make such a presentation and to point at certain problems and their consequences regarding the establishment of EHNA. It should be noted that this section partly is very detailed and technical.¹

The SEEA is presented in several subversions.² The basic versions, I and II, concern non-monetary natural resource accounting and are therefore not considered in this context. SEEA III is a system of integrated economic and natural resource accounting without the use of so-called imputed costs. Thus, SEEA II does not include adjustments of the items in the production accounts. In other words, adjusted macro aggregates are not elaborated. The SEEA IV subversions differ from SEEA III since they include imputed costs. Therefore SEEA IV versions are needed in order to estimate the environmentally adjusted macro aggregate EDP. SEEA V versions share the basic structure of the other versions but also include an extended production boundary which comprises environmental services. Since SEEA III is the basis system for integrated environmental and economic accounting, it also serves as the base for the presentation in this chapter.

The System of integrated Environmental and Economic Accounting

A simplified version of SEEA III (monetary and physical accounts) is shown in matrix 1. If EHNA is to be based on the SEEA accounting principles, simplifications of the system are necessary. In the SEEA matrix the monetary accounts are based on market prices. Extended SEEA versions, including imputed environmental costs as well as the links to HNS (Historical national accounts for Sweden), will be presented in the text.

¹ Those not specifically interested in these aspects of the investigation, could begin their reading with the section entitled "Some basic indicators in EHNA".
Matrix 1. EHNA matrix with physical and monetary accounts

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<th>Domestic production of industries</th>
<th>Final consumption</th>
<th>Non-Financial assets (uses and stocks of assets)</th>
<th>Exports</th>
<th>Total uses</th>
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<td>Agriculture</td>
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<td>Forestry, Fishing</td>
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<td>Mining, electricity, water (ISIC 10-14, 40, 41)</td>
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<td>Other industries</td>
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<td>Final consumption</td>
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<td>Subsoil assets</td>
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<td>Water</td>
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<td>Area</td>
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<tr>
<td>1. Opening Stock</td>
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<td>2. Use of products of industries</td>
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<tr>
<td>3. Use of non-produced Natural assets</td>
<td>Depletion of domestic assets:</td>
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<td></td>
<td>4. Wild biota</td>
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<td>5. Subsoil resources</td>
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<td>6. Use of water</td>
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<td>7. Use of air, wind</td>
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<td>8. Soil erosion</td>
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<td>Depletion of foreign assets:</td>
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<td>9. Wild biota</td>
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<td>10. Use of land</td>
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<td>11. Discharge of residuals</td>
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<td>12. Treatment of residuals</td>
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<tr>
<td>13. Use of produced fixed assets</td>
<td>A+ A+ A+ A-</td>
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<tr>
<td>14. Net value added/NDP</td>
<td>A A A A</td>
<td></td>
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<tr>
<td>15. Gross output of industries</td>
<td>B A B A B A</td>
<td></td>
<td></td>
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<tr>
<td>17. Revaluation due to market price changes</td>
<td>A A A A A A</td>
<td></td>
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<tr>
<td>18. Closing stock</td>
<td>B, A</td>
<td></td>
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</tbody>
</table>

Note: B are physical entrances and A are monetary entrances. Source: SEEA matrix with linked physical and monetary accounting (version III), SEEA handbook, table 3.4 page 82.
Domestic production of industries

Row 2 under the columns of domestic production of industries in matrix 1 shows the use of intermediate goods in the production. In SEEA III the following sub-categories have been used.3

1. Domestic production: natural grown products
2. Domestic production: other products
3. Imports: natural grown products
4. Imports: other products

Only the main row use of products of industries is shown in matrix 1. It is worth noticing that the published HNS do not show the destination of imports. However, a disaggregation in two or even four rows may be possible in future EHNA elaborations.

The production boundaries in SEEA are the same as in SNA93. In the matrix they are (column 1 - 3):

1. Agriculture, forestry and fishing
2. Mining, electricity and water
3. Other industries

HNA and SEEA Classifications

In HNS the production accounts consist of seven industrial sectors: agriculture with its ancillaries, building, transports and communications, and private services, including household production, public services and services of dwellings.4

This classification of economic activities is not consistent with SNA93 and is not suitable for environmental accounting.5 In SEEA, primary and secondary production (column 1 and 2) comprise the economic activities which (along with some household production) use non-produced raw materials. Thus, a disaggregation of the HNS accounts is motivated in order to show flows of en-

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3 SEEA, 1993, p. 82.
environmental goods in a satisfactory manner. In this case it should be easiest to follow the classifications used in SNA93.

If a production activity which belongs to other industries is using non-produced natural assets (except water and air), the use is accounted for in column 1 or 2. For instance, if an iron work is logging timber for charcoal in a natural forest, the use of non-produced natural assets (logging of timber under the column wild biota), should be accounted for under forestry.

**Final consumption**

Column 4 (final consumption) shows flows to and from the environment due to final consumption. On the emission side the generation of household garbage is an important environmental accounting item which is caused by final consumption. In addition environmental goods may be subject for final consumption. As stated above HNS use different classifications of economic activities as compared to SNA93 and SEEA. The production boundary is also different in one version of HNS since some non-market household activities, which are not included in SNA93, are treated as production.

**Produced Assets**

The category produced assets shows non-financial man-made assets. In HNS, capital accounts are not included at all. EHNA, therefore, require a capital account extension of HNS. Three approaches are possible.

1. The capital accounts may be considered as implicit. Even though depreciation is estimated there are no corresponding asset accounts.

2. Capital accounts may be constructed with the help of ‘keys’, i.e. assumptions concerning for instance changes in investments and capital stocks. One example is the Perpetual Inventory Method (PIM), in which investments are transformed to stocks. This results in a more complete accounting system as compared to approach 1. It is, however, worth noticing that the information carried by the system is not improved.

3. Capital stocks may be independently estimated for natural resources in EHNA.

In SEEA the capital accounts comprise man-made assets (column 5) and produced natural assets (assets which are made by man with the help of nature (column 6)).
Produced natural assets are assets which are naturally grown in processes controlled by man through different modes of cultivation. This includes cattle, fish in ponds, forest assets in timber tracts etc. The capital stocks are shown in both monetary and physical terms. Use decreases the stock value.

In SEEA, nature is considered as being able to sustain capital formation without corresponding balancing accounts, such as investments.

Gross capital formation concerning man-made assets is shown in the HNS figures for investments. Use of capital, or other stock changes, are not shown in the HNS. Accordingly, the net value added is not estimated in HNS. This represents a major simplification of HNS in comparison with SEEA and SNA93. In order to link EHNA to HNS it is therefore necessary to make historical estimates of net investments. An open question is how far these extensions can be made with respect to the quality of historical data and the desired credibility of HNS.

Non-produced natural assets

Non-produced natural assets are assets which are not produced by man or with man's help. As pertaining to its institutional status, the asset may either be economically controlled or not. Furthermore, the asset may or may not have a market price.

The use of non-produced natural assets is shown by flows expressed in physical terms from the environment to production or consumption. Depletion is considered as both diminishing physical stocks and reducing the asset's market value. The use of non-produced natural assets may also take the form of use of environmental services. One important environmental service is the absorption of a pollutant by an environmental media.

Use of non-produced natural assets

Use of non-produced natural assets is shown under the columns domestic production and final consumption (columns 1 to 4 and the rows 4 to 12). Here, flows of environmental goods for use in the production or as consumption are shown together with flows of residuals going in the opposite direction. It is also possible to understand the residual flows as a flow of environmental services for use in the production or consumption. The origin is the non-produced natural assets. In SEEA versions which do not use imputed items these flows are shown as physical flows.
In SEEA III, environmental damage is only shown indirectly through changing land values or through stock changes in physical and/or monetary terms. The rows corresponding to the extended asset boundary in SEEA are:

*Depletion of domestic non-produced natural assets*

4. Wild biota  
5. Subsoil assets  
6. Water  
7. Use of air, wind etc.  
8. Soil erosion

Under the heading *depletion of foreign assets* is

9. Wild biota

One example is fishing in foreign waters. In other cases the non-produced natural assets are treated as imported products when they enter the domestic economy. Under the heading *depletion of domestic non-produced natural assets* are the rows

10. Use of land  
11. Discharge of residuals  
12. Treatment of residuals

Row 10 includes, for instance, polluted industrial sites. Historical estimates of land use, especially for housing, industry and infrastructure, remains largely to be done.

Rows 11 and 12 show residual flows from the economy. Rows 11 and 12, columns 5 and 6 show residual flows from produced assets of industries. One example is discarded machinery. Regarding residuals from transports, a division is made between transports for industrial purposes and transports for private purposes. In the first case the residuals are accounted for in the production (transports) and in the latter case their origin is final consumption.

**Use of residuals**

Residuals can be used in the production if they are recycled. In the case of recycling, the original residual production is shown as a negative entrance and the part which is re-used is shown as a positive entrance in the production account.
In EHNA, recycled material is considered to be included in HNA as inputs. It is therefore not included in EHNA.

**Treatment of residuals**

If the residual is treated as e.g. being stored this is shown as a negative entrance under production or consumption without corresponding positive items. In EHNA there is no immediate need to include this category. One practical example is stored radioactive waste.

**Imported residuals**

Residuals of foreign origin are shown with a negative sign under the column total uses and the heading foreign origin. When imputed environmental items are used, residuals with a foreign origin may in some cases be omitted. In all cases, imported residuals (and exported) are difficult to account for. In EHNA it is preferable to account for residuals according to the cost-caused principle. In that case only the domestic production of residuals is considered.

**Non-produced natural assets**

Non-produced natural assets are found in columns 7 to 12.

7. Wild biota  
8. Subsoil assets  
9. Water  
11. Land (soil)  
12. Land (area)

Here is shown the origin of environmental goods and the destination of residual flows. Some flows also take place within the environment. For instance, in SEEA soil erosion is shown by a flow from the asset soil to water or land.

In column 8 there is also one entrance in row 2 which represents costs for subsoil prospecting. Improvement of land is counted as part of the capital formation and is shown in monetary terms in row 2, column 12. This corresponds to the costs associated with land improvement.
Other stock changes

Other stock changes include row 16, with sub-rows 16.1, 16.2 and 16.3, and columns 5 to 12. The matrix of tables 3.1, 3.2 and 3.3 does not show the sub-rows. In SEEA the rows are:

16.1 Due to economic decisions
16.2 Due to other economic causes
16.3 Due to natural or multiple causes

The row 16.1 includes the following sub-rows:

16.1 Due to economic decisions
a. Depletion (wild biota, subsoil assets, water)
b. Changes in land quality due to changes in land practices.
c. Degradation of land due to soil erosion
d. Other degradation of land
e. Discharge of residuals (water, cultivated land, uncultivated land)
f. Restoration (wild biota, water, cultivated land, uncultivated land)

The sub-rows under 16.1 are only expressed in monetary terms.

Row 16.2. represents stock changes due to other economic causes and includes

a. Discoveries and new estimates of reserves (wild biota, subsoil assets, water)
b. Changes of classification (cultivated land, uncultivated land)

The entrances are only expressed in monetary terms.

Row 16.3 includes
a. Natural net increase (wild biota, water, air, soil, cultivated land, uncultivated land)
b. Catastrophic losses;
   -Natural disasters (all except subsoil assets and air)
   -Economic causes (the same as above)
   -Political events (all except subsoil assets and air)

Row 17 shows revaluation due to market price changes. The row shows the part of changing asset values which are due to price changes. In practice the row becomes important because opening stocks are valued in the prices of the last year and the closing stock is valued in the prices of the accounting year.
SEEA as an accounting framework for EHNA

SEEA also include opening stocks (row 1) and closing stocks (row 18). Stocks are shown for non-financial assets (row 7 to 12) and for assets produced by man with the help of nature. In EHNA it may prove difficult to fill all the boxes with data. Only a careful examination of the empirical data may give an indication about what can be done.

**Valuation of natural assets in SEEA**

The estimation of monetary values for natural assets is one of the most difficult steps in environmental accounting. In the version of SEEA presented above only market prices and physical values are used. This means that the system only allows monetary estimates of assets which are traded on markets. Many of the natural cycles and eco-systems which are in focus in the environmental debate are not traded. In order to overcome this drawback, the system can be extended to incorporate imputed environmental costs. This gives a fuller coverage of the monetary accounts, allowing the construction of new macro-aggregates. It should be clear that this extension is made at the expense of objectivity of the accounts since imputed prices per definition are fictive. One type of credibility is thus traded for another.

Monetary values can be achieved via several approaches. These can be more or less suitable for historical series depending on the sources. Without examining the historical sources it is therefore difficult to recommend the valuation methods which could be appropriate for practical EHNA work.\(^6\)

**Market valuation** has its strength in the use of concrete price data. The following areas are those where market valuation is likely to be the most appropriate method:

(a) *Produced natural assets*. When the case is stocks of for example agricultural products, such as growing grain or cattle, which directly are objects of market transactions, market prices can be used to value stocks and stock changes.

(b) *Produced fixed natural assets*. Depreciation and values of man made assets can be estimated by the current replacement cost and the remaining asset life. The current replacement cost is the market price of a similar new asset. Subsequently, the cost for use of the asset is equal to the depreciation. The depreciation is estimated by multiplying the current replacement cost by the rate of depreciation. The rate of depreciation equals the age of the asset in relation to

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\(^6\) The presentation of methods are based on SEEA, 1993, pp. 14-20 and pp. 60-62.
its remaining life. The same approach may also be used to estimate values and
depreciation of produced fixed natural assets.

(c) Non-produced fixed assets. In this case of transacted non-produced fixed
assets, for example, land, market prices may of course be used. If the asset is
not object for market transactions, market prices of similar assets may be used
as a ‘shadow price’. What is done is a so-called benefit transfer. Also land rents
may be used for valuation purposes.

(d) Non-produced natural assets. Values of depletable natural assets such as
wild biota and subsoil assets may be estimated by reducing the gross production
value by all extraction costs including capital costs.\(^7\) If exploitation continues
over longer periods, the net income has to be discounted. In some cases market
prices for exploitation rights or the resource in itself may reflect the expected
net proceeds. One example is shares in mining companies. However, the share
value does also reflect other assets than the deposit itself.

One version of the method described above is to subtract all unit production
costs including a normal profit from the final prices. This unit net price can then
be multiplied with the remaining stocks to give a valuation of the stocks. The
net price can also be used to estimate depletion of the asset without having ex­
licit asset accounts.

An alternative approach, the user cost approach, has been proposed by El
Serafy.\(^8\) The user cost is conceived by dividing the net proceeds in the part
which has to be re-invested to compensate for depletion and the part which can
be considered as the true income. The advantages of this approach are that
negative net prices are avoided and that GDP is instantly adjusted. Furthermore,
it is not necessary to estimate normal profits when using this method.

When it comes to natural assets which are not transferred on markets,
methods based on direct or indirect non-market valuation can be applied.\(^9\)

Direct non-market valuation can be used for assets like air or water. Here in­
quiries are used to investigate the willingness to pay for a certain environmental
quality. For historical investigations a non-market valuation of an asset a mod­
ern base year may be used. Historical non-market valuation is per definition not
possible.

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\(^7\) Dasgupta, P. Exhaustible Resources, in Friday, L./Laskey, R (eds.) *The Fragile

\(^8\) El Serafy, S. The Proper Calculation of Income from Depletable Natural Resources, in
Ahmad, Y.J./El Serafy, S./Lutz, E. (eds.) *Environmental Accounting for Sustainable

Indirect non-market valuation is based on hypothetical or actual cost data.\textsuperscript{10} Actual costs are the costs that are associated with keeping an environmental asset intact. This involves for example undertaken pollution abatement costs. The drawback is that the protection costs do not reflect the true environmental costs in terms of depreciation of the value of the non-produced asset. This may be further complicated if the actions taken are not sufficient to offset the environmental damage. Nonetheless, it could be argued that actual protection costs reflect an absolute minimum estimate for environmental costs which take into account the social valuation of the environmental assets versus other assets.

If hypothetical data are used, the cost of environmental damage is the cost that would have occurred if the environment had been used in such a way that its future production of environmental services had remained intact. This corresponds to a hypothetical avoidance cost concept. The asset value may be estimated on the basis of the discounted value of maximum sustainable environmental services. The method is useful for valuation of biological resources and cyclical resources like water.

Imputed environmental costs

An environmental cost is defined as the cost which is associated with the degradation or depletion of natural assets through economic activity. Environmental costs may be either actual or imputed.\textsuperscript{11} Actual environmental costs are included in SNA and, depending on the environmental valuation approach used, to a certain extent in HNA. The actual environmental costs are not always explicitly shown. Imputed environmental costs are recorded as additional cost items in SEEA. Imputations include both the estimate of an economic value and a construction of a transaction.\textsuperscript{12}

In an accounting context the environmental costs may be seen from two perspectives.

(a) Costs caused. Here, the costs are accounted for the economic activity which is actually or potentially causing the environmental cost.

(b) Costs borne. Here the costs are accounted for the economic unit which is carrying the environmental cost, regardless of whether the economic unit has caused the cost or not.

\textsuperscript{10} SEEA, 1993, p. 17.
\textsuperscript{11} SEEA, 1993, p. 93.
\textsuperscript{12} SNA93, 3:34.
Environmental costs are divided in depletion costs and degradation costs.

*Depletion costs* refer to quantitative depletion of natural assets by economic activities.\(^{13}\) An example is the depletion of iron ore deposits. Depleted natural resources are used as raw materials in the economy. Depletion costs may be both actual and imputed and may refer to a cost caused or a cost borne concept.

*Degradation costs* refer to qualitative deterioration of the natural environment as a result of economic activities. Discharge of residuals and the subsequent environmental damage is an example of qualitative deterioration. Degradation costs may comprise:

- Prevention costs, reflecting the expenditure needed to prevent qualitative deterioration
- Repercussion costs, reflecting how costs are borne due to qualitative deterioration. One example is the decrease of land value due to pollution.
- Restoration costs, reflecting the costs borne (actual costs) and/or costs caused (imputed costs) for restoring damaged environmental qualities.

Concerning imputed environmental costs, the SEEA is presented in three subversions reflecting different methods.\(^{14}\)

A. SEEA IV.1 Imputed environmental costs at market values

B. SEEA IV.2 Maintenance cost approach

C. SEEA IV.3 Contingent valuation of the imputed repercussion costs of households

A common feature of all versions of the SEEA dealing with imputed environmental costs is that a new aggregate called the EDP (Environmentally Adjusted Net Domestic Product) is estimated. The following relation between the NDP and EDP concepts is used in SEEA IV.1-3.

\[
\text{EDP} \\
+/- \text{ Adjustments due to market valuation (SEEA IV:2)} \\
= \text{EDP at market values (SEEA IV:1)} \\
+ \text{The Eco-margin} \\
= \text{NDP}
\]

\(^{13}\) SEEA, 1993, p. 93.
\(^{14}\) SEEA, 1993, pp. 91-177.
The contribution from different branches to the EDP is called the environmentally adjusted value added or eco-value added for short. Adjustments due to market valuation are necessary in accounts based on the version IV:2. This is because the asset valuation at maintenance costs is not consistent with the valuation of stocks and flows in the natural asset accounts.

In SEEA imputed costs are attributed to the following rows:

1. Depletion of natural assets
   a. Domestic origin
   b. Foreign origin
2. Use of land, landscape etc.
3. Discharge of residuals
4. Restoration of natural assets
5. Shift in environmental costs

**SEEA IV subsystems. An overview**

SEEA IV.1

Depletion only concerns non-produced natural assets, namely wild biota, sub-soil assets and water. Depletion may also regard some foreign assets if the environmental goods do not reach the country as imported products. In practice this refers to the use of common global assets such as fish in international waters.

The use of produced natural assets is treated as depletion and is also incorporated in SNA93. A valuation of stocks and depletion is performed according to methods attributed to the three accounting approaches.

The use of land, landscape etc. includes quality changes either due to changes in land practices, land use and degradation of land due to soil erosion as the most important posts. In monetary terms soil erosion is reflected through diminishing land values at market prices.

Expenses connected with land improvement are shown as capital formation. If land improvement takes place at the same time as the quality of land is changing, the quality change is indicated by the difference between expenses connected with land improvement and the market value of the land. Therefore it is possible that the imputed environmental costs may have either positive or negative values.
Degradation of natural assets due to discharge of residuals is only shown if the pollution leads to a diminishing market value for a certain natural asset. In EHNA a distinction is not made between residuals of domestic and foreign origin. In matrix 1 the row treatment of residuals is not included because it only shows flows in physical terms and is therefore not used to calculate imputed costs.

Degradation of natural assets may be offset by restoration. Restoration is shown by changing market values for the natural asset in question. This is corresponding to imputed costs with opposite signs in the columns 1 to 3.

In the SEEA the row shift of environmental costs is introduced. It implies that imputed costs caused by final consumption and by use of produced assets are shifted to domestic production. Consequently, residuals caused by household consumption are treated as negative household production. The procedure is introduced in the SEEA to avoid a broadening of the production boundaries used in the SNA. In the SNA household production is only included if it involves market transactions. However, in the HNS a flexible production boundary is used which allows certain non-market activities in the households to be treated as production. If the concept of non-market household production is introduced also in the EHNA the row becomes unnecessary. The row adjustment due to market valuation is not included since imputed costs are directly estimated at market values in SEEA IV.1.

The possibility to use SEEA IV.1 as a point of departure for EHNA is dependent upon simplifications. The possibility to trace the effect of emissions on, for instance, land values is minimal. At the same time the chances of estimating historical depletion costs concerning for instance iron ore may be higher. A possible approach could be to depart from present calculations of damage costs attributed to emissions. These unit costs could subsequently form a base year for the historical emission volumes. It would even be possible to reflate the unit costs, by assuming that the unit damage cost depends on previously accumulated emissions. KI (Konjunkturinstitutet) and SNV (Statens Naturvårdsverk) are constructing physical and economic environmental accounts which to a high degree are based on SEEA IV.1.
SEEA IV.2

SEEA IV.2 involves environmental costs caused estimated at maintenance costs. Maintenance costs are the costs which would have occurred if a certain environmental quality should have been kept in its original status. Since SEEA are based on yearly changes, the concept of ‘original status’ is not referring to a hypothetical virgin state but to the assets status in the beginning of the accounting period. Furthermore, maintenance cost are accounted for the economic activities immediately responsible for the environmental damage.

The concept of maintenance costs is very much like the concept of depreciation. According to the Perpetual Inventory Method (PIM), depreciation is estimated as the expenses which would have been necessary to keep the fixed assets intact. Furthermore, maintenance costs are associated with the concept of sustainable development. The definition of maintenance costs in SEEA is the additional imputed costs that would have been incurred if the domestic economic activities of an accounting period had been modified or their impacts mitigated in such a way as to have impaired the long-term quantitative and qualitative levels of the domestic and world-wide natural environment.18

In the SEEA five strategies are suggested which can form a starting point for the calculation of maintenance costs:

1. Reduction of economic activities or complete abstention from certain activities
2. Production of different products
3. Substitution of inputs for economic activities without changing the final product
4. Activities to avoid environmental degradation without affecting the economic activity per se.
5. Restoration of the environment and actions taken to lessen the impact of the economic activity.

Also maintenance costs imply certain problems for historical studies. What is the maintenance cost for a certain type of residuals during a historical period when an end-of-pipe technology known today did not exist? The problem is resembling the classical index problem, which is caused by a changing product mix, and thus changing technology, over time. A possible method could be to let the maintenance cost equal the loss of income if the economic activity had been abolished or if it had been reduced in such a way that the emissions had not exceeded what is today considered to be sustainable levels. If there were several activities causing the same kind of emissions the hypothetical reduction should be performed in such a manner that the loss of income is minimized. Of

course this neglects to take into account that economic activities are intertwined in a complex way. 'Reversed multiplicator effects' could possibly lead to a much larger cost than what is indicated by the direct reduction of economic activity. Since capital has alternative uses it could be reinvested in some other activity. This is very difficult to consider in the estimates.

One possibility to operationalize EHNA based on the SEEA IV.2 is to depart from present estimates of abatement costs. Modern unit abatement costs at present emission levels, knowledge about critical loads, state of environmental regeneration capacity and pollution abatement technology, would form a base year for the historical series which are based on estimated emission flows. It would also be possible to try to compensate for the different biases which occur when using modern estimates as base year cost estimates. It is however difficult to tell if a more complicated estimation method is more relevant since it may complicate the interpretation of the time series by obscuring biases. The great advantage of the approach is that it is in many cases relatively easy to estimate historical emission flows. In addition, there are already several avoidance cost investigations available.

SEEA IV.3

As stated before SEEA IV.3 are based on imputed repercussion costs of households. These are accounted as costs borne and are estimated by the willingness-to-pay approach. The approach has been subject to controversy. It is for instance difficult to grasp the free-rider problem, the amount that the household actually would pay in a real market. Since the willingness-to-pay approach focuses on the value of the experienced environmental problem in relation to other goods, it is not primarily intended to estimate actual environmental damage. The willingness-to-pay does also reflect the household's budget restriction. In that way the environment is usually seen as a luxury good. This means that a poor country with the same environmental problems as a rich one will have lower environmental costs. The hypothetical market may also be investigated through a willingness-to-avoid approach.

The willingness-to-pay may be investigated as:

- The willingness-to-pay for the preservation of certain environmental qualities

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19 As already touched upon this approach has been used for all pollutants in the Danish WI investigation. Rørmose-Jensen, P./Møllgaard, E. Measurement of a Welfare Indicator in Denmark 1970-1990, Copenhagen 1995.

20 This problem is discussed in Krantz, O./Lindmark, M. Environmental Historical National Accounts. Some problems and prospects, Umeå papers in economic history 14, Umeå 1995.
SEEA as an accounting framework for EHNA

- The willingness to reduce consumption levels

The repercussion costs are recorded in two steps:

- Degradation of landscape by inappropriate land use and environmental degradation by pollution

- These imputed repercussion costs are recorded as reduction in individual consumption and as additional costs of different activities of households. The costs are then imputed and shifted to the production accounts. Finally NNP is adjusted.

In SEEA IV.3 some environmental costs, primarily depletion costs, are measured at market prices according to SEEA IV.1.

Also in the case of SEEA IV.3 it is not possible to find any historical estimates. The costs must be based on present investigations. An advantage of the approach is that willingness-to-pay investigations are comparatively common. They are, for instance, used in cost-benefit analyses of different projects. If the willingness-to-pay could be adjusted with an income elasticity model, perhaps extended with accumulated emissions, it would even be possible to achieve historical environmental costs. Here, the possibility to use present cross-country comparisons should be stressed. With regard to the accounting system, SEEA IV.3 assumes more than the other approaches a household income account. It could, however, be treated as explicit.

Some basic categories of indicators in EHNA

EHNA may be discussed in terms of three categories of indicators. This is true concerning both the accounting framework and data sources. The indicators represent the economy-environment linkage suggested in the ecological model. (See also table 1).

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21 The ISEW investigations also employs contemporary WTP investigation for the construction of historical time series. See for instance 'loss of wetlands' in Jackson/Stymne (1996).

Table 1. Indicators and basic data sources in EHNA

<table>
<thead>
<tr>
<th>Indicator type</th>
<th>Historical (examples)</th>
<th>Data</th>
<th>Economy-environmental linkage</th>
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<tbody>
<tr>
<td>Causal</td>
<td>HNA</td>
<td>Abundant</td>
<td>Source of emission, extractive industry</td>
</tr>
<tr>
<td>Effect</td>
<td>Historical environmental investigations, Historical geological investigation, Forest and land assessments</td>
<td>Very sparse to sparse</td>
<td>Degradation of environment or depletion of natural resource.</td>
</tr>
<tr>
<td>Influence</td>
<td>Relevant input statistics: -fuels, chemicals etc. Output data: -production of hazardous products</td>
<td>Sparse</td>
<td>Flow of emissions or environmental goods from environment to economy.</td>
</tr>
</tbody>
</table>

Causal indicators

The first type of indicator is labeled *causal indicators*. This category refers to the economic activity which is the immediate cause of environmental impact. In terms of HNA and EHNA the causal indicator is the deflated economic volume of a sector. The idea of immediate cause or responsibility reflects an EHNA accounting principle which says that it is the immediate generator of the environmental impact who is accounted as responsible and thus bearing the costs for it. In environmental policy this is formally known as the polluter pays principle, PPP. Thus, even if in reality it may be someone else who carries actual environmental costs, such as when the state finances the chalking of acidified lakes, the accounting principle is to charge the polluter. Also the principle of immediate responsibility is important to observe. If forestry causes environmental problems then these costs are not accounted on behalf of, for instance, paper mills or saw mills, even if it is obvious that without these there would be no reason for large-scale forestry! It should also be observed that EHNA do not account for exported and imported environmental problems. In practical terms the reason is that it would be far too difficult to make the necessary estimates, but 'imports' may also be ruled out, due to the polluter pays principle. In EHNA, the domestic polluter bears the responsibility—the imputed environmental costs— even if the actual damages are carried by another country. On the other hand the EHNA do not account for imported environmental damage either.
Influence indicators

The second type of indicator is called *influence indicators*. They reflect the flows between the economy and the environment which may be proven or suspected to cause present or future environmental damage. In practice this category of indicators would, for instance, include carbon dioxide emissions, garbage and sewage. It would also include so-called environmental goods, such as cut timber and minerals under excavation.

There can, of course, never be any guarantee that some harmful substance has not been left out simply because its harmful potential is unknown. What we do not know we do not know and we can therefore never judge how good the coverage of any environmental accounting system or any other monitoring system is in relation to 'reality'. A likely bias is therefore that the pollutants which are easiest to calculate will be included first. That could easily lead to an underestimation of the real environmental costs. There is however no protection against these biases, apart from being aware of the risk.

Regarding for instance industrial process emissions (industrial emissions not caused by fuel combustion) there exist very few direct estimates previous to the last decade. In order to estimate these emissions it is necessary to use some kind of indicator which is related to economic activity. It is, of course, inconvenient to have the same indicator directing both the first and the second category of indicators due to the fact that the use of the same numerator and denominator produces a dull result. It should be observed that several historical pollution estimates are based on output data. There may therefore exist a certain degree of confusion between causal and influence indicators in EHNA. Ideally, the emission estimates should be based on input data. One example may be fuel consumption.

Effect indicators

The third type of indicator is called *effect indicators*. This category represents how the environment is affected by human activity via the flows described by the influence indicators. This is a type of indicator referring to environmental damage. This may be acidified lakes, intoxicated land, loss of biodiversity, etc. The difficulty, however, is that data is usually very hard to obtain although environmental historical investigations may add some pieces of information here and there. It is also very hard to say which emissions are causing a specific environmental problem. The connection between *influence* and *effect* indicators

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*Emission data are usually estimated with so called emission factors, i.e. the relation between for instance a unit of a fuel (of certain qualities) and the pollution which is caused by combustion. Emission factors may also be used for estimating industrial process emissions.*
may be hard to obtain in a historical context. This is simply a field where present knowledge is limited. In some cases influence indicators, like SO₂ emission data, may be used to model an environmental effect, such as the loss of buffering capacity in soils. There may therefore be a diffuse boundary between influence and effect indicators as well.

**Economic valuation in EHNA**

Many of the monetary time series featured in EHNA are to be based on unit prices obtained from non-market valuation of environmental goods or services. The estimation of non-market prices in EHNA is necessary if a transaction takes place outside the market as a negative external effect. Obviously, non-market prices are fabricated data, something which should be dealt with carefully. It may be foreseen that non-market prices will be principally used concerning pollutants. Regarding environmental goods, such as ores and standing timber, there is a good chance of finding relevant price data. An example of an approach which may be used for estimating economic volumes of pollutants hereby follows. First, the quantity of emissions expressed in physical units is estimated on the basis of, for instance, fuel consumption. Second, by using estimates of present day avoidance costs, an economic volume is created. It should be observed that the base year in such a time series tends to be very recent. Third, the economic volume may be reflated by using, for instance, an industry investment deflator or the implicit GDP deflator. The deflator should be the same as used for the aggregate which is compared to the emission volume. This eliminates confusing results due to price movements of imputed (non-existing) prices.

Economic measures are used in EHNA to aggregate, for instance, different pollutants in order to suggest answers to questions like: how do environmental costs develop in relation to the resources which can be used to overcome the problems or abate the pollutants. In a historical perspective, such aggregated series give hints on how the present day environmental situation has evolved historically, even if the possibility to abate pollutants or restore environmental damage in many cases has only recently been made available.

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24 In Rörmose-Jensen/Möllgaard, 1995, the avoidance costs used for the environmental cost series are reflated to a mid period base year. The avoidance costs are then kept constant in order to reflect a proxy for the price development of cleaning technology.
Comments and conclusions

An extension of the present HNA for Sweden requires a new approach towards historical national accounting. In order to link an environmental dimension to HNA, it is necessary to see the HNA as an accounting system comprising more than production accounts. In SEEA, the proposed environmental satellite accounting system to SNA93, environmental costs are treated as negative capital formation in an extended capital account. Since capital accounts are missing in HNA, it is necessary to introduce at least implicit capital accounts. A reasonable goal should, however, be to develop explicit capital accounts comprising both man-made capital and natural capital. Before EHNA can be wholly integrated in HNA it is necessary to perform historical NDP estimates which at least assume implicit capital accounts.

It is also noted that an immense problem concerning EHNA is the lack of sufficient data. This leads to several complications:

-First, it may be necessary to consider a shorter time period in EHNA than in HNA. Swedish HNA concern the period from 1800. The necessary limitations of time periods must be decided when the historical sources are examined more carefully.

-Second, historical environmental cost data will in many cases be lacking, regardless of which approach that is pursued. In the cases where market price data are lacking, it may be necessary to depart from modern cost estimates as base years. The degree of simplification resulting from adopting such measures is probably comparable to several 19th century HNA series. One example in Swedish HNA is household production and consumption of fire wood. It is also noted that the use of contemporary base years especially for estimates of historical pollution costs implies that the historical cost series are of a subjective character.

-Third, the simplifications should primarily focus on the detail level of the accounting system. The robustness of SNA93 makes it suitable as a point of departure for extensions of HNA as well. An integration of EHNA in HNA based on simplification of the system itself or through extended production boundaries may cause severe problems if HNA is to undergo other extensions.25 The same is true in the case of linking between historical and present accounting series.

Fourth, the choice of accounting system is also dependent on data sources. For this work a damage cost approach (SEEA IV.1) is used for iron ore and timber in uncultivated forests. Damage cost estimates are infrequent and probably unreliable for pollutants. Avoidance costs have therefore been used. Thus, the approach is based on SEEA IV.2. Ideally, all costs should be constructed within exactly the same framework for the sake of consistency and comparability. This is, however, considered as a task for the future improvement of EHNA.

Finally, because of the uncertainties associated with environmental accounting, it is advisable to regard EHNA as a satellite system. This implies that EHNA will not alter any of the established aggregates in HNA and extended HNA based on SNA93. Incomplete HNA will however not make a full linkage possible. It is therefore imperative that a comprehensive linking with HNA to be illustrated, at least for some non-produced asset. This will include the estimate of a net value added, including consumption of fixed capital, for a specific industry, in this thesis the iron ore mining industry. Thereafter, the environmental cost of the capital account may be imputed to the production account.
3. IRON ORE: STOCK ESTIMATES IN PHYSICAL UNITS

Introduction

Iron ore mining has historically been of major economic importance for Sweden. It formed the natural resource base for the iron industry already during the Middle Ages. Beginning in the latter part of the 19th century iron ore became an important export commodity. Consequently economic and economic historical research has paid more attention to iron ore and its related industries, than to other metallic minerals industries. Also from a geological point of view, more attention has been paid to iron ore than to other minerals. Therefore, the historical sources can also be expected to be more extensive and accurate concerning iron ore.

The structure of the iron ore section is as follows. This chapter starts with a comparison between SNA and SEEA and leads up to a presentation of the SEEA entrances that are to be estimated in EHNA. Thereafter follows a section in which the stocks in physical units are estimated. In the next section the economically extractable part of the reserves is estimated in physical units. The subsequent chapter provides an estimate of the iron ore net price. The net price is needed in order to express stocks and flows as economic quantities. The iron ore section is closed with the chapter "Integrating environmental and economic accounting" in which the linking between iron ore industry production accounts and the accounts for non-produced natural assets is provided.

Subsoil assets in SNA93, SEEA and EHNA

Subsoil assets in SNA93 and SEEA

In SNA93, a subsoil asset is defined as the proven reserves of mineral deposits located on or below the earth’s surface which are economically exploitable, given current technology and relative prices. Mine shafts, wells and other extraction sites are included as structures rather than subsoil assets.1 In SNA-93, transactions in subsoil assets are recorded in the capital account when the ownership of the subsoil asset passes from one institutional unit to another.

1 SNA93, 13.59.
Depletion and addition to reserves

Depletion and additions to reserves are taken into account when the asset is valued in the opening and closing balance sheets. Natural assets are not automatically included in the SNA93 asset boundary. Economic appearance—or the inclusion of an asset into the asset boundary of SNA93—is indicated by large scale commercial exploitation. Additions to a reserve are treated as economic appearance (K.3). Economic appearance is an item in the other changes in the volume of assets account (Account III.3:1). Economic appearance of a subsoil asset may be the result of:

- discoveries
- changes of conditions due to technological change
- market price changes.
- move to the status of economic control by an institutional unit

Non-produced assets leave the SNA through economic disappearance of non-produced assets (K.6). Economic disappearance can take form as depletion (K.61) but also as a reflection of relative price changes or technological change. Such changes are recorded in the other economic disappearance of non-produced assets (K.62).

In SEEA the other volume changes account is more detailed. In SEEA it is called Other volume changes of non-produced assets due to economic decisions (CR 6.1). The classification of other volume changes in SEEA are abbreviated COVC. Depletion (K.61, CR 6.1.1.1) is recorded in a similar way in SNA and SEEA. Depletion is defined as the reduction in the value of the deposits of subsoil assets as a result of the physical removal and exhaustion of the asset.

Discoveries of new resources are part of K.3 and K.62 in SNA, as it constitutes a separate entry in SEEA (CR 6.1.2.1.2). Also adjustment due to technological changes (CR 6.1.2.1.2.1), adjustment due to price and cost changes (CR 6.1.2.1.2.2) and adjustment due to new estimation methods (CR 6.1.2.1.2.3) are recorded separately in SEEA. The part of the other volume changes which are due to depletion is transferred as a cost item to the production account in SEEA versions which uses imputed costs.

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2 SNA93, 12.18.
3 The code refers to SNA entries.
4 SNA93, 12.14-17.
5 SNA93, 12.16.
6 SNA93, 12.29.
Iron ore: stock estimates in physical units

Entrances in EHNA

The entrances which should be estimated in EHNA, with references to SEEA entrances, are:

- Depletion of non-produced assets due to economic activity (CR 6.1.1)
- Discovery of new resources (CR 6.1.2.1.1)
- Adjustments of volume (CR 6.1.2.1.2)
- Revaluation due to market price changes (CR 7)

Even if this is a simplification with respect to SEEA, it is still accounting performed on a very detailed level with respect to HNA.

Iron ore assets in EHNA

In order to include iron ore in EHNA it is necessary to account for stock changes. The intention is therefore, as stated above, to include the following entrances in the EHNA iron ore accounts:

- opening stocks
- depletion
- new discoveries
- adjustments of volume changes including changes due to technological changes, price and cost changes, and new estimation methods.

Due to lack of data approximating methods have to be used. It should be noted that in the case of imputation of environmental cost items in the production account, it is sufficient to have estimates of depletion.

