ACCOUNTING FOR GOODS AND FOR BADS

MEASURING ENVIRONMENTAL PRESSURE
IN A NATIONAL ACCOUNTS FRAMEWORK

PROEFSCHRIFT

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Preface

The possibility of writing a thesis crossed my mind at several occasions throughout the eight years I worked at Statistics Netherlands on the development of environmental accounts. Eventually, in the year 2000, when I changed jobs and shifted my line of work to other subjects, I felt a strong desire to properly bring together my contributions to environmental accounting and so I was very pleased to find Bert Steenge willing to act as my promotor.

Statistics Netherlands has a tradition in environmental accounting. Roefie Hueting is one of the founding fathers of environmental accounting who carried out much of his work as head of the environmental statistics department of the Dutch statistical office. The national accounts department started the development of environmental accounts in the beginning of the