To accomplish this, several steps must be taken in the investigation. This chapter focuses on estimates of iron ore stock changes in physical terms. This includes an investigation concerning previously made estimates of geologically proven reserves. The intention is therefore to use historical geological investigations in order to establish a rough picture of the stock changes. The second question addressed is to what extent these estimates correspond to economically extractable reserves. Finally, a method for using geological and economic data in order to estimate approximative entries in physical terms is tested.
Resource definitions

Geological resource definitions

Iron ore extraction in EHNA represents a case of depletion of a non-renewable natural resource. This category of natural resources is not regenerated except in a geological time scale.

When stocks of non-renewable natural resources are concerned, the term 'reserve' is often applied. The absolute reserve—which at least could be imagined—corresponds to the total amount of the mineral in the earth's crust. The geological and geographical distribution of the absolute reserves is not known with any precision. About 5% of the total mineral content in the crust is iron. It is therefore regarded as one of the most common minerals on earth. A small fraction of the crustal iron deposits contain as much as 70% of iron. The principal ore minerals of iron are called hematite, magnetite, siderite and geothite, all representing different geological qualities.7 The major iron ore deposits in Sweden are situated in the central and northern parts of the country. The both areas contain magnetite bodies of various types.8 Also apatite occurs in varying amounts.9 The ores in the northern part of the country are mostly high phosphorous magnetite and hematite ores.10 There are however also low phosphorous ores, so called A-ores, in Kirunaavaara. The central Swedish deposits consists of quartz-banded ores, skarn and limestone ores and apatic ores.11 The two first mentioned are characterized as being very low in phosphorous. It is worth noticing that the differences in geological qualities may affect the economic usefulness of the deposits.

The concept of known reserves is commonly used in geological surveys. Known reserves are always a fraction of the absolute reserves. Usually known reserves are expressed in tons or as the reserve to extraction ratio. The latter option gives the expected remaining life span of the deposit at a given rate of extraction. Depending on the degree of certainty by which the find is known, the known reserves are divided into different sub-categories: proven reserves, likely reserves and possible reserves.

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10 Magnusson et al. (1957) p. 53.  
Resource definitions in SNA and SEEA

In both SNA93 and SEEA the definition of a proven reserve is "the estimated quantities at a specific date, which analysis of geological engineering data demonstrate, with reasonable certainty, to be recoverable in the future from known reservoirs under the economic and operational conditions at the same date". Statistics Sweden (SCB) makes a distinction between a narrow and a wider resource definition. The narrow definition is similar to the concept of proven reserves and corresponds to the quantities which may be utilized from deposits which are presently being exploited. The wider definition includes the geological concepts of likely and probable reserves. The definitions used in SNA93 and SEEA implies that reserves or stocks in EHNA should be based on the proven reserves at certain historical dates.

Historical geological investigations

Ore prospecting can probably claim to be as old as metallurgy itself. Before the latter part of the 19th century, the development of modern geology and the invention of devices like rock drills, investigations were based on more or less random approaches. Mine compasses could provide mountain men with a rough indication about where to look for magnetic ores. However, the possibility to estimate and quantify ore reserves must be considered as having been close to non-existent. Systematic investigations of the Swedish iron ore reserves where first made in the late 19th century. Technological change and the development of modern geology was providing the scientific preconditions for ore prospecting, while promotion of industrial development was a strong motivation for surveys. Concerns regarding the long-term sustainability of iron ore exploitation were, however, also present.

An overview of Swedish historical geological investigations are found in the appendix.

It should be noticed that all estimates of reserves express certain geologists' views at the time. It is only in this respect that they can be claimed to be exact. Not even at the time of the investigations was there total agreement. Criticism

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12 SNA93, 21.152.
14 For an overview concerning prospectation methods see for instance Höök, R. Sveriges gruvhantering, Industrins upplysningstjänst, Stockholm 1950, pp. 21-26.
15 Adelsköld, C.L. Uttalanden i malmfrågan och andra i sammanhang med denna på dagordningen stående för Sverige viktiga frågor, Stockholm 1907.
usually consisted of statements claiming that the estimates were too high or too low. No examples of critics presenting alternative estimates have been found.

Notes on terminology in early geological investigations

The basic unit used in investigations before 1898 is the ore area, (malmarean), or more specifically, the general horizontal through-cut area of the ores, (den generella horisontalgenomskärningsareaen av malmerna).16 Usually, the Swedish deposits were considered as being vertically, or almost vertically, standing. On the basis of the ore grade, it was easy to estimate the quantity of ore per square meter. Together with the ore area, the quantity of ore per square meter allowed estimation of the annual sinking of the mine (avsänkningen). This corresponds to how much deeper the mine becomes in one year. The sinking per unit of ore therefore varies from mine to mine depending on the extraction rate, the ore grade and the ore area. It was however difficult to grasp the vertical depth of the deposit. Usually a maximum sinking of the mines was assumed. It could then be related to the sinking per unit of extracted ore. A rough estimate of the extraction to reserve ratio, expressing the expected life of the mine could then be obtained.

In later geological investigations the reserves were expressed in tons of ore. This means that earlier and later investigations can not be compared directly. It is however possible to transform reserves expressed as deposit areas to tons if data on annual sinking and maximum sinking depths are provided. This is also done later in this chapter.

Swedish iron ore reserve investigations

The first national iron ore investigation conducted in a systematic manner was made by professor G. Nordenström in the early 1890s.17 In the investigation the total iron ore area of the country was elaborated. The results were published in 1893. For the 15 mining sites which were exploited in Bergslagen 1891, the ore area was estimated to about 168 370 m². The estimates of the deposit area for the additional 59 mining sites were based on data regarding production quantities. Here, Nordenström arrived at a figure somewhere between 54 003 m² and 75 605 m². As a compromise 64 000 m² was chosen for the category "other mining sites".

16 Nordenström, G. Sveriges malmtillgångar, Jern-konorets annaler, 1893, pp. 198 - 211.
17 Nordenström (1893)
Also the areas for abandoned mining sites were included to arrive at a total for Bergslagen. On the basis of experience Nordenström assumed that the abandoned mining sites constituted at least 20% of the area of the operational mines i.e. about 46 000 m². To this Nordenström added the titaniferous ores of Taberg (about 260 000 m²) and the deposits in Norrbotten. These consisted at the time of Kiirunavaara-Loussavara (about 500 000 m²), Routivara (about 300 000 m²), Gällivare (about 245 000 m²) and Svappavara (about 38 000 m²). Finally Nordenström concluded that the total area of all iron ore deposits in Sweden amounted to roughly 1 623 000 m².

In the course of discussions at a meeting a few years later, Nordenström revised some of his earlier estimates. The revisions concerned mainly the deposits in the central parts of the country. For the operational mines in central Sweden, with the exception of Grängesberg, the deposit area for 1897 was claimed to be 208 544 m². Concerning the abandoned mines the corresponding figure was about 33 600 m² and for other mining sites about 50 000 m². Accordingly, the aggregated deposit area for central Sweden then amounted to roughly 300 000 m² and with Grängesberg included, about 390 000 m².

For the whole country Nordenström meant that the ore area for operational mines amounted to 928 544 m² while the corresponding figure for abandoned mines equaled about 643 000 m². For 1897 the total Swedish deposit area according to Nordenström was about 1 572 144 m².

The first attempt to express the iron ore reserves in Bergslagen in tons was made in 1898 by H. Sjögren and H.V. Tiberg. For Grängesberg the reserves were estimated to 70 Mt. Concerning other mines in the area the reserves were claimed to be 40 Mt. These estimates departed from an assumption of a maximum additional depth of 130 meters.

The first systematic and thorough made investigation of the deposits in Norrbotten was conducted as early as 1875 by O. Gumælius. He estimated the ore reserves at Kiirunavaara for the level above the lake Loussajärvi and reached a figure of 265.1 Mt. For the neighboring Loussavaara deposit, the reserves were estimated to 27.7 Mt.

In 1897 Gumælius revised his earlier estimates. He thought that the iron ore vein rapidly narrowed with increasing depth. This, however, later proved to be incorrect. The new estimates for the deposits were 215 Mt for Kiirunavaara and 18 Mt for Loussavaara.

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18 Nordenström (1899).
20 Mt = Mega tonnes.
In the light of new observations these estimates were later substantially adjusted upwards by professor W. Peterson. The deposit below the Loussajärvi surface level had at the time been discovered. Peterson claimed that the Kiirunavaara deposit was as large as 480 Mt. Of the total about 200 Mt was situated above lake Loussajärvi's surface level.\textsuperscript{22}

For 1905 professor A.E. Törnebom estimated the deposits at Grängesberg to 60 Mt at a depth of 300 meters.\textsuperscript{23} For other mines in the central parts of Sweden the reserves were estimated to be between 40 - 45 Mt with an additional sinking of 100 meters. Yet another investigation concerning Grängesberg was published in 1907 by N. Hedberg.\textsuperscript{24} He was of the opinion that the reserves down to the 350 meter level were about 51 Mt.

F.R. Tegengren estimated, for 1910 the total deposits in the south and central parts of Sweden to 122.3 Mt.\textsuperscript{25} To this figure should be added 40 Mt in inadequately investigated deposits and 15 Mt of titaniferous iron ore in Taberg. In Tegengren's publication from 1912 these estimates were marginally changed.\textsuperscript{26} About 120.5 Mt were claimed for exploited deposits, 37 Mt for less well known deposits and 50 Mt for titaniferous ore. The figures correspond to directly usable ore and dressed ore, except for the titaniferous ore which is categorized as concentrating ore.\textsuperscript{27}

W. Petersson together with his colleague H. Lundbohm made investigations of the Norrbotten deposits.\textsuperscript{28} These estimates concerned the year 1910. For Kiirunavaara the reserves were said to be 740 Mt down to the 300 meter level below the lake Loussajärvi surface level. They also pointed out that magnetic investigations made in 1900 indicated total reserves amounting to 865 Mt. At the time this method was however judged as unreliable. For Toullavaara the deposits were estimated to 6.85 Mt, for Gallivare malmberg about 233 Mt, Koskullskulle; about 40 Mt, Svappavaara; about 30 Mt down to the 200 meter level, Leveåniemi; 30 Mt, Ekenströmsberg; 50 Mt and finally Mertainen; 5 Mt. No estimates were made for Painirova. Petersson and Lundbohm concluded that

\begin{itemize}
\item \textsuperscript{22} Iron Supplies of the World, Stockholm 1910. p 562.
\item \textsuperscript{23} Törnebohm, A.E. Teknisk tidskift, 1905:35, p. 74.
\item \textsuperscript{24} Hedberg, N. Jernkontorets annaler, 1907:62 pp. 67 - 122.
\item \textsuperscript{25} Iron Ore supplies of the World, Stockholm 1910, p. 597.
\item \textsuperscript{26} Tegengren, F.R. Järnmalstillgångarna i mellersta och södra Sverige. Utredning verkställd åren 1907 - 1909, SGU avhandlingar No 8, Stockholm 1912.
\item \textsuperscript{27} Concentrating ore: Anrikningsmalm. Concerning the products of the iron ore mines it is worth noting the difference between ores ready to use and ores which after dressing (sovering) and concentration (anrikning) becomes dressed ore. The dressed ore may either be melted to iron directly or be refined to briskettes. These products allow low quality ores and low grade ores to be used. Also, less coal is needed in the subsequent smelting process when dressed ore or briskettes are used. Even though the share of dressed ores and briskettes have increased since the late 19\textsuperscript{th} century ores for direct use still dominate the production.
\item \textsuperscript{28} Iron Ore Supplies of the World. (1910) p. 564.
\end{itemize}
1158 Mt was a good estimate for the Norrbotten deposits. For the whole country the reserves around 1910 were estimated to 1280 Mt. In 1922 it was stated that the Swedish reserves could be estimated to about 1350 Mt.

Prospecting activity was increased during the Second World War. In 1944 The Swedish Geological Investigation (SGU) published a comprehensive report on the deposits in central Sweden. It was conducted by P. Geijer and N.H. Magnusson. The deposits were estimated to about 220 Mt. In a publication from 1948 professor P. Geijer meant that a approximation for the Norrbotten deposits was about 2000 Mt.

After Geijer and Magnusson's investigation was completed additional prospecting was conducted by the mining companies resulting in the reserves being adjusted upwards. Magnusson argued for additional prospecting due to the uncertainties concerning the minor Norrbotten iron deposits. It was also decided that new prospection should be performed. In SOU 1959:9 the Norrbotten deposits were said to be 2413 Mt and the central Swedish deposits 263 Mt. Roughly the same figures are also found in a publication a few years earlier.

In SOU 1963:36 the Norrbotten deposits were claimed to contain 2720 Mt while the Central Swedish reserves amounted to 650 Mt. Thus, the total iron ore reserves were estimated to about 3370 Mt.

In SOU 1969:10 there are references to a major investigation conducted by Svenska Gruvföreningen in 1967. Again the result was an upward adjustment showing that the reserves in Central Sweden amounted to 695 Mt. For Norrbotten the corresponding figure was over 3000 Mt. The total reserves were estimated to somewhere between 3.4 and 4 billion tons.

In the book Malm i Sverige (Ores in Sweden) it is stated that the reserves in Norrbotten probably amount to about 4000 Mt; equalling 1980 Mt of iron. Also here references to Geijer and Magnusson's investigations are made as well.

32 Geijer./Magnusson (1944) p. 617.
34 Frågan om statsinlösen av stamaktierna i LKAB. Betänkande avgivet av särskilda utredningsmän. SOU 1955:59, Stockholm 1959, p. 159.
as to the mining companies' prospecting during the late 1940's. A total figure for the country can be obtained if the figures for the Central Swedish deposits from SOU 1969:10 are added. Around 1970 the total reserves could be estimated to almost 5 billion tons. These estimates are strictly based on geological evidence. Other figures can be projected when economic considerations are added. Such estimates are however well kept secrets and public access to company archives is prohibited by the leading mining companies Loussavaara-Kirunavaara AB (LKAB) and Boliden AB. According to LKAB's official estimates from 1995 the total reserves for Norrbotten are stated of about 2000 Mt. At the same time there were no iron ore mining activities in the central parts of Sweden.

Finally, but not strictly chronologically, the reserves in Norrbotten for 1986 were estimated to 2900 Mt in SOU 1989:93. Of these, 1 100 Mt were ores at great depths. The central Swedish deposits were not included in the survey since these at the time were economically useless. Of the Norrbotten deposits about 350 Mt were classified as immediately extractable (tillredda). Thus, approximately 12% of the known reserves were to be considered as economically extractable reserves.

Early estimates expressed in tons

In order to facilitate comparisons with later investigations the earliest estimates of deposit areas are transformed to tons. It should be pointed out that these calculations can be made along different lines according to which ore grade is being used. Here the point of departure is the grades used by Nordenström for the estimates in 1893 and 1899.

In his calculations, Nordenström departed from a quantity of extracted ore in 1891 amounting to 982 371 tons. The average sinking of the 230 000 m², which corresponded to the worked in the Central parts of Sweden, was estimated to 2.6 metres, i.e. 1.65 tons of ore per cubic meter. The ore content was assumed to be 50%. The mass of one cubic meter of ore was estimated to 4 tons while one cubic meter of rock is assumed to weigh 2.8 tons. For the total worked deposit area this equals about 38 Mt of ore with a sinking of 100 meters.

The total Swedish deposit area at the time was, according to Nordenström,

39 Figures obtained from LKAB's information office 1994-12-04 according to the categories proven, likely and possible reserves in Malmberget, Kirunavaara, Svappavaara and the so-called Lappmalm.
41 Nordenström (1893) and (1899).
1 623 000 m\(^2\). If that area had been lowered by one meter, the corresponding iron ore quantity would have been 2.67 Mt. If the average maximum sinking was 100 meters that would equal 267 Mt of iron ore. The estimate is then based on the assumption that 1.65 tons of ore can be extracted from one cubic meter of ferriferous rock. This figure is of the same magnitude as those of other early investigations and can thus be considered as an approximation of Nordenström's investigation expressed in tons.

In his estimations for 1897, Nordenström departed from an extraction of 805 344 tons in Bergslagen. The deposit area was estimated to 208 544 m\(^2\). Thus 1.87 tons were extracted per cubic meter while the average sinking per year was 2.06 meters.\(^{42}\) One reason for the difference between the two estimates, is that Nordenström for the 1897 calculation had used statistics for the quantities of mined rock and ore. Another difference is that Grängesberg is included in the 1893 but not in the 1899 investigation. In the case that Grängesberg is included in the 1899 investigation, the sinking would be 2.0 meters and extraction will be 2.0 tons of ore per cubic meter ferriferous rock.\(^{43}\) This means that roughly 60 Mt of iron ore could be extracted with a 100 meter sinking of the deposit area in Bergslagen and Grängesberg. If the estimate is made for the whole Swedish deposit area, the iron ore mass equivalent would be 314 Mt in 1897.

**The geological investigations in conclusion**

The following figures and estimates have been used to calculate bench marks for the known iron ore reserves.\(^{44}\) The years refer to the publication of the investigations. In some cases the investigations were performed during previous years. Two exceptions are however made in this respect, namely Nordenström's investigation where the investigated years are used. The reason is that the sample period can be extended by two years. For the exact references to the base years, see appendix 3:1.

\(^{42}\) Nordenström (1899) p. 211. Nordenström assumes that one cubic metre of rock and ore has a mass of 3.5 tonnes.

\(^{43}\) Grängesberg: Area: 90 000 m\(^2\), extracted ore: 652 977 tonnes, extracted ore and rock: 953 136 tonnes. See Nordenström (1899) p. 220, and BiSOS Bergshandelringen 1897.

\(^{44}\) Here, I use the term *known reserves as stated in different investigations* since it is uncertain whether the estimates refer to proven, likely or probable reserves.
Table 1: Iron ore reserves in Sweden 1893 - 1995 as stated in different investigations.

<table>
<thead>
<tr>
<th>Year</th>
<th>Iron ore reserves (Mt iron ore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1893</td>
<td>436</td>
</tr>
<tr>
<td>1899</td>
<td>449</td>
</tr>
<tr>
<td>1910</td>
<td>1280</td>
</tr>
<tr>
<td>1912</td>
<td>1365</td>
</tr>
<tr>
<td>1922</td>
<td>1350</td>
</tr>
<tr>
<td>1948</td>
<td>2220</td>
</tr>
<tr>
<td>1957</td>
<td>2676</td>
</tr>
<tr>
<td>1963</td>
<td>3370</td>
</tr>
<tr>
<td>1969</td>
<td>3695</td>
</tr>
<tr>
<td>1972</td>
<td>4695</td>
</tr>
<tr>
<td>1986</td>
<td>2900</td>
</tr>
<tr>
<td>1995</td>
<td>2000</td>
</tr>
</tbody>
</table>

Note: The lower figures 1986 and 1995 are due to the exclusion of central Swedish deposits. The reason for the exclusion is that they at the time did not represent economic extractable reserves.


Estimating proven reserves according to SNA definitions

Even if the historical geological investigations may provide useful data, a lot of difficulties remain before iron ore accounts can be elaborated. The data in table 1 indicates that the known reserves according to the investigations almost certainly do not equal economically extractable reserves (proven reserves according to SNA-93/SEEA). One example of this is the reserves in the Norrbotten deposits according to LKAB. The reserves are presently estimated to be roughly 2000 mega tons. In the brochure Vision och verklighet (Vision and reality), LKAB states that production is secured for the coming 25 years. At the present level of extraction that equals an extractable reserve of ca 200 Mt. Obviously the latter is the reserve which is to be considered as economically extractable. In this investigation the figure 350 Mt from SOU 1989:93 is however used. It is also clear that the lower estimates after 1972 can only be interpreted as if economic considerations have been made. Thus, the problem is to establish

Iron ore: stock estimates in physical units

a transfer or a link between possible and economically extractable reserves, or known reserves according to SNA definitions. Of course, this can only be achieved in approximate terms.

Some kind of iron ore price and extraction cost model for estimation of the proven reserves could of course be imagined. Such a model would certainly be highly complex. Extraction costs, which together with the iron ore price affect the economically extractable reserves, are influenced by numerous factors. Some examples are the depth of the mine, the quality of the surrounding rock, hydrological factors, the iron grade of the ore, transports and logistics, energy prices, wages and the overall technological level. It will therefore be extremely difficult, if not impossible, to construct some kind of cost function which must be based on variables which often will prove very difficult to quantify. Therefore it is concluded that this is not a suitable approach for estimating economically extractable reserves for historical dates. Another method is therefore needed.

Mining concessions

Birger Taube has suggested that mining concessions could be used as an indicator for successful ore prospecting. In this investigation the mining concessions are viewed as an indicator of changes in the proven reserves (economically extractable reserves), since a deposit which is not economically extractable will not be mined. Therefore, the mining concessions could be seen as an indicator for the SEEA entrance adjustment of volume.

Using the mining concessions as an indicator for volume changes raises some questions. Large mining sites, like Grängesberg and Kiirunavaara, may or may not consist of a large number of mining concessions. In 1981, the Grängesberg deposit consisted of 63 mining concessions while Kiirunavaara only consisted of four. It can also be assumed that the mines that are shut down and opened over a period of time, generally contain comparatively small deposits which are associated with high extraction costs. Accordingly, these sites are marginal deposits. It could therefore be argued that changes in the mining concessions are over proportionate to the changes of the proven reserves according to SEEA.

However, it could be argued that new mining concessions also indicate that the reserves attributed to mining concessions which are already defended by work, have increased in proportion to the net change of mining concessions.

47 BiSOS Bergshandteringen, SOS Bergshantering, SGU Bergverksstatistik. Note: Bi-SOS/SOS give number of mines until 1922, thereafter mining concessions.
Imagine one large deposit of 20 Mt and several minor deposits of, for instance, 0.1 to 0.5 Mt. New prospecting methods, rising relative prices for iron ore or improved extraction techniques may lead to three results.

-First, completely new deposits may be economically extractable. At the same time, the volume of stocks are adjusted upward. This is indicated by new mining concessions.

-Secondly, deposits in conjunction to an old deposit may be economically extractable. This is also indicated by new mining concessions.

-Finally, it may be proven that already worked deposits have larger economically extractable reserves than previously expected. This upward adjustment of the reserves is not indicated by new mining concessions.

Assume the number of mining concessions increases by 10%. Also assume that the reserves of the large deposit increase by the same proportion. Then it would not matter what kind of the reserves that the mining concessions are representing in reality. Whether or not matters is that all reserves are increased in proportion to the change of mining concessions. If this is the actual case can probably not be proven. The limitation of the study in this respect has therefore been recognized.

Proven reserves according to SNA93: base years

The only known figures of economically extractable reserves are the SOU 1989:93 and LKAB figures. For the earlier estimates, Tegengrens figures from 1910 may be considered as close to the economically extractable reserves. They were for instance used by Flodström et al. in order to find the appropriate discounting period for the iron ore industry in their major work on the national wealth in 1912.49

Thus, an assumption is made that geologically proven reserves during these base years equaled the economically extractable reserves. This is not unrealistic since Tegengren’s investigation mainly was based on worked mines. Also, the methods for prospecting at the time were not very advanced as compared to the methods used today. Overestimates are therefore assumed to be less likely in earlier then in later investigations.

49 Sveriges nationalförmögenhet omkring 1908 och dess utveckling sedan mitten av 1800-talet, Stockholm 1912.
Establishing EHNA iron ore accounts in physical terms

Given the previously made assumptions, the following data have been obtained:

- Tegengren’s and figures obtained from SOU 1989:93 provide base years for the proven reserves (opening and closing stock) according to the SNA definitions in ca 1910 and about 1985.

- Data on mining equals depletion.

- The mining concessions provide an indicator for changing economic and technological conditions. Mining concessions therefore indicate adjustments of volume.

- The geological investigations provide an indicator for discovery of new resources.

The volume changes of iron ore assets are thereafter calculated in the following way:

1. Adjustments of volume. In 1985 the number of mining concessions was approximately 46% of the number in 1910. This development of the number of mining sites means that the adjustment of volume for the whole period was -584 Mt, since the proven reserves in 1910 equaled 1280 Mt. The physical change of the proven reserves that a mining concession represents is then 584 Mt divided by the difference between the number of mining sites in 1910 and 1985.

2. Depletion: the total mining between 1910 and 1985 was approximately 1246 Mt.\(^{50}\)

3. Discovery of new resources. Given that the proven reserves in about 1985 was 350 Mt, the total discoveries can be estimated as a residual, amounting to 900 Mt over the period. First, the geological reserves were indexed with 1910 = 1. Secondly, the distribution of new discoveries over time was modeled on the assumption that the change as indicated by the geological surveys has taken place linearly during a five year period prior to the survey. In the cases when the period of time between the surveys is less than five years, interpolation was made for the length of time in question. For periods between two surveys that exceeded five years, no new discoveries are assumed. Third, a unit discovery was calculated as 900 Mt divided on the added index changes.

\(^{50}\) Own estimates based on SOS Begshantering.
4. **Opening and closing stocks**: opening stock less depletion plus new finds plus/minus adjustments of volume. A specific year's *opening stock* equals the previous year's *closing stock*.

The volume changes of iron ore assets: basic estimates

\[ +1280 \text{ Mt} \quad \text{Opening/closing stock in 1910} \\
- 584 \text{ Mt} \quad \text{Adjustment of volume} \\
- 1246 \text{ Mt} \quad \text{Depletion} \\
+ X \text{ Mt} \quad \text{Discovery of new resources} \\
= 350 \text{ Mt} \quad \text{Opening/closing stock in 1985} \]

Volume changes of iron ore assets 1893-1910

The estimates in 1893-1910 are probably more uncertain than those in the later period. Basically the same method as described above is used also for this period. For 1899-1909, the accumulated depletion was 40.4 Mt, and the change of mining concessions indicates an *adjustment of volume* of -58 Mt. *Discovery of new resources*, estimated as a residual, amounts to 930 Mt. For the period 1893-99 the corresponding figures are: *depletion* 11.7 Mt, *adjustment of volume*: -25 Mt and *Discovery of new resources*: 49.7 Mt. Since it is known that geological investigations were conducted from the late 1890's and the following decade, the new finds indicated between 1899 and 1910 are spread over the whole sub-period.

Comments and conclusions

It has been possible to reconstruct the development of proven iron ore reserves in Sweden from 1893 to the present. The series are of course characterized by a high degree of uncertainty, but probably the main tendencies are shown. In this kind of investigation it is rather pointless to indicate the reliability of the series in quantitative terms. To accomplish that the model should be a more formalized one, where different parameters could be changed. The figures presented here possess therefore more of a 'take it or leave it' character. For imputation of the environmental cost to the production account it is only necessary to estimate depletion and a relevant net price. Depletion can be estimated with a high degree of confidence, while volume changes due to new discoveries and adjustments of volume only can be estimated in approximate terms. Even in this case some fairly definite conclusions can be drawn. It is, for instance, indisputable
that new discoveries have not fully compensated for depletion and changing technological and economic conditions.

During the whole period depletion has reduced the reserves. In this investigation, it is shown that new discoveries have not sufficed to compensate for the depletion. The data is, however, uncertain. In diagram 1, it can been seen nonetheless that the largest fluctuations on annual basis are caused by adjustment of volume.

**Diagram 1. Iron ore: other volume changes, Sweden 1910-1985**

Note: The legend shows Discovery of new resources (New disc.), Depletion (Depl.) and Adjustments of volume (Adj.).


The underlying factors are changing economic and technological conditions. Thus, it may be concluded that economic conditions are very important whether or not a 'natural item' like iron ore is defined as a resource. New discoveries are concentrated to the 1940's and to the period between the late 1950's and early 1970's. There was also an ore prospecting boom during the late 19th century. In diagram 2 the effects of these developments are shown as sharp increases of the
proven iron ore reserve between about 1900 to about 1918 and between about 1940 and 1960.


Technological change affects both production costs and the quantity of extractable reserves. It is clear that the Norrbotten deposits could be defined as resources largely because of technological advances. Already in the mid 17th century there were small scale mining activities at Junosuando near Kiruna.\(^{51}\) Large-scale extraction of these deposits could not take place before the problems of using high phosphorus ores had been solved by the Thomas process. Also ore transportation and the energy supply were major obstacles for large-scale exploitation of the deposits. The first period during which new mining technology was introduced was about 1890-1910.\(^{52}\) Electricity was first used in Grängesberg in the 1890’s, and in 1915 the great power plant at Porjus was

Iron ore: stock estimates in physical units

built in order to provide the Kiirunavaara mine and the Malmbanan railway with electricity.53 Also pneumatic drilling techniques, bricking and new mining techniques were introduced during this period.

The next phase of introducing new technology occurred during the 1940's.54 New transportation vehicles and diesel-driven drills were in operation. The leading manufacturer of mining machines and equipment in Sweden was Atlas Copco, while Sandviken developed and manufactured hard metal drills. The 1950's and 60's were characterized by further mechanization and rationalization. The reconstruction of Europe after the war, higher growth rates and new consumption patterns contributed to a high demand for steel. Also the transport shipping tonnage increased rapidly, something for which the increasing need for oil tankers played a large role. At the same time steel manufacturing technology was improved, as new techniques like the LD process, large converters with oxygen injection via a lance into the molten iron, and the electric arc furnace became widespread. The prosperous period lasted until the 1970's. In combination with the general economic decline in 1973, the Swedish iron ore mining industry faced severe problems. The last top year was 1974 which was followed by the iron ore market collapse in 1975. This crisis also provided incitements for technological improvement. LKAB launched a product development program which resulted in new pelletizing methods and the introduction of so-called direct reducing pellets and other highly upgraded iron ore products. The production of directly useful ores gradually came to be totally abolished. The automatization of the mining process also developed rapidly during the 80's.

Successful overseas ore prospecting also contributed to the decline of Swedish iron ore mining. On the international scene, numerous new mines were opened during the 1950's and 60's. One example was the Canadian open shaft mine in Knob Lake, which first was mined in 1954.55 In the early 60's new mines were also opened in South America, West Africa and India.56 Australian, Venezuelan and Indian mines were able to operate under very low production costs.57 The South American mines proved to be the most successful. U.S. Steel and Bethlehem Steel Corporation channeled large investments into South America resulting in an increase of the iron ore exports to the European market. The Brazilian mines were open shafts with ores of a very high iron content.58

55 Järnmalmsbrytning i Kanada, LKAB tidningen 1958:3 pp. 8-14.
57 Hellmer, S. Competitive Strength in Iron Ore Production, Department of Business Administration and Social Sciences, Division of Economics, Luleå University of Technology, 1997, Tab 4.5.
One of the most impressive of these deposits was the Carajás mine discovered in 1967.\textsuperscript{59} It consisted of an amazing 18 billion tons of iron ore, but since it was situated in the eastern Amazon, the need for large investments in infrastructure etc. for the Great Carajás Programme delayed the first deliveries from the Carajás mine to the European market until 1985.\textsuperscript{60} The Companhia Vale do Rio Doce (CVRD), which operates the Carajás mine, is presently the leader in the world iron ore market.\textsuperscript{61} Thus, there is a clear connection between the decline of the Swedish economically extractable iron ore reserves and the increase of the reserves from an international perspective.

Another very important trend which affected iron ore costs was the reduction of transatlantic freight rates from the 1950’s.\textsuperscript{62} The main reason was the increased freight ship tonnage based on ship building technology developed during the war.\textsuperscript{63} Transoceanic freights experienced sharper declines in costs than short distance transports. Prices therefore developed in favor of the transoceanic iron ores relative to European ores on the European iron ore market. One consequence was the closing of several mines in, for instance, Germany and France. From the early 60’s the western European iron ore production’s share of consumption fell from about 80\% to 25\% in 90’s.\textsuperscript{64} The general conclusion is therefore that the creation of a world market for iron ore, technological change and foreign iron ore discoveries are more important than depletion and new discoveries in explaining changes in the Swedish proven iron ore reserves.

\begin{footnotes}
\item[63] Two examples are the mass produced U.S. \textit{Liberty} and \textit{Victory} transports.
\item[64] Lundgren (1996).
\end{footnotes}
For table 1 the following data have been used:

1891: Nordenström's investigation recalculated to tons is used and for 1897 Nordenström's revised figures for Central Sweden deposits including the Grängesberg deposit are used. To this figure Gumaelius' estimate for Kiirunavaara and Loussavaara from 1897 is added. The deposits in Gällivare are estimated to 33.6 Mt with a sinking of 100 metres. This figure is added to the former leading to a total of about 326 Mt for 1897. If Nordenström's method based only on deposit areas is used also for the Norrbotten reserves the aggregate figure becomes 314 Mt. Since both methods do produce figures of the same magnitude the choice of method is of less importance.

1910: Tegengren's and Magnusson's estimates published in *Iron ores of the World* are used. The adjustments in Tegengren's publication are marginal but still used for including also 1912 as a benchmark.

1922: The figures from the book *Iron Ore* are used.

1948: The calculations on the deposits in Central Sweden for 1944 are used along with Magnusson's estimate of the Norrbotten deposits from 1948.

1957: The figures in *Sveriges Geologi* are used.

1963: The figures in SOU 1963:36 are used.

1969: The figures in SOU 1969:10 are used.

1972: The figures from the book *Malm i Sverige* are used for the Norrbotten deposits. The estimate of the Central Swedish deposits from 1969 is added to this figure.

1986: The estimates from SOU 1989:93 are used.

1995: LKAB's unofficial sum on the Norrbotten deposits is used. At the time no iron ore mining was conducted in the Central parts of Sweden and therefore estimates of these reserves are not included in the total.

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4. IRON ORE: STOCK ESTIMATES IN MONETARY UNITS. AN ESTIMATE OF THE IRON ORE NET PRICE

Introduction

Since SEEA works with the concept of natural capital, it is necessary to use appropriate valuation methods for estimates of the economic value of the stocks.

In this chapter, the main question concerns methods for natural asset valuation that can be used in EHNA. Of course, the opportunity to make historical valuations of stock and stock changes are crucial for EHNA. Both theoretical relevance, consistence with SEEA/SNA, and the possibility of operationalizing the method, given available historical data, must therefore be considered when a method is finally chosen. In this work, special attention is given to two methods which often have been suggested in the literature. Price series are also estimated and the result is briefly discussed in an economic historical context.

Methods for valuing exhaustible natural resources

As pointed out earlier, several valuation methods have been suggested for environmental accounting purposes. The first one to be considered is the estimation of the present value of expected net proceeds. According to this method the net proceeds of the extractive activity are first calculated. The net proceeds correspond to the gross proceeds minus extraction costs including a normal profit on working capital. The normal profit equals the proceeds which had been gained if the capital had been invested in an alternative economic activity of the same risk class. In estimates of the environmental capital stock, present values are calculated by discounting the expected income flow by a discount rate which reflects the preferences of future versus present incomes and the risk connected with the investment. In the asset accounts, costs of ore prospecting should be deducted from the total stock value.

The second method is the net price method. Here, a net price is calculated as the gross unit price minus the unit extraction costs and a normal unit profit. When estimating the value of the environmental capital stock, the net price is

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1 SEEA, p. 61.
2 SEEA, pp. 60-61.
Iron ore: Stock estimates in monetary units multiplied by the relevant stock of reserves which are expressed as quantities. These stocks are the quantities which are extractable under present economic conditions.

The third method is the user-cost-approach.³ Here the concept of a normal profit is avoided by dividing the income into two parts. The first part represents the ‘true’ income of the mining activity. The second part is the part of the total incomes that has to be reinvested in another economic activity in order to secure the same income when the capital stock is depleted.

A fourth method may also be mentioned, namely the estimation of the present value of expected proceeds. This method was, for instance, used in early national wealth investigations. Here, only the unit extraction costs are considered when the net price is estimated. The net price then corresponds to the unit net-operating surplus. The method has also been used by Repetto et al in an investigation concerning extractive activities in Indonesia.⁴ In the investigation, a net price is calculated by deducting unit extraction costs from the gross unit price. Thus, the capital cost does not enter the calculation. This simplified unit price is then multiplied by the relevant physical quantity of the natural resource stock and by extraction in physical units in order to obtain stock values and depreciation costs.

The net price method and the Hotelling rule

The net price method is based on the so called Hotelling rent, which is a well-known concept among resource economists. It was introduced by Harold Hotelling in the 1930’s as his contribution to the debate on saving scarce natural resources for the future.⁵ Hotelling argued that under perfect market conditions, the depletion rate would be optimal in respect to the mix of present and future consumption. He viewed a scarce natural resource as an asset, when lying untapped underground. After extraction it was seen as an ordinary good. Thus, Hotelling considered both the asset market and the goods market as relevant for the natural resource price formation. The Hotelling rent concept is based on the premise that the price of the extracted natural resource, under conditions of perfect competition on the asset and goods markets, does not


equal the marginal extraction cost if the resource is scarce. The Hotelling rent is therefore equal to the profit on the marginal extracted resource. This may be contrasted with ordinary production in neo-classical economic theory. Here, the price is assumed to equal the marginal production cost in perfectly competitive markets.

Thus, for an exhaustible and scarce natural resource, the price also includes a scarcity or a Hotelling rent. Owning a mine means that capital is bound in the asset. Capital does, however, have alternative uses. The mine could be sold and the capital could be invested in an alternative asset. That would be a reasonable strategy if the other asset yields a higher return on capital at the same risk level. To hold capital in a natural resource therefore implies that it must yield a return on the invested capital. In other words it has to yield a rent. If it does not, the natural resource is not scarce and will not have an economic value. Everybody who wants it, may have it for free. This does of course not mean that extractive industries based on the utilization of a non-scarce natural resource do not yield a profit or contribute to value added.

A natural resource asset in itself can only yield a rate of return by appreciating in value. The returns from mining activities, if the Hotelling rent is deducted, is a return on produced capital, like buildings and machinery.

If investors are to hold natural resource assets, the rate of appreciation of the asset must, according to the Hotelling rule, equal the rate of return on other investments of the same risk class. In the case of a lower rate of appreciation, investors will not be interested in holding the asset. Facing the choice of mining today or saving the asset for tomorrow, the investors will choose to increase mining. This means that depletion causes the resource to become increasingly scarce, causing the Hotelling rent to rise. The asset market for the natural resource in question clears when the rate of appreciation has been brought up to the same rate of return as for other capital assets. In other words, the Hotelling rent represents income earned on the marginal unit extracted at the expense of reduced value of the asset.

The Hotelling rent can be written;

$$R = P - MC$$

where R is the Hotelling rent, P is the final price and MC is the marginal extraction cost.

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Solow presented an illuminating example of the scarcity rent by letting a mine owner look down an empty mining shaft yelling "what have you done for me lately". The answer is that the mine’s value has risen if the metal in it has recently become more scarce. This occurs if other mines have been depleted in such a way that the Hotelling rent—or scarcity rent—has grown at a compound rate. This is referred to as the Hotelling rule.

The Hotelling rule does not imply that final prices of natural resources always grow at a compound rate. The final price also includes production and refinement costs. It is likely that these costs form the lion’s share of the final price. Due to technological advance, but also due to new discoveries, the production costs may fall. If the production costs form a large proportion of the final price and at the same time is falling, the final price may fall at the same time as the Hotelling rent is rising. In the long run, the exponentially growing Hotelling rent will form an ever larger fraction of the final prices. Since production costs theoretically only can fall to zero the Hotelling rent will sooner or later come to dominate the final prices.

The final gross unit price of a transported and refined natural resource (actually a raw material) can be seen as an approximation of the sum of its scarcity rent and its extraction, refinement and transportation costs. Thus, the scarcity rent is the gross market unit price minus the marginal unit extraction cost. This means that the market price of a resource is not necessarily a good scarcity indicator. As pointed out above, the market price may fall while the net price is rising, if at the same time extraction costs are falling, and the scarcity rent is not too large a proportion of the market price. Partha Dasgupta therefore conceives the scarcity rent as a fraction of extraction costs, as an appropriate index of resource scarcity. However, what has been calculated is still only an approximation of the Hotelling rent. First, a normal profit on working capital should be deducted. This is because the investment in working capital which is necessary for mining is expected to earn a normal dividend. Second, since marginal extraction costs are a fundamental part of this approach and since data usually concerns average costs, it is extremely difficult to operationalize this approach in a way which is strictly correct from a theoretical point of view. A production cost function (from which the marginal cost can be calculated) for the Swedish iron ore industry proved impossible to establish. This is probably due to the fact that different producers face different production cost functions and the impact of changing external conditions on, for instance, factor markets.

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8 A famous investigation concerning market prices and extraction costs was done in Barnet, M.J./ Morse, C. *Scarcity and Growth. The Economics of Natural Resource Availability*, Maryland 1963.
Critical Assessment: The net price method

The expected bias when average extraction costs instead of marginal production costs are used is that the Hotelling rent becomes exaggerated. It is, however, always impossible to know by how much the estimated net price differs from the true Hotelling rent. Another practical problem concerns the calculation of the normal profit. It is a reasonable assumption that the scarcity rent for iron ore is small. The world resources total 800 billion tons of which 230 billion are considered to be economically exploitable.10 Concerning estimates of the normal profit, Statistics Sweden (SCB) calculates it as equal to the proceeds from all working capital in the private sector of the economy.11 The national accounts’ operating surplus for the mines minus the normal profit then approximates the scarcity rent. In practice this means that the scarcity rent for Swedish iron ore mines in most years during the 1980’s was negative. It should also be observed that the risk premium may be higher in the mining industry compared to other sectors due to the high sensitivity of the business cycle. Also, markets are usually not characterized by free competition. For example, cartels and government interventions, including subsidies and operation of state-owned companies operating at an economic loss, are commonplace among mineral extraction activities.

It is not fully clear if the SCB method, which basically is adopted also in the present computation, actually encompass the scarcity rent. It may also be a Ricardian type of differential rent and/or a monopoly rent—or a combination of the three types of rent—that is operationalized. Both the Ricardian rent and a monopoly rent are ultimately caused by the heterogeneous distribution of natural resources. Since the Ricardian rent and the monopoly rent per definition are perpetual (they are not compensations for depletion) they should not be used for estimating depletion costs. However, if the rent in extractive industries is caused by other factors than depletion-induced scarcity (e.g. a monopoly rent) it is far from certain that it can be used in order to estimate depletion costs in the national accounts.

A practical problem is that the present Swedish HNA do not provide capital accounts or income accounts. Therefore it is not possible to calculate the normal profit on capital in the economy or even industry as a whole. Hence, approximations must be used.

10 http://www.rnp.br/english/1.5.2.4E.html#245, (1998-09-13)
The problem of finding an appropriate interest rate

The method based on the present value of expected net proceeds has in common with the net price method the problem of estimating the normal profit. An additional difficulty lies in choosing an appropriate rate of interest when discounting the expected net income. This problem is also present in the user cost approach. Discounting is not directly performed in the net price method. Here, the interest rate is assumed to be directly taken into account when the Hotelling rent is formed.

With respect to the choice of an interest rate economic theory can not give any guidelines. Asking the question 'what rate of discount should be adopted' is, according to Martinez-Alier, equivalent to asking which weight should those actors already born give to the demand of those not born, against the rule that all are entitled to come to the market with their preferences and goods. Some critics have therefore stated that the discounting procedure is not appropriate at all when applied on a macro level. The arguments are worth examining. The first objection has already been mentioned, namely that economic agents in the present can not bid on future markets and vice versa. Another, is the fact that depletion –or other major environmental catastrophes such as global warming– may affect the production capacity of the economy. If so, the costs for restoring a damaged asset may be extreme, or even infinite if restoration was impossible, as compared with the costs that would occur if the production capacity was intact. Also it is basically only consequences which affect the production capacity which are relevant when sustainable development, or growth, is discussed. In conclusion there is nothing that says that future relative prices will be the same as today's. Along these lines Herman E. Daly states that if a discounting procedure is to be adopted when considering depletion, it is reasonable to expect rising prices for the mineral in question. However, this reasoning is also based on an assumption, namely that depletion will have consequences for the economy's production capacity. Due to the possibilities imposed by substitution this does not have to be true. Both ways of looking at the problem may therefore be in line with present knowledge. Actually this problem boils down to one question to which there is no answer: will it be possible to find a substitute for the depleted resource?

What should be kept in mind is that economic values are reflections of the economic actors' subjective values and preferences. A quest for an objective economic or other social scientific measure of the state of the environment is

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13 Georgescu-Roegen proposed a zero rate of discount, arguing that the choice of interest rate was a question for institutional rather than analytical economics. Martinez-Alier (1987) p. 169.
therefore doomed to fail. Analogous to this is the fact that, natural scientific approaches cannot tell us anything about how to choose between conflicting goals. As I see it, neo-classical approaches are suitable when the center of interest is a better understanding of how value is created in the economy. Neo-classical approaches are also useful for studying how the environment is subjectively valued in relation to other goods and services and also, through the interest rate, how the present is valued in relation to the future.

**El Serafy’s User-Cost-Approach**

Both the net price method and the present value of expected future returns suggest that depletion costs should be considered as depreciation of capital.\(^\text{14}\) Thus it may be used to adjust NNP while GDP remains unaffected according to the SNA and SEEA guidelines. The conceptual point of departure for the approach is that natural resources can be substituted by man-made capital. In practice the net prices have often been estimated by subtracting production costs from the final prices.

Salah El Serafy rejects methods aimed at primarily adjusting NNP for two reasons. First, he claims that it is wrong to treat extractive activity as value added when it is not. The point is that it will not do to adjust NNP, if GDP is calculated incorrectly. This happens, according to El Serafy, if revenues from extractive activities are counted totally as income. The other objection is based on practical reasoning. A country with large deposits of, for instance, oil is *de facto* usually better off than a similar country which does not have oil exports. This is the probable result if for instance living standards are examined. El Serafy says that this also should be reflected in the income level of the countries. If the depreciation method is used this means that the net income from exhaustible assets is always zero. Concerning a country whose income is totally based on exhaustibles, the national accounts would show a GDP of, say, 100 monetary units and a NNP of zero. The approach would therefore not show any advantage at all for the country with large exhaustible assets in comparison with the country which lacks resources of the kind.

In SNA93 the proceeds from for example mining are treated as an income stream even though it depreciates some of the capital which generate the proceeds. In this context it is important to make a distinction between assets and incomes. If the capital is depreciated the proceeds can not entirely be treated as income. This is the basics behind the user-cost-approach.

The method aims at estimating the "true" income from exhaustible assets. An advantage with the approach is that the complicated calculation of normal profits can be avoided. Negative net prices can also be avoided. Since the

\(^{14}\) El Serafy (1989) and (1991)
approach implies that the use of natural resources is intermediate consumption, GDP is directly adjusted when value added is lowered. The approach is therefore inconsistent with SNA93 and SEEA.

Mineral deposits are to be considered as assets. If they are sold no value added is created by them. Such transactions do therefore not affect GDP. On the contrary, a transaction of mined minerals generates income which can be spent in different ways, either as consumption, investments or a combination of both. The proceeds are therefore net of extraction costs.

If the owner of the asset does not wish to spend more than his income in the long run, he must reinvest some part of the proceeds in order to secure the same income stream when the natural asset is depleted. It is therefore important to specify the part of the income which may be consumed and the part which has to be reinvested.

The fraction of the proceeds which is to be regarded as "true" income is given by the following formula:

\[ R - X = R \left( \frac{1}{1 + r} \right)^{n+1} \]

where \( X \) is the true income, \( R \) is total proceeds, \( r \) is the interest rate and \( n \) is the number of years in which the asset is expected to generate incomes. \( R - X \) is then the part of the proceeds which has to be reinvested, here called the depletion component.\(^{15}\)

The depletion component should not be part of GDP. Accordingly it must be seen as intermediate consumption. Therefore, the user-cost-approach also requires an extended production boundary as compared to SNA-93/SEEA. This additional sector could be described as the natural sector. In order to really adjust GDP it is necessary to calculate the natural sector's value added as zero. Therefore the natural sector's inputs must be imputed to equal the sector's production value. These inputs can not have corresponding balancing accounts which implies that the approach is inconsistent with SNA93.

For using the user-cost-approach the reserves to extraction ratio must be known and, as seen in previous chapter there are only uncertain figures on this ratio. It is also necessary to adopt an appropriate interest rate.

Critical assessments: The user-cost-approach

The user-cost-approach imposes problems of theoretical and practical nature. First, an appropriate discount rate has to be chosen. As pointed out in above, economic theory can not provide an objectively correct discount rate. However,

\(^{15}\) Hartwick/Hageman (1990) p. 233.
it has been suggested that the long-term GDP/capita growth rate should be regarded as the appropriate interest rate for long-term discounting on a macro economic level.\textsuperscript{16}

Second, the user cost approach requires that the extraction to reserves ratio must be estimated. The stock estimates in the previous chapter together with extraction data makes such an estimate possible. It should be realized that the margin of error in these estimates may be substantial.

Third, as discussed above the user cost approach is not consistent with SNA accounting practices. Needless to say, this is a major complication.

Additional methods and approaches

In the U.S.A., The Bureau of Economic Analysis (BEA) has conducted initial estimates for natural resource accounting.\textsuperscript{17} In the BEA work, several methods have been used for valuing resource stocks, depletion and additions to stocks. It is worth noticing that the user-cost method has not been used since it is not compatible with traditional SNA concepts. In short BEA use the following methods:

\textit{The current rent method I} is an operationalization of the Hotelling rule. Basically, the method corresponds to the net price method discussed above. In the BEA estimates a constant normal rate of return is approximated to 6\% for the whole period. Further, all estimates are constant-dollar estimates. In resource accounting this implies that the natural resource rent is calculated for a base year.

\textit{The current rent method II} is based on the Hotelling rule. Here, a unit gross revenue is estimated by division of the gross revenue with the quantity extracted during the year. Subsequently, a value of the proven reserves (including fixed capital) is estimated by multiplication of the unit gross rent and the proven reserves. The value of the resource stock is subsequently estimated as the residual of the value of the proven reserves less the net stock of capital valued at current replacement cost. The resource rent per unit is obtained by the division of the total value with the proven reserves. The advantage of this method is that it avoids estimates or assumptions of return on invested capital. The major disadvantage is that it requires uncertain estimates of proven


reserves in order to obtain the resource rent per unit. This method would also be possible to utilize in EHNA.

**The net present discounted value method** is based on the assumption that the resource rent does not rise enough to compensate the owners of the resource for the nominal interest rate they could earn on other investments. Therefore, the stream of future rents is discounted by the difference between the rate of increase in resource rent and the nominal interest rate. The drawbacks are that also this method requires the use of proven reserves in the estimates and that the real interest rate (actual less increase rate of the Hotelling rent) must be assumed. Its main advantage is that the method does not dependent on the assumption that the natural resource rent rises at the same rate as other rents. Also the net present discounted value method can be used in EHNA, but since it is hard to determine the difference between the different types of rents, estimates are not performed in this work.

**The replacement cost method** is based on subtracting from the gross rent the unit cost of adding new reserves. The method is foremost compatible with the avoidance cost approach in SEEA IV.2. Thus, the resource rent is obtained as a residual. From an EHNA perspective, the method is hard to operationalize due to insufficient data on the cost for ore prospecting.

**Transaction-price** estimates are based on prices paid in actual transactions. This is probably the best valuation method from a theoretical point of view since it is a direct market price. Unfortunately, transactions of deposits in Sweden are very rare and have (for instance the state acquisition of LKAB from TGO) been heavily influenced by heterogeneous distribution of negotiation power between the parties.

**Concluding remarks on the valuation methods**

A valuation method to be used for EHNA purposes must be compatible with SNA93. In other cases the linkage of EHNA to HNA becomes problematic. The user cost approach does not meet these conditions and the replacement cost and transaction price methods can not be supported by historical data. Thus it may be concluded that the net price method and the present value of expected net proceeds are the methods which can be utilized in EHNA. In this work, the net price method has been chosen since it is relatively easy to operationalize.
Calculation of iron ore net prices: the net price method

When the net price method is utilized all costs which are associated with mining should be included. This includes depreciation of capital and capital costs. A basic data source is therefore the mining companies’ annual financial reports. Swedish iron ore mining has during the 20th century been dominated by two major owners, Trafikbolaget Grängesberg-Oxelösund (TGO) and the state. The leading iron ore producer has been Luossavaara Kiirunavaara AB (LKAB). In this investigation the economic results of LKAB have formed the point of departure.

Concerning natural resources some basic features may be worth noticing. First, if there is a natural resource rent the profit rate on capital is higher than for alternative investments of the same risk class. To gain control over the scarcity rent is therefore a desirable goal for all economic actors including the state. In practice the property right of the scarcity rent has been the object of substantial struggle at least in Sweden between the state and private interests.

In order to correctly evaluate the economic results in the iron ore mining industry it is important to know the ownership structures as well as some institutional arrangements, since these may directly have affected the profit rates. To estimate the true profit some alteration may then have to be made. In other words, since LKAB’s economic results form the basis for substantial parts of the investigation, it is important to examine how different institutional arrangements may have affected the company’s results in a manner which may be suspected to differ from other companies.

Thus, the royalties for iron ore extraction paid by LKAB to the state has been added to the net profits. This is also the case concerning the payments to the Swedish State railways (Statens järnvägar, SJ) that LKAB made in order to secure a desired profit on capital invested in Malmbanan (The Luleå - Narvik railway line). This is motivated since no other companies were forced to conduct payments on similar terms, and since Malmbanan has been more profitable than other parts of the Swedish railway system.18

The net proceed is approximated as the net profit less a normal profit on working capital. Thereafter, a unit net price is obtained by dividing by the extracted iron ore. The normal profit rate is of course hard to estimate. SCB data on the rate of return on working capital is available from 1970 and onwards.19 From the 1920’s there are estimates of returns as a percentage of gross income.20 These estimates are insufficient since what is really desired is

an estimate of the normal yield of capital. If there is a significant scarcity rent in iron ore mining it will also form part of the total income. It has therefore been essential to estimate historical returns on capital, both for LKAB and for other companies.

To start with, the yearly percentage changes of the total stock values at Stockholm stock exchange\textsuperscript{21} were checked against the SCB figures for return on both total and working capital during the period 1970-90.\textsuperscript{22} The correlation was judged not to be good enough to allow extrapolation of returns on capital on basis of historical stock market data.

Instead a more time consuming but probably more reliable method was used for estimating returns on total capital. A number of Swedish companies was examined from the 1920’s and onwards with respect to their balance-sheet total and net profits.\textsuperscript{23} As is well known, the praxis for companies’ financial accounts has changed over time. This concerns profit and loss accounts as well as balance sheets. On the basis of the profit and loss accounts, the item result after financial net is a fairly new phenomenon. As an approximation the proceeds are instead estimated as the net profit before paid taxes. With respect to the balance sheets it has not been possible to obtain estimates of working capital. The profit rate, which automatically is weighted, is therefore estimated on the basis of total capital given by the balance sheet total. Concerning the examined companies a strong emphasis has been given to industrial enterprises in foremost the export sector. Hopefully, this reflects a risk, and thus a risk premium, which is similar to that of the iron ore industry. Table 1 shows the companies and their respective share of total capital in 1956.

For the period from 1860 to 1913 data on return on total capital has been obtained from an investigation made by Torsten Gårdlund.\textsuperscript{24} Thus Gårdlund’s series\textsuperscript{25} together with the series obtained from the present investigation and SCB’s series from 1970\textsuperscript{26} mean that a total series for returns on total capital can be obtained from 1860 to the present. The linkages were done without level adjustments. Due to lack of appropriate data, the period 1913-1924 has been interpolated with Åberg’s figures on the capital volume in the Swedish industry.\textsuperscript{27} Here, the capital volume has simply been indexed with 1913=1. The index has subsequently been linked to the return on capital the same year. The

\begin{itemize}
\item \textsuperscript{22} Näringslivets ekonomifakta. Faktapärm 1996-12-18. Tab 3.13
\item \textsuperscript{23} Data have been collected from the periodical \textit{Svenska Aktiebolag}
\item \textsuperscript{24} Gårdlund, T \textit{Svensk industrifinansiering under genombrottsskedet 1830-1913}, Stockholm 1947, pp. 267-278.
\item \textsuperscript{25} Gårdlund (1947) pp 267-278.
\item \textsuperscript{26} Näringslivets ekonomifakta. Faktapärm 1996-12-18. Tab 3.13
\item \textsuperscript{27} Åberg, Y. \textit{Produktion och produktivitet i Sverige 1861-1965}. IUI, Stockhom, 1969, tab B:6.
\end{itemize}
linkage 1923/24 is done without level adjustments. The development of the normal profit is shown in Diagram 1.

Table 1. The reference group of enterprises. Data for 1956

<table>
<thead>
<tr>
<th>Company</th>
<th>Main Object of Company</th>
<th>Share of total capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allmänna Svenska Elektriska AB (ASEA)</td>
<td>Electric engineering</td>
<td>10.4</td>
</tr>
<tr>
<td>AB Atlas Diesel/Atlas Copco</td>
<td>Turbines/Compressed air</td>
<td>1.9</td>
</tr>
<tr>
<td>Svenska Amerika Linjen</td>
<td>Shipping</td>
<td>1.9</td>
</tr>
<tr>
<td>Billeruds AB</td>
<td>Pulp and paper</td>
<td>3.4</td>
</tr>
<tr>
<td>AB Bofors</td>
<td>Armament</td>
<td>8.4</td>
</tr>
<tr>
<td>AB Elektrolux</td>
<td>Household electr.equip.</td>
<td>3.8</td>
</tr>
<tr>
<td>Telefon AB L.M. Ericsson</td>
<td>Telephones/Switchboards</td>
<td>7.6</td>
</tr>
<tr>
<td>Svenska AB Gas Accumulator (AGA)</td>
<td>Gas</td>
<td>1.9</td>
</tr>
<tr>
<td>Gäfle-Dala Järnvägs AB</td>
<td>Railway</td>
<td>0</td>
</tr>
<tr>
<td>Höganäs-Billesholms AB</td>
<td>Coal and clay products</td>
<td>1.9</td>
</tr>
<tr>
<td>AB Investor</td>
<td>Investment in industries</td>
<td>1.4</td>
</tr>
<tr>
<td>Kopparfors AB</td>
<td>Saw mills, Pulp/paper</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Korsnäs Sågverks AB/Korsnäs-Marma</td>
<td>Saw mills, Pulp/paper</td>
<td>3.4</td>
</tr>
<tr>
<td>AB Nordiska kompaniet</td>
<td>Retail</td>
<td>1.6</td>
</tr>
<tr>
<td>AB Pripp&amp;Lyckholm/Prippbryggeriema</td>
<td>Breweries</td>
<td>1.2</td>
</tr>
<tr>
<td>Sandvikens Jernverks AB</td>
<td>Iron and steel</td>
<td>3.5</td>
</tr>
<tr>
<td>AB Separator/Alfa Laval</td>
<td>Dairy equipment</td>
<td>3.3</td>
</tr>
<tr>
<td>Skånska Cement AB</td>
<td>Concrete</td>
<td>2.6</td>
</tr>
<tr>
<td>Stora Kopparberg</td>
<td>Copper/pulp and paper</td>
<td>8.2</td>
</tr>
<tr>
<td>AB Svenska Kullager Fabriken (SKF)</td>
<td>Ball bearings</td>
<td>8.3</td>
</tr>
<tr>
<td>Svenska Sockerfabriks AB (SSA)</td>
<td>Sugar</td>
<td>3.9</td>
</tr>
<tr>
<td>Svenska Aeroplan AB (SAAB)</td>
<td>Aircraft/automobiles</td>
<td>4.2</td>
</tr>
<tr>
<td>Volvo</td>
<td>Automobiles</td>
<td>10.7</td>
</tr>
<tr>
<td>Uddeholms AB</td>
<td>Iron,paper,pulp.chemical</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Source: Svenska Aktiebolag
Diagram 1. The normal profit rate. Return on total capital. Sweden 1890-1990


Iron ore production data 1800-1990

One basic data series in this investigation is extracted iron ore expressed in tons. It is based on Lennart Schön’s estimates from 1800 to 1871. Thereafter, data is taken from the official statistics series in BiSOS and SOS. Generally speaking, the reliability of the series must be considered as very high. Conceptually, it expresses the quantitative flow of iron ore resources from the environmental sector to the economy.

The net price 1889 - 1990

The calculation of iron ore net prices between 1889-1913 is based on an investigation by Martin Fritz and the already mentioned study made by Torsten Gårdlund. Fritz presents rates of return on paid-up capital for the iron ore exporting companies during the period. Thus, the rate by which the returns

29 BiSOS Bergshantering and SOS Bergshantering.  
in the iron ore export industry supersedes the returns in the Gårdlund companies can easily be calculated. The net price is then arrived at as iron ore industries’ profit per ton less the normal profit which would have been obtained if the profit ratio had been the same as for the companies included in Gårdlund’s study. Subsequently, the unit net price is obtained on the basis of the quantity of mined iron by the respective companies.

From 1914 onwards, financial data is solely based on the official financial statistics of LKAB. Unfortunately the gross income is not included until 1935. Between 1951 and 1975 all financial data is taken from the company paper *LKAB-tidningen* and the company’s annual financial reports. During the years 1928, 1932, 1933, 1934 and 1945 the company displayed losses. The same is true for the 1975 to 1983 period. During these years it was not possible to detect a positive iron ore net price. Since a negative scarcity rent would be difficult to interpret, a zero-rent is assumed for these years. The production statistics concerning mined quantities refers to the mines operated by LKAB. These include Kiirunavaara and Gällivare and minor deposits like Luossavaara and Leväniemi.

Basically the same procedure as employed during the 1892 - 1913 period has been used for the period 1913 - 69. Thus, a net income including a normal profit has been estimated for the whole period.

The iron ore rent 1970-90 is calculated on the basis of LKAB financial reports and SCB series of return to total capital in Swedish business life. Positive scarcity rents are only obtained for the earliest and the latest years of the period 1970-90. It should also be mentioned that accounting practices concerning the estimates of total capital were changed in the 1973. In practice this meant that the value of the ore stocks was included as an asset. This means that the profitability of iron ore companies were presented in a slightly more disadvantageous, but perhaps also a more realistic light. New calculations of LKAB’s assets were, however, also made for 1971 and 72.

### The iron ore net price as a percentage of extraction costs

Since the net price reflects scarcity it is interesting to explicitly examine its development. Dasgupta has pointed out that the true scarcity indicator is the scarcity component’s part of total extraction costs. In this work the natural

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31 LKAB financial reports. The reports are kept in the head office in Luleå, and in the old office in Kiruna. The reports are also kept in Patent- och registreringsverket, in Sundsvall.

32 Since the group of companies displayed positive rates of return on capital.

33 *SOS Bergshanteringen*.


resource scarcity component has been operationalized in what has been named the Dasgupta scarcity index. Here, the extraction costs have been calculated as the gross income less the normal profit. Thus, they do not only comprise ordinary production costs including transports, but also depreciation of capital and the capital cost. According to the Hotelling rule, the net rent is expected to rise exponentially over time. However, factors such as interest rate, new finds, and changed extraction costs affect the net price. An obvious question to pursue is whether the net price has undergone such a development. From diagram 2 it can be seen that there probably was a period with exponentially rising net prices from ca 1907 to ca 1952.

Diagram 2. The Dasgupta scarcity indicator (net price/production costs) 1889-1969

Note: the indicator is estimated as: 100 x (net price/(gross price-normal profit-netprice)).

This is particularly clear if the peaks are considered. However, the fluctuations surrounding the possible trend are substantial, and more decisive conclusions require a more sophisticated time series analysis. If the analysis is correct, it suggests that there may be longer periods of increasing scarcity which are offset by increases of the resource base. At the same time, as seen in the previous chapter, other parts of the resource base are redefined as non-resources. This approach is further examined in chapter 6.
was the case with the central Swedish deposits. The new resources were concentrated to other countries in, for instance, South America and Africa. In this context, it would be interesting to investigate the net price from the perspective of the new market leaders, for instance, Brazil or Venezuela.

**Comments and conclusions**

To summarize, a unit iron ore resource price was estimated in this chapter. It was recognized that several valuation approaches exist and that the choice of valuation method affects the result. The net price is an approximation of the iron ore resource rent and the method used was the so called net price method. The choice of this method was motivated by the relative ease by which it may be operationalized and since relevant historical data could be found. The net price was estimated by deducting the unit production cost, including a normal profit on capital from the gross unit price. Thus, the net price made it possible to construct EHNA iron ore accounts in monetary units for the period 1892 to the present. The accounts are shown in the next chapter. It was also noticed that the iron ore net price may in its turn be subject for analysis. This includes for instance the identification of trend periods. A preliminary analysis suggested the presence of longer periods with exponentially rising iron ore net prices.

Also the relation between the net price and factors which theoretically affect the resource rent could be investigated. In the chapter it was pointed out that it is uncertain what the net price actually measures. Besides a Hotelling rent, the net price may also include a monopoly rent and a Ricardian differential rent. This means that also the net price is affected by uncertainties, and that the characterization of EHNA series as interpretations of a historical reality must be stressed. Certainly, the uncertainties call for further investigations. However, this will not be done within this thesis.
5. IRON ORE: INTEGRATING ENVIRONMENTAL AND HISTORICAL NATIONAL ACCOUNTING

Introduction

The full integration of the environmental accounts in the HNA requires a broad approach towards the latter. Additional accounts must be introduced in HNA mainly to allow accounting for consumption of fixed capital. In this work emphasis will be laid on broadening the HNS with explicit iron ore industry accounts by estimating the following entrances:

- Historical gross production values
- Inputs from other sector (use of products) and value added
- Wages to estimate the gross operating surplus at factor prices
- Depreciation to estimate the net value added

Value added estimates for the iron ore industry 1800-1952

The official industrial statistics include value added estimates for the iron ore mining industry from 1952 and onwards. However, iron ore mining is not separately shown in the NA. Instead, iron ore mining is included in Mining and quarrying (ISIC 2000/SNR2000). Total output statistics are included in BiSOS Bergshandteringen and SOS Bergshantering from 1896. Since the iron ore mining industry includes dressing, briquetting and sintering plants, the production value also includes refined products like fines. From 1833, the annual quantities of extracted iron ore are found in the BiSOS mining statistics.

In the Swedish HNA, separate accounts for the iron ore industry have not been established either. In the first Swedish national income investigation (NI), data in current prices were estimated for what is called "the mining sector". It is worth to notice that the reliability of the product value estimates is deemed as being rather uncertain. Furthermore, it is not fully clear what NI actually in-

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1 SOS Industri. Production costs are shown for, among others, the iron ore mining industry.
cluded in this sector, but there is reason to assume that also iron manufacturing was included. The product value of the mining industry according to NI is, for instance 70% of Schön’s gross production value for mining and metal industries (IG 1) in 1870. Thus, it can be concluded that also iron manufacturing was included in NI’s mining sector. Also the comparability between the values in the mining statistics and the NI estimates is restricted. The mining statistics give the value of extracted ores at the mines while NI departures from the export (FOB) prices. In NI, the prices are subsequently divided by the ratio export prices/manufacturing prices in 1896.

In HNS, Schön made new gross production value estimates for the mining industry. The value added estimates were made for the whole branch bergshantering, including mining of other minerals and metal production. For the iron ore industry, a constant value added share of 85% was used for the period 1800-1912. Value added for the period 1913-55 has been constructed as a index for intermediate consumption with weights corresponding to the composition of inputs in 1926. Schön’s new estimates of the iron ore production in physical quantities for the period 1800 to 1870 are in this investigation used for the period 1800-33. The prices which Schön used were obtained from Jörberg.

Value added in the iron ore mining industry 1925-52

In order to estimate value added, the value of inputs from other sectors should be deducted from the gross production value. Concerning quantities of inputs, the available source material is the official statistics, which foremost offers data of used fuels (1925) and electricity (1933). Also the special investigation Sveriges Bergshantering for 1913 provides benchmark estimates of production costs. The earlier mentioned work by Fritz proved to be difficult to use in this context. This is because Fritz only shows production costs, of which wages represents an unknown share. In table 1, the indicators, prices and benchmarks the are summarized.

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4 Lindahl et al. (1937) part 2, p. 185, table 87, and Schön L. HNS. Industri och hantverk, Lund 1988, p. 209, table 11. Note: IG is industry group of HNS. See list of abbreviations.
5 Lindahl et al. (1937) part 2, p. 184-185.
8 SOS Sveriges bergshantering. Specialundersökning av kommerskollegium, Stockholm 1917
Table 1. Summary of indicators used for the value added estimate 1925-1933

<table>
<thead>
<tr>
<th>Input item</th>
<th>Direct data</th>
<th>Indicator</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuels</td>
<td>SOS Industri</td>
<td></td>
<td>Ljungberg, various</td>
</tr>
<tr>
<td>Electricity 1933-52</td>
<td>SOS Industri</td>
<td>Installed horse power. Index 1933=1</td>
<td>Ljungberg, electricity</td>
</tr>
<tr>
<td>Electricity 1925-32</td>
<td>Installed horse power. Index 1933=1</td>
<td>Bench-mark for total cost: 1913</td>
<td></td>
</tr>
<tr>
<td>Repairs</td>
<td>Installed horse power. Index 1913=1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw materials</td>
<td>Tons of Dressing ores, SOS Industri</td>
<td>50% of iron ore price</td>
<td></td>
</tr>
<tr>
<td>Spare parts</td>
<td>Iron ore production, index (1913=1)</td>
<td>Deflator: 50% IG 1, 50% IG 3. (1913=1)</td>
<td>Benchmark for total cost: 1913</td>
</tr>
</tbody>
</table>

Note: For exact references, see text.

In this investigation, fuel costs were calculated on the basis of used quantities of charcoal, coal, coke, fire wood and gas. Data were obtained from the official statistics.\(^{10}\) The prices were obtained from Jonas Ljungberg.\(^ {11}\)

An estimate of repairs costs was made by using the installed motor power as an indicator of the amount of repairs needed. The repair costs were fixed in 1913 with total repair costs according to the special investigation of the mining industry from 1917.\(^ {12}\) Electricity costs were also been estimated on the basis of installed motor power as an indicator. Electricity prices were obtained from Ljungberg.

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\(^{10}\) The gas price is obtained from SOU 1924:32, p. 286.

\(^{11}\) Ljungberg, J. *Priser och marknadskrafter i Sverige 1885 - 1969. En prishistorisk studie*, Lund 1990. For charcoal; P8516 (average prices at the iron works), p. 489-490, for coal; P9166 (gas coal, 1941 interpolated), p. 346 - 347, for coke; P9166, p. 346-347, for fire wood; P0957, p. 275-276. For gas, the price is assumed to equal 0.325 kg coal per m³ gas has been assumed. (SOU 1924:32, p. 286). Thus, the gas price is a shadow price based on the coal price (P9166).

The costs of dynamite were estimated by assuming the same ratio between extracted ore and dynamite costs as in the 1917 investigation.\textsuperscript{13} To estimate the inputs of dynamite, quantities of extracted ore were used as a ‘shadow variable’. Economic quantities were then calculated by applying dynamite prices from Ljunberg.\textsuperscript{14}

The item ‘raw materials’ in Sveriges Bergshantering was assumed to correspond to dressing ores. The price was assumed to equal 50\% of the price for directly useful ores.\textsuperscript{15} Dressing ore input data in tons were obtained from SOS Bergshantering.

Costs for spare parts and other materials were calculated using the costs from 1913 as a bench-mark. The price were constructed as an index (1913=1), in which the industry group indices for metal (IG 1) and wood industries (IG 3) each were given the weights 50\%. As already mentioned, the quantities were extrapolated by applying an index (1913=1) of extracted iron ore.

Added together, this gives a rough estimate of production costs which are dominated by fuels. The value added is then, as already mentioned, obtained by subtracting the total production costs from the gross production value. The linking to the SCB value added series in 1952 is done without adjustment of the series.

**Value added estimates 1896 - 1925**

The possibility to make value added estimates before 1925 is more restricted than for later periods not the least because since fuel inputs are not included in the mining statistics. A input cost index approach was therefore used. Also here, the special investigation from 1917 is used. Therefore, 1913 is used as a bench-mark year and as a base year for the price indices. The weights in the input cost index are shown in table 2. Also here the weights were calculated on basis of the investigation Sveriges Bergshantering.\textsuperscript{16}

\textsuperscript{13} SOS Sveriges bergshantering, Stockholm 1917, table 57, p. 236.
\textsuperscript{14} Ljunberg (1990) Series P8550, p. 489-490.
\textsuperscript{15} Ljunberg (1990) Series P190, p. 341-342.
\textsuperscript{16} SOS Sveriges bergshantering, Stockholm 1917, table 57, p. 236.
Table 2. Input cost index 1896 to 1925

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<tr>
<th>Item</th>
<th>Weight</th>
<th>Price indicator</th>
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<td>Materials</td>
<td>40.3%</td>
<td>50% wood, 50% metal goods</td>
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Value added estimates 1800-1895

Also for the 19th century an input index price approach was chosen. A production cost index was constructed with the following weights: charcoal 1/3, pine wood 1/3 and nails 1/3. Nails were used as an approximation for metal tools etc. The weights are basically conjectures based on previously mentioned production costs in Sveriges bergshantering. The production cost index is linked to the estimated production costs in 1896 and further adjusted by an iron ore production index (Index 1896=1). Thus, the costs of inputs in current prices have been estimated. The iron ore prices were computed by linking Jörberg’s iron ore price series to the estimated unit price in 1896 (ca 4.50 SEK/ton). Thus, production quantities in current prices can be elaborated. Compared to Schön’s estimates, the production series calculated here shows higher values. For 1871 Schön’s unit price is 2.94 SEK per ton, while this investigation concludes a price of 4.83.

Micro-level studies may provide additional information concerning a plausible price level. At the iron manufacturing plants at Västanfors and Fliken, the iron ore cost per ton of pig iron was 12 SEK in 1871.17 If it is assumed that the production of 1 ton of pig iron required 2.15 tons of iron ore18, the unit cost at the furnace would have been ca 5.60 SEK per ton. The corresponding unit cost for the plant Valla was 11 SEK.19 In 1870, the Österby iron ore cost per ton of produced pig iron was 17 SEK, leading to an estimated iron ore unit cost of 6.80 SEK per ton.20 From these figures the transportation cost has to be deducted in order to arrive at the iron ore price at the mine. The plants at Västanfors and Fliken probably faced very low transportation costs, while the distance from Valla to the closest mine (Norberg) was approximately 40 km. Österby is situated close to the Dannemora mine and probably faced low transportation

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17 Attman, A. Fagerstabruks historia. 1800-talet, Uppsala 1957, p. 323.
18 The relation is used by Schön (1988) p. 27.
costs. At the plant at Långshyttan the iron ore cost was very low. If the same estimation method is used, the iron ore price can be estimated to 3.25 SEK. Also at Långshyttan, the transportation distance was short. Although uncertainties are present, like different ore qualities, but also differences in productivity among the different plants, the prices were possibly closer to five than to three SEK per ton in 1871. However, systematic micro-level investigations are needed in order to solve this dilemma.

**Gross operating surplus at factor prices**

The gross operating surplus at factor prices was obtained by deducting compensation of employees from the value added. The first period for which compensation to employees is estimated is 1929 to 1951. For the period, hourly wages as well as hours worked in the iron ore mining industries are obtained from the official statistics from 1929. Thereafter, the total wages are estimated as hours worked multiplied by the hourly wage. Linking these figures to the statistics in 1952 is not unproblematic since the estimated wage cost is approximately 30% too low. The wage series has therefore been multiplied by 1.3. A check of the reliability of the linking was conducted by examining the wage share of value added, which for the critical years 1951/52 fail to show any aberrations. Therefore, it can be concluded that the linking is acceptable. For the period 1914-1929 the compensation to employees was estimated by multiplying the number of workers by the annual wages obtained from Björklund/Stenlund. The series have subsequently been linked to the wage series in 1929. For the period 1889-1914 the gross operating surplus was directly estimated on basis of Martin Fritz’ figures. The unit profit per ton before depreciation was multiplied by the mined iron ore. This figure was then deducted from the previously gross production value in order to approximate the wage cost. This series corresponds neatly with the other wage series and no further adjustments was made.

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21 Worked hours from 1920 (SOS *Industri*) and hourly wages from 1929 (SOS *Lönestatistisk årsbok*).

22 The wages includes over-time, piece wages, and later when that was introduced holiday wages.

Consumption of fixed capital

Consumption of fixed capital is estimated for the whole economy for the period 1950-68 and for separate industry branches for the period 1968-88 in the national accounts. For the periods in which data for the capital consumption is provided for the entire business community it is assumed that the ratio of capital depreciation to value added has been the same in the mining industry. Depreciation was therefore estimated on the basis of this ratio and value added. For the periods in which depreciation is shown for separate branches, a similar assumption was made, with the difference that the figures now concern mining industries (which include other mines than iron ore mines). For the period 1889-1914, depreciation is directly calculated as the residual of Fritz' figures for unit profits before and after depreciation. Total depreciation was estimated as the product of the unit depreciation cost and total iron ore extraction. Between 1914 and 1952 depreciation is modeled after the total value of installed motor power in the iron ore industry. Thus, motor power is assumed to approximate the real capital stock in fixed prices. To obtain current prices Ljungberg’s index for electrical motors (transformed to 1913=1) was applied to the installed motor power. Unfortunately, the procedure leads to an underestimate of the real depreciation in 1952. Therefore, the series was further adjusted with a positive linear trend constructed in order to make a smooth linking of the series in 1952 possible.

Comments and Conclusions

In order to establish a linking between HNA and EHNA, the traditional HNA have to be made more detailed. Therefore, the value added for the iron ore industry was calculated for the period 1800 to 1952, when SOS started to show production costs for the iron ore mining industry. Certainly, the estimates for primarily the period 1800 - 1869 are uncertain. One reason is that constant weights had to be used in the input index. The estimates for the subsequent period are probably rather reliable. This is indicated by the unproblematic linking to the SCB figures. From 1893 additional HNA entries have been constructed. Thus, the value added was divided on compensation to the traditional production factors, labor and capital in a first step. The reliability is probably similar to the bulk of HNA estimates. Furthermore, consumption of fixed capital was calculated. Thus, the net value added for the iron ore industry was obtained. From this, the costs for use of non-produced capital, iron ore,

24 SCB, Nationalräkenskaperna.
could be deducted. These costs correspond to the depletion costs of iron ore—the eco-margin—which originally were recorded in the extended asset account of EHNA. Thus, the iron ore mining industry’s eco-value added was obtained. Still, explicit accounts for fixed capital are missing. Also, degradation costs caused by iron ore mining were not included in the estimates.

**EHNA IRON ORE ACCOUNTS**

**TABLE 1. STOCK CHANGES, SUBSOIL ASSETS, IRON ORE**

(CNFA 2.1.1.3.)

Sweden 1893-1988, Current prices, mill SEK, net-price method

Note: rows 2-7 are entries in the extended capital account of SEEA/EHNA.

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<th>New discoveries</th>
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<th>Adjustment of volume</th>
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Source: own estimates

**TABLE 2. IRON ORE INDUSTRY. PRODUCTION AND DISTRIBUTION OF INCOME.**


Note: rows 6 and 7 are SEEA/EHNA entries.

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Iron ore: Integrating Environmental and Historical National Accounting

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1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954

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749,03

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625,38

Compen­ Gross
Eco-value EcoNet value
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margin
added
employees surplus
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Source: SCB national accounts, own estimates

Eco-margin estimated by net-price method, Current million SEK
### TABLE 3. IRON ORE INDUSTRY. GROSS PRODUCTION VALUE, VALUE ADDED, INPUTS FROM OTHER SECTORS 1800-1888

<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Production Value</th>
<th>Value Added</th>
<th>Inputs from other sectors</th>
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<tr>
<td>1800</td>
<td>286.6</td>
<td>246.5</td>
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<td>232.1</td>
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<td>1840</td>
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6. TIMBER: ESTIMATES OF CHANGES IN THE SWEDISH STANDING TIMBER VOLUME

Introduction

Throughout the history of Sweden, forests and forest-related products have played an important economic role. Therefore, it is obvious that standing timber should be included in EHNA for Sweden. Forests were, and still are, an important part of the Swedish economy's natural resource base. Starting in the 1840's, sawmills came to play an increasingly important role in the Swedish exports and, accordingly, in the Swedish industrialization process. Around the end of the century the role of sawmills diminished as the forest industry became increasingly dominated by the paper and pulp industries. The latter are major contributors to the country's total current export value. Furthermore, iron and steel were export goods with an even longer tradition on the export market. Already during the Middle Ages, Swedish Osmund iron was known on the Continent. Fuel, either firewood or charcoal was used during practically every stage of iron manufacturing, from extraction of iron ore to pig iron processing and finished metal products. Early iron manufacturing therefore depended as well on timber as on iron ore. But the forests were also of major importance in household production and consumption. Wood was used for all kinds of construction purposes and provided the necessary fuel for heating. Many agricultural supplementary activities also depended upon the raw materials supplied by the forest. Brick, tar and potash production may be mentioned in this respect. Forests were also used as grazing for cattle, goat and sheep. In addition woodlands served as a habitat for wild game, like moose, and provided a rich source of berries. Both of these were important dietary supplements. Beside these 'user values' forests have also been, perhaps more so lately, cherished for recreational purposes.

Structure of the timber section

The timber section is divided into two chapters. The first is aimed primarily at estimating the standing timber volume in physical units, while the following chapter's main objective is the estimation of a net unit price. In the present chapter, an overview of the accounting principles used in SNA and

SEEA for timber in forests is first provided. This serves to decide how timber in forests should be treated in EHNA. Certain problems relating to proper definitions etc., are also discussed. Estimates of physical stock changes regarding the standing timber volume are performed in the second part of the chapter. The estimates focus on the period 1800-1925. The reason for this is that there are no national forest surveys for this period. For the post-1925 period, the national forest surveys are the basis for the estimates. Needless to say, several important environmental features of forests are exempted from analysis. Wild animals and recreational values are for instance excluded. In the following chapter, environmental historical accounts for depletion and other stock changes concerning the Swedish standing timber volumes are established. As in the case of iron ore reserves, both depletion costs and the total stock value is estimated.

Methodological notes

A forest is a complex and dynamic eco-system, in which changes often elude full comprehension. This means that a reliable model of the changes in the standing timber volume requires that significant factors affecting forest growth are recognized, that they may be quantified for historical time and that their effects on forest growth is known. Factors which affect the standing timber volume are for instance cutting regimes, fire regimes, activities such as cattle grazing, climatic factors, agriculture, etc.

This investigation aims at constructing a forest growth model which may suit the needs for economic historical generalization, but perhaps not, natural scientific demands on accuracy. However, and this should be made very clear, a simplified method as the one used here, only provides a tool for qualified guessing since it does not capture the real mechanisms behind changing standing timber volumes.

The method used in this chapter is the following:

First, some earlier estimates of the Swedish standing timber volume are examined in order to find out whether there is any correlation between these changes and available estimates on logging.

Second, the depletion data and stock estimates form the point of departure for an estimate of the standing timber volume from 1800 until 1925. This simple model is then evaluated, and finally complemented with additional assumptions in order to improve its creditability.
Accounting principles in SNA93, SEEA and EHNA

When trying to establish forest accounts, it is important to consider that a forest includes a great variety of resources. In SEEA the forest, as it is generally thought of from a common sense perspective, is comprised of several types of assets. These include forest land, wild plants, wild animals and trees in cultivated and uncultivated forests. Forest land is assumed to include ecosystems and soil.

The basic procedure for handling timber in forests resembles that in handling other natural resources. As for other natural assets, the accounting system comprises extended capital accounts in which stock changes due to depletion are imputed to the production account. In the capital accounts opening stocks along with net natural growth and extraction are shown as well as closing stocks. The closing stock is equal to the next accounting year's opening stock. Net natural growth less extraction might be either positive or negative, indicating positive or negative capital formation.

Forests in SNA-93

Trees in cultivated forests are in SNA recorded as assets in the capital account. Trees that are used repeatedly over periods of time of more than one year in order to produce goods or services are recorded as fixed assets. Assets are defined as entities:

a/ over which ownership rights are enforced by institutional units, individually or collectively

and

b/ from which economic benefits may be derived by their owners by holding them, or using them, over a period of time.2

An example of a fixed growing asset is fruit trees, a category which is not included in this study, since forestry is economically more important in Sweden. Horticulture is however a special category in Swedish HNA, and, items from this should in principle be included in the stock of non-financial assets, too. An increase of this capital category is recorded as capital formation, and reduction as consumption of fixed capital.

2 SNA93, 10.2.
Trees grown for timber that yield a finished product only once, which happens when the tree is felled, are not fixed assets. Instead, these so called single use plants are treated as work-in-progress. Work-in-progress is production which is not yet finished. Conceptually, timber trees are regarded as a growing crop.

The growth of trees, crops, etc. constitutes a process of production if it is controlled, organized and managed by institutional units. Since growing trees by definition are not yet sufficiently processed to be marketed they are— as stated above— treated as work-in-progress. The production process is completed when the tree is felled. Then the work-in-progress is transformed to inventories or products of industries.

Output in forestry is therefore measured as the value of sales plus changes in inventories, including additions to work-in-progress. Additions to work-in-progress in forestry should therefore be included in the calculation of GDP also in HNA. Finally, it should be observed that it is necessary to record the reduction of work-in-progress when the production process is finished. Otherwise, output would be recorded twice. Thus, the negative figure for the reduction of work-in-progress cancels out the value of sold finished products or additions to inventories.

### Forests in SEEA

In SEEA the asset boundary is extended in comparison with the asset boundary in SNA. Capital formation in SNA is also replaced by the broader concept of capital accumulation, which includes both produced and non-produced capital. In SNA93 assets are included as long as they provide economic benefit to the owner. This is considered to be manifested by control through institutional units. Trees of an uncultivated forests, which are not controlled assets, are therefore excluded from SNA93, but included in SEEA as a non-produced asset. Furthermore, use of such an asset is recorded as a cost item in SEEA. In versions which do not use imputed costs (SEEA II and III), depletion is recorded in physical terms and in monetary terms under other volume changes of non-financial assets (SEEA III). Thus, in SEEA III, the production account remains unaltered. In versions using imputed costs (SEEA IV, SEEA V), depletion has an imputed monetary value. The

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3 SNA93, 10.83.
4 SNA93, 10.105.-107.
5 SNA93, 6.94.
6 SNA93, 6.95.
7 SNA93, 6.76.
8 SNA93, 21.150.
monetary value of net-natural growth is recorded as other volume changes of non-financial assets due to natural and multiple causes, n.e.c (CR 2). The value of net-depletion (net-natural increase less depletion) is transferred to the production account as a cost item which is imputed after the calculation of net-value added. Volume changes of natural assets due to a shift from one classification are recorded under as volume changes of non-produced natural assets due to other economic decisions (CR 1.2.2).

Trees and other plants of uncultivated forest

In SEEA forests are divided into two main asset sub-categories. The first is trees and other plants of uncultivated forest (CC.2.1.1.4) which belong to the broader category wild biota9 (CC. 2.1.1) An uncultivated forest should not be confused with the concept of a virgin forest, which is a biological term, referring to a forest unaffected by human activity. In other words a virgin state eco-system. Usually it is very difficult to find examples of true virgin forests, since impact caused by man can be traced even in remote or sparsely populated areas. Therefore, the less rigid definition of uncultivated forest is used in SEEA. An uncultivated forest corresponds to a forest, which is not actively managed.

Trees of timber tracts

The second category used in SEEA is trees of timber tracts,10 (CC.1.2.2.2.2). Contrary to the uncultivated forest, a timber tract is actively managed by man through various measures. Timber tracts do not belong to the broad category wild biota, but to capital produced by nature with the help of man, or more precisely, cultivated natural growth assets.11 This is an asset which is included in SNA (AN.1114). The category trees of timber tracts is however not specifically shown in SNA. Instead trees of timber tracts is included in work-in-progress on natural growth products (AN.1221). In SEEA, only cutting of timber in uncultivated forests should be treated as depletion.

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10 CNFA item 1.2.2.2.2
11 CNFA item 1.2
Growth in timber tracts is recorded in SNA gross fixed capital formation if it takes place as own-account production. Historically, growth on own-account may be relevant for certain categories of small-holders. In other cases growth should be treated as work-in-progress. A more detailed discussion on the accounting principles is carried out in the next chapter.

An accounting problem is how to transfer the standing timber volume from the category of uncultivated forests to timber tracts, since the latter category can be expected to evolve over time, and finally –more or less– replace the natural old growth forests.

Forests in EHNA

The ambition here has been to follow as closely as possible, the definitions in SNA-93/SEEA. The crucial question concerns the institutional status of the asset, which determine whether it should be treated as a produced or a non-produced asset. If the trees of the forest are treated as a produced natural asset, GDP should directly be adjusted by adding the value of net-growth as a change in inventories to the value-added of forestry. If forests are treated as a non-produced natural asset, GDP remains unaltered compared to the ordinary HNA, while net-depletion is added to the eco-margin.

In the SEEA handbook, the uncertainties concerning forest asset classification are underlined. From an economic historical perspective it is obvious that the development of both the institutional units and the development of their legal control (property rights) over forest related assets are complicated historical processes. In the southern parts of the country, most standing timber was under legal control of institutional units already during the 18th century while timber in the Norrlandish forests is characterized by Gaunitz as free goods until the 19th century. Thus, a considerable part of the standing timber volume may be seen as a non-produced asset in the sense of SNA93 around 1800. The expansion of the saw-mill industry, and the subsequent increase of the economic value of lumber, meant that a conflict over forest property rights took place between ca 1820 and 1880. In one sense all Swedish forests can be seen as being brought under institutional control during this period. On the other hand, it could be claimed that timber in forests were more or less the property of the state already at the beginning of the period. This is indicated by the fact the state granted logging privileges

12 SNA93, 10.109.
to Norrlandish saw-mills starting in the 1780's. Thus, it could also be claimed that timber in forests were produced assets already during the 18th century.

In SNA93, the status of a natural asset is also indicated if its growth is managed. One could argue that if an asset is economically controlled it is also managed, at least in an economic sense. From an ecological point of view, this is not obvious. It could therefore be argued that a natural asset is uncultivated as long as the management of its growth is not included in the property right definitions which regulate the institutional unit's economic control over the asset. The legal regulation of forest management is also a complicated historical process. In 1903 in Sweden, a law on management of private owned forests was introduced, followed by an intermediate forest law in 1918 with the aim of protecting growing forests. The law of 1918 was replaced in 1923 by a law which imposed stricter regulations of regeneration obligations for forest owners as well as protection against devastation. If this approach towards determining the proper asset classification for timber in forests, it could be argued that Swedish forest should be regarded as non-cultivated assets until approximately 1923, and thereafter as cultivated assets. (The more exact description of the accounts for 1926 - 1980 is found in the appendix.)

As the forestry industry expanded more and more of the forests were utilized for saw timber. The geographical expansion of saw timber cutting has been referred to as the timber frontier.

There is also evidence that the so-called timber frontier had swept the entire country around 1920. This means that there was very little of the old growth forest left at the time. Also, this lend support for changing of the timber asset classification in this period.

The approach chosen in EHNA is pragmatic in that it allows all negative net-growth of the standing timber volume to be counted as depletion, and all positive net-growth as additions to inventories. In conclusion the approximate timing is also supported by the fact that modern forest management, securing growth, became regulated at this time. The timing is also supported by evidence that most old growth forest in the country had been cut at the time.

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14 Gaunitz (1992)
15 SNA 93, 10.106.
In EHNA the following accounting principles are used:

1/ Depletion is recorded as a contribution to the eco-margin (an environmental cost) if the total standing timber volume is decreasing. A decreasing standing timber volume therefore means that forests are treated as un-cultivated forests, and part of the broader category wild biota. If the timber volume is increasing, forests are treated as cultivated forests, and part of the broader category natural assets of industries.

2/ Depletion cost is calculated as the volume of actual or estimated stumpage prices and the net decrease of the standing timber volume.

3/ For cultivated forests, the value of net changes of the standing timber volume is counted as changes in inventories which is part of forestry's value added.

4/ The value of the standing timber volume is the volume of the unit value of growing forest, based on general forest assessment, and the standing timber volume. A forest is not a homogenous asset. Major parts of the forest reserves are growing trees which are not ready for economically profitable extraction. Other factors—among several additional ones—that affects the forest value are the mix of species, timber quality, site quality and geographical factors which influence transportation costs. Therefore, if the net price of saw timber is applied on the whole standing timber volume, the value of the asset would be exaggerated.

5/ The value of growth is estimated as the volume of net natural growth and the stumpage price. For cultivated forests, growth is counted as work-in-progress (in the SEEA matrix use of products of industries 2.1). For un-cultivated forests growth is recorded as net natural increase in the asset accounts only (CR 6. 2.1).

6/ Revaluation due to market prices changes (nominal holding gains or losses) is calculated as the difference between the closing stock valued in the accounting year's prices and the closing stock valued in the previous year's prices.
Identities used in the accounts

1. \( OS_t = CS_{t-1} \)
2. \( CS_n = STV_t \times UPG_t \)
3. \( UPG_n = AST_t/STV_t \)
4. \( Gecon_t = NNG_t \times SP_t \)
5. \( D_t = C_t \times SP_t \)
6. \( Cinv_t = CS_t - OS_t \)
7. \( Cprice_t = (UPG_t \times CS_t) - (UPG_{t-1} \times CS_t) \)
8. \( EM_t = Gecon_t - D_t \)

where:

- \( OS \) = opening stock
- \( CS \) = closing stock
- \( STV \) = standing timber volume
- \( UPG \) = unit price for growing timber
- \( AST \) = Value of standing timber volume according to AST
- \( Gecon \) = Value of net natural growth (monetary units)
- \( NNG \) = Net natural growth (physical)
- \( SP \) = stumpage price
- \( Cinv \) = change in inventories
- \( D \) = depletion of natural asset
- \( Cprice \) = revaluation due to market price changes
- \( EM \) = eco-margin in the production account

Estimates of the standing timber volume 1800-1990

Previous attempts to estimate the standing timber volume

In the early 1920’s the first national forest survey (Riksskogstaxeringen) was carried out in Sweden. The aim was, among other things, to estimate the standing timber volume. The summary results were officially published in 1933. Since the 20’s an additional seven surveys have been carried out and, thus, the development of the standing timber volume is rather well known not only with regard to volumes but also to growing timber dimensions, age structures and distribution of different species etc. The overall picture is one of steady growth for the standing timber volume since the 1920’s, although logging has increased during the period.

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19 See SOS Skogsstatistisk årsbok for summaries of results.
21 Lars Östlund has pointed out for the author that method changes between the second and the third surveys imply that the results are not perfectly compatible.
For the period preceding the first survey the only way to get a picture of the standing timber volume, since systematic surveys covering the whole country do not exist, is to make estimates or, rather, 'guesstimates'. One such estimate -that was nonetheless qualified- was made by Lars Östlund. On the basis of an investigation of the standing timber volume in Norrland, published in 1871, Östlund and his colleague Per Linder estimated the standing timber volume of the counties of Norrbotten, Västerbotten, Västernorrland, Jämtland and Gävleborg. Thereafter Östlund has departed from these results to estimate the standing timber volume for the entire country for the year 1870. The general conclusion was that a significant decrease of the standing timber volume took place up to the first national forest survey. This interpretation is also supported by several eye-witness reports in which deforestation is reported as being a major problem.

In order to make estimates for even earlier periods, the correlation between logging data and changes in the standing timber volumes between 1870 and 1925 was tested. If such a relation is found, it may be claimed that:

a/ logging data can be used as an indicator in order to extrapolate the standing timber volume back to 1800.

b/ logging of saw-timber and appropriate net-prices may be used to estimate not only gross, but also net depletion costs in Swedish forestry.

National data on standing timber volumes after 1925 is impossible to use in order to examine the relation between changes in the standing timber volume and logging during the 19th century, because of the introduction of better and more widely used forest management methods, which along with the forest conservation act of 1923 led to new relationships between forest net change and logging. Also the new regime of selective logging was introduced in the 1920's at least in central Norrland. Furthermore, the post-1925 forest growth was also affected by previous logging. Therefore the only usable


24 Östlund (1992)

25 See for instance Wieslander, G. Skogsbristen i Sverige under 1600- och 1700-talen. Svenska skogsbrädsföringens tidskift, 1936, pp. 593-663.

26 Gross-depletion cost = depletion. Net depletion cost = depletion + net natural growth.

benchmark years are 1870 and 1925, the latter taken as a representative year for the first forest survey.

Östlund’s estimates compared with logging data

The still most comprehensive historical work on the total utilization of Swedish forests is Gunnar Arpi's contributions to *Sveriges skogar under 100 år* (Swedish Forests During 100 years).\(^\text{28}\) Here estimates and 'guesstimates' of wood consumption by the sawmills, in charcoal production, by the pulp and other industries, household consumption and industrial use of firewood from 1850 to 1950 are provided. The figures are presented as five year averages.

Concerning the standing timber volumes Östlund's estimate for 1870 is 2250 million m\(^3\) while the corresponding figure in 1925 is 1761 million m\(^3\). These figures concern stem, top, but not stumpages and branches except for certain foliar trees. The difference between the benchmark year figures is thus a net decrease by 489 million m\(^3\). Further, Östlund showed in his thesis that along with this decrease the structure of the forest also changed. Generally, the early 19\(^{\text{th}}\) century forest was dominated by rather few but large old trees, while the modern forest is characterized by many but smaller and younger trees. All in all the timber quantity per hectare was considerably larger in the 19\(^{\text{th}}\) century forest.\(^\text{29}\) Thus, the decrease is probably related to increased logging of large trees. Large trees were used by the saw-mill industry and therefore the most obvious relationship to investigate is that between decreasing timber quantities and the utilization of timber by the saw-mill industry. Large trees were also used for raft booms and other devices associated with floatways. This category, however, is ignored in this investigation because it is hard to find pertinent data and because its importance probably should not be exaggerated in this context. With respect to firewood for industries and households timber of lesser dimension and dead trees were used. Timber of lesser dimensions were also used for charcoal production, which usually was controlled by the iron works. The pulp industry, which developed rapidly round the turn of the century, also used timber of lesser dimensions.

When Arpi's figures for the sawmills' wood consumption between 1871 and 1925 are summed up, a total of 596 million cubic meters is reached. This

\(^{28}\) Arpi, G. *Sveriges skogar under 100 år*, Stockholm 1959.

corresponds surprisingly well with the decrease between Östlund's estimate for the 1870's and the first national forest survey. This relation can be further tested by applying the same technique to Östlund and Linder's investigation on the Norrland forests. They claim that the standing timber volume in the counties of Norrbotten and Västerbotten in 1870 was 595 million cubic meters. The forest survey in 1925 stated that the standing timber volume in the same counties was 500 million cubic meters and, thus, there is a net decrease of 95 million cubic meters between the benchmark years. Arpi's figures for the same counties show a total for the sawmill wood consumption of 86.5 million cubic meters. Adding the net export of timber of the counties leads to an almost perfect matching of the estimates.

However, when the counties of Västernorrland and Jämtland are concerned the discrepancy between Östlund and Linder's estimate and Arpi's figures is considerable. Between 1870 and 1925 there was a net decrease of 330 mill cubic meters, while the sawmill timber consumption was 180 million cubic meters. This is difficult to explain. If the possibility is ruled out that the initial estimates for these two counties are fundamentally wrong, it is necessary to look for discrepancies in other forms of timber consumption in comparison with the rest of the country.

One obvious difference is that the wood pulp industry developed faster between 1870 and 1925 in these counties than in any other part of Sweden. But the total wood consumption during the period can not explain the reduction of standing timber volumes even in the unlikely event that all consumption is accounted for as depletion of the standing timber volumes, since the total only reaching 36 million cubic meters. Furthermore, there is nothing to indicate that any of the other forms of wood consumption described by Arpi should have developed in such a way that it could explain the discrepancies.

As to demographic development, the population doubled in Västernorrland and Jämtland between 1870 and 1925 while the national average shows an increase of 145 percent. This also suggests that the cultivated area in these counties probably increased at a rate exceeding the national average. Could this loss of forest land explain the decline of the standing timber volume?

First, it is assumed that the wood extracted from the land when it was cleared is encompassed in Gunnar Arpi's figures. According to Robert Mattsson the cultivated area in Sweden in 1865 was 4258 thousand hectares. By 1927 it had risen to 4985 thousand hectares, i.e. by 700

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31 Mattsson, R. Jordbrukets utveckling i Sverige, Aktuellt från lantbruksuniversitetet 344:1985, Table 1, p. 13. According to Bengt Holgersson's estimate from 1974 the total cultivated area was 3327 thousand hectares 1870/74. Holgersson, B. Cultivated Land in
thousand hectares. Västernorrland and Jämtland's share of the Swedish population was about 5% ca 1870 and about 7% in 1925. Assuming the same share of the cultivated land area would mean 212.9 thousand hectares in 1870 and 348.9 thousand hectares in 1925. If the population would have developed in the same way as in the rest of the country, that is assuming that it made up 5% of the national population also in 1925, the cultivated area in the two counties would have been 249.2 thousand hectares in 1925.

The conclusion is that the above average population growth caused a slower forest growth than in the rest of the country, but this can hardly explain the discrepancies observed in the standing timber volumes. Even if we make the generous assumption that the extra 100 thousand hectares were cultivated already in the 1870's, and using an assessment of the site quality to 3 cubic meters per hectare, which is slightly below modern assessments of site quality for the counties, it would mean an additional loss of forest growth amounting to ca 16.5 million cubic meters for the period 1870 to 1925.

Thus, it is hard to find any reasonable explanation for the dramatic reduction of standing timber volumes, in Västernorrland and Jämtland along these lines. However, Sven Gaunitz has found that around the turn of the century there was an excessive logging activity in this area. This involved timber dimensions as little as 8" and it took place in forests with logging rights (avverkningsrättsskog). Most likely this was a case of final logging. It is important that the dimensions involved are those with the highest absolute growth. Thus, Gaunitz argues that growth rates probably declined in both counties. Also the growing population with the subsequent increase in firewood use coupled with forest fires, may have contributed to the rapid decline of standing timber volumes in Västernorrland and Jämtland. The combination of factors discussed above may suggest the lines along which the observed discrepancy may be resolved.

**Estimates of the sawmill wood consumption 1800-1870**

If the simple assumption is accepted that the reduction of standing timber volumes corresponds to the sawmill wood consumption, the next step is to estimate these figures for the period prior to 1870. It is then possible to ex-
Timber: Estimates of the standing timber volume

Timber: Estimates of the standing timber volume

trapolate Östlund's estimate for 1870 backwards, in order to get a picture of the development of the standing timber volume since 1800.

The following method is utilized to estimate sawmill wood consumption between 1800 and 1870. The basic figures are the export statistics for Sweden.\(^{33}\) First the cubic volume of exported balks and spars is calculated for 1800-1913. The statistics are given in number of pieces. The transformation into cubic feet is made with the point of departure in the figures for 1830, which provide number of pieces as well as cubic feet. Also, the export from Finland is deducted from the total between the years 1800-1809. However, the statistics are lacking between 1814 and 1819. This gap is interpolated with Lennart Schön's economic quantities for the sawmill industry, assuming corresponding changes in the physical export figures and the economic volumes.\(^{34}\) The statistics on exported deals and boards starts in 1830 and are given in cubic feet. These figures are extrapolated back to 1800 by assuming that the relation between deals and boards on the one hand and balks and spars on the other in 1830 was the same throughout the period 1800 to 1830. For the whole period 1800 to 1860 figures in cubic feet are transformed to cubic meters. The statistics after 1860 are all given in cubic meters. Thus we have a series expressing the exports in cubic meters from 1800. Nevertheless, an important problem is that statistics for sawmill production for the domestic market is missing. Here, Lennart Schön's economic volumes, which are divided into exports and domestic use, are utilized in the assumption that the ratio of domestic production/exports, is the same as the ratio of domestic production/exports, with regard to the physical volume.

Thus, construction of the series on sawmill wood consumption between 1800 and 1870 is almost complete. Still remaining is the predicted relation between the cubic volume of the sawn products and the timber volume used. Arpi states that for the production of one cubic meter of deals and boards 2.1 cubic meters of wood were needed during the 19th century. Possibly, this figure is a bit too high since a good part of the production involved balks and spars of large dimensions, where we can assume a better utilization of the timber.\(^{35}\)

To test the estimate the period is extended to 1890 to allow a comparison with Sven Gaunitz' figures on the Swedish forest industry's wood consumption from 1870 to 1980.\(^{36}\) The series correlate very well between 1870 and

\(^{33}\) SCB. Historisk statistik för Sverige. Utrikeshandel 1732-1970,. Stockholm 1972, Table 1.2; 1.4; 2.5.


\(^{35}\) Not all balks and spars were sawn products during the 19th century.

1890. With a slight downward adjustment of the assumed relation between saw products and used timber the series can easily be linked. The good correlation also suggests that the estimates for the period before 1870 are plausible.

**Standing timber volumes 1800 to 1925**

It is now possible to estimate the development of the standing timber volume between 1800 and 1870. This is done by asking what was the standing timber volume was in 1800, if the reduction due to sawmill wood consumption caused a standing timber volume in 1870 which equals Östlund's estimate.

Creating an annual series of accumulated sawmill wood consumption between 1800-1870. Thus the series of the type $X_{(t+1)} = X_{(t+1)} + X$, where $X$ is cutting.

When the value of the series in 1870 is added to Östlund's estimate for the same year the result is an estimate of the standing timber volume in 1800, of ca 2355 cubic meters. $X_{(1870)} + Östlund_{(1870)} = $ Standing timber volume$_{(1800)}$

From this standing timber volume in 1800, the yearly sawmill wood consumption is deducted resulting in a series of the estimated standing timber volume from 1800 to 1870. It may be compared to the results presented by Astrid Kander, who has basically used population as a depletion indicator, to reach an estimate of the standing timber volume in 1800 between 2500 and 2900 million cubic meters.\(^{37}\)

The next step is to interpolate between the bench-mark years of 1870 and 1925. Here Sven Gaunitz' figures are used, but since they include timber consumption of wood-pulp industries, these figures, taken from Arpi, are removed. In all other respects the method used is the same as above. The result leads to an estimate of 1718 cubic meters in 1925 which is an underestimate by 43 mill cubic meters or 2.4 percent. However if the net exports of logs, amounting to 56 million cubic meters are included the underestimate rises to 99 cubic meters which is still only 5.6 percent of the total. This underestimate could be explained if forest growth, treated as a residual post, is included in the analysis.

New assumptions

The method used above is probably fairly accurate for use in the linking between Östlund’s estimate of the standing timber volume in 1870 with the national forest survey estimate of the standing timber volume in 1925. Still, it remains unsatisfactory. Perhaps the greatest source of concern is the fact that other uses of wood are significant in comparison to sawmill wood consumption and that the data concerning these categories is uncertain. Therefore, the assumption that growth and other categories of wood consumption cancel out is also uncertain.

It is also worth pointing out that a linkage to the national forest survey in 1925 is problematic since the change in the growth rate is modeled as an abrupt deviation, rather than a smooth process. This development is implausible, and it is obvious that new assumptions must be introduced. It is also difficult to explain why the single indicator model is deprived of its explanatory property during the course of a single year corresponding to the first national forest survey.

The strategy has been to more carefully consider forest growth, in which the following method has been used:

1/ First, a rough estimate of other aspects of timber cutting than saw-timber has been made. The procedure is described in appendix.

2/ Growth has been modeled after the assumption that a unit of cut timber is, on average, naturally reproduced in 60 years. This growth process has been assumed to follow the growth rates depending on age computed by the national forest survey. For use in this investigation, the growth rates are calculated as the mean growth rates of spruce, pine and birch. Further, cutting and growth has initially been assumed to be equal in the year 1800.

3/ A matrix consisting of 125 x 125 boxes has been constructed. For each year the regeneration process is estimated by assuming that cutting in year \( n \) is reproduced along a growth function based on the growth rates described above, so that total reproduction is reached in the year \( t+60 \). Adding the column leads to an annual accumulated growth estimate. The first log gives annual growth figures. Also, in 1800 growth is assumed to have equaled cutting.

4/ Growth rates are adjusted for climatic factors by taking into account results from dendrochronology. Hofgaard et al. has shown that forest growth
rates have varied considerably during the period 1770-1988. The investigation showed that the annual growth rate increased by ca 50% between 1840 and 1920. Since the investigated forest is a natural grown forest, these fluctuations can be assumed to have been caused by climate changes. Hofgaard’s annual growth series has been indexed as 1800=1 for use in this investigation. The annual growth rates estimated under 3 alone are adjusted by multiplication with this index. Total annual growth is estimated on basis of the adjusted growth rate, and a starting growth value in 1800 which is assumed to equal cutting except for saw-timber logging.

5/ Accumulated saw timber cutting and other accumulated cutting then represents total depletion during the 1870-1925 period. Thus, accumulated growth can be estimated as the difference between accumulated cutting and the standing timber volume change between 1870 and 1925.

6/ Even if growth is adjusted for climatic factors, the model does not offer an estimate in which growth eventually becomes larger than depletion. Among factors that may have influenced growth, ditching of wet-lands has been assumed to be the most significant. Since information of ditching is included in the official forestry statistics it is also easy to quantify. It may also be seen as an indicator for other forest management measures which were taken during the late 19th century. The level of the series of the accumulated length of ditches, beginning in 1872, is adjusted in such a way that it equals the difference between predicted accumulated growth in the period 1870-1925 (see above) and the model growth estimate.

7/ Finally, the changes in the standing timber volume are modeled as growth minus cutting, with the 1870 volume estimate as the point of departure. For 1925 the model gives a natural growth estimate of 24 mill m³ forest and an additional growth, due to improved forest management of 38 mill m³ forest. The lowest value of the standing timber volume is reached in 1925, and the net natural increase between 1924 and 1925 is, on an annual basis, ca 10 mill m³ forest per year. On a general level this produces a rather neat linking with the results from the first and second national forest survey, where the annual average net natural increase of the standing timber volume between ca 1925 and 1944 is ca 28 mill m³ forest. The linking of the estimated series to the national forest survey standing timber volumes are shown in diagram 2.

8/ The same method is also used for giving an estimate for the development of the standing timber volume in 1800. Of course, there are no effects of ditching in this estimate.

Comments and conclusions

The standing timber volume represents an important part of the Swedish EHNA. It is, however, extremely difficult to estimate these changes since a dynamic eco-system is concerned. For EHNA purposes, the standing timber volume was, however, estimated for the period 1800-1925. For the period after 1925, national forest survey data could be used. Needless to say, the degree of uncertainty is considered to be high prior to 1925.

The method takes into consideration both cutting and factors that affect growth. The change of growth rate (from negative to positive) was for instance modeled as a continuous process rather than as a disruption in the curve. This was the case when only saw timber cutting was used as a depletion indicator. Furthermore, both other uses of timber and growth modeled as a function of dendrochronological results and previous cutting, were included in the model. For the period from 1870 - 1925, ditching is used as an indicator for improved forest management. Thus, growth is not modeled as a residual variable.

When a larger number of quantitative variables are used, the problem of implicitly assuming that one single variable –for instance saw timber cutting– also captures the effects of all other factors like climatic factors, changes in silviculture, grassing and population growth was reduced. Further, the problem of explaining why the model ceases to work at the time of the first national forest survey was reduced by a multivariable approach.

The greatest disadvantage of the model from the perspective of input data is probably that other categories of cutting except from saw timber may be estimated more carefully. Due to other sources of error it has, however, not been considered as time effective to invest more resources in the improvement of these estimates. A test, in which the timber consumption, except saw timber, was adjusted with +/- 20 %, with a corresponding adjustment of the initial growth assumptions, lead only to small implications for the development of the standing timber volume (see diagram 1). The basic assumption was that growth and cutting were equal in 1800. To obtain an improved estimate it is necessary to estimate the difference between growth and cutting in 1800.

In this investigation, the development of the standing timber volume for the whole period corresponds in general terms with previous estimates for
Sweden. Basically the investigation showed that the standing timber volume in the early 19th century was slightly above the present figures (see diagram 2). Furthermore, the investigation pointed at a decline of the standing timber volume until the first decade of the 20th century, followed by a comparatively rapid increase. This general picture also corresponds rather well to the result in a recent report concerning the standing timber volume in Finland.


Note: the diagram shows the basic scenario and two adjusted series. One corresponds to 20% additional use, and the other to 20% less use of timber for other purposes than saw-mill timber.

Sources: Östlund (1992) and own estimates.


From an environmental accounting perspective, the principal interest is to make estimates of the part of depletion to which a natural resource rent may be attributed. This is the net change of the timber volume.

An estimate which is more accurate, but which includes an unknown mix of ordinary capital depreciation and environmental capital depreciation (contribution to the eco-margin) is given by the natural resource rent and the part of logging which may be attributed to this rent. This is, among other things, dealt with in the following chapter.

**Diagram 2. The Swedish standing timber volume 1800-1980.**

![Diagram of Swedish standing timber volume 1800-1980]

*Sources: Östlund (1992), national forest surveys, own estimates*

**APPENDIX**

**Estimating additional cutting 1800 to 1925**

For estimating standing timber volumes according to the extended model it is necessary to estimate saw timber consumption beside sawmill wood consumption.

In this appendix some crude calculations are made for the period 1800 to 1850. With a few exceptions the figures are then linked to Arpi’s estimates. Basically, the same categories as Arpi uses are also applied here.
As already mentioned the wood pulp industry is negligible before 1870. Accordingly, this category is not dealt with in these estimates. This is also true for other industries dealing with wood refinement; joinery goods, match industry, woodwool manufacturing, veneere- and wallboard industries.

However, one important wood consumption category is charcoal production. Charcoal was mainly used for iron and steel manufacturing. Arpi has also dealt with this aspect of forestry. The following assumptions, taken from Arpi, are used in the relationship between charcoal consumption and iron manufacturing. Between 1800 and 1825 the required amount of charcoal for the production of one ton of pig-iron is assumed to have dropped from 120 hecto liters to 110 hecto liters, with a further decrease in 1850 to 83 hecto liters and a subsequent drop to 70 hecto liters in 1875. Concerning the transformation of pig iron to bar iron 215 hecto liters were needed in 1800, and 150 hecto liters in 1850. In 1875 the corresponding figure was 90 hecto liters, with a reduction to 30 hecto liters in 1900. All changes are assumed to have occurred linearly. Concerning cast iron, a consumption of 150 hecto liters per ton is assumed.

These figures are multiplied by the corresponding physical iron output data given by Schön. Further, it is assumed that the production of ten hecto liters of charcoal required 1.1 cubic meters of wood. The series are linked to Arpi's calculations in 1870 and not in 1850 because Schön's iron output figures probably are better than the data used by Arpi in his own calculations for the period prior to 1870, when iron and steel production were included in the official statistics.

One industry not considered by Arpi is iron ore mining. Here an ore grade of 50% is assumed suggesting that one ton of iron ore meant that two tons of rock had to be mined. Prior to 1860 iron ore mining was conducted by heating the rock with burning firewood. This is called fire setting. However, during the 1860's the method was quickly abandoned after the introduction of dynamite. In the calculation it is supposed that 4 cubic meters of fire wood was required to mine one ton of rock. From 1860 the use of fire wood is assumed to have dropped linearly down to zero in 1870. This assumption is supported by the fact that iron ore mining increased during this decade. Lennart Schön's iron ore production statistics is multiplied by 2 and then 4 to arrive at total fire wood consumption in mining until 1860.

Arpi assumes that the industrial fire wood consumption was 1.2 mill cubic meters throughout the period 1851 to 1915. This seems unlikely since the

41 Arpi (1951) pp. 86-112.
43 Information provided by Bob Engelbertsson, expert on the Sala silver mine, is gratefully acknowledged.
Swedish industry developed rapidly particularly after 1890. Therefore I have used an official investigation from 1918 on the industrial fuel consumption, which takes the fire wood consumption of 1.2 mill cubic meters in 1913, as the point of departure.\textsuperscript{44} Subsequently, this figure is multiplied with an index (1913=1) based on Schön's industrial output series. However, these estimates are uncertain. There is information suggesting that the firewood consumption per produced unit of goods dropped during the period. With respect to brick manufacturing firewood consumption is assumed to have dropped by 70 percent due to the introduction of new ovens in the 1850's.\textsuperscript{45} Since this category is not a major one no further adjustments are made in this work.\textsuperscript{46}

The most difficult part of the calculations concerns the household consumption of wood. This is also the single largest wood consumption category up until 1950. Wood was primarily used for fuel and construction work. Here, saw timber and waste are excluded. As the point of departure Arpi's per capita consumption figures for 1851 to 1875 are used. These vary for the different region groups, reflecting, among other things climatic differences and diverging levels of urbanization. Thereafter, these figures are multiplied by the population development in the region groups.

To arrive at the total wood consumption, excluding sawmills and net timber exports, between 1800 and 1925 the following procedure has been used. First, the estimates of household wood consumption are linked to Arpi's figures in 1851. Subsequently, the series on wood consumption related to charcoal production is linked to Arpi's figures in 1870 and, further, the estimates of industry fire wood consumption are linked to Arpi's corresponding figures in 1913. These series are then added to form a total which also includes wood pulp timber consumption and other wood consumption by industries.

According to an article by Gösta Wieslander the total annual fuel requirements for Swedish mines and metalworks during the 17\textsuperscript{th} and 18\textsuperscript{th} centuries only corresponded to approximately 8 percent of the forest growth in the 1930's.\textsuperscript{47} Still, local shortages might have existed although market imperfections due to strict price regulations are likely to have affected reports concerning shortages.

\textsuperscript{44} Kommerskollegium. Bränsleförbrukningen åren 1913-1917 vid industriella anläggnings, kommunikationsanstalter samt allmänna verk och inrättningar, Stockholm 1918.
\textsuperscript{45} Bruno, W. Tegelindustrin i mälarprovinserna 1815-1950, Geographica, No 28, Uppsala 1954, p. 45.
\textsuperscript{46} Although the official report Förslag till skogshushållning. Underdånigt betänkande och förslag angående åtgärder för befästnande av en förbättrad skogshushållning, Stockholm 1856, could be considered for further adjustments for industrial consumption of fire wood.
\textsuperscript{47} Wieslander (1936).
7. TIMBER: THE ECONOMIC VALUE OF TREES IN TIMBER TRACTS AND UNCULTIVATED FORESTS

Introduction

The purpose of this chapter is to elaborate upon the monetary data necessary for establishing historical environmental accounts for standing timber. The period in question is 1800-1980. The main focus is on the period 1800-1925 for which substantial estimation work must be made. As previously discussed, appropriate net prices are needed in order to value stocks and flows. In order to estimate net prices, two general approaches have been used in this work. For the period after 1876, regional net prices are found in the official forest statistics. These have been used for estimating a national net price series. For the early 19th century, net prices are missing, and have therefore been estimated indirectly.

Forest prices

Gross prices include extraction, refinement and transportation costs which are not parts of income but expenses necessary for the earning of income. As has been previously argued, net prices should therefore be used for valuation purposes. Since net prices seldom show up in statistical records they must be established by deducting production costs from gross prices. In Sweden there are, however, two kinds of forest net prices available in the statistical records. This reflects the fact that timber is transacted in two contractual forms on the market, namely in delivery sales and in stumpage sales. The net conversion value concerns delivery sales and is estimated as the gross price for timber less the estimated expenses for cutting, refinement, transportation and so on. These expenses are borne by the seller who accordingly receives a gross price for the delivered product. Accordingly, net conversion values are not direct market prices. Net conversion values for timber of different dimensions and geographic origin are found in the official statistics from the 1920's.

2 SOS Statens domäner.
The other kind of net price is the stumpage value or stumpage price. Sometimes the stumpage value is also referred to as the timber rent. The stumpage price is the price for standing forest or the market price for timber before cutting. In this case the buyer bears the cost for extraction, etc. In the official statistics stumpage values are available from 1876 to 1910. There is, however, a gap in the statistics for the period 1910 and 1952, for which Streyffert has collected and estimated stumpage prices.

If free market conditions are assumed, the stumpage value does not differ very much from the net conversion value, since at the marginal stumpage price the owner of the forest is indifferent to the options of selling standing forest at the stumpage price or selling logged timber to the gross price as he himself undertakes cutting and related activities. Stumpage prices are therefore a directly recordable market net price, which eliminates the need for the troublesome estimation of extraction costs. It should be noticed that the use of stumpage values for national accounting purposes is not without risks since the representativity of the actual transactions in relation to the total asset or the total flow is crucial for the reliability of the generalization.

Stumpage prices in the official Swedish forest statistics

Forestry entered the official statistics in 1870. Logging data was sparse and concerned only state managed forest. It was only during the 1940's, when series for private managed forest entered the statistics, that the forestry series became somewhat complete. From 1951, the two separate publication series were joined in one single series.

As mentioned above, stumpage prices are found in the official statistics from 1876. They are shown as 'prices for trees sold on root' (Noterade priser för trädfällda å rot) for the different forest management districts in Sweden. The districts in their turn are divided into revirs and it is on this level that the price data is found. For a district like Norrbotten this means that more than ten prices may be found. It should be noted that the area size of both districts and revirs

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4 BiSOS Skogsväsendet, BiSOS Statens domäner.
6 BiSOS Skogsväsendet.
7 SOS Det enskilda skogsbruket.
8 SOS Skogsstatistisk årsbok.
9 BiSOS Skogsväsendet. From 1889-1908 BiSOS Statens Domäner.
may differ significantly. Later the forest management districts were changed into region groups. Also a few revirs changed districts, among them Gotland.

The division of prices on different timber dimensions is to be considered as rough when compared with practices in modern forest statistics. Instead of a division into certain dimension intervals, a few broader timber categories are used in the old statistics. These are among others oak, trees for square timber, saw timber trees and house timber trees. In the old statistics, the actual dimensions under each timber category probably varied considerably. Generally, with the exception of oak, trees for square timber are most valuable followed by saw timber trees.

Furthermore, it is not perfectly clear whether the prices concerns only state managed forests or whether prices on private forests also sometimes are included. This may matter if the prices for some reason differed among private and state-owned forests of equal quality. Some indications can be found when the geographical distribution of prices is compared with data on sold saw timber trees. It is then clear that the number of revirs with price data greatly exceeds the number of revirs with data on sold saw timber trees. This state of affairs is considerably more common in the central and southern parts of the country than in the northern parts, were the state was the predominate owner. Probably this indicates that the prices in the official statistics pertain to both state and privately owned forest. It should also be noticed, that the Norrlandish forests at the time consisted of more old growth timber than forests in the southern parts of the country. Also this may have affected the representativity of the prices.

**Reconstructing missing price data**

A major problem accompanying the historical forest accounts is that they should cover the entire period from 1800, while easily accessible net timber prices are only available from 1876. The problem demands reconstruction of the missing price data which of course is difficult. Needless to say, this lowers the credibility of the series for this period.

In this work, the existing price statistics for stumpage values are collected and weighted for the period 1876-1908 for the whole country. The period ending in 1908 is motivated by reorganization of the statistics which makes the weighting procedure impossible to use. The stumpage prices refer to prices for saw timber trees. Behind this decision lie the indications from the previous chapter of the decrease in the Swedish timber reserve during the 19th century being primarily caused by the extraction of old growth lumber. It was also saw timber trees that dominated the transactions. For the period before 1876, the missing price data is constructed by linking different price series.
Stumpage values for saw timber 1876-1908

The stumpage values are collected from BiSOS *Skogsväsendet* 1876-1888 and thereafter from BiSOS *Statens Domäner* 1889-1908. The prices are given both per tree and per physical volume unit. In this study the prices per physical volume unit are used since the standing timber volume, as well as logging, often are expressed in cubic feet or cubic meters. Also as shown in several investigations, the volume per log decreased during foremost the 1890s. Jörgen Björklund has shown that the sawmills of the Sundsvall district faced severe problems with raw material supplies during the same decade. Transformation from cubic feet to cubic meters has been achieved by using the coefficient 0.00382.

For each year the average price and the standard deviation are estimated on the basis of the prices of saw timber sold on root at the revir level.

When it comes to historical price data the number of observations, ca 60 to 75 per year, can be considered as rather large. Jörberg usually used about 10 to 30 observations when the national averages of the market scale prices was calculated. However, the standard deviations from the stumpage values are large, especially in the beginning of the period. In 1878 the coefficient of variation is as large as 0.67, while the coefficient of variation in Jörberg’s series is usually around 0.20. Mean values for the whole country as well as standard deviations are shown in table 1. There may be several explanations for the large standard deviations. Probably a not fully integrated domestic market for forest, different transportation capacity, geographically heterogeneous demand, regional wage differences and shifting forest qualities can account for this. In order to construct a more consistent price series, the following method was used.

First, the revirs were grouped according to the region groups used by Arpi. The exception is region group five, corresponding to *Södra distriktet* (the southern district) and Gotland with only five revirs. This is because price data is missing for several years and that the other years are only represented by very few observations. These price observations were instead transferred to region group four. Accordingly, the price material is divided into four region groups, three Norrland groups and one for southern Sweden.

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12 Jörberg, L. *A History of Prices in Sweden 1732-1914*. Lund 1972, p 95. For transforming one cubic foot into litres, multiply the former with 3.82. 1 m$^3$ equals 1000 litres. Thus one cubic foot should be multiplied by 0.00382 for conversion to cubic meters.
14 Arpi, G. *Sveriges skogar under 100 år*, Stockholm 1959.
15 Usually that means one or two observations and never more than five.
Second, an average for each region group was computed. This is shown in table 2 and in diagram 1. This time the coefficients of variation are more reasonable, which indicates that prices mostly differed between -and not so much within-the region groups. In table 3 coefficients of variation are shown for selected years.

Third, the region group average prices are weighted in accordance with their share of total logging. What is produced is a weighted average price for the whole country, which appears in table 2. The regional distribution of logging is taken from Arpi which means that the weighting system is changed every five year. The weights are shown in table 4. This also explains the regional heterogeneity of price data as indicated above.

Of course other weighting procedures could be thought of. Nils-Gustav Lundgren used for instance statistics on the physical size of the forest transactions.\textsuperscript{16} This is a method well suited for a county like Norrbotten, but it is hardly advisable on the national scale. This is due to the relatively few forest transactions in the central and southern parts of the country, while logging was substantial in these districts.

Table 1. Average stumpage prices for Sweden 1876-1908.

<table>
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<th>Year</th>
<th>Mean value. (kr/m$^3$)</th>
<th>Standard deviation</th>
<th>Number of observations</th>
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Sources: Own estimates based on BiSOS Skogsväsendet
Table 2. Weighted average stumpage prices in Sweden 1876-1908.

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Sources: Own estimates based on BiSOS Skogsväsendet. Note Rg=region group
Table 3. Coefficients of variation. Selected years.

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Note: The CV’s in column 2 are from table 1.

Source: table 1 and 2.

Table 4. Weights 1876 - 1908

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Source: Own estimates based on Arpi (1959) p. 154.
Diagram 1. Estimated, weighted stumpage prices. Sweden 1877-1908

Sources: Own calculations based on BiSOS Skogsväsentet 1876-1888 and BiSOS Statens Domäner 1889-1908.

Linking price series

A major problem in this study is to estimate net prices for the period 1800-75. One approach could be to link the HNS deflator of industry group 3 (saw-mills) – or a gross timber price index – to the calculated stumpage prices. On a general level it could be argued that the stumpage values follow the general price index of sawn products. Such a development does, however, imply that timber scarcity – and thus the natural resource rent – remain as a constant proportion of extraction and refinement costs. Thus, relative scarcity must always be constant. This may only occur if an increase of scarcity is accompanied with a proportional rise in extraction and refinement costs. What is more likely – given the general knowledge on industrialization and the depletion of saw timber in Sweden – is that extraction costs were lowered, due to increased factor productivity, and timber became increasingly scarce. Since the saw-timber exports started to increase already from ca the 1840’s, the timber rent may have increased faster than final prices already before the 1870’s. However, the findings in the previous chapter indicate an increasingly widespread scarcity beginning circa 1870. An argument which supports this considers the so-called timber frontier. When the Swedish saw mill industry expanded after ca 1850 the increasing demand for raw materials, as well as the shortage in the more established regions,
was met by a geographic expansion of the logging activities. The expansion spread from the heartland, in the midwestern regions of the country, towards the north and west. From an international point of view, the timber frontier actually had its origin in the Oslo region. By ca 1875 the timber frontier had swept across the whole country. It is therefore likely to suspect that the difficulties concerning the saw timber supply increased from that period and onwards.

A linking of the deflator—or any other gross price index—with the stumpage price series should be given a good theoretical justification. The discussion above supports the view that stumpage prices may have increased relative to the industry group deflator but the question is when this began. The further back in time this happened, the weaker the linking approach becomes.

A relative price increase of natural assets can theoretically be foreseen when the extraction rate reaches its peak value. It is therefore of great importance to investigate when the timber extraction rate was at its highest. Diagram 2, shows saw timber logging in a semi-logarithmic scale. The diagram therefore gives a fairly good idea of when the increase of the extraction rate was at its highest.

Diagram 2. The timber extraction rate 1831 to 1908.

Sources: see text in chapter 6.

From diagram 2 it is seen that the increase of extraction peaked around 1870. The exact timing is difficult to determine, but 1873 can be seen as an approximate year. Therefore, it can be argued that the stumpage prices may roughly have followed the gross prices until 1873. Thus, the rise of net prices relative to final prices could be expected to be a late 19th century phenomenon. It could therefore be claimed that there are theoretical support for linking the deflator—or any other gross timber price index—to the stumpage values in 1876.

**Estimating the net price 1800-1875**

Even though the linking suggested above seems to be a fair construction in the absence of more conclusive data, the industry group deflator—or a gross timber price index—may not be the best price series to use. As a matter of fact, it could be possible to detect net prices in a more direct manner. According to the net price approach discussed in chapter 4, the gross price may be considered as the scarcity rent plus the extraction costs. This offers some interesting opportunities.

The official statistics do not only provide stumpage prices, but also prices for cut timber, corresponding to the timber gross price. As for the stumpage prices, gross timber prices have been collected for the period. Since it is a time-consuming process, the gross prices have not been weighted. With these two series, the extraction costs per cubic meter can be elaborated as the difference between the gross and the net price series. By comparing this extraction costs series with an extraction cost series collected by Nils Gustaf Lundgren, the reliability of the estimate may be tested. Lundgren's data have been obtained from forest company accounts. The data covers only sporadic years during this period. Still, it is clear that the estimates made in the present investigation lies close to Lundgren's series. It should be noted that Lundgren's investigation concerns Norrbotten, for which the general impression is that production costs are higher than average due to higher nominal wages. This is well in line with the bias in the comparison. Also worth noticing is that negative extraction costs are produced for two years. This reflects inconsistencies in the price material caused by the weighting procedure. The series are shown in diagram 3.

A price series for a forestry commodity for which it could be assumed that no scarcity rent is included would, beside a normal profit, only include extraction costs. Such a price series can therefore be used as a 'shadow price' for extraction costs. If scarcity foremost concerned saw-timber, prices for timber of other dimensions should not include a scarcity component. Such a commodity is pine

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The Economic value of trees in forests

wood used as firewood for which Jörberg provides a price series.\textsuperscript{21} As expected the price series lies close to the estimated extraction costs.

Jörberg also provides several price series for log timber.\textsuperscript{22} These series have been elaborated to form an average price series. When compared to the official price data, it is clear that Jörberg’s prices are lower by approximately a factor of 2. Still, Jörberg’s prices are linked to the official prices in 1876 forming a gross price series. The firewood prices are subsequently linked to the extraction cost estimate (gross price minus stumpage price) in the same year forming an extraction cost series. Then the net price, or the scarcity rent, may be obtained as the difference between gross prices and the extraction costs. This reconstruction of net prices is considered as the most reliable for the EHNAs concerning the period in question. The series are shown in diagram 4.

Diagram 3. Gross saw timber prices, saw timber stumpage prices, estimated extraction cost and Lundgren's extraction costs 1878 - 1908. (Öre per cubic metre)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{diagram3.png}
\caption{Gross saw timber prices, saw timber stumpage prices, estimated extraction cost and Lundgren's extraction costs 1878 - 1908. (Öre per cubic metre)}
\end{figure}

\textit{Note:} The curves are gross unit price, stumpage unit price, Lundgren's unit extraction cost (BD extr.) and the estimated extraction cost.


\textsuperscript{21} Jörberg (1972) pp. 691.
\textsuperscript{22} Jörberg (1972) pp. 538.
Diagram 4. Estimated gross timber price, stumpage price and extraction cost 1803-1908.


Dasgupta's scarcity indicator

A side effect of the elaboration of net prices provides an opportunity for elaborating economic indicators for previously made assumptions on forest scarcity during the late 19th century. As discussed in chapter 4, the scarcity rent is the gross market unit price less the marginal unit extraction cost. This means that the market price of a resource is not necessarily a good scarcity indicator. The market price may fall while the net price is rising, if at the same time extraction costs are falling, and the scarcity rent is not too large a proportion of the market price.\(^{23}\) Partha Dasgupta therefore conceives the scarcity rent, as a fraction of

\(^{23}\) A famous investigation concerning market prices and extraction costs in the raw material sector was done in Barnet, M.J./Morse, C. Scarcity and Growth. The Economics of Natural Resource Availability, Maryland 1963.
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In the present work, a scarcity indicator has been calculated as the fraction of net price of extraction costs. The extraction costs were calculated as the gross price minus net price. This scarcity indicator can therefore be seen as an approximation of Dasgupta’s “true” scarcity indicator. It is clear, that if the scarcity rent increases more rapidly than the extraction costs, that indicates economic scarcity. This could be expected to have started in Sweden sometime around 1870. The assumption is based on the fact that the extraction rate of saw timber peaked around this period and that the timber frontier had swept across the country by ca 1875. Such a result would also suggest that the major decrease of the standing timber volume occurred after 1870. A further accentuation of the scarcity indicator could also be expected to occur around 1895. Around this period the saw mills were forced to use smaller timber dimensions.

The scarcity indicator has, as mentioned above, been estimated as the ratio between the elaborated scarcity rent and extraction costs for the period 1803 to 1980. As expected the scarcity indicator is fairly stable until the 1870’s. From this period an increase takes place. Possibly it becomes even more pronounced from the 1890’s. An investigation by Sven Gaunitz also indicates that the stumpage price as a fraction of felling costs rose in 1883 and during the 1890’s. This investigation considered parts of Västerbotten county. As has been previously discussed, an increased scarcity is reflected in a rising scarcity indicator. The result therefore suggests a good correlation with the expanding saw mill industry, but also with the estimates of a decreasing standing timber volume which were made in the previous chapter. The scarcity indicator’s trend becomes negative some time around the turn of the century. An exact interpretation of the trend is, however, difficult. External factors, like the First World War, cause, for instance, the indicator to rise. The falling scarcity indicator from approximately the 1910’s seems to be correlated to the increase in the standing timber volume, but also to the declining importance of saw mills. Therefore, the comprehensive conclusion is that there is economic evidence which supports the fundamental assumptions about changes in the standing timber volume which were made in the previous chapter. The estimates of both the standing timber volume and the net prices are therefore supported independently of each other.

25 Hammarland (1961)
Diagram 5. The Dasgupta scarcity indicator


Comments and conclusions

In conjunction with the previous chapter the building blocks for EHNA for the standing timber volume and corresponding changes have been established. In this chapter, an estimate of timber net prices for the period was made. The main problem was the lack of direct data material for the period preceding 1876. Reconstruction of price data was therefore necessary for long periods of time. Support for the methods used was found in economic resource theory. As for environmental accounting in general, these results are possibly less reliable than for instance production accounts. This is specially the case for the period prior to 1876. On a general level, however, the result supports previous views that the timber scarcity increased during the latter part of the 19th century.

Concerning accounting practices the unclear institutional status of forests during foremost the 19th century provides difficulties in determining whether the forest should be treated as cultivated or un-cultivated. This determines whether logging should be treated as depletion or not. In this work forests are treated as un-cultivated prior to 1925 and as cultivated after 1925. Thus,
depletion costs are only estimated for periods prior to 1925. For periods after 1925 logging is treated as reductions of work-in-progress.

APPENDIX. Accounts for cultivated forests 1926-1980

The accounts for cultivated forests 1926-1980 are based on the national forest surveys (Riksskogstaxeringarna) for standing timber volumes. For economic values, the General Assessments (GA) and Special Assessments (SA) for real estate have been used. In GA and SA, both the value of timber in timber tracts and the value of land of timber tracts are estimated. For both assets, the stumpage price is the key-variable. The same type of valuation method has been used throughout the period. In order to value closing stock, the annual changes of the standing timber volume has first been estimated by the following method:

1/ The change between two national forest estimates has been calculated. This equals net growth (net natural growth minus logging).

2/ The total logging during the same period has been calculated.

3/ Thus, total logging plus net-growth equals total growth. By division with the number of years between the national forest survey estimates, annual total growth is estimated.

4/ Annual total growth less annual total logging then equals annual net growth.

5/ Since logging data basically covers logging for industrial purposes, the net growth figures actually equal the net growth after other cutting.

6. Annual net growth is treated as change of inventories, which is part value added of forestry.

It is important to notice that the accounts before and after 1925 respectively are not fully compatible. This is due to the fact that logging in the post-1925 accounts reflects mainly industrial logging. This means that both additions and reductions of work-in-progress in reality were larger than indicated in the accounts.

Valuation of the standing timber volume was been done by:

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28 SOS Skogsstatistisk årsbok.
1. The unit value of growing forest was estimated by division of the value of growing forest according to GA in 1981 by the standing timber volume the same year.

2. Thereafter the stumpage price index (1981=1) was linked to the unit value.

3. The value of the standing timber volume, finally, was estimated as the volume of the standing timber volume and the unit price series. This method was used throughout the period 1800-1980.

**EHNA TIMBER ACCOUNTS**

**TABLE 1. STOCK CHANGES IN THE STANDING TIMBER VOLUME**

(CNFA 2.1.1.3.)

Sweden 1800-1925, Current prices, mill SEK

*Note:* rows 2-6 are entries in the extended capital account of SEEA/EHNA. Row 7 is an imputed cost item in the production account.

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### TABLE 1. CHANGES IN THE STANDING TIMBER VOLUME 1918-1980

(CNFA 1.2.2.2.2)

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<th>Revaluation due to market prices</th>
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### TABLE 2. CHANGES IN THE STANDING TIMBER VOLUME 1926-1980

(Mill SEK, Current prices)

*Note: all entrances according to SNA-93*

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8. POLLUTION: FLOWS AND AVOIDANCE COSTS. ESTIMATES IN MONETARY UNITS.

Introduction

A central issue in the modern environmental debate is the discharge of harmful substances to land, air and water. Since environmental policy has come to evolve as a separate area of policy-making starting in the 1960's, it is easy to get the impression that pollution is a recent phenomenon. This is not, however, the case. Rather, the treatment and storage of wastes are an integral part of with the process of production and consumption. The problem of waste disposal has therefore always accompanied man. There is evidence for the existence of poor sanitary conditions, particularly in urban areas, in pre-industrial society. The Romans considered the Tibern too polluted for use as a drinking water source already by 312 B.C.\(^1\) The formation of hazardous smog, a combination of smoke and winter fog, has accompanied industrial development since the 19th century.\(^2\) Here, the British experiences are perhaps the most well known. Also acids, dust and offensive odors had early on become common discomforts in industrialized areas.

Emissions may cause damage to, respectively or in combination, eco-systems, human health and produced assets. An example of the latter is the increased corrosion of historical buildings due to acid rain. Of course, even assets like cars and various immobile structures, like bridges, may be affected by increased corrosion. Effects on human health cover a wide range of problems from annoying noise pollution to acute toxic poisoning with death as the result. Eco-system related damages cover a broad spectrum from the disruption of micro-organisms to potential global climate changes. The possible danger of an accelerated greenhouse effect due to the combustion of fossil fuels, was pointed out by Svante Arrhenius already in 1896.\(^3\) Pollution may have multiple consequences contingent not only upon the substance properties and the characteristics of the environment, but also upon whether the pollutant is combined with other pollutants. The substances discharged may consist either of animate or inanimate matter. The significance on human health of discharges containing animate matter, such as bacteria or parasites, should not be underestimated from a his-

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The hazards that arose from contaminating drinking water with human faeces included the outbreak of deadly epidemics of, for example cholera. Between 1834 and 1879, Sweden was ravaged by nine cholera epidemics. There was doubtlessly an awareness of pollution problems already during the 19th century. The fact that other problems at the time often were seen as more acute is another matter.

In this chapter, emissions of inanimate matter which are causing or have the potential to cause damage to human health and/or to eco-systems which are related to human welfare are dealt with. The emissions included in the study are generally accepted as being potentially dangerous by most scientists and environmental authorities. Needless to say, the study does not cover all emissions which would be relevant to include from an environmental perspective.

**General notes on the method employed**

The method involves the estimation of historical discharges. The source material includes existing emission estimates and different indicators to which emission factors may be used. Thus, the emission series are a mix of existing and new estimates. There exists uncertainty pertaining to relevant historical emission factors as well. The guiding principle has been to estimate minimum discharges.

As discussed in the first chapter, the estimates of necessity have to be approximate in many cases. The strategy chosen is to estimate as many emissions as possible. Because of the sporadic nature of benchmarks and indicators, the estimates for some of the pollutants are made for every fifth year. The series therefore do not allow exact periodizations and may be affected by the place of benchmark years in the business cycle. Note for instance that there was a major metal workers strike in 1945 in Sweden and that the economic crisis of the 1930’s was yet hardly discernible in Sweden in 1930.

Monetary series are estimated at contemporary average avoidance costs for "a hypothetical decrease of the polluting activity to a level where residual emissions are safely absorbed by environmental media or to defensive reactions of people to avoid the health/welfare consequences of decreases in environmental quality". Historical environmental costs are estimated for net pollution: original pollution minus actual abatement. The environmental costs are not adjusted for the fact that environmental protection activities in many cases contribute to

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GDP. The contribution from (the hypothetical) abatement measures like additional water cleaning or the contribution from a filter factory which is receiving extra orders are, for instance, ignored.

It is also worth to notice that expenditures on actual pollution control are not shown in EHNA. They are however included, but usually not separately shown, in the ordinary HNA and NA. There are also SEEA versions in which these environmental protection activities are externalized. The value added of these activities add to the ordinary GDP, just like other production activities.

In this chapter, a calculation is made of pollution abatement costs (or avoidance costs) at a present price level (a late base year) for the flow of pollutants from the economy to the environment. These series are possible to impute in order to estimate an environmentally adjusted net product. The avoidance costs roughly correspond to the question; how much of the actual GDP should have been spent on pollution abatement instead of consumption or investments in order to eliminate the pollution or reduce it to an acceptable level. What is acceptable can, of course, not be determined objectively. As far as possible, politically formulated environmental targets and/or environmental targets suggested by the Swedish environmental protection agency (Naturvårdsverket, SNV) have been used. In the case of pollution, details on the basic procedure and the linking to EHNA has been described in chapter 2. Further details concerning the accounting practices are therefore not necessary.

As been previously stated, the series are directly estimated at fixed prices. In order to achieve comparable estimates, the unit average abatement costs have been recalculated to 1994 prices by the implicit GDP deflator. The choice of the GDP deflator is motivated by the fact that historical abatement costs are fictitious in part, since no historical prices/costs exist before actual abatement became frequent in the 1970’s. Since some of the abatement costs concern countries other than Sweden, official exchange rates have been used for conversion between different currencies. Finally, the estimated costs have been added up, to form a series of imputed gross environmental costs.

The most obvious biases and problems caused by the method are the following.

1. The timing of the exceeding of sustainable levels. It may be argued that it is not correct to impute avoidance costs for historical periods where the sustainable level for a pollutant is not exceeded. Since such a correction is quite unproblematic to perform alternative series will be estimated. The procedure does, however, distort the analysis of the historical roots of the environmental problem.

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6 All unit cost estimates dates from the late 1980’s or the 90’s.
2. Fixed avoidance costs cause two biases. First, there is the ignorance of technological improvement. Sulfur dioxide abatement costs have, for instance, fallen drastically during the last 10 to 15 years. This tends to underestimate historical environmental costs. Second, there exists ignorance concerning rising marginal abatement costs, and thus rising average abatement costs, as a function of the amount of pollution that has to be dealt with. If the exceeding of sustainable levels is moderate (as for some historical period), the unit abatement cost is lower than the unit abatement cost for a period where the emissions are higher. This may lead to underestimates as well as overestimates of historical environmental costs.

3. Failing to acknowledge ignorance. It is only recently that the hazardous nature of many substances have been recognized. It is therefore a clear case of transferring present values to historical periods when historical environmental costs are estimated. The principal problem is, however, often present in historical research. It is also clear that the valuations of conflicting goals, which are also included in political actions like pollution reduction plans, are those of a modern western society. The avoidance costs therefore reflect values expressed not only on markets (like the price for abatement technology) but also in the political arena.

4. The cost of using political instruments. One important factor for reducing pollution is environmental politics. The cost is not only attributed to the protective actions themselves but also to the use of policy instruments. There are transaction costs of governance and measurement. This is valid for both command and control, as well as subsidies, taxes and tradable emission permits strategies. Many (but not all) avoidance cost investigations do not consider transaction costs, and may therefore underestimate the real costs.

Investigations of environmental costs

Primarily during the 1990’s, numerous investigations of environmental costs have been carried out as a response to the call for economic policy instruments. These investigations are aiming at tackling different environmentally related questions which, for instance, include specific product, municipal, sectoral, national, and international environmental problems. In the present study, the ambition is been to find a set of cost estimates which allow the construction of aggregated environmental volume series to be used in an analysis of imputed environmental costs in a long term perspective. Naturally, it has not been possible to cover all environmental costs in this survey.
The environmental costs estimates are heterogeneous with respect to the method employed. Each investigation involves considerations which influence the environmental pricing. Alongside the choice of general approach, different assumptions concerning interest rates, abatement potential of available technology, the environmental pollution reduction target, the effectiveness of regulations etc. affect the estimates. Also conditions, like the presence of substitutes, such as natural gas instead of coal, which differs internationally may influence the result. The estimated costs may therefore not be fully compatible between countries.

SNV, The Swedish Environmental Protection Agency, has made several environmental cost estimates. Usually, these investigations provide so-called control cost valuations. This means that the cost for reaching the suggested or decided environmental targets are investigated. Such investigations have been made for NO\textsubscript{x}, CO\textsubscript{2} Nitrogen leakage and partly for VOC.\textsuperscript{7} Internationally, several avoidance cost investigations are also found. The most ambitious avoidance cost investigations have probably been made in the United States. \textit{The Industrial Pollution Projections Project (PREDI)} conducted by the World Bank\textsuperscript{8} and a data base constructed by \textit{Convergence Research (CR)} deserve special attention.

- The PREDI investigation includes estimates of pollution coefficients as well as average abatement cost coefficients for the manufacturing industry down to the 4-digit ISIC level. The abatement costs refers to actual costs for emissions reductions in the US for the period 1979-85. Since the investigation covers ca 100,000 U.S. production facilities, it may be judged as the most reliable actual abatement cost estimates available.

- The Convergence Research database concerns environmental costs in foremost the energy sector.\textsuperscript{9} It is based on average cost estimates from up to 38 separate investigations, including nine types of emissions to air. The average cost estimates can be seen as good approximations reflecting the marginal cost effects of further emission reductions. It is, however, worth noting that the separate investigations are not fully compatible because of different

\textsuperscript{7} For a survey see SNV rapport 4592, \textit{Luftföroreningar - vad kostar de samhället? En kunskapsöversikt}, Stockholm 1996.


methodological considerations. This is a drawback, but at the same time it reflects a compromise between different approaches, in a situation when a paradigm for environmental valuation is lacking. Kevin Bell of Convergence Research claims that the numbers are solid and that "they have been fire-tested in multiple venues". Furthermore, avoidance cost estimates produce series which are compatible with SEEA IV:2 approaches to EHNA.

International and Swedish contingent valuation approaches, including willingness to pay (WTP) and willingness to avoid (WTA) investigations are also found. They are, for instance, used on the benefit-side of environmental cost-benefit analysis for different projects or environmental policy programs. WTP/WTA investigations provides series which are compatible with SEEA IV:3 to EHNA.

Damage cost investigations are also available. In Sweden KI/SCB have carried out an investigation of the social cost of acidification. Damage cost approaches, based on direct market valuation, are comparatively infrequent, probably because of methodological difficulties. However a very ambitious and comprehensive damage cost investigation has been presented by the U.S. Department of Energy (DOE), and the Commission of the European Communities. Since this investigation covers a vast number of emissions, it may also be used for estimates of damage cost series in EHNA. Damage costs produces series which are compatible with SEEA IV:1 approaches to EHNA.

As has been previously stated before, a calculation of pollution abatement costs (or avoidance costs) at the present price level (a late base year) for the flow of pollutants from the economy to the environment is made in this investigation.

The first priority in this study is to depart from avoidance costs, including avoidance and restoration costs. They represent, at least when the investigation is carried out, a real cost which in principle is determined on a market. Avoidance cost estimates are also often elaborated as control cost investigations. In

Pollution: Flows and avoidance costs. Estimates in monetary units.

In this respect they indirectly include the recommendations of natural scientists as well as political considerations of risk assessment, costs and benefits. A practical advantage is that avoidance cost investigations are rather frequent. In the case of restoration costs, they were transformed to unit costs per unit of pollutant causing the environmental degradation. This was done in order to arrive at the same accounting principles as in SEEA. The accumulated cost of the flow is recorded as a stock effect. In practice this means that if a historical emission have ceased, no contribution to the eco-margin is recorded. There may however still exist reasons for restoring environmental damage incurred as a result of historical emission. Polluted industrial sites is an example. This kind of environmental damage is recorded in the accounting system as a lower stock value in comparison, not to the beginning of the accounting period (which is a year), but to the stock value before the pollution flow started.

A second priority is to use Swedish investigations, since these in many cases are control cost estimates calculated with respect to special Swedish conditions.

A third priority is to use CR environmental costs. The reason for this is that the costs are based on a fairly large number of single investigations. Also, they are probably closer to the cost for further pollution reduction than to the PREDI investigation. In order to moderate the variation underlying the mean results, the extreme minimum and maximum values have been removed. Obviously, in order to use environmental cost estimates which concern other countries than Sweden, it is assumed that abatement costs are approximately the same throughout the industrialized world.

The fourth priority is to use estimates from the PREDI investigation. It should be observed that these estimates in many cases are lower than in most other investigations. The reason is that they cover real historical abatement expenditures including (probably) lower marginal costs than in the present.

Foreign cost estimates were transformed to SEK by the use of official exchange rates. All costs were reflated or deflated to 1994 prices, which is the base year in the PREDI investigation. For the fixed price calculation, the implicit GDP deflator calculated by SCB was used.\textsuperscript{15}

\section*{Estimates of historical emissions}

\subsection*{Nitrous oxides: NO\textsubscript{x}}

Nitrogen dioxide (NO\textsubscript{2}) and nitrous oxide (NO) are together known as nitrous oxides (NO\textsubscript{x}). NO\textsubscript{x} are causing acidification and eutrophication of waters. Ni-

\textsuperscript{15} SCB. Statistisk årsbok.
trous oxides also absorb infrared radiation and is therefore a greenhouse gas.\textsuperscript{16} The greenhouse effect, in most cases associated with emissions of carbon dioxide (\(\text{CO}_2\)), is discussed later in this chapter. Acidification involves the formation of acids in the atmosphere and the subsequent acid deposition, which is the real environmental problem.\textsuperscript{17} The other major contributor to acidification besides \(\text{NO}_x\) is sulfur dioxide (\(\text{SO}_2\)). Acidification was first identified as a major environmental problem in Scandinavia during the late 1960's.\textsuperscript{18} The phenomenon of acidification as a local problem was, however, recognized already in 1872.\textsuperscript{19} The mostly discussed environmental effects of acidification include severe ecosystem damage to lakes, precipitation of heavy metals and forest death. Acidification may also, besides having these environmental effects, cause damage to manmade structures by promoting corrosion. Specially historical buildings made of sandstone are sensitive to the corrosive effects of acidification.\textsuperscript{20} Euthrophication involves enrichment of waters by an increased nutrient input, thereby causing a rapid increase of water based organisms.\textsuperscript{21} Since this increase of the biomass consumes oxygen, the result may have severe effects, and major changes in the micro and macro biota of waters may incur. Typical signs of eutrophicated water include unclear water, immense growth of algae, offensive odor, and fish death. The main sources of \(\text{NO}_x\) emissions due to human activity are traffic and pulp industry emissions.

\textit{NO}_x\textit{ Emission estimates}

Historical estimates of \(\text{NO}_x\) emissions to air have been calculated by IVL (\textit{Institutet för Vatten och Luftvårdsforskning}) for the period 1900 to 1990.\textsuperscript{22} The categories included in this report are energy, forest industry (ISIC 34), iron and steel manufacturing (ISIC 3710) and traffic.\textsuperscript{23} Diagram 1 shows the development of \(\text{NO}_x\) emissions in Sweden according to the IVL study. Basically, the development is characterized by a sharp increase in the emissions around 1950. This reflects the rapid development of car traffic after the war, but also the ef-

\textsuperscript{17} Mannion. (1994) p. 162.
\textsuperscript{20} Nationalencyklopedin, Stockholm 1992, article "förurning", 7: 258.
\textsuperscript{21} Mannion. (1994) p. 132.
\textsuperscript{23} In the category 'Traffic' air transports and shipping are excluded.
Pollution: Flows and avoidance costs. Estimates in monetary units.

Effects of increased industrial production, not the least paper and pulp, are significant. The diagram also shows that the emissions stabilized around 1970. This is interpreted as being a result of reduced consumption of oil and responses to environmental legislation in the paper and pulp industry. However, reduction of emissions due to catalytic converters on cars and effects of the law on car exhaust gases (1986:1386) cannot be expected to be noticeable prior to 1990.

Diagram 1. NO\textsubscript{X} emissions to air. Sweden 1900-90.

Source: Kindbom, K., et al. 1993

\textbf{NO\textsubscript{X} Environmental costs}

For NO\textsubscript{X}, several avoidance cost estimations are found. The main results of the investigations are presented in table 1. According to the previously mentioned priority principles for this investigation, the SNV 4530 report clearly represents the most suitable cost estimate for NO\textsubscript{X}.\textsuperscript{24} It is worth mentioning that the investigation takes into account cost effective combinations of avoidance strategies in different sectors.

\textsuperscript{24} SNV rapport 4530, Kostnader för att minska utsläpp av kväveoxider och flyktiga organiska ämnen, Stockholm 1996. See also SNV rapport 4532, Flyktiga organiska ämnen och kväveoxider. Fortsatt arbete med utsläppsminskningar, Stockholm, 1996.
Table 1. NO\textsubscript{x} Environmental costs

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<td>Hartman et al</td>
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<td>USD 20-11918/ton\textsuperscript{15}</td>
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MAC = Marginal Abatement Cost, AAC = Average Abatement Cost, AC = avoidance cost, WTP = willingness-to-pay, DC = damage cost

Sulfur dioxide: \text{SO}_2

Sulfur dioxide causes, among other negative environmental effects, acidification. As commented above this was recognized as a major environmental problem in the late 1960’s. There are also direct toxic effects on plant and animal physiology from sulfur dioxide.\textsuperscript{26} The existence of these effects, was known already during the early 20\textsuperscript{th} century.\textsuperscript{27} Also human health may be negatively affected by high concentrations of sulfur dioxide. Respiratory problems, specially among asthmatics, may occur at comparatively low concentrations.\textsuperscript{28} More than 4000 people died for instance during the great London smog of 1952. Sulfur dioxide may also contribute to respiratory diseases, like bronchitis and cancer.\textsuperscript{29} These direct effects on human health by air pollution, in which sulfur dioxide is a significant component, was the major motive behind the introduction of the clean air act in Great Britain of 1956.\textsuperscript{30}

The main source of \text{SO}_2 emissions due to human activity is combustion of fuels with high sulfur contents. This includes both coal and oils. Also wood pulp production produces large emissions of sulfur dioxide. New technology, basically closed pulp production processes, were, however, introduced in the early 1970s. The first attempts to clean flue gases from most sulfur dioxide content, were made in the British power stations at Fulham and Battersea in the 1930s.\textsuperscript{31} However, the techniques became more commonly used first during the

\textsuperscript{25} Includes ISIC 3110-3900, AAC 1979-85. Examples ISIC 3410 = USD 20, 3710 = USD 115.
\textsuperscript{27} Nordisk familjebok, article "rökskada", Stockholm 1916 p. 150. A reference is made to Haselhoff, E./Lindau, G. *Die Beschädigung der Vegetation durch Rauch*, 1903.
\textsuperscript{28} Nationalencyklopedin, article, "svaveldioxid", Stockholm 1995, 17:459.
\textsuperscript{29} Clapp (1994) p. 67-68.
\textsuperscript{30} Clapp (1994) p. 45
\textsuperscript{31} Clapp (1994) p.47
1950s. In Swedish pulp production so called Woulfe's bottles were used to reduce emissions of sulfurous acid already during the founding years of the chemical pulp industry. Thus, it can be concluded that the technology for reducing SO$_2$ emissions was operational decades before desulfuration became a common practice.

**SO$_2$ Emission estimates**

Estimates of sulfur emissions have been obtained from the previously mentioned IVL-report.$^{32}$ These are shown in diagram 2. The rapid reduction of sulfur dioxide emissions from the early 1970s can be explained by the closed pulp production processes, together with reduced fuel consumption, a lower sulfur content of fuels, (regulated in a law from 1976)$^{33}$, and the increased use of various scrubbing techniques.

**SO$_2$ Environmental costs**

In 1977, the OECD estimated the costs for yield losses in Sweden caused by SO$_2$ emissions to between 1.2 to 2.4 million USD.$^{34}$ In Sweden, KI/SCB has estimated the SO$_2$ damage cost to SEK 6425 (1991) per ton. This estimate includes the discounted cost for future damages on growing forests and the cost for corrosion of manmade structures. Wheeler et al., have in the *Industrial Pollution Projections Project (PREDI)* estimated actual avoidance cost in the U.S. manufacturing industry.$^{35}$ On the 3-digit ISIC level the unit SO$_2$ varies between USD 19 and USD 11297/ton (USD 1994).

For SO$_2$ the U.S. emission trading auction provides a unique market valuation of SO$_2$ avoidance costs. The average winning bid on the spot market was in 1993, USD 156 and in 1994, USD 159.$^{36}$ It is worth noticing that the U.S. spot market price is of the same magnitude as the PREDI estimates.

In the present investigation, the SO$_2$ costs have been calculated as the adjusted mean (removal of extreme values) obtained from the CR. It is worth to notice that this cost is considerably higher than the PREDI costs as well as the SO$_2$ trading auction price.

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$^{32}$ Kindbom, et al. (1993)
$^{33}$ Lagen om svavelhaltigt bränsle, SFS 1976:1054
$^{35}$ Wheeler, et al. (1997)
Carbon dioxide: $\text{CO}_2$

Emissions of carbon dioxide are closely related to combustion of fossil fuels.\(^{37}\) It is by far the most controversial of the emissions. $\text{CO}_2$ is the most abundant greenhouse gas. Together with methane, water vapor and other gases, it tends to increase global temperatures by reducing the heat outflow from the earth. The greenhouse effect is a natural condition in the global climate. The current debate relates to how much more heat that is trapped by greenhouse gases emitted by human activities and what the consequences of this might be.\(^{38}\)

The UN Intergovernmental Panel on Climatological Change, IPCC, claims that $\text{CO}_2$ emissions caused by human activities are causing the natural greenhouse effect to increase.\(^{39}\) The consequences of this may be very costly. In a worstcase scenario, a runaway greenhouse effect will eliminate the preconditions for life on earth. Thus, the dangers of the possible effects of $\text{CO}_2$ contribute to make this issue controversial.

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Another factor which makes the question CO₂ a hot topic, is that the main source of man-made CO₂ emissions is the combustion of fossil fuels. Fossil fuels provide ca. 80% of the global produced energy. Substantial reductions therefore require a major alteration of the energy system. Thus, the costs –monetary and social– for drastic reductions of CO₂ may be very high.⁴⁰

CO₂ control is also a controversial issue since there are several climatologists who claim that there exists no clear evidence of CO₂ emissions do influence the climate. Natural climatologic explanations of the observed temperature increases are instead put forward. Recently Danish researchers have explained historical temperature fluctuations by changes in the solar activity and the flux of cosmic particles.⁴¹ Other criticism of the increased greenhouse effect hypothesis concerns the unreliability of temperature data.⁴² Geologists have also stated that the atmospheric CO₂ concentrations seldom have been lower than today.⁴³ The CO₂ concentration was, for instance, higher during the last glacial period, some 10 000 years ago.⁴⁴

**CO₂ Emission estimates**

In Sweden, historical CO₂ emissions have been calculated by Thomas Levander⁴⁵ and Astrid Kander.⁴⁶ Levander uses data from the historical statistics on concrete production and statistics imports and domestic production of fossil fuels to estimate the historical emissions. Kander makes estimates of other CO₂ sources, most notably from forestry and agriculture, since changes of the biomass affects the amount of CO₂ in the atmosphere. It is also worth noting that Kander tries to estimate natural sinks for CO₂ and therefore aims at reconstructing net emissions of CO₂. Kander’s estimates are not yet published as annual data in tables. In the present investigation, a reconstruction of Levander’s series has therefore been made for the period 1800 - 1972. Levander’s data has been used for the period 1973-90. The emission series here are therefore reflecting emissions mainly from combustion of fossil fuels. Historical import

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⁴⁰ For Sweden drastic means a reduction exceeding 25% of mid 1995 levels, without a closing down of nuclear power.
⁴¹ Svensmark, H./Friis-Christensen, E. Variation of cosmic ray flux and global cloud coverage, a missing link in solar-climate relationships, Danmarks Meteorologiska Institut, Scientific report 96-6. 1996.
⁴⁴ Wentzel. (1997)
statistics and production statistics of the Skåne coal fields have been used as well as emission factors obtained from Statistics Sweden.\(^47\) Also statistics on concrete production have been used. For estimates of CO\(_2\) emissions from concrete production a production volume index have been constructed (1973=1). The index is subsequently multiplied with Levander’s concrete production emission figure for 1973. Needless to say, this implies that the carbon dioxide series Diagram 3 shows the CO\(_2\) emissions. The reduced emissions after the early 1970’s is explained by reduced consumption of fossil fuels, which in Sweden not the least is associated with the nuclear power program.

**Diagram 3. CO\(_2\) Emissions. Sweden 1900-90.**

Note: emissions from combustion of fossil fuels

*Source:* Own estimates. For exact references see text.

**CO\(_2\) Environmental costs**

Also concerning CO\(_2\), several investigations of environmental costs have been made. Most of these focus on the cost of CO\(_2\) reduction expressed in terms of

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\(^{47}\) All emission factors have been provided by Sara Ribacke, SCB, 1996-06-14.
Pollution: Flows and avoidance costs. Estimates in monetary units.

reduced economic growth for a period of time.\textsuperscript{49} In those cases unit costs are not provided. Another approach is to estimate the cost of binding \( \text{CO}_2 \) in growing bio-mass. In his calculation of the environmental debt, Jernelöv used a cost of 0.1 SEK per kg \( \text{CO}_2 \). This is the same cost as Jackson/Stymne used for the calculation of the cost of "long term environmental damage" in their Swedish ISEW estimate.\textsuperscript{49}

In a recent SNV report, an estimate of \( \text{CO}_2 \) avoidance cost for Sweden is provided.\textsuperscript{50} The scenario concerns basically a 25\% reduction of the \( \text{CO}_2 \) emissions during a 10-15 year period. An implicit assumption is that nuclear power plants remain in operation. The investigation points to the fact that a considerable \( \text{CO}_2 \) reduction potential is associated with zero costs or even negative costs. For the present estimate an average avoidance cost of SEK (1994) 0.095/kg has been estimated on the basis of the SNV report. This correspond to a marginal cost of 0.25 SEK/kg which was calculated with a reduction of 25\% of present emission levels. In the Kyoto summit on greenhouse gases it was agreed on \( \text{CO}_2 \) reductions of 5\% until the year 2013. With respect to the previously mentioned SNV report this would be possible to accomplish without any social cost. \( \text{CO}_2 \) is therefore excluded from the calculation of the eco-margin which is analyzed later in the chapter. A \( \text{CO}_2 \) series calculated on basis of a cost of SEK 0,095 per kg is however provided in the table appendix. The difference between the eco-margin excluding \( \text{CO}_2 \) and the eco-margin including \( \text{CO}_2 \) is shown in the end of this chapter.

Chlorofluorocarbons: CFC’s

CFC’s (or freons) belong to a group of contaminants which are associated with the development of industrial chemicals during the 20\textsuperscript{th} century. CFC’s were invented in the 1920’s.\textsuperscript{51} Between 1930 and 1950 the world CFC production increased from 100 to 35,000 tons.\textsuperscript{52} CFC’s have many applications, including, for instance, in refrigerants, as cleansers for electronic components and in the production of styrofoam. The expansion of CFC emissions, and development of the electronics industries and the increased demand for household appliances such as refrigerators after approximately 1945 is obvious. Besides being so-called green house gases, CFC’s are believed to cause changes of the ozone


\textsuperscript{50} SNV 4632.

\textsuperscript{51} Ponting (1992) p. 385.

\textsuperscript{52} Ponting (1992) p. 385.
layer in the stratosphere. The problem was first recognized in the 1970’s.\(^\text{53}\) During the 1980’s and 1990’s several reports showed that ‘ozone holes’ had developed over the polar regions.\(^\text{54}\) A damaged ozone layer would cause an increased inflow of ultraviolet solar radiation, which among other things would increase the cases of malignant melanoma.

The first action against CFC’s was taken in the US, when CFC powered spray cans were prohibited in 1978 after a consumer boycott.\(^\text{55}\) Even though controversies exist among climatologists as to the connection between CFC’s and the observed ozone holes over the poles, the Montreal meeting in 1987 resulted in a total CFC ban in the industrialized world from 2002. The agreements on CFC reduction according to the Montreal convention was further strengthened in the London conference of 1990.

**CFC Emission estimates**

There is no easily accessible data on Swedish CFC production. A similar method as the one used by Jackson/Stymne\(^\text{56}\) has therefore been employed also in this investigation. Sweden is assumed to be responsible for 0.5 % of the global CFC production. Data has been taken from Jackson/Stymne but –in accordance to SEEA accounting practices– are expressed as annual, instead of accumulated emissions. Emissions between 1945 and 1950 were estimated by the trend \(Y=19.67t + 51.9\) which was obtained from an OLS regression of the emissions between 1952 and 1960 \((r^2 = 0.947)\). The CFC emissions used in the present investigation are shown in diagram 4. According to SNV, the Swedish CFC emissions amounted to slightly above 4500 tons in 1988.\(^\text{57}\) In 1995 they had been cut by 90%.

**CFC Environmental costs**

An estimate published in the *Science* magazine has been used for obtaining CFC avoidance costs.\(^\text{58}\) The global avoidance cost is estimated to USD 10 billion. The Swedish share of the global cost is assumed to equal 0.5 %.

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\(^{56}\) Jackson/Stymne (1996)

\(^{57}\) http://www.environ.se/index_4.htm (1998-07-26)

Diagram 4. CFC Emissions in Sweden. 1948-90. Index 1960=1


Volatile organic compounds: VOC

The group volatile organic compounds (VOC’s) consists of a large number of easily diffused carbon based (organic) compounds. VOC’s are in varying degree hazardous to human health. They may, for instance, cause neural disorders as well as cancer. Concentration and exposure to humans are crucial factors affecting the risks for VOC’s to cause negative health effects. Together with NO\textsubscript{x}, VOC’s also contribute to the formation of photochemical oxidants, which have negative effects on humans and ecosystems.\textsuperscript{59} The problems with photochemical oxidants have been known since the 1970’s.\textsuperscript{60}

The VOC sources are varying, but a major one is fuel remains in the exhaustion gases due to incomplete combustion in engines. The transport sector is in the present one of the dominating VOC sources, while for instance commercial energy production produces far less VOC’s.\textsuperscript{61}

Another VOC source is leakage during the handling of liquid (and gaseous) fuels. An example of this can be found at service stations. The additions from the industry sector are concentrated primarily to the use of lacquer and thinners

\textsuperscript{59} SCB, Naturmiljön i Siffror, Stockholm 1993, p. 30.
\textsuperscript{60} SCB, Naturmiljön i Siffror, Stockholm 1993, p. 33.
\textsuperscript{61} SNV 4532.
in the metal and engineering industry, but also refineries, and the paper and graphic industry are significant VOC sources.

Even the household sector is a major VOC producer even if private car driving is omitted from the picture. This is primarily due to smallscale fire wood combustion. In addition the household use of chemicals associated with car and boat care as well as paints, lacquer, white spirit etc. contributes significantly to the total VOC emissions.

**VOC Emission estimates**

Historical estimates for road traffic VOC emissions are found for 1950, 1960, 1970, 1975, 1982 and 1988. Registered private cars have been used for interpolation between these benchmark years 1950.

The basic procedure was to link a private car index (index = 1 for the early benchmark year (t=0)) to the emission estimate for that benchmark year. The difference which usually occurs for the later benchmark (t+n) is adjusted with a linear trend of the type: Y = b(t) + 0. Thus, the value of Y is 0 in the early benchmark year. In the late base year, the difference between the actual emissions that year, and the estimated emissions (obtained as the sum of the index and the linear trend) is zero.

The number of registered private cars have also been linked to the emissions in 1950 in order to accomplish an historical estimate from 1916. For power tools there are estimates for 1975 and 1988. Linear interpolation is used between these two benchmark marks. Prior to 1975 the number of registered tractors has been used as an emission indicator. Prior to 1950, lorry traffic from HNS was used as an indicator. Since the efficiency of the engines probably improved also prior to 1950 this estimate should be considered as being conservative.

For air traffic there are estimates for hydro carbon emissions in 1975 and VOC for 1988. For better comparability, hydro carbon emission data from Luftfartsverket (LFV) for 1990 has been used. Domestic air traffic has been used as an emission indicator prior to 1975. This does probably lead to an un-
Pollution: Flows and avoidance costs. Estimates in monetary units.

derestimate since the environmental standards of jet engines improved also prior to 1975. A methodological problem which makes further adjustments difficult is the lack of emission factors for valve propeller engines. Valve engine aircraft types, like the DC-6 and Convair 40, were widely used in Swedish domestic air traffic during the 1960's.

Concerning boat traffic the only estimate that has been found is for 1988. Boat traffic in HNS was been used as an emission indicator. A correction for sailing ships was done until 1945. In table 3, the shares of motor shipping are shown.

Table 2. The share of motor vessels in inland shipping

<table>
<thead>
<tr>
<th>Year</th>
<th>Motor Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>0,83</td>
</tr>
<tr>
<td>1905</td>
<td>0,72</td>
</tr>
<tr>
<td>1910</td>
<td>0,88</td>
</tr>
<tr>
<td>1915</td>
<td>0,90</td>
</tr>
<tr>
<td>1920</td>
<td>0,9</td>
</tr>
<tr>
<td>1925</td>
<td>0,95</td>
</tr>
<tr>
<td>1930</td>
<td>0,95</td>
</tr>
<tr>
<td>1950</td>
<td>1,0</td>
</tr>
</tbody>
</table>

Note: The table shows the steam vessel tonnage as a share of total tonnage. Own approximates have been used from 1920. 1915 corresponds to shares for 1913. Source: Krantz (1986) p. 41. And for 1905 Krantz (1986) p. 57. table T8b.

The only reliable estimate for manufacturing industry is for 1988. The difference between the figures for VOC emissions in SNV 4532 (for 1988, 110,000 ton) and SNV report 3379 (for ca 1985, 73,000) for the mid 1980's, probably reflects differences in calculation methods rather than real changes. The SNV 4532 estimate was therefore chosen. The report includes emission figures for certain industry branches. It has therefore been possible to use the production volume of the corresponding industry groups (1, 3, 4, 7) in HNS as separate indicators. Here, the production volume have been indexed (1988=1) and multiplied with the benchmark year emission. For the other industry groups, a similar indicator for industry groups 2, 5, 6 was constructed on basis of their weighted

71 SNV 4532.
73 SNV 4532.
indexed production volume (1988=1). This index is multiplied with the emission for the category "other industries" in the SNV report.

VOC emissions from the energy sector were estimated with 1988 as a benchmark and coal consumption as a historical indicator.\(^{74}\)

Leakage due to handling of oils and petroleum product also departure from the 1988 benchmark, with oil import as an indicator.\(^{75}\)

Concerning the household sector, estimates were obtained for 1988.\(^{76}\) The use of chemicals was divided into two groups: chemicals for cars on one hand and boats and other uses, on the other hand. The indicators are, respectively, registered cars and the production volume of chemical industries. The indexation is similar to that in the cases previously described. Small-scale combustion of firewood in 1988 was equal to 34.7 TJ which produced ca 150 kton of VOC emissions. For 1985 the use of firewood equaled 46.9 TJ. The emissions are assumed to have been constant since 1955, when Gunnar Arpi’s estimates of household wood consumption (of which firewood is a significant share) are used as an indicator.\(^{77}\) All estimates of household firewood consumption are, of course, uncertain.

An historical estimate for VOC emission due to production and consumption of charcoal was done on basis of Arpi’s estimates of wood consumption for the purpose. It was assumed that the total emissions per cubic meter equals those of small scale firewood combustion.

The aggregated VOC estimates are shown in diagram 5. The initially high VOC emission levels are explained by the wide spread practice of small-scale firewood combustion for household heating purposes. After the Second World War, small-scale firewood combustion stagnated and eventually declined. Instead, oil came to play a more important role. Due to the expansion of automobile traffic, and associated activities, such as handling of fuels and the consumption of chemical products for cars, the emissions again to rise. The development of the chemical industry, with a rapid volume increase and the introduction of new products, has also contributed to the increase of VOC emissions after 1950.


\(^{76}\) SNV 4532.

\(^{77}\) Arpi, G. *Sveriges skogar under 100 år*, Stockholm 1959.
VOC Environmental costs

Complete VOC avoidance cost estimates have not been made in Sweden. Costs in the range of SEK 20,000 to 40,000 per ton may however be assumed.\textsuperscript{78} WTP investigations suggests costs up to SEK 49,000 per ton.\textsuperscript{79} The difference as compared to the PREDI investigation is striking. Therefore, the Convergence Research (CR) adjusted mean has been used for obtaining VOC avoidance costs in the present investigation.

Diagram 5. VOC emissions. Sweden 1900-90

\begin{center}
\includegraphics[width=\textwidth]{voc_emissions.png}
\end{center}

Source: Own estimates. For exact references see text.

Carbon monoxide: CO

Carbon monoxide is a rest product from combustion with an insufficient oxygen supply. If CO exists in high concentrations in for instance city air, it may be hazardous to human health. The primary CO producer is automobile traffic.

\textsuperscript{78} SNV4530. appendix 3.
\textsuperscript{79} SNV 4592, p. 41.
**CO Emission estimates**

Estimates of emissions from road traffic have been obtained from SCB 1993.\(^{80}\) The benchmarks are for 1950, 60, 70, 80, 85 and 88. The same indicator, and interpolation approach as used for traffic related VOC emissions have been used also in this context.

Emissions from coal combustion and industry are estimated on basis of 1969 and 1975 benchmark data.\(^{81}\) In 1969, the energy emissions and industry emissions were 40,000 tons respectively. Of the HNS industrial groups, IG 2 (stone industry) was the most dominating source. A joint index (1970=1) with equal weights for coal consumption and the production volume of IG2 was therefore constructed for the historical estimates prior to 1969. The index was also used for estimates to 1990. When considering the reliability of the estimates for the energy and industry sector, it should be observed that the emissions from these sectors only was 2.6% of the traffic CO emissions in 1990. The CO emissions are shown in diagram 6.

The development of CO emissions shows a 'typical' development for most fuel-related emissions, with a sharp increase from 1950 and reductions from around 1970. Again, the explanation lies in the development of automobile traffic, the reduced use of fossil fuels and sharpened environmental regulations starting in the late 1960's. Effective combustion in, for instance, engines can also be assumed to have contributed to the reduction of CO emissions. Regulation of automobile exhaust emissions was introduced in 1972 by an ordinance outlining direct emissions standards.\(^{82}\) This type of regulation was introduced in the USA in 1968.\(^{83}\) Furthermore, CO emissions are reduced by the use of catalytic converters. However, prior to 1987, the use of catalytic converters was insignificant in Sweden.\(^{84}\)

**CO Environmental cost estimate**

The only investigation which was found dealing with CO costs is the CR.\(^{85}\) Therefore the CR adjusted mean was used also in this case.

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80 SCB. *Naturmiljön i siffror*, Stockholm 1993, table 2.92, p.79.
85 Jacson/Stymme (1996) use the Tellus report estimate (SEK (1985) 4245 per tonne). This investigation is included in the CR survey.

Source: Own estimates. For exact references see text.

Fine particulates: PM10

This category of pollutants includes solid and liquid particles of various chemical compositions. They are very small, having a diameter of 10 microns or less. Fine particulate can, in addition to being toxic by themselves, also be potential carriers of other toxic substances. Since they are so small, fine particulate can penetrate the respiratory system and since they may carry other substances, PM10 particles can carry these harmful substances deep into the lungs. The resulting effects on human health include the development of respiratory problems and cancer. The dominant source of fine particulate is traffic. Minor contributors are combustion of fuels and industrial processes, with concrete production as one of the most significant.

PM10 Emission estimates

Total emissions were estimated by SCB for 1969, 1975 and 1990. Car traffic emissions are also made for the same years as for CO emissions.

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87 SOU 1975:98.
88 SNV PM 1078.
For estimates of the development of PM10 emissions between 1960 and 69, figures on dust levels in the Gothenburg air were used.\footnote{SCB. \textit{Naturmiljön i siffror}, Stockholm 1993, p. 30. The figure refers to the late 1980s.}

For estimates prior to 1960, an emission index was constructed with changing weights. The HNS industrial groups were disaggregated to roughly correspond to the 4-digit ISIC with a residual group for unclassifiable or uncertain branches. The weights were obtained from Ljungberg's HNS deflators and from the official industrial statistics.\footnote{Ljungberg, J. \textit{HNS. Deflatorer för industriproduktionen 1888-1955}, Lund 1988.} For industrial process emissions, emission factors calculated by the World Banks PREDI project were used.\footnote{PREDI http://www.worldbank.org/nipr/ippdata.htm (1997-07-31).} These emissions factors correspond to emissions per unit of production value on the 4-digit ISIC level. Coal emissions are calculated with the emission factor 25mg/MJ.\footnote{SCB. \textit{Naturmiljön i siffror}, Stockholm 1996, p. 94. 1996:3. (Coal = 26.5GJ/ton)}

Diagram 7 shows the development of emissions of fine particulate. In these estimates, the use of coal is given a significant role. The reduction of emission levels are, for instance, obvious during the world wars. A drawback with this approach is, of course, that firewood related emissions are not included. The lack of proper emission factors was the main reason for using coal as a general indicator. According to these estimates, the reduction of emitted particulate started already during the 1930's. As mentioned above, this basically reflects the use of coal. The industry's increased use of various emission control methods, like electrostatic precipitators, fabric filters and afterburners have also, most likely, contributed to the reduction of the emissions.\footnote{Ledbetter, J.O. \textit{Air Pollution. Part B. Prevention and control}, New York, 1974, p. 31.}

\textit{PM10 Environmental costs}

The CR data include TSP (Total Suspended Particulates) which is a less rigid measure than PM10. Fine particulates are included in the PREDI investigation, but in accordance with the priorities set up in the beginning of the chapter, the adjusted mean of the CR data has been used also in this case.
Pollution: Flows and avoidance costs. Estimates in monetary units.

Diagram 7. Emissions of fine particulates. Sweden 1900-90

Source: Own estimates. For exact references see text.

Sewage: BOD$_7$: Biological oxygen demand

Biological oxygen demand is defined as the amount of dissolved oxygen which is consumed during the decomposition of organic material in water during a seven day period. BOD$_7$ is associated with biological remains in sewage water. Also surface runoff and natural biotic processes contribute to introduce BOD$_7$ in water. High BOD$_7$ levels lead to low levels of dissolved oxygen in the water. This may in turn lead to the damage and extinction of aquatic life. Closely associated to BOD$_7$ is COD$_7$ (chemical oxygen demand). Like BOD$_7$ also COD$_7$ reduces aquatic oxygen and causes disturbances to aquatic eco systems.

The main sources of BOD$_7$ are paper and pulp industries and municipal sewage treatment facilities. Besides paper and pulp industries, even food and chemical industries contribute to BOD$_7$ emissions. This occurs on a much lower level, however. It should also be observed that many industrial plants are connected to municipal sewage treatment facilities. There is also a substantial flow of BOD$_7$ from rivers. It has not been possible to account for these emissions, since the ultimate sources are both natural and due to human activity (primarily agricultural).

There are also other relevant measurements besides BOD$_7$ which are used when sewage is concerned. Total phosphorous (Tot-P) and total nitrogen (Tot-N) are for instance commonly used measurements. It should also be noticed that

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sewage treatment may be effective with respect to one effluent but not with respect to another.

**BOD**₇**Emission estimates**

With respect to the insufficient historical data on emissions and the difficulties in finding proper avoidance costs for each type of sewage related measure BODᵭ and tot-P are chosen as general sewage water pollution indicators in the present investigation.

For the paper and pulp industries there are BOD₇ emission estimates from various sources available from the mid 1950s.⁹⁷ Prior to 1955 pulp production has been used as an indicator.⁹⁸

It is more difficult to estimate emissions from municipal sewage treatment. When calculating the economic costs for sewage treatment, also, for instance, total nitrogen and total phosphorous are included in the total costs. It is certainly difficult to account for these measures separately. Therefore a sewage treatment index was constructed which includes both BS₇ (which is very similar to BOD₇) and total phosphorous.⁹⁹ Both types of emissions are given equal weight in the index. The index covers the period starting in 1940. From 1915 to 1940, the emissions are approximated by the municipal water consumption.¹⁰⁰

Thus, the underlying assumptions are that no sewage treatment was conducted and that the concentration of BOD₇/Tot-P in the sewage water was constant. For the period 1900 to 1915, the emission levels were assumed constant. This index (1970=1) is linked to the BOD₇ emissions from municipal water cleaning facilities for that year (65 kton).¹⁰¹

Emissions for other industries (HNS IG 5 and IG 7) were estimated on basis of the respective industry groups emissions in 1970 (65kton and 9,3 kton).¹⁰² Furthermore, it is assumed that the ‘sewage treatment performance’ has developed the same way as concerning municipal sewage treatment. This ‘sewage treatment performance’ was obtained by dividing the sewage emission series described above with the series for municipal water consumption.¹⁰³ Thus, low levels of emissions and high levels of water consumption gives a low index value, which indicates the ‘sewage treatment performance’ is high.

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⁹⁸ SOS Industri.


¹⁰¹ SOU 1975:98. *Note*: IG, industry group according to HNS. See list of abbreviations.

¹⁰² SOU 1975:98.

To obtain an estimate for sewage emissions from 'other industries', the 'sewage performance index' (1970=1) is multiplied with the production volume (index 1970=1) of the industry groups and the sewage emissions from IG 5 and IG 7 in 1970.

**BOD<sub>7</sub>, Environmental costs**

Concerning purification of domestic effluents there are several avoidance cost estimates. U.S. investigations from the late 1950's estimated the total cost for purification of effluents from 22.2 million inhabitants to 1800 million USD (1957). The total cost for sewage treatment plants were at the same time estimated to 10 000 million DM for the Federal Republic of Germany, and 20 000 AUS for Austria. In the present investigation, more recent estimates are, however, needed.

Costs for conventional water (BOD<sub>7</sub>) from ISIC 32, 34 and 35 were obtained from the PREDI investigation. Emissions from municipal water facilities were estimated on the basis of the total cost for municipal water plants in 1991.

-First, the municipal water consumption was divided by the emission index for 1940 (no sewage treatment was assumed in 1940).

-Second, this ratio was multiplied by the water consumption in 1990. This gives an index figure for sewage, as if there were no sewage treatment in 1990. In that case the emission index would have been 11.01. The true index was however 1 in 1990. Thus, 11.01 - 1 = 10 emission index units were abated in 1990. The unit abatement cost per emission index unit is therefore equal to 1/10 of the total abatement costs in 1990.

-For municipal sewage the costs and emissions are estimated every fifth year (1900, 1905 etc). Linear interpolation has been used in order to obtain annual values. Diagram 8 shows the estimated industrial and municipal sewage emissions.

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105 Na 23 SM 9301.

106 Actually the costs refers to 1991.
Diagram 8. BOD7 Emissions. Sweden 1900-90

Note: The estimate includes emissions from municipal sewage and manufacturing industries.
Source: Own estimates. For exact references see text.

It is clear that the forest industry has been the predominant source of this type of emission during, probably, the whole 20th century. In this calculation of BOD7 emissions, the emissions peak in the early 1960's. This reflects the fact that emissions in water were given a high priority early on in the forest industry. One reason was the higher concentration in the industry, which, as a result of larger plants, created more serious local environmental problems. Also, water pollution from the pulp industry was debated upon already during the 19th century. Thus, it was a well known problem and regulation was probably expected by the representatives of the industry. The Swedish paper industry association established a committee which in 1937 tried to find suitable strategies for reducing water pollution. The water law from the early 1940's mandated that industrial waste water should be treated in such way that inconvenience for

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107 The forest industry contributed with nearly 90% of the total emissions of oxygen demanding substance during the early 1970's. See for instance Carlsson, C-G. Kemiindustrin i miljön, Lund 1971, p. 14.
109 Rydberg, S. Papper i perspektiv, Uddevalla 1990, pp. 142.
humans and nature could be avoided.\textsuperscript{110} The forest industry’s water protection institute was created during the 1950’s and developed in 1965 to the Institute for Water and Air Research (IVL). IVL also involved other industries in addition to the forest industry. Urbanization during the 19\textsuperscript{th} century and the increased use of indoor toilets during the 20\textsuperscript{th} century precipitated the need for action taken against water pollution. There was also, in comparison to previous periods, other options for technical fixes at this time. Generally speaking, it was necessary to avoid having increased use of water in industries and households conflicting with the future water supply and recreational interests.\textsuperscript{111} Water pollution-related issues were for the first time regulated in part by a law passed in 1868.\textsuperscript{112} In the health care ordinance from 1874 the protection of wells were, for instance, regulated.\textsuperscript{113} The first steps toward modern legislation were taken already in 1915, but the introduction of effective legislation was delayed until the 1940’s. During the 1950’s, a series of laws were introduced.\textsuperscript{114} This resulted in a rapid increase of the number of municipal sewage treatment facilities after 1950. In 1935 there was only one modern sewage treatment facility in Sweden. In 1950, the number amounted to 12.\textsuperscript{115} Ten years later there existed not less than 276 facilities in 30 municipalities. Thus, the development described in the diagram is the result of increased production of pulp and increased consumption of water in the other industries and in households, which caused an increase of the emissions until the 1960s. Thereafter, various measures for reducing water pollution, including industrial and municipal sewage treatment facilities, have reduced the emissions significantly.

**Heavy metals: Emissions to air and water**

Heavy metals include lead, mercury, zinc, cadmium and arsenic. All of those have a detrimental effect on human health. Usually, most attention has been given to lead since this metal in most cases is the predominate one with respect to pollution. From a medical perspective lead is a cumulative neurotoxin which can combine with a large number of biomolecules, including enzymes, haemoglobin, DNA and RNA.\textsuperscript{116} Contact with elevated levels of lead may, for instance, cause impaired blood synthesis, hypertension, hyperactivity and brain damage.

\textsuperscript{110} See SOU 1939:40. *Betänkande angående åtgärder till motverkande av vattenförorening m.m.*

\textsuperscript{111} SOU 1964:60, *Vattenvårdens organisation m.m.* p 8.

\textsuperscript{112} SOU 1967:43, p. 75-76.

\textsuperscript{113} SOU 1967:43, p 75-76.

\textsuperscript{114} SOU 1967:43, p 75-76.

\textsuperscript{115} SOU 1964:60, *Vattenvårdens organisation m.m.*

\textsuperscript{116} Mannion (1994) p. 175.
Heavy metals are significant from an environmental historical perspective. This group of substances was recognized comparatively early as problematic, and together with pesticides, the menace of heavy metals became a significant issue when environmental problems were put on the political agenda after the Second World War. The poisonous effects of, for instance, lead and arsenic have been recognized for a very long time. Perhaps it is overflous to mention Lucrezia Borgia in regard to this. It was, however, the Japanese Minamata-bay mercury poisoning tragedy of the 1950’s which drew attention to the hazards of unchecked use and emissions of heavy metals.

**Heavy metal emission estimates**

The estimates of heavy metal emissions to air and water are generally unreliable also for the most recent parts of the period. Due to separately made calculations of lead and mercury emissions, these estimates are shown separately.\(^{117}\) Observations for heavy metal emissions are found for 1970/73, 1977/78, 1985 and 1990. The main sources of these pollutants are steel production, other metal manufacturing industries, non-ferrous mines, municipal sewage treatment and oil combustion. On the basis of emission data for 1970, indicators have been constructed for each heavy metal with respect to the production volume of the main industrial emission source.\(^{118}\) When more than one activity is concerned, the separate indices have been weighted in accordance with the emission contribution of each separate activity. An exception is zinc and copper emissions during the period 1930-65. These emissions are calculated on the basis of the metal input to the steel and metal manufacturing industry.\(^{119}\) The air emissions are dominated by zinc (66% of the total in 1970) while the percentage of zinc in water emissions was 44% in 1970. For the period beginning after 1970, linear interpolation was used in order to obtain annual data. Diagram 9 shows the estimated heavy metal emissions to air and diagram 10 the emissions to water.


\(^{118}\) SCB, *Naturmiljön i sifror*, Stockholm 32, table 2.4, p. 32.

\(^{119}\) SOS Industri.
Heavy metals show the 'typical' development of share increases after 1950, followed by reductions from the early 1970's. The increase basically follows the volume growth of certain industries, like metal works, while the reductions appear to be related to the introduction of modern environmental legislation, basically the Environment Protection Act (1969:387), the Products Injurious to Public Health and Environment Act (1973:329) and the certain parts of the Nature Conservancy Act (1974:822). Also the ban of 1966 concerning treatment of cereals with methyl mercury, could be put forward in this context.\textsuperscript{129}

\textsuperscript{129} Thunberg (1979) p. 95.
Diagram 10. Emissions of heavy metals to water. Sweden 1900-90.

Note: The estimate includes Cu, Zn, An, Ni, Cr, Kd

Source: Own estimates. For exact references see text.

Heavy metal environmental costs

Costs for heavy metal (except lead) emissions to water (Toxic water) and air (Toxic air) were obtained from the PREDI investigation. The mercury costs are corresponding to PREDI Toxic air.

Lead(Pb) and mercury(Hg) emission estimates

Historical estimates of Swedish lead emissions to air and water have been made by Anderberg, Bergbäck and Lohm. For the period 1985 to 1988 data is taken from the SCB environmental statistics. Between 1980 and 1985 linear interpolation was made to obtain annual figures. Since data for 1990 is missing the annual reduction of the emissions is assumed to have been the same as for the period 1985-88. The use of batteries, other sources, patrages and lead shots are assumed to have been constant during the period. The mercury emissions are

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121 Anderberg et al. (1990).
122 SCB Naturmiljön i siffror, Stockholm, 1993, table 2.4, p. 32.
Pollution: Flows and avoidance costs. Estimates in monetary units.

estimated by Levander. Both the lead and mercury estimates are made for every fifth year. Linear interpolation was made in order to obtain annual data. This causes some distortion of especially the lead series. The lead emission peak during the late 1930’s and early 40’s is caused by intensive use of ammunition. Besides ammunition, important contributors to lead emissions are metal works, use and production of accumulators and mining. The perhaps mostly discussed source is, however, the use of leaded gasoline. It became common to add tetraethyl lead to gasoline in the 1920s. The reason for this was to obtain an acceptable engine performance with the introduction of high compression engines. The proportion of lead in gasoline has been cut back since the first maximum limit was stipulated in 1973. In the United States, the reduction of lead in gasoline was mandated by the Clean Air Act of 1970.

Diagram 11. Lead to air, water and land. Sweden 1900-90.

Source: Anderberg et al. (1990)

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Diagram 12. Mercury emissions to air. Sweden 1900-90

Lead environmental costs

Lead abatement costs is a special case in the present investigation. A significant amount of emissions originates from outside the industry sector. Although this is also the case concerning lead, the historical investigation of lead is very detailed. Lead is also, the most quantitatively significant of the heavy metal emissions in Sweden. Since the emission estimate is comparatively detailed it has been possible to conduct a separate lead avoidance cost estimate. Abatement costs for industrial activities have been taken from the PREDI investigation.

The cost for lead batteries and accumulators is based on the proposed Swedish tax for collection and waste management at 40 SEK per battery. A total tax revenue of 48.6 Mill SEK is estimated for 1997. This figure, expressed in SEK (1994), was linked to the battery emission estimates made by Anderberg et al.

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127 Anderberg et al. (1990).
A major source of lead emissions is lead shots and patrages. Lead shots may be substituted by steel shots at a cost of ca 2 SEK for a 30 g shot. Lead emissions may then be avoided at a price of SEK(1997) 67 000/ton.

For patrages, the cost is estimated on the basis of restoring contaminated land on adjacent to and including shooting ranges. In Sweden there are 4000 civilian and 290 military shooting ranges and there are approximately 30,000 tons of lead in these surroundings. The environmental restoration cost is approximated by assuming that 3,000,000 tons of wall sand must be sanitized at the cost of ca 250 SEK/ton. The total sanitation cost is then estimated to SEK 75 million, implying a unit cost of SEK 2500 per ton of lead.

Avoidance costs for different miscellaneous sources, like lead pigments, cables etc. have been estimated as a mean of the other sources.

Another major emission source is leaded gasoline. The production cost for unleaded gasoline according to STATOIL is roughly 0.1 NOK higher per liter as compared to leaded petrol. In the present investigation it has been assumed that 0.5 g of lead is added per liter of gasoline. Thus, 2000 liters equals one Kg of lead. The unit avoidance cost is then roughly NOK(1997) 200/Kg of lead.

The same price is also used for coal and oil emissions.

Concerning leakage from mine waste deposits the total sanitation costs are estimated at SEK 300 million by Jernelöv. Dividing the accumulated lead emissions from mine waste gives a unit cost of SEK 80 per ton.

The lead avoidance costs, expressed in SEK 1994 are shown in table 3. To estimate total costs, the unit costs with regard to each separate source have been applied to the respective historical emission series.

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128 Approximate price according to local weapon and ammunition dealers.
130 SNV 4662, p. 7.
131 STATOIL information office, Norway. Letter to the author 1997-07-01
Table 3. Lead avoidance costs

<table>
<thead>
<tr>
<th>Emission source</th>
<th>Cost/ton</th>
<th>Unit cost (SEK 1994)</th>
<th>Reference</th>
</tr>
</thead>
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<tr>
<td>Leaded petrol</td>
<td>200 (NOK 1997)</td>
<td>202</td>
<td>STATOIL 970701</td>
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<tr>
<td>Patrages</td>
<td>2500 (SEK 1996)</td>
<td>2366</td>
<td>NVV 6462</td>
</tr>
<tr>
<td>Lead shot</td>
<td>67 000(SEK 1997)</td>
<td>63 000</td>
<td>Prices 1997</td>
</tr>
<tr>
<td>Mine waste</td>
<td>80 (SEK 1992)</td>
<td>84</td>
<td>Jernelöv 1992</td>
</tr>
<tr>
<td>Metal non-ferrous</td>
<td>1284 (USD 1993)</td>
<td>10290</td>
<td>Wheeler et al 1994</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>779 (USD 1993)</td>
<td>6170</td>
<td>&quot;</td>
</tr>
<tr>
<td>Accumulator prod</td>
<td>26 (USD 1993)</td>
<td>210</td>
<td>&quot;</td>
</tr>
<tr>
<td>Rubber</td>
<td>132 (USD 1993)</td>
<td>666</td>
<td>&quot;</td>
</tr>
<tr>
<td>Glass</td>
<td>186 (USD 1993)</td>
<td>1490</td>
<td>&quot;</td>
</tr>
<tr>
<td>Coal/Oil</td>
<td>same as petrol</td>
<td>210</td>
<td>&quot;</td>
</tr>
<tr>
<td>Miscancellous</td>
<td>Mean of other sources</td>
<td>2100</td>
<td>&quot;</td>
</tr>
<tr>
<td>Accumulators</td>
<td>40/battery (SEK 1996)</td>
<td>38</td>
<td>Current Swedish tax</td>
</tr>
</tbody>
</table>

Source: see text

Fertilizers

During the 19th century, guano from Africa and South America became important for increasing agricultural output. Somewhat later, phosphate mining provided easily accessible fertilizers for the industrialized countries. New artificial fertilizers were also introduced, Superphosphates in the 1840's and nitrogenous fertilizers in the 1920's. Without doubt, the use of commercial fertilizers was important for the development of modern agriculture. Commercial fertilizers have been used in Swedish forestry since the 1960's. Certainly, this has contributed to the positive development of the standing timber volume. However, the use of commercial fertilizers is not a total success story. The primary environmental problem caused by use of fertilizers, or rather overuse of fertilizers, is eutrophication. Thus, fertilizers add to environmental problems caused by NO\textsubscript{x} emissions and sewage.

Estimates of fertilizer use

Historical statistics of the use of fertilizers in Swedish agriculture have been published by Naturvårdsverket. Total emissions of ammonium (NH\textsubscript{3}) have been estimated by IVL. The origin of ammonium in agriculture is basically urine from cattle and hogs. Subsequently, a total fertilizer series consisting of

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ammonium leakage to air, and used quantities of commercial fertilizers (nitrogen, potassium and phosphorous fertilizers) have been created. Diagram 13 displays the total fertilizer series. The diagram shows that the reduction of fertilizer use have been comparatively modest. However, the reductions that has taken place can probably be explained as the effect of taxes on commercial fertilizers.

Diagram 13. Use of K, P, and N fertilizers. NH3 emissions. Sweden 1900-90


Fertilizer environmental costs

Swedish agriculture is responsible for annual N-emissions to the seas amounting to ca 24 000 tons. The environmental goal is a reduction of the leakage by 10 500 tons N per year. According to a proposal from Naturvårdsverket the tax on fertilizers should be raised to 3 SEK/kg N to achieve a reduction of the annual emissions by between 2000-2500 tons. A tax of 4.25 SEK/kg N would reduce the emissions by 5000 tons. Thus, even the higher tax option is not alone sufficient to reach the environmental targets. The total tax revenue is higher than the total cost that the reduction of fertilizer use. According to SNV, this total cost is estimated to 200 M SEK. Furthermore, some of the tax revenue is supposed to be transferred to the agriculture in order to finance different proj-

pects aimed at further reducing the N-leakage. The total social cost is therefore 350 M SEK. This sum corresponds to an approximative cost of 1.85 SEK/kg N fertilizer in order to reduce N-leakage to sustainable levels. In the present investigation this unit cost was used for the fertilizer total series. Finally, it should be noticed that estimates of the total cost for stopping eutrophication in the Baltic sea have also been made. The measures include action taken against air pollution, for instance. In this investigation such an approach would lead to double accounting, and is therefore not used.

Pesticides

Pesticides, or biocides, includes various chemicals usually intended for crop protection in agriculture and forestry. The use of highly effective pesticides is almost solely a post-war phenomenon, the first substances being so called organo-chlorides, such as DDT. Also this case was an economic success story. U.S. investigations showed a rate of return of between 400% to 500% for every dollar spent on pesticides. The potential dangers associated with pesticides was first put on the public agenda by Rachel Carson. A number of scientific investigations in the U.S.A. and Canada confirmed that DDT accumulated in body fats. It was also shown that the near extinction of large birds of prey was a tragedy in which DDT played a significant role. A number of laws restricting and in some cases prohibiting the use of pesticides were introduced during the 1960s. In Sweden the forestry practice of using phenoxy herbicides was a hotly debated issue during the 1970's. Since the excessive use of pesticides may cause toxic poisoning in humans and other species than those the pesticides are intended for, control has been aimed at reducing the use of pesticides. This has been achieved by imposing direct maximum levels and a general prohibition of household use of pesticides. Also taxes is an instrument which encourage reduction in the use of pesticides. Furthermore, the most dangerous substances like DDT and phenoxy herbicides have been outlawed. The use of biocides and pesticides in modern Swedish agriculture is at the present not viewed as a major problem.

138 SNV 4735 p. 27.
144 The first restriction in Sweden was "Gränsvärden enligt kommerskollegii kungörelse (Ser A 1966:5).
Estimates of pesticide use

Data on the use of pesticides, expressed as an active substance, is found in the official agricultural statistics from 1960. For earlier dates the use has been approximated by the production figures in the official industrial statistics. The figures have also been transformed into a proxy for active substance, based on the statistics of total use and active substance in 1975. It should be observed that these figures include very harmful substances like DDT and C₆Cl₅OH (outlawed in 1978) as well as less destructive ones.


Note: five year bench-marks have been used in diagram.
Source: SOS Jordbruk, SOS Industri.

Pesticides environmental costs

Cost estimates for pesticides have not been found. Due to different climatic conditions, the international cost variations may be expected to vary substantially. In this case Sweden is favored by cold winters Even though the approach is not formally correct the present tax level could be used as an approximation.

146 SOS Jordbruk.
147 SOS Industri.
for pesticides/biocides avoidance costs. The tax rate is 30,000 SEK per ton of active substance. However, due to lack of proper cost estimates, biocides are not included in the calculation of the eco-margin. A biocide cost series estimated at the present tax rate is however included in the EHNA table of this chapter.

Table 4. Avoidance costs in the investigation

<table>
<thead>
<tr>
<th>Emission</th>
<th>Cost</th>
<th>Source</th>
</tr>
</thead>
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<tr>
<td>SO2</td>
<td>20404</td>
<td>CR</td>
</tr>
<tr>
<td>NOx</td>
<td>15143</td>
<td>SNV</td>
</tr>
<tr>
<td>CO</td>
<td>5052</td>
<td>CR</td>
</tr>
<tr>
<td>FP</td>
<td>3830</td>
<td>CR</td>
</tr>
<tr>
<td>VOC</td>
<td>4667</td>
<td>CR</td>
</tr>
<tr>
<td>CFC</td>
<td></td>
<td>Science</td>
</tr>
<tr>
<td>Lead</td>
<td>var.</td>
<td>Various: see text</td>
</tr>
<tr>
<td>CO2</td>
<td>95</td>
<td>SNV</td>
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<tr>
<td>Tx. air</td>
<td>18974</td>
<td>PREDI</td>
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<tr>
<td>Tx. water</td>
<td>3369</td>
<td>PREDI</td>
</tr>
<tr>
<td>Conv. water</td>
<td>552</td>
<td>PREDI</td>
</tr>
<tr>
<td>ISIC 32</td>
<td>1802</td>
<td>PREDI</td>
</tr>
<tr>
<td>ISIC 34</td>
<td>653</td>
<td>PREDI</td>
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<tr>
<td>ISIC 35</td>
<td>81</td>
<td>Own based on SCB</td>
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<td>Municipal</td>
<td>1850</td>
<td>SNV</td>
</tr>
<tr>
<td>Pesticide</td>
<td>30000</td>
<td>Swedish tax-rate</td>
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</table>

*Note: All prices SEK (1994) per ton
Sources: See table and, for exact references, the text

Additional estimates: the 19th century

The estimates of the eco-margin during the 19th century are approximate. The majority of the emissions has been considered to be associated with the combustion of fossil fuels. A fossil fuel index has been constructed by adding the physical quantities of imported and domestically produced coal and oil, whereby the figures are obtained from the import statistics. The latter is of minor significance throughout the century. This index was linked to the combined cost of NO\textsubscript{x}, SO\textsubscript{2}, CO, particulates, and heavy metals in 1900. Also the

Pollution: Flows and avoidance costs. Estimates in monetary units.

Fraction of the VOC cost which is not associated with small scale firewood combustion and charcoal is included. The VOC cost associated with small-scale firewood combustion has been indexed by Arpi’s estimates of household firewood consumption which in its turn is linked to the population development in 1840. VOC costs associated to charcoal production have been indexed by the estimated quantities of wood consumption for charcoal production.

Comments and conclusions

The investigation has shown that many important emissions can be estimated historically. It has also shown that it is possible to construct economic emission volumes. This thereby constitutes a method which allows the aggregation of emissions, and thus the incorporation of emissions in the macroeconomic framework which is provided by the NA and HNA.

There may be some errors in the estimates, but generally speaking most of the estimates may be regarded as fairly reliable. Admittedly, in practically all cases, the estimates could perhaps have been made more accurate. This was, however, considered counterproductive, since fewer emissions could have been considered in this case. Certainly, this investigation does not cover all emissions which ideally should be included in a historical estimate of the contribution of the discharge of residuals to the eco-margin. The most important are, however, included, and to estimate the rest is a task for future research. Also left for future research is the division of the emissions to the economic sectors of HNA as well as to the non-financial assets of EHNA.

The final step in the investigation was to calculate avoidance cost series by applying the unit cost estimates to the quantity estimates. When the series were aggregated, an approximation of the historical eco-margin, with respect to the included residuals, expressed in 1994 prices was obtained. This approximation of the eco-margin is shown in diagram 15. A preliminary analysis of the series is made in the final chapter. Diagram 16 shows the difference between including or excluding CO$_2$. In general terms, the curves are similar, but it may be concluded that the EHNA results are very dependent on which costs are used, especially for quantitatively dominating emissions like CO$_2$. With a higher avoidance cost for sufficient CO$_2$ reduction it can easily be imagined that CO$_2$ would appear as the totally dominating environmental problem.

Note: The series shows the combined contribution to the eco-margin of the following types of emissions: NOx, SO2, CO, VOC, FP, heavy metals (including lead), fertilizers (including NH3), CFC, BOD7.
Sources: Own estimates. For exact references see text.


Note: The series shows the combined contribution to the eco-margin of the following types of emissions: CO₂, NOx, SO2, CO, VOC, FP, heavy metals (including lead), fertilizers (including NH3), CFC, BOD7. Total = eco-margin l (excl. CO2)
Sources: Own estimates. For exact references see text.
EHNA POLLUTION FLOW ACCOUNTS

TABLE 1. TOTAL ECONOMY: EMISSIONS OF SELECTED POLLUTANTS

Sweden 1900-1990 imputed 1994 avoidance costs (mill. SEK)
Classification according to main environmental impact
Destination according to main environmental destination (SEEA CC)

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<th>Acidification</th>
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<td>HM's, pesticides</td>
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Pollution: Flows and avoidance costs. Estimates in monetary units.

Note: the environmental impact is often complicated. Impact from one pollutant may concern health, acidification and eutrophication. The destination is difficult to determine too. The initial destination may be air, while the subsequent fall-out causes damage in water and land eco-systems.

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Note: Sweden 1800-1899 imputed 1994 avoidance costs (mill. SEK).
9. ANALYZES OF EHNA SERIES

Introduction

Accounting is never an end in itself, only a means to an end. Therefore, accounting systems have many times evolved due to new questions addressed in a changing society. The EHNA framework is intended as a tool for investigating new questions in economic history, namely economic and environmental interaction. Two questions concerning the historical characterization and long term development of natural resource depletion and of environmental degradation due to pollution and their correlation to economic growth Swedish economy were therefore addressed as an additional objective of the thesis. In this chapter, a preliminary interpretation and overview of the historical pattern of depletion and degradation is made. It should, however, be noticed that the elaboration of a special explanatory framework has not been a purpose of the thesis. HNA and EHNA are good for answering questions about, for instance, how the present environmental-economical situation has evolved. They are, however, not sufficient for answering questions about why, for instance, sulfur dioxide emissions decreased during the 1970's. Therefore, the following analyses should be regarded as preliminary and presented with the objective of pointing at the kind of investigations in which EHNA may be used. The need for incorporating EHNA results in a wide societal context is also recognized. This brings back EHNA to its context in contemporary and -most importantly- economic historical environmental research traditions, where for instance technological and institutional changes have been emphasized.

Structure of the chapter

The structure of the chapter is the following. First, a brief introduction to a previous periodization of the economic development in Sweden is made. This periodization is based on what is here referred to as the theory -or model- of structural transformation. Thereafter follows a second section focusing on depletion related issues. It is in its turn divided into iron ore net prices, stumpage prices and the contribution to value added from the iron ore rent and the timber rent. The changes of these net prices, which reflect scarcity, are compared to the periodization according to the theory of structural transformation. The third section deals with the contribution of pollution to the eco-margin. This section includes a periodization of this part of the eco-margin and also an investigation of the so-called EKC hypothesis. These findings are
subsequently compared with the periodization according to the theory of structural transformation. Finally, the main results are discussed and future research issues are pointed at.

A previous periodization

The theory of structural transformation

The theory of structural transformation was, as mention in the first chapter, put forward by the Swedish economic historians Olle Krantz and Lennart Schön. The theory was inspired by, among others, the Austrian economist Joseph Schumpeter and the Swedish economists Johan Åkerman and Erik Dahmén. A strength of the theory of structural transformation is that it offers a periodization pattern of the Swedish macro-economic development which can be compared with periodizations obtained from the environmental time series. Since the theory focuses on macro-economic events it may be expected that societal factors which, somehow, interact with the macro economic changes reveal a similar periodization pattern. A main idea put forward in economic historical environmental research is that the economy and the environment interacts. Thus, it is reasonable to compare the pattern of structural transformation in the Swedish economy with the EHNA depletion costs series and the degradation costs series. Finally, it should be noticed that the periodization offered by the model of structural transformation has been widely used in Swedish economic history.

According to Olle Krantz and Lennart Schön Sweden's economic development can be interpreted in terms of succeeding periods of structural transformation and structural rationalization as can be observed in the aggregates of the historical national accounts. Basically, the theory is operationalized through examination of HNA quotas, where a certain sequence of maximum and minimum values are supposed to indicate spread and saturation of technological systems. Structural transformation occurs when basic features of economic conditions are altered, such as the breakthrough of the manufacturing industry. Structural rationalization takes place when the production within given struc-

---

tural boundaries is made more efficient. When rationalization reaches certain limits due to market saturation, a structural crisis will lead to the destruction of old ways of organizing production. Individual companies will go bankrupt and whole industrial branches will stagnate. But the crisis also creates opportunities for new companies and new industries. This is what Schumpeter has called creative destruction. Thus, every major phase with a length of about 40 to 50 years comprises two sub-phases. In Sweden, the major phases occurred roughly between 1850 and 1890, 1890 and 1930, and between 1930 and 1970. Structural transformation dominated the periods between 1890 and 1910 and between 1930 and the mid 50's. Accordingly structural rationalization occurred roughly between 1910 and 1930 and between 1955 and 1970. Doubtlessly, this theory or model, especially in the form it has been interpreted by Schön, resembles a long wave theory. Most importantly, it includes a mechanism which may produce long term fluctuations and the empirical operationalization suggests a periodic pattern of changes, at least up to the 1970’s.

Conjunctions between environmental changes and long waves

Relationships between long wave patterns and environmental impact have been suggested by several researchers. The explanation is that most long wave theories center around discoveries of innovations and their diffusion. Since the use of technology —due to the laws of thermodynamics— always has environmental consequences it is reasonable to assume a relationship between changes in technology and changes in environmental impact. One rather well known attempt to describe this relationship is the identity \( I=f(PAT) \), according to which environmental impact (I) is a function of Population (P), Affluence (A) and Technology (T). Intersections between long waves and environmental impact are for example found in Rostow’s theory of long waves in which trend periods with respect to prices for “basic goods” (more or less raw materials) and finished industrial products were identified. Even though this theory is not entirely environmental, the step from basic goods to natural goods is a small one. It is therefore at least associated with the environmental issue of depletion. Also worth noticing is Watt who has presented a long wave theory in which energy resources and

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3 Later Krantz has argued against the long-wave character of the periodization in Krantz, O. Vad är det för sorts kris egentligen? Ekonomisk Debatt, 1993:6, pp. 541-550.
associated industries, through various feed-back mechanisms, give rise to long waves in the economy.\textsuperscript{6} Furthermore, a long wave approach was used by Earle in order to interpret changes in agricultural regimes in the U.S. south during the 18\textsuperscript{th} and 19\textsuperscript{th} centuries.\textsuperscript{7} Contemporary developments in research concerning long waves and environmental changes have taken into account both technological and institutional aspects.\textsuperscript{8} Not least information technology and its environmental consequences has been emphasized in this context.

**Interpretations of the iron ore net price and the stumpage price**

Natural assets, or in the SEEA terminology non-produced assets, are production factors together with capital (produced assets) and labor. Produced assets and labor are rewarded, –or contributes to the value added– through profits and wages. Use of non-produced assets is rewarded with its natural resource rent. In EHNA, the natural resource rent is operationalized as the net-price. Since structural change can be interpreted as the introduction of new combinations of production factors\textsuperscript{9}, the correlation between net price changes and structural transformation is obviously important to examine.

In previous chapters depletion costs were estimated for iron ore and timber in uncultivated forests. As mentioned above, the quantity of extraction and unit prices represent the contribution to value added due to depletion of scarce resources. This part of the investigation has the following structure. First, a periodization of the iron ore net price is made. The reason for making a periodization is to obtain a basis for comparison with the previously mentioned periodization of the macro economic history of Sweden, interpreted in trend periods of structural transformation and rationalization. Secondly, stumpage prices (forest net prices) are made subject to a periodization. Also in this case the purpose is a comparison with the previously mentioned periodization.


\textsuperscript{9} Krantz, O. *Utrikeshandel, ekonomisk tillväxt och strukturförändring efter 1850*, Malmö 1987, p. 52.
Thirdly, the importance of the iron ore and timber net prices in the Swedish industrialization process is investigated in terms of its contribution to the value added in the economy. The issue addressed here is whether net prices may have facilitated economic development significantly by providing additional incomes to the country.

The iron ore net price

The iron ore net price, deflated with the GDP deflator, is shown in diagram 1. Beginning in the late 1890's, the net price increases. This trend continues until approximately 1910, when a period of a declining resource rent seems to have commenced. The lower turning point is possibly around 1933, keeping in mind that the negative value in 1928 was caused by a miners strike. Preparations for the Second World War probably started a subsequent period of sharply rising net prices. The peak was probably reached around 1937 and the subsequent low turning point in 1945. There may however be an alternative interpretation of the curve. If the Second World War is seen as an abnormal disturbance, the peak may instead have occurred in 1952 during the Korean boom. It is thereafter followed by a longer period of falling net prices. The creation of a world market for iron ore due to falling overseas freight rates, and the opening of new overseas deposits with lower production costs than the Swedish ones played an important role. In 1975 the net price was eliminated. The investigation only occasionally showed positive values thereafter.

The long investment horizon in the raw material industries induces lags between supply and demand. This phenomenon, which creates a long term wave-like movement of the raw material relative prices was originally described by Rostow. In Sweden, Schön has interpreted the movement of the iron and steel industry relative prices as part of a general pattern of structural change in the Swedish economy.

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10 The periodisation is based on a visual interpretation of the series
11 Rostow (1985)
Another conclusion from the movement of the iron ore net prices is that falling net prices seem to be correlated to periods of structural rationalization. Schön has argued that the demand for raw materials increases during the structural transformation phase, since new infrastructures are created. A bottleneck effect occurs when the demand for natural resources increases.

This causes both the final prices and the net prices to rise. During the rationalization phase, production factors are increasingly allocated to the raw material sector. At the same time, the shortage of production factors due to the economic growth causes production costs to rise. An inflationary pressure may also be built up. This inflation causes the real interest rate to fall if *ceteris paribus* is assumed. At the same time, investments tend to encourage production capacity to exceed demand. This tends to reduce the profitability of investments and the real profits and natural resource rents will fall. Eventually, the overproduction tendency which is described by Schön and Krantz drives the economy towards a structural crisis. The demand for raw materials falls. The net price therefore reaches its lowest position during the structural crisis. After the depression a new phase of structural transformation takes place accompanied by rising resource rents. After the Korean boom a new period of structural rationalization occurred with saturation problems which resulted in the eruption of the the iron industry structural crisis of the 1970’s.

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13 Schön (1990)
Stumpage prices

A study of the stumpage prices for standing timber reveals a slightly different pattern. The prices increase throughout the 19th century. There is, however, a sharper increase from the late 1880’s/early 1890’s. Even without a more sophisticated time series analysis it seems as if the stumpage prices relative to the GDP deflator peaks around 1909. The lower turning point correlates to the crisis of the early 30’s and in parallel to the iron ore net price, the stumpage prices peak during the Korea boom. A general observation is that the fluctuations of the stumpage price are less violent than the iron ore rent fluctuations. In most cases it also seems as if the iron ore rent lags behind or exhibits a sluggishness in comparison to the stumpage price. This may be explained by a shorter investment horizon in forestry, which includes faster responses to market signals.

The relatively modest fall of stumpage prices after the Second World War may suggest that scarcity concerns renewable resources, such as timber, to a higher degree than non-renewable resources such as iron ore. This conclusion is, however, highly speculative.

The stumpage prices do not obviously correlate to the Krantz/Schön structural transformation pattern during the 19th century. If the period 1890-1910 is accepted as a trend period with respect to the net price, it is correlated to the corresponding period of structural transformation. However, the period of structural rationalization around 1870 to 1890 is not correlated to falling net prices. Still, it is worth noticing that the correlation between net prices and structural periods is better during the 20th century. The trend period of falling net prices between 1910 to 1930 corresponds to a period of structural rationalization and the same is true for the period 1955 to 1970. Moreover, the period of structural transformation between roughly 1930 and the mid 1950’s is corresponding to rising net prices.
Diagram 2. Stumpage prices relative the GDP deflator

![Diagram showing stumpage prices relative to the GDP deflator from 1800 to 1980.]

Sources: Own estimates based on Jörberg(1972), BiSOS skogsväsendet, Streyffert (1960), SOS Skogsbruket, Krantz (1995)

Conclusions from the net price study

The general conclusion of the study of iron ore net prices and stumpage prices is that the behavior of these net prices seems to coincide with the original periodization put forward by Krantz and Schön. However, the periodization is based on visual interpretation of the series which doubtlessly makes the conclusion uncertain. Furthermore, the periodization of structural periods and the net prices used in this investigation are not fully independent data sets. In this investigation the GDP deflator was used to obtain deflated net prices\(^{14}\) and in Krantz and Schön's original analysis the various HNA quotas were estimated on basis of deflated series.\(^{15}\)

A general long-term trend of increasing scarcity is not confirmed. As discussed earlier, the net price method is based on the so-called Hotelling rule. The Hotelling rule predicts that if certain assumptions are made, the net price is expected to rise at a compound rate, due to increased scarcity. This investigation does not support that such a scarcity effect exists for the whole period.

Nonetheless, in regard to the iron ore net price, the subperiod lasting from 1890 to ca 1952 may be interpreted as indicating an underlying trend of growth.


\(^{15}\) A discussion on the use of deflated quotas are found in Lindmark, M./Vikström, P. *Den deflaterade kvotens dilemma*, forthcoming.
M. Lindmark. Towards Environmental Historical National Accounts

at a compound rate. This period does include both periods of structural transformation and rationalization. However, this development was halted after the Korea boom. This in turn was the result of reactions to high prices. However, technological development which cannot be related as obviously to high iron ore price also influenced the development of iron ore net prices. This is the case, for instance of the development freight rates, which fell as a result of improved shipping capacity. What is seen is a long-term adjustment of the resource base to accommodate increased scarcity. It is therefore suggested that the iron ore net price has been influenced by ordinary market forces, such as demand, interest rates, production costs etc. and, to some degree up until the 1950's, by a compound increase of the natural resource rent. Indications for economic adjustments to scarcity both in the short, medium and long run therefore exist.

Depletion and the industrialization process of Sweden

It is easy to get the impression that the direct economic importance of natural resources should equal the value added of the resource industry. Traditional Swedish economic historical works, have often implicitly assumed an obvious relation between raw material export values and rich natural resources.\(^\text{16}\) Value added, however, is also (and traditionally solely) regarded as compensation to capital and labor. Value added of a certain natural resource-based industry is therefore not the same as a measure of the direct economic value created by rich deposits of iron ore and unexploited forests. Capital may be employed in different ways. Imagine that Sweden did not have any timber forests or iron ore deposits. In that case the resources which were invested in the iron ore mining and forestry sectors could have been used for other purposes. The true direct economic role of iron ore deposits and timber is instead the extra revenue which can be obtained from investments in these natural resource sectors as compared to investments in other economic activities. This is indicated by the net price.

Clearly, the role of natural resources for creating economic values during, for instance, the industrialization phase needs to be examined. How much better off was a country like Sweden due to its natural resource endowment during certain historical periods? If these periods coincide with the development of a domestic market it is easy to suppose a causality. Higher incomes due to natural resource possession could have been instrumental to a certain extent in the formation of rising demand for both consumer and investment goods. A contemporary example may be the oil incomes in Norway which have affected the country's

\(^{16}\) Gårdlund, T. Industrialismens samhälle, Stockholm 1955, pp. 63.
economic performance and even the rate of economic growth.\textsuperscript{17} In the same way it is relevant to ask whether Swedish natural resources, primarily forests and iron ore, have played a similar role in a historical perspective. During periods of positive net prices Sweden enjoyed supplemental incomes from the iron ore and timber export. Thus, it was possible to increase consumption and investments. In this way consumption and investment opportunities were transferred from abroad via the export market. The economic actors who are likely to have benefited from the iron ore rent are the Grängesberg company (TGO) and later, when LKAB was nationalized in the 1950's, the state. The beneficiaries of the timber rent varied from smallholders, to large forest companies and the state.

When a scarce resource is extracted, a certain part of the income represents a liquidation of wealth. As El-Serafy argues this is not a real income, but a transformation of a non-financial asset into a financial one.\textsuperscript{18} The money supply may therefore be expected to increase during periods of positive resource rents. Assuming ceteris paribus, this lowers the interest rate. Thus, it becomes less expensive to invest. It can therefore be expected that a rising net price is accompanied by an increasing investment ratio, at least if the total revenue from the net price is a large proportion of the total incomes. What a large share of the incomes means exactly cannot be objectively determined. It is also likely that the natural resource rents affect the prices of refined products like steel and pulp. In that case a 'multiplier effect' may cause a larger economic effect than initially had been indicated by the resource rents.

A high resource rent implies a high profit rate in the natural resource sector. Due to the high profit rates production factors will be drawn to the natural resource sector from other economic activities. The high resource rent may also force a currency appreciation if the natural resources form a large part of the exports. If so, other industries will meet increased difficulties on the export market and home market orientated industry will confront a harder competition from imports. The economic resources will therefore be concentrated to the natural resource sector. When a depression or a structural crisis eventually sets in, the profits fall in the natural resource sector. Due to the previous crowding out effect of other industries having experienced a relative decline in relation to the natural resource sector, the crisis becomes more severe. This scenario is

\textsuperscript{17} Maddison, A. Dynamic Forces in capitalist Development. A Long-run Comparative View, Oxford University Press 1991, p. 157

A relevant question is therefore whether any of the Swedish economic crises can be described as a "Dutch disease" crises. If it can be proved that such crises have occurred in Sweden, it could also be concluded that natural resources have played a significant direct economic role.

Diagram 3 shows the depletion cost share of GDP (or total incomes), both in current prices. The curve indicates a rise of the depletion related incomes from ca 1820. This continues until the 1850's, when the share is approximately 3.5-4% of the total incomes. It is difficult to say whether or not this is a large proportion. It is, however, possible that the early modernization phase of Sweden at least to some degree was facilitated by "withdrawals" from the natural assets.

The share of depletion costs remained at this level during the industrialization phase of the late 19th century. The fall of the share from ca 1900 is basically due to the increase of standing timber volume. According to the accounting princi-

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20 The depletion cost here includes iron ore and timber in uncultivated forests and is therefore an approximation of the 'true' depletion cost.
Initial EHNA Analyzes

Samples used in EHNA depletion costs are therefore not recorded. It may therefore be relevant to study natural resource rent related incomes irrespectively of their being regarded as depletion or not.

Diagram 4 shows the share of iron ore and timber rents\(^{21}\) to GDP. The curve reveals that the natural resource rents started to fall in proportion to other incomes already at the turn of this century. This ‘turning point’ does not bear a clear correlation to a structural crisis. Still it is fairly close time-wise to the structural crisis of the 1890’s. The possibility that at least the crisis of 1890 could be described as, or contained some elements of a Dutch disease crisis can therefore not be ruled out. Accordingly, conclusive results were not found in this investigation and thus further research on the issue is needed.


Sources: Own estimates

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\(^{21}\) Calculated as total commercial cutting multiplied with the stumpage price, see chapters 6 and 7.
An interpretation of the contribution of pollutants to the eco-margin

Notes on the method

The aggregated avoidance costs for pollutants (degradation) and depletion costs, associated with natural resource extraction, constitute the eco-margin. In this section an analysis of the degradation costs' contribution to the eco-margin is performed. For the sake of consistent terminology, the aggregated degradation costs are referred to as the eco-margin I, while the contribution to the eco-margin from depletion is called eco-margin II. The analysis of the eco-margin concerns a periodization with respect to:

a/ The performance of the eco-margin I in absolute terms

and

b/ The performance of the eco-margin I compared to GDP

In order to make a periodization, modern time series analysis has been employed as an appropriate tool. The software used for this is the STAMP package (Structural Time series Analysis and Model Program). This approach has mainly been used by Harvey, Crafts, Mills and Capie. A discussion and presentation of this method is provided in the appendix.

Periodization

A directly observable result of the eco-margin I series is that pollution has increased during the major part of the period 1800-1990. Evidence therefore exists to support a historical positive correlation between growth and pollution. However, the trend of increasing environmental impact is broken during the late 20th century.

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22 The contribution of Peter Vikström for making this analysis is greatly acknowledged. The expertise knowledge on this method is Vikström's. However, the author's responsibility for all conclusions etc. is self-evident. See also Vikström, P. Time Series Modelling in Economic History. An Application of Structural Time Series Models. Paper presented at the 5th Umeå-Würzburg conference in statistics, Umeå May 1998.

1960’s. After that there is evidence of a negative correlation between growth and pollution. This is seen in diagram 5.


It was not possible to make a homogenous model for the whole period. Instead the period had to be divided into sub-periods.\(^{24}\) The choice of periodization was determined by practical tests of the results with different period lengths. The main characteristics of the periods are shown in table 1.

The first period is between 1800 and 1870. It is best expressed by using a model featuring a stochastic level and a stochastic trend, but without a cyclical component. This model passes all diagnostic tests and has a \(R^2_D\) of 0.11. \(R^2_D\) is a measure of the explanationary power of the model, in comparison to a so-called random walk. The random walk is lacking structural components, but is only explained by chance and the previous observation. During the period, the growth rate of the eco-margin I increases from approximately 0 to 2.4% on an annual basis. A sharp increase of the growth component can be noticed between ca 1840 and 1858. This probably reflects population growth, urbanization and a beginning of the industrialization.

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\(^{24}\) It should be pointed out that the model is comparatively simple. Auto-regressive elements could be added, that is assumptions that the residuals change in a systematic way due to for instance new patterns of business cycle fluctuations. Explanatory variables could also be added, including for instance dummy variables for environmental policy or wars.
The next homogenous period is between 1870 and 1913. The model which is best suited features a constant growth factor, or trend, and a cyclical component. The model passes all tests. It is a period with a constant annual growth rate of the eco-margin of 2.4%. This period is probably best understood as a period during which pollution induced by population growth gave way to industrial pollution. This is, of course, also reflected in the construction of the series. Similar interactions between demographic and ecological transitions have been described for developing countries.

The third period is between 1913 and 1947. It is well known that several exogenous shocks affected the economy during this period. The world wars, the economic crisis of the 1920’s and the 1930’s, as well as the Swedish metal workers’ strike in 1945 are the most obvious ones. From an environmental perspective the fluctuations of air pollution in particular are likely to be more pronounced than the economic fluctuations reflected in the GDP. This is an effect caused when the opportunity arose to replace imported fossil fuel with domestic bio fuels. Fuel imports were, for instance, cut during both wartime periods. Since different fuels have different environmental finger prints (emission factors) there may be significant changes in the pattern of air pollution. Particularly during the wartime periods it was also possible to redirect the use of fuels from consumption, such as private transports and heating, to industrial purposes. This may have caused a larger decrease of the use of fuel than the decrease of economic activity recorded in HNA. On the other hand, there are certain types of pollution which are not very dependent on economic fluctuations. This concerns sewage, for instance. As has been previously discussed the 1930’s can be seen as a period of structural transformation. For instance, the traditional iron industry which was based on 19th century technology received its final blow and hydro-power generated electricity evolved rapidly. Both the structural transformation, which may have been triggered by some of the external shocks, and the shocks themselves reduce the possibilities of finding a good model for the period. A visual examination of the eco-margin does, however, suggest that there may be an underlying trend which is similar to that of the previous period. However, the STAMP model fails to construct a trend which is different from a random walk. The deterministic ‘visual’ linear trend has a very poor fit during the period. The visual impression of a trend can therefore be rejected on statistical grounds as ‘a trick of the eye’. One conclusion is that the interwar period is so chaotic that it is difficult if not impossible to make generalizations about it. Accordingly the development of the eco-margin I during the interwar period is best understood as the result of a series of random shocks.

25 The period is homogenous with respect to the statistical model of the measured factors.
The final homogenous period is between 1947 and 1990. Here, the model features a stochastic level and a stochastic slope and a cyclical component, which produces a fit which is very good. The high growth rate of the eco-margin I during the last years of the previous period continues, with an accelerating annual growth rate of more than 8% after the Second World War. This reflects the fast adaptation to normal conditions after the war. After this the annual growth rate declined continuously, except for the period ca 1956 to ca 1964. This means, generally speaking, that the eco-margin continued to increase, but, with the exception of the late 1950s and early 1960s, at an increasingly slower rate. In 1969 the growth component is 0%, implying a zero growth of the eco-margin. Thus, 1969 marked the beginning of a decreasing eco-margin. At the later part of the period the growth rate was -7%.

Table 1. Trend periods of the eco-margin I (except CO₂)

<table>
<thead>
<tr>
<th>Period</th>
<th>Trend of growth rate</th>
<th>Model trend break</th>
<th>Growth rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800-1869</td>
<td>increasing</td>
<td>ca 1840 and 1860</td>
<td>+/-0 to +2,4</td>
</tr>
<tr>
<td>1870-1913</td>
<td>constant</td>
<td>no</td>
<td>+2,4 (linear)</td>
</tr>
<tr>
<td>1913-1947</td>
<td>no trend</td>
<td>no</td>
<td>varying</td>
</tr>
<tr>
<td>1948-1990</td>
<td>inverted U</td>
<td>ca 1967</td>
<td>+8 to -7</td>
</tr>
</tbody>
</table>

The initial phase of increasing pollution levels during the postwar period has an obvious connection to the 'wear and tear' mentality, increased real incomes, a high economic growth rate and new consumption patterns. The post-war increase of private and commercial automobile traffic cannot go unnoticed. The principal energy carriers, besides electricity, shifted from wood and coal to oil. Action aimed at improving environmental standards was taken already during the 1950’s and 60’s. Generally, the focus of this action seems to have been on health-related environmental issues. The environmental policy also seems to have started as a technical question before it was generally discussed in the public debate. An example is Statens Luftvårdsnämd (the Air Protection Agency) which was established already in 1963. It can also be seen that the decline of the eco-margin’s growth rate starts before the introduction of modern environmental policy in 1969. The period of decline in the eco-margin does, however, represent a historically unique phase as a movement towards sustainability. Emissions like SO₂ were reduced to 19th century levels while NOₓ emissions, for instance, remained on a historically high level. In 1990 the level of the eco-margin had roughly been reduced to the same level as that in the early 1950’s.

The explanations for this development can probably only be found if the analysis considers several interacting levels. Exactly how this should be opera-

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[^27]: Bonniers lexikon pt 9, Article "Luftvård", Stockholm 1965, p. 464
tionalized is an issue which deserves further research. Therefore, some possible explanatory levels and factors will be sketched upon in this preliminary analysis.

- Macro-economic change involves growth rates and structural changes. An analysis should therefore include HNA data. An important issue is to identify the expanding sectors and their likely environmental impact. Also the relationship between slower growth rates and the more defensive measures taken in the economy needs to be examined. A slower economic growth rate can clearly be noted in Sweden, as in most industrialized countries, starting in the early 1970's. Everything else being equal, a lower growth rate indicates a slower increase of environmental pressure. Obviously, the slower growth rate does not explain the reduction of emissions. However, the internalization of environmental costs due to environmental legislation may have affected the growth rate. Economic structural change during the last decades includes that the service sector, including public services, has become an important sector during the 1970's. Basically, the level of industrial activities has increased, but not at the same rate as the service sector. A probable effect of this structural transformation is reduced environmental stress. However, it should be pointed out that it is far from obvious that the service sector causes less environmental problems than the industrial sector. Transports can serve as an example.

- Technological change may cause both increased and decreased environmental stress. It is for instance worth noticing the increased array of chemical products during the postwar period. Pesticides, like DDT, are dismal examples. Increased engine performance and improved technology for controlling various production processes can, on the contrary, be expected to have reduced environmental stress through more effective use of resources, including pollution control. The emergence of a new technological paradigm, information and communications technology (ICT) including cheap microelectronics, computers and telecommunications has for instance been put forward in this context.\(^\text{28}\) In a full analytical context it is important to recognize that technological and economic change interact. This has been emphasized in most so-called long wave theories.\(^\text{29}\) There are also evidence for a learning-by-doing-effect in pollution control. It is clear that once pollution control got underway or came into practice there have been significant learning-by-doing-effects. One of the most obvious cases concerns sulfur dioxide abatement, where the price development for emission permits on


the US SO$_2$ market suggests technological improvements.\textsuperscript{30} A general trend with respect to the energy system in Sweden after ca 1970 is a decline of fossil fuel consumption. Rising fuel prices were significant factors in the reduction of fossil fuel consumption. The declining use of fossil fuels has in turn lead to reduced emissions of for instance sulfur dioxide and carbon dioxide. In Sweden, this transition was facilitated by the implementation of the nuclear power program. However, the risk for nuclear disasters and the problem of nuclear waste storage have led to a referendum calling for the abandoning of nuclear power.

- Institutional change can in this context be seen as a process of defining property rights for environmental qualities. It includes for instance the breakthrough of modern environmental legislation which came to develop as a separate policy making field during the 1960’s. International influences should also be noticed. In many cases, the Swedish environmental legislation lagged a few years behind the legislation in the U.S.A. This was for instance the case concerning the Clean Air Acts, the limitation of leaded gasoline and restrictions in the use of pesticides. One could argue that the process of environmental legislation was facilitated by the development of the modern ‘planning state’, but it is probably incorrect to discuss any Swedish environmental model on this general level. In the case of institutions it is also clear that they influence and are influenced by technological and economic changes.

- Changing attitudes towards the environment, sometimes referred to as the \textit{New Environmental Paradigm} are important,\textsuperscript{31} in order to understand institutional change, but also changes in economic preferences. Clearly, what can be called an environmental awareness has developed during the last decades. This includes a notion of society as being an integrated part of nature, and not a separate entity. Some important factors are already distinguishable. First, there is the occurrence of spectacular local or regional environmental catastrophes, which became concerns in the whole industrialized world due to the recent innovations within media, of which television is a primary example. In this case, a link to technological change can in this case easily be distinguished. One could mention the Japanese Minamata Bay catastrophe in 1959 which put the heavy metal toxification resulting from industrial activity on the agenda not only in Japan. A number of oil tanker disasters such as the


Torrey Canyon in 1967, the Amoco Cadiz in 1978 and the Exxon Valdez in 1989 revealed the devastating effects of accidents associated with economies of scale. Even though it is likely that a larger percentage of the transported oil was lost in accidents during earlier periods, the leakage from the Torrey Canyon was so large that it surpassed the annual Swedish oil consumption at the turn of this century. The accidents were probably significant in shaping environmentalism. This can be attributed in part to the fact that industrialized countries all participated in the basic economic activity which had caused the catastrophes. Environmental organizations, foremost Greenpeace, developed strategies for gaining attention for environmental problems which directly were based on the new information technology. The cumulative effect of these factors, in conjunction with the democratic systems in practice in industrialized nations can be seen as significant in understanding the development of modern environmental policy.

- Environmental research has come to play an increasingly important role for identifying environmental problems after foremost the 1960's. Probably there is also a cumulative effect, in which the identification of one environmental problem encourages and, through the gained research experience, facilitates further research. DDT can serve as an example. What Rachael Carson did was mainly to predict the environmental effects of DDT. Later empirical investigations could confirm her assumptions. It is obvious that these types of investigations encouraged further environmental research funding. Eventually this research could point at hitherto unknown problems, such as the major impact of acid rain, ozone depletion and global warming. All of them have got attention in media. The social sciences were also influenced by the natural scientific research results and questions concerning the relation between society and environment were raised. Gradually, the environmental and societal system has been viewed upon as dynamic and structural changes of the system and other complex responses to changes have been brought into focus of the scientific discussion. Therefore, one can probably identify a strong linkage between research results –both natural and social scientific– and changing environmental attitudes.

Exactly how these mechanisms functioned calls, as has been previously discussed, for investigation outside the domain of environmental accounting. These research issues are therefore subject of analysis within various disciplines

33 See for instance SOU 1967:43
outside economic history. This concerns for instance, how the environmental questions became a policy field of their own, how environmental property rights were defined in comparison with other types of property rights, how environmental issues became ‘visualized’ in the public opinion, and how this process was connected to economic development. Did, for instance, the oil crisis increase environmental awareness even though the crisis was an effect of a successful cartel maneuver rather than depletion? Another tendency which may have affected the environmental values is automobile traffic which, on one hand, increased pollution, but on the other hand allowed for increased access to nature for recreational purposes, which in turn may have affected the importance attributed to environmental values. Certainly the actual environmental impacts should also be examined. Here, different non-monetary indicators can also be used for historical investigations. The macro-economic approach offered by EHNA provide a framework and make possible a relevant base of periodization which is important. It can, for instance, be concluded that a appropriate period for future research is the post-war period with special attention to the late 1960’s.

The long term economic growth and pollution: Testing the EKC hypothesis

The relationship between economic growth and environmental change has been widely discussed in the literature. For instance, in the report *Limits to Growth* a constant relationship was assumed between growth and depletion and degradation of the environment. As discussed in the first chapter, this assumption has been criticized by many economists who argue that substitution and new preferences change this relation. A common description of the relationship between economic activity and environmental impact is the so-called *Environmental Kuznets Curve* (EKC). The EKC describes the relationship between environmental impact per capita and deflated income per capita as an inverted U. Also the concept of "intensity of use" has been used in this context. First, a higher economic activity, with subsequent rise in incomes, causes pollution to increase. At a certain income level the demand for an improved environment increases. The EKC is therefore mainly explained as an effect of high income elasticity on demand for environmental quality. Empirical investigations have confirmed the presence of an EKC for certain pollutants like sulfur.

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dioxide and particulate matter. Other pollutants like CO₂ and municipal waste per person do not confirm the EKC hypothesis.⁹

The general conclusion which may be drawn from studying the eco-margin/GDP ratio is the absence of a constant ratio between growth and environmental impact. This is shown in diagram 6. During most years of the 20th century, the ratio is actually declining. The investigation of the eco-margin's development in absolute terms shows that during the last 20 years there is even a decline of the eco-margin in absolute terms.

A tentative interpretation of the EKC is that three EKC phases may be distinguished from the second part of the 19th century and onwards. The first starts in 1870 and peaks around 1898. The phase reaches its lowest point approximately in 1920. This corresponds rather well with the second period obtained through the time series analysis of the eco-margin I. It should also be noted that there may be a phase which begins in approximately 1820, peaks during the early 1840's and ends around 1870. This is, however, a very uncertain interpretation.

The second EKC phase occurs between approximately 1920 and 1947, with a peak around 1937. A general impression here is therefore that the crisis of the 1920's seems to be what could be called a demarcation crisis, separating the phases. Thus, there is a difference to the original periodization according to Krantz and Schön who put forward the crisis of the 1930's as a structural crisis.

The third EKC phase occurs between 1947 and the present, with a peak around 1972. It would be unwise to take this preliminary periodization as a point of departure for criticism of the other periodization. Still the question could be raised: is it the crises of the 1920's and the Second World War which separate important structural periods in Swedish 20th century economic history, or could several periodizations be found depending on what structures are studied? Future research may either confirm or invalidate the periodization put forward here. International comparisons should also be conducted, in order to clarify whether there is a specific Swedish pattern or a pattern for a certain group of countries.

One possibility, which has previously been hinted at, is the introduction of modern environmental legislation being seen as the result of influences from leading countries, most notably the U.S.A., but also the U.K. and Japan. This contradicts—or perhaps complements— the view that environmental concern should be seen as a result of income elasticities on the demand for a clean environment. One could argue that the environmental legislation in the leading countries was a necessary response to environmental impact. Within a brief time span, emerging environmental awareness inspired corresponding legislation in countries such as Sweden, even if the environmental situation was not as alarming as it was—say—in major urban areas in the U.S. and U.K.

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London smog was clearly having lethal effects, while the consequences of air pollution were not as dramatic in Sweden. Since economic development, through a catching-up effect, by the late 1960's had caused a convergence of GDP per capita levels, the close timing of the launching of environmental legislation could be interpreted as a function of income levels. But it may also have been changing environmental perceptions originating in the 'leading countries,' which explains the rise of modern environmental legislation in Sweden around the late 1960's. Thus, it may be more of an event in time, in a certain political and cultural context, rather than a simple function of income levels. This could also rather easily be tested by examining whether the correlation between decreasing environmental impact is higher for GDP per capita level or for chronology.


Source: Own estimates

A Structural explanation for new environmental preferences

This study has shown a historical pattern which features a long-term increase of environmental stress. On the other hand, the environmental cost intensity of economic growth has decreased throughout the period. These two trends offer a structural framework for explaining changing environmental values. It is widely accepted that different forms of environmental values exist. These include everything from so called use-values to non-use values. On the real markets

direct environmental use-values, like timber from forests are measured. In some cases indirect use-values such as soil conservation, for instance, can also be found. But there are also 'softer' values. Option values reflect possible future use values for a certain resource. Existence values, are on the other hand, not related to immediate use, but rather to indirect use. One could perhaps say 'use by not using'. The existence value reflects for instance the value of knowing that there are whales in the sea. Perhaps the individual holding the existence value does not even have any plans to actually experience a whale. It is nonetheless of value to him to sit in his living room, and know that there exist wild creatures in the world-at-large.

The falling environmental cost intensity of growth suggests that it has become less expensive to hold existence values over time. The avoidance cost for a pollutant declines in real terms when the share of total avoidance cost of total incomes fall. This trend pertaining to declining avoidance costs is a structural feature of growth which predates most environmental protection policies. Important in this structural feature of growth is therefore that non-use values become steadily less expensive over time. This is because the environment is a resource with alternative uses. It can be utilized either as a sink for residuals or as a means of creating existence values. When the avoidance costs are high in real terms, the opportunity cost of holding existence values is also high. At the same time, the investigation has shown that the absolute levels of many pollutants increased up until the late 1960's in Sweden. This is also a structural feature of growth. Here, the causality works in conversely. Basically, the higher the pollution levels, the less healthy environment will be left. While time passes and growth continues, the 'environmental existences' become more scarce. The value of environmental existences therefore increases. The joint effect of the structural features of growth is rising non-use values and falling use values. There is a structural pressure which works towards increasing benefits from trade-offs between the two categories of uses. There will also emerge a need for regulating the use of environmental existence values for use value purposes. What is actually done is that the cost of using the environment is internalized through the introduction of various environmental policy instruments. These may be environmental taxes or command and control strategies. Thus, the costs of degrading the environment (or the option value of holding existence values) become reflected in traditional markets for goods and services. This is the economic-environmental-historical explanation of what can be called the post-1965 movement towards sustainability.
Comments and conclusions

The study has sought to point at some preliminary investigations that can be performed with the help of EHNA. A general question concerns the relationship between the environmental indicators and the previously made periodizations in economic history. The results are presented in table 2.

Table 2. Periodizations of trend periods in Swedish economic development and environmental indicators.

<table>
<thead>
<tr>
<th>Year</th>
<th>Krantz/Schön</th>
<th>Iron ore net price</th>
<th>Stumpage price</th>
<th>Eco-margin I</th>
<th>EKC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1840-50</td>
<td>STF</td>
<td></td>
<td></td>
<td>I+</td>
<td>-</td>
</tr>
<tr>
<td>1850-60</td>
<td>STF</td>
<td></td>
<td></td>
<td>I+</td>
<td>-</td>
</tr>
<tr>
<td>1860-70</td>
<td>STF/STR</td>
<td></td>
<td></td>
<td>I+</td>
<td>-/+</td>
</tr>
<tr>
<td>1870-80</td>
<td>STR</td>
<td></td>
<td></td>
<td>II+</td>
<td>-/+</td>
</tr>
<tr>
<td>1880-90</td>
<td>STR</td>
<td></td>
<td></td>
<td>II+</td>
<td>+</td>
</tr>
<tr>
<td>1890-00</td>
<td>STF</td>
<td></td>
<td></td>
<td>II+</td>
<td>+</td>
</tr>
<tr>
<td>1900-10</td>
<td>STF</td>
<td></td>
<td>0</td>
<td>II+</td>
<td>-</td>
</tr>
<tr>
<td>1910-20</td>
<td>STR</td>
<td></td>
<td></td>
<td>III?</td>
<td>-</td>
</tr>
<tr>
<td>1920-30</td>
<td>STR</td>
<td></td>
<td></td>
<td>III?</td>
<td>-</td>
</tr>
<tr>
<td>1930-40</td>
<td>STF</td>
<td></td>
<td></td>
<td>III?</td>
<td>-</td>
</tr>
<tr>
<td>1940-50</td>
<td>STF</td>
<td></td>
<td></td>
<td>III+</td>
<td>-</td>
</tr>
<tr>
<td>1950-60</td>
<td>STF/STR</td>
<td>+/-</td>
<td>+/-</td>
<td>IV+</td>
<td>+</td>
</tr>
<tr>
<td>1960-70</td>
<td>STR</td>
<td></td>
<td></td>
<td>IV+</td>
<td>+</td>
</tr>
<tr>
<td>1970-80</td>
<td>STF?</td>
<td></td>
<td></td>
<td>IV-</td>
<td>-</td>
</tr>
<tr>
<td>1980-90</td>
<td>STF?</td>
<td></td>
<td>n.a.</td>
<td>IV-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: STF denotes structural transformation period, STR denotes structural rationalization, + denotes increase of indicator, - denotes decrease, +/- denotes trend shift. Roman numbers refers to structural model number.

It is possible to make an instant check of the correlation by asking, first, is it true that structural transformation is correlated to positive or zero indicator values and, secondly, is it true that structural rationalization is correlated to negative or zero values? An instant check with the table above shows that this is not generally the case. However, a suggestive interpretation is that periods of structural transformation are correlated with positive net prices and a falling EKC. Still there are periods of structural rationalization which are correlated with positive net prices (1860-1890) and a falling EKC (1910-1930). Obviously, this weak correlation makes it difficult to explain patterns of a changed relationship between economy and environment as an outcome of structural change taking place during the periods that has been suggested by Krantz and Schön.
Especially concerning the development of the contribution of pollution to the eco-margin it is clear that the post 1970 period represent a historically unique period of decreasing environmental pressure. It is, however, not the first period of structural transformation. Thus, it can be concluded that general structural transformation is not sufficient and not a principal explanatory factor for the decrease of emissions. However, it should be noticed that it is far from certain that the 1970's and onwards represent a period of structural transformation. Thus, one could at least imagine two new types of phases both concerning economy and environment occurring at the same time.

Another historically unique period was the 19th century during which the share of natural resource rents to the value added in the Swedish economy was increasing. Whether this resource rent effect was significant for promoting economic development is hard to tell. Still, the findings suggest that the 19th century may be looked upon as a unique phase of depletion intensive growth.

It is, however, noticed that formal testing of the correlation of the variables is needed in order to establish decisive conclusions. Furthermore, the periodization according to the structural model and the EKC are not based on totally independent sets of data since deflated GDP series are numerators in both cases. This imposes a risk of auto-correlation.

One general observation is that the periodizations of the model of structural transformation and those of the aggregated emission series are made with different methods. The structural transformation model has for instance been constructed on basis of visual analysis of linear (deterministic) trends, while the eco margin I has been analyzed with the help of non-deterministic structural time series analysis. Naturally, this reduces the possibility for compatible results. Therefore, this means that the results must be carefully used.

It should also be recognized that these two methods for analyzing time series implicitly reflect different assumptions concerning historical change. The non-deterministic approach departures from a gradualist approach to change. Changes are assumed to be gradual. Furthermore, they are dependent both on previous occurrences and chance.

The deterministic trend shifts implies discontinuity. A trend shift is modelled as a sharp and sudden disruption. During the trend periods, the rate of change is instead assumed to be constant. In evolutionary science, the view on changes has been referred to as a "constant speedism" approach. The non-deterministic


41 The term ‘constant speedism’ is a biological term which refers to interpretations of a more or less constant rate of change in evolutionary processes. According to Dennet, D.C. *Darwin’s
approach does not require that the rate of change is constant. Instead, changes are likely to be more pronounced during certain periods. Therefore, the periodizations also tend to become more approximative when the structural time series analysis is used.

This means that further investigations of the relationships between environmental and economic changes, among other things, would require a new investigation of the periodization made in the structural model by using non-deterministic structural time series analysis. Of course, the opposite may also be considered. Ultimately, the choice of method must be based on what method the researcher believes offers the best model of change.

The result of a non-deterministic analysis of economic change may for instance be a revision of the established pattern of structural change and transformation in Sweden. Secondly, it is also recognized that the eco-margin I model needs improvement so that, instead of being divided into four sub-series (which implies discontinuity), it can be captured in one homogenous model. If the correlation between structural change and environmental impact is still weak after improvement of the models, it is obviously necessary to search for other explanations than structural change.

Most apparent here are institutions. The example of the post 1965 decrease of the eco-margin is striking. One can certainly claim that there is a strong correlation between two unique occurrences. First, that emissions start to decrease and, secondly, the establishing of environmental policy as a separate field in policy making.

It may be pointed out that this thesis provides a representation of relationships—or perhaps continuities—between society and the natural world. Society, and its material artifacts, are indeed natural, not unnatural. The society is an integrated part of the natural world. Artifacts and technology are all adapted to various homogenities within the natural world, homogenities that, when humans discover them, are called natural laws. One may therefore view the connections between society and the natural world as continuities. However, a relationship between humans relating to any object can be thought of as a social construction. Furthermore, it is evident that the social constructions are shaped both by the needs of man and by the natural structures. The social constructions, of which economic relationships form a part, may only vary within the limits set by the natural structures. A lot of effort will be needed in order to provide interpretations of society and its development from this point of view. The dynamics of the society as being part of the natural world, therefore, deserve more attention in economic history than it has so far been given.

APPENDIX

In this type of analysis the time series is seen as being constituted by several components. A general impression is that the model that the approach offers is more realistic than for instance moving averages. A moving average implies, for example, that the trend value in a specific year is determined not only by historical, but also by future events. When ordinary linear trends are used it is assumed in advance that a certain period does not involve trend-shifts. The trend is in this case said to be deterministic.

In the type of structural models used here the trend is determined by what happened during most recent the last year and during preceding years. The model can therefore be said to be evolutionary, which implies that events in the present are determined by the accumulated effects of events in the past. In addition a random element affects the trend. This reflects the presence of chance in history. The correct terminology for this is a constituent trend with a stochastic component. It may be noted that the natural sciences, natural history being not the least of these, for a long time have been interpreting historical changes as evolutionary processes.42

Furthermore, the model involves a cyclical component. Theoretically, cycles can be expected in this type of economic historical time series. The presence of a business cycle can for instance be foreseen. The STAMP does however allow model testing with or without cycles and stochastic elements. In some cases a deterministic trend without stochastic components may prove to offer the best option. The basic model which has been used is of the type:

\[ Y_t = \mu_t + \psi_t + \epsilon_t \]

where \( \mu \) is the stochastic trend and \( \psi \) is the cyclical component and \( \epsilon \) is a random element.

Furthermore, the stochastic trend is:

\[
\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \\
\beta_t = \beta_{t-1} + \zeta_t
\]

were \( \beta \) is a stochastic component which describes the change of the trend (stochastic slope). In other words, it describes the growth of the trend.

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42 Darwin started this revolution in thinking by explaining how form and structure can evolve without a master plan.
Also the cyclical component, which is determined by sinus and cosinus components, may be given stochastic characteristics. This means that also the cyclical component may change over a period of time. The accuracy of the model is subsequently tested by using various diagnostic tools. The main assumptions behind the model is that the stochastic components are assumed to be uncorrelated, normal distributed with a waiting value of zero and a constant variance. The assumption that the stochastic components should be uncorrelated reflects that random components should not show a similar behavior. If they do, they are related to each other or to another component. In that case, their behavior is no longer fully the outcome of chance. The values of the stochastic components are also assumed to be normal distributed. If they are not, this indicates that some kind of systematic force is influencing the component. In that case, the component can not be random. The same is true for the variance, which is also assumed to be constant if the component is stochastic. A variance which is, for instance, increasing reflects the presence of an external systematic force which is acting upon the component. If one or more of the variances for the stochastic components can be given the value zero, this means that the model becomes deterministic. The deterministic model is not evolutionary, in the sense that the present observation is determined by the accumulated effects of past events and chance. Instead, the trend is determined through some external structure. Thus, the equation which describes the trend is not dependent on time.

Basically, these tools test whether the residuals are randomly distributed, if the variance is constant, etc. The ideal is that after the model is run and checked against the original series only irregular ‘unexplainable’ random noise is left. This is occasionally referred to as ‘white noise’. This random noise do not carry any information which can be interpreted and it also suggests that the events are not dependent on history.43

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10. SUMMARY

Purpose of the thesis

The main purpose of this thesis was to extend the existing historical national accounts (HNA) for Sweden by including environmental items. Swedish HNA cover the period 1800-1980. The ambition was therefore to cover the same period in this work. Needless to say, it would have been impossible within the framework of this thesis to construct complete EHNA for Sweden. Instead some parts of the accounts –probably some of the most important– were dealt with.

In the extended HNA, environmental monetary values were linked to traditional economic values within a framework of Environmental Historical National Accounts (EHNA). To determine how such a framework should be constructed with respect to data and credibility was one of the major problems which had to be solved before the main purpose of the thesis could be approached. Methodological development and the use of methods within environmental and resource economics for HNA purposes was therefore a central part of the work.

Given the main purpose of the thesis, a quantitative generalization of the historical development of environmental costs, estimated and treated in accordance with other economic values and costs were sought for. The specific questions which were dealt with were:

1) How can depletion of natural assets be characterized from an economic historical point of view and how has it been correlated to economic growth?

and

2) How can environmental degradation due to pollution be characterized from an economic historical point of view and how has it been correlated to economic growth?

The thesis was divided into five main sections including preliminary analyzes and a summary of the results. The first section concerns the accounting framework and addresses methodological issues of importance when integrating EHNA and HNA.

The second section concerns iron ore extraction. The focus is on estimating physical stocks of economically extractable iron ore resources, calculating a relevant unit price for stock valuation, and establishing a broad HNA framework for the iron ore industry which allows a full integration of environmental accounts.
The third part concerns the standing timber volume. In this section, the historical development of the standing timber volume was reconstructed. Subsequently, the economic value of the stock was estimated.

The fourth part concerns pollution. Most environmental accounting systems pay attention to costs associated with different kinds of pollution. In this section, emitted quantities of a number of hazardous substances were estimated. Subsequently, the economic cost which could be attributed to each type of emission was collected and estimated in order to allow the construction of an aggregated pollution cost series.

In the fifth part, analyzes of the results were done basically in accordance with the questions raised above. A periodization and a preliminary analysis was made for both the iron ore depletion series and the corresponding series for forestry. Also in the case of pollutants a periodization was made. Furthermore, the economic historical context of these findings were discussed and a structural interpretation of the long term relationship between growth and the environment was proposed.

**The accounting framework**

In this thesis it was shown that it is possible to integrate historical environmental and economic accounting in a framework of environmental historical national accounts (EHNA). Given the main purpose of the thesis, the important results are therefore the EHNA tables provided. An overview of the accounts of HNA, NA and EHNA is presented in table 1.

It was concluded that an appropriate historical accounting framework must have the same features as the proposed system for contemporary integrated economic and environmental accounting, SEEA. It was argued that this would be, if not obvious, so at least practical since HNA implicitly are based on the System of National Accounts (SNA). Furthermore, if HNA are to be extended with additional accounts, for instance distribution and use of income, SNA must be the point of departure. It should be noticed that a fully integrated accounting framework for historical economic and environmental accounting both calls for a broadening of the traditional HNA and a simplification of the SEEA. The Swedish HNA are still far from being fully established in comparison to SNA. At present, only production accounts exist and HNA are therefore not yet based on a system of integrated economic accounts.
Table 1. HNS/NA/EHNA Overview

<table>
<thead>
<tr>
<th>FORESTRY</th>
<th>IRON ORE MINING</th>
<th>PRODUCTION/CONSUMPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC/ISIC</td>
<td>ISIC 02</td>
<td>ISIC 13 (part)</td>
</tr>
<tr>
<td>CR/NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1800-1980</td>
<td>1892-1988</td>
</tr>
<tr>
<td>3.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1.3</td>
<td>part implicit</td>
<td>part implicit</td>
</tr>
<tr>
<td>3.3.1</td>
<td>no</td>
<td>1892-1988</td>
</tr>
<tr>
<td>4</td>
<td>no</td>
<td>part 1892-1988</td>
</tr>
<tr>
<td>4.2.1</td>
<td>only depl. 1800-1925</td>
<td>only depl. 1892-1988</td>
</tr>
<tr>
<td>4.2.2</td>
<td>no</td>
<td>1892-1988</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1.1.1</td>
<td>1800-1925</td>
<td>1889-1988</td>
</tr>
<tr>
<td>6.1.2.1.1</td>
<td>not relevant</td>
<td>1892-1988</td>
</tr>
<tr>
<td>6.1.2.1.2</td>
<td>not relevant</td>
<td>1892-1988</td>
</tr>
<tr>
<td>6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.2.1</td>
<td>1800-1925</td>
<td>not relevant</td>
</tr>
<tr>
<td>7</td>
<td>1800-1980</td>
<td>1892-1988</td>
</tr>
<tr>
<td>8</td>
<td>1800-1980</td>
<td>1892-1988</td>
</tr>
<tr>
<td>AN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.2.1</td>
<td>1925-1980</td>
<td>not relevant</td>
</tr>
</tbody>
</table>

Note: the table shows assets etc. according to Classification of columns (CC), Classification of Rows (CR) and non-financial assets (AN), relevant for this EHNA work, that are covered for certain periods in HNA, EHNA and NA. HNA denotes data included in HNS, NA data in SCB's NA for Sweden. All other boxes denotes data in EHNA. 4.2.3 denotes value added (not explicitly in SEEA). CC/CR/AN/ISIC are classifications used in SEEA and SNA93. 3.1.3 part, implicit: some pollutants from ISIC 02 and 13 are internalised in production/consumption. They are accordingly not explicitly shown.

EHNA were in this investigation approached as an extension of the asset boundary used in SNA. Since HNA do not comprise accounts of financial and non-financial assets, the concept of asset boundary has so far been superfluous in historical national accounting. The environment was accordingly treated as capital. Environmental degradation and depletion in EHNA therefore resemble consumption of fixed capital (depreciation) in SNA.

The SEEA approach means that the main aggregates of HNA remain unaltered. Thus, EHNA can be seen as a satellite accounting system of HNA. A
new environmentally adjusted aggregate is, however, introduced. This is the environmentally adjusted net value added (EDP) which corresponds to NNP from which environmental costs have been subtracted. Capital accounts and consumption of fixed capital are items which are not included in HNS. It should be noted that a fully integrated framework of the historical environmental accounts which allows the estimation of a historical EDP, therefore, only is possible to obtain as an extension of contemporary NA, computed by Statistics Sweden. Aggregated environmental costs series have, however, in this investigation been constructed between 1800-1990.

More specifically, the EHNA framework shows explicitly how components in nature are perceived as resources, or as means to achieve economic goals, and explicitly how a resource becomes included in the economic system. The EHNA framework also shows how a natural asset is used in the economy for the purpose of reaching specific ends. Furthermore, the economic value of the natural asset is shown in EHNA. In a complete HNA framework, this value may be related to other categories of economic assets.

If the physical use and the unit value of the resource are combined, the economic flow emanating from use of the asset can be visualized. This concerns both quantitative and qualitative uses. The economic resource allocation questions include what is to be produced, how it is to be produced, and for whom it is produced. The national accounts, based on micro and macro economic theory, offer a methodological tool for examining these questions on a macro-economic level. While HNA focus on the allocation question of what is produced, the EHNA focus more on the allocation question of how it is produced. In this case, how natural assets are used for creating economic values.

The uncertainties present in EHNA were generally judged as being of a greater magnitude than in most ordinary HNA series. Both the accuracy of the estimates, which reflects the underlying data quality, and the choice of method for value estimates affect the results. It was pointed out that this is not unique for EHNA but possibly the difficulties are more pronounced here than in ordinary HNA. Problems relating to the establishment of theoretical guidelines for the choice of proper methods and approaches are, for instance, also present in HNA. Deflation methods are good examples of this. Different methods produce different results when it comes to volume estimates. The same is true for various aspects of classification of industries in HNA. Is it, for instance, reasonable to treat shipyards as part of the metal manufacturing industry also during the 19th century? Both HNA and EHNA results are therefore affected by the researcher’s choices. In contemporary national accounting and recently also to some extent in HNA, these questions are being approached through agreements about different conventions. It was suggested that such conventions will be needed in EHNA too.
M. Lindmark Towards Environmental Historical National Accounts

It was also necessary to point out that the monetarized and aggregated EHNA series represent abstractions. From the economic point of view, several costs which are used in EHNA do not represent costs (or benefits) which are measured on markets. In many cases the prices are therefore hypothetical. It is also an abstraction to construct environmental cost series for historical periods when the awareness of the environmental problem was lacking, the emissions were too low yet to have caused real damages and/or realistic options to avoid the emissions were lacking.

It should therefore be kept in mind that the EHNA series represent one possible interpretation of a reality. The limits to EHNA are therefore, not the least, imposed by the researcher’s acceptance of abstractions. Of course this does apply to HNA as well.

Furthermore, it was pointed out that EHNA and HNA are not themselves dynamic, but deserve further model development, preferably in form of systemic approaches, in order to provide an interpretation of dynamic system change. Still, even approaches with the ambition of integrating economical, political, social and environmental dimensions, require quantification, preferably as simple as possible. Hopefully, EHNA will provide such a straightforward method for quantification of environmental and economic variables.

**Depletion costs**

In this investigation, EHNA asset accounts for iron ore and timber in uncultivated and cultivated forests were established. These include several items to show stock changes, among them depletion costs. The methodological difficulties concern estimating the physical stock of resources and finding a proper unit resource value. The economic quantity of extraction and unit prices represents the contribution to value added due to depletion.

**Iron ore**

Regarding iron ore, historical geological investigations and mining concessions were used for estimating stocks and the so-called net-price method was used for estimating unit values.

This method is based on the assumption that the unit value of the resource is equal to the profit on the marginal extracted resource unit. Since true marginal extraction costs are extremely difficult to obtain it is not possible to perform a test of the method itself. It is certainly problematical that the assumptions which are made affect the result, at the same time as the assumptions cannot be tested in a satisfactory manner. The dilemma resulting from the lack of opportunity to
perform empirical testing does however concern all micro economic theory and many other social scientific theories. Since the possibility of testing is lacking, it is also impossible to state what a reasonable unit price could be. The variation is between the obtained unit price estimate and zero. Thus, it is likely that the estimates provide maximum values for depletion. As an accounting convention it was suggested that maximum values obtained by the net price method should be used in EHNA, since overestimates of environmental costs probably are to prefer in environmental accounting, at least when sustainability is the focus of the analysis.

Furthermore, iron ore was the only asset for which a full integration between the EHNA asset accounts and the HNA production accounts was made. This was accomplished by explicitly showing iron ore industry in HNA and through an extension of the production account in order to estimate a net value added. The environmental costs of depletion, recorded in the EHNA accounts, were imputed in the production account and thus an eco-value added could be estimated for the iron ore industry. EHNA for iron ore were made from 1890.

Standing timber

The standing timber volume was estimated by using various kinds of historical data and previously made research for the period 1800-1925. A model in which growth, logging and other factors were taken into consideration was constructed for estimate stock changes in physical units from 1800. Needless to say, these estimates are uncertain. Official forest survey data was used for the period after 1925.

With respect to timber in uncultivated forests, net prices were obtained as direct prices as well as indirect estimates. Direct net prices, so called stumpage prices, were obtained from 1876 and onwards. It was, however, pointed out that the regional heterogeneity of the prices do make the data uncertain. For the period 1800 to 1875 an indirect method was employed to estimate net prices.

It was also noticed that the institutional status –whether the asset is controlled by an institutional unit or not– is important for deciding if use of the asset is to be treated as depletion or not. The gradual development of forest property rights motivated an EHNA approach in which depletion costs were calculated between 1800 and 1925. From 1925 onwards, stock changes were instead treated as changes in work-in-progress.

Furthermore, an investigation of an economic scarcity indicator seems to confirm previously made assumptions about the development of the Swedish standing timber volume characterized by a reduction from around 1850 and a positive net growth during the first decades of the 20th century.
Degradation costs

Pollutants

Historical discharges of some common types of pollutants to air, water and land were also estimated in the study. Certainly, not all emissions which ideally should be included in a historical estimate of the contribution of the discharge of residuals to the eco-margin were covered by this investigation. The most obvious ones were, however, included. In order to make these estimates different types of data sources and indicators were used. Furthermore, historical estimates based on so-called emission factors (the relationship between, for instance, a fuel and a specified emission) were performed. Also in the case of pollutants there are, of course, uncertainties present. The impression is however that the estimates display the general development of these discharges.

Avoidance costs at fixed prices were used for imputing monetary values of the discharges. These avoidance costs were obtained from numerous Swedish and foreign, mostly American, investigations. Swedish avoidance cost estimates, elaborated for meeting present or suggested environmental targets, were, however, used whenever possible.

It should be observed that avoidance costs in different investigations are affected by numerous factors, such as environmental targets, technology, assumptions on interest rates etc. Therefore, the results from different investigations are not always fully compatible.

In the present study, the monetarized pollution series were aggregated. The contribution of a comparatively large number of pollutants to the eco-margin measured in 1994 avoidance costs was accordingly obtained.

Analyzes

The concluding investigations sought to perform some initial analyses of the EHNA series and to point at the kind of investigations that can be performed with the help of EHNA. A general issue of immediate interest concerns the relationship between the EHNA series and previously made periodizations in Swedish economic history. The periodization that was chosen was originally put forward by Krantz and Schön and seeks to interprete Swedish economic development in terms of periods of structural change, structural crises and structural transformation.
Depletion

The first specific question that was raised in the introductionary chapter concerned depletion:

*How can depletion of natural assets be characterized from an economic historical point of view and how has it been correlated to economic growth?*

Both concerning iron ore and timber it was considered relevant to investigate what the historical contributions of natural resources to value added had been in the Swedish economy. It was pointed out that value added of a certain natural resource-based industry is not the same as a measure of the direct economic value created by rich deposits of iron ore and unexploited forests. Capital may be employed in different ways. The true direct economic role of iron ore deposits and timber is therefore the extra revenue which can be obtained from investments in these natural resource sectors as compared to investments in other economic activities. This is indicated by the net price. Higher incomes due to natural resource possession could have been instrumental to a certain extent in the formation of rising demand for both consumer and investment goods. In the same way it is relevant to ask whether Swedish natural resources, primarily forests and iron ore, have played a similar role in a historical perspective.

During periods of positive net prices Sweden enjoyed supplemental incomes from the iron ore and timber export. Thus, it was possible to increase consumption and investments. In this way consumption and investment opportunities were transferred from abroad via the export market. The economic actors who are likely to have benefited from the iron ore rent are the Grängesberg company (TGO) and later, when LKAB was nationalized in the 1950’s, the state. The beneficiaries of the timber rent varied from small holders, to larger forest companies and the state.

The investigation indicated a rise of the depletion related incomes from around 1820. This continued until the 1850’s, when the share was approximately 3.5-4% of GDP. It is difficult to say whether or not this is a large proportion. It was, however, pointed out that the early modernization phase of Sweden at least to some degree was facilitated by "withdrawals" from the natural assets.

The share of depletion costs remained at this level during the industrialization phase of the late 19th century. The fall of the share from around 1900 was basically due to the increase of standing timber volume. According to the accounting principles used in EHNA depletion costs were not recorded. It was therefore considered relevant to study natural resource rent related incomes irrespectively of their being regarded as depletion or not.
This study revealed that the natural resource rents started to fall in proportion to other incomes already at the turn of this century. This ‘turning point’ does not bear a clear correlation to a structural crisis.

However, in order to further examine the importance of natural resources in the Swedish economy it was suggested that it could be investigated whether any of the structural crises share the characteristics of a so-called "Dutch disease" crisis, a crisis which is clearly associated to natural resources.

Concerning the periodization, the general conclusion of the study of iron ore net prices and stumpage prices was that the behavior of these net prices seemed to coincide with the original periodization put forward by Krantz and Schön. However, the periodization was based on visual interpretation of the series. Without doubt this makes the conclusion uncertain. Furthermore, the periodization of structural periods and the net prices used in this investigation are not fully based on independent data sets. In this investigation the GDP deflator was used to obtain deflated net prices and in Krantz and Schön’s original analysis the various HNA quotas were estimated on basis of deflated series.

Furthermore, a general long-term trend of increasing iron ore scarcity was not confirmed. As discussed earlier, the net price method is based on the so-called Hotelling rule. The Hotelling rule predicts that if certain assumptions are made, the net price is expected to rise at a compound rate, due to increasing scarcity. This investigation did not support that such a scarcity effect exists for the whole period.

Nonetheless, in regard to the iron ore net price, the sub-period lasting from 1890 to ca 1952 may be interpreted as indicating an underlying trend of growth at a compound rate. This period does include both phases of structural transformation and rationalization. Nevertheless, this development was halted after the Korea boom. This was seen as a long-term adjustment of the resource base to accommodate increased scarcity. It was therefore suggested that the iron ore net price has been influenced by ordinary market forces, such as demand, interest rates, production costs etc. and, to some degree up until the 1950’s, by a compound increase of the natural resource rent. It was concluded that indications for economic adjustments to scarcity both in the short, medium and long run exist.

Pollution

The second specific question which was raised in the introduction was

*How can environmental degradation due to pollution be characterized from an economic historical point of view and how has it been correlated to economic growth?*
The question was examined by first making a periodization of the contribution of the aggregated pollutants to the eco-margin and, secondly, by making a periodization of the so called environmental Kuznets curve (EKC), which describes the relation between environmental degradation and economic growth over time.

Concerning the periodization of the contribution of the aggregated pollutants to the eco-margin four sub-periods were identified. This was done by a visual interpretation of the series. The first period was between 1800 and 1870. During this period, the growth rate of the eco-margin increased from approximately 0% to 2.4% on an annual basis. A sharp increase of the growth component could be noticed between ca 1840 and 1858. This was probably a reflection of population growth, urbanization and a beginning of the industrialization process.

The next homogenous period was between 1870 and 1913. It was a period with a constant annual growth rate of the eco-margin of 2.4%. It was suggested that this period probably is best understood as a period during which pollution induced by population growth gave way to industrial pollution.

The third period was between 1913 and 1947. It is well known that several shocks affected the economy during this period. The world wars, the economic crises of the 1920's and the 1930's, as well as the Swedish metal workers’ strike in 1945 were the most obvious ones. The interwar period was so chaotic that it is difficult, if not impossible, to make generalizations about it. Accordingly it was suggested that the development of the contribution of the eco-margin during the interwar period is best understood as the result of a series of random shocks.

The final homogenous period was between 1947 and 1990. The high growth rate of the eco-margin I during the last years of the previous period continued, with an accelerating annual growth rate of more than 8% after the Second World War. This was seen as a reflection of the fast adaptation to normal conditions after the war. After this the annual growth rate declined continuously, except for the period ca 1956 to ca 1964. This means, generally speaking, that the eco-margin continued to increase, but, with the exception of the late 1950s and early 1960s, at a successively slower rate. In 1969 the growth component was 0%, implying a zero growth of the eco-margin. Thus, 1969 marked the beginning of a decreasing eco-margin. At the later part of the period the growth rate was -7%.

Generally, it was concluded that this periodization did show a weak correlation with the periodization pattern that previously has been suggested by Krantz and Schön. Concerning the development of the contribution of pollution to the eco-margin it is clear that the post-1970 period represents a historically unique period of decreasing environmental pressure. It was, however, not the first period of structural transformation. Thus, it could be concluded that general structural transformation \textit{per se} is not sufficient and not a principal explanatory factor for the decrease of emissions. However, it should be noticed
that it is far from certain that the post-1970 period was a period of structural transformation similar to those in ca. 1890-1910 and ca. 1930-1955. Thus, it was pointed out that the post-1970 period may include two historically unique phases concerning both economy and environment.

Furthermore, the eco-margin/GDP ratio which indicates the EKC was studied. The general conclusion which could be drawn from this study was the absence of a constant ratio between growth and environmental impact. During most years of the 20th century, the ratio was actually declining.

A tentative interpretation of the EKC suggested that three or even four EKC phases could be distinguished. It was proposed that periods of structural transformation may be correlated with positive net prices and a falling EKC. The first EKC period started in 1870 and peaked around 1898. The phase reached its lowest point in approximately 1920. This corresponds rather well with the second period obtained through the time series analysis of the eco-margin I. It was also suggested that there may be a phase which began in approximately 1820, and peaked during the early 1840's. It ended around 1870. A general impression is therefore that this interpretation is, very uncertain. The second EKC phase occurred between around 1920 and 1947, with a peak approximately in 1937. A general impression here was therefore that the crisis of the 1920's seemed to be what could be called a demarcation crisis, separating the phases. Thus, there is a difference to the periodization according to Krantz and Schön who put forward the crisis of the 1930's as a structural crisis. The third EKC phase occurred between 1947 and the present, with a peak around 1972. Future research may either confirm or invalidate the periodization put forward here. Furthermore, international comparisons should be conducted, in order to clarify whether there is a specific Swedish pattern or a pattern for a certain group of countries.

In conclusion the following results could be pointed at:

- It is possible to construct environmental historical national accounts for both depletion and degradation costs.
- The series are clearly dependent on the choice of methods and must be considered as interpretations of a historical reality.
- Furthermore, lack of data frequently produces significant uncertainties concerning measurement.
- The depletion costs were increasing as a share of GDP throughout the 19th century and reached its highest approximately 4% of GDP at the turn of the century 1900.
- The natural resource unit prices, the net prices, seem to have developed in a way which resembles the periodization based on structural transformation and rationalization in the Swedish economy.
- The pollutants' contribution to the eco-margin has increased up to the late 1960's. Furthermore, the development of the pollutants' contribution to the eco-margin may be described in terms of four sub-phases.
- The eco-margin's share of GDP has generally fallen throughout the period, and this process can be described as a series of three or four periods, which at least partly seem to be correlated to the periodization based on structural transformation and rationalization in the Swedish economy.
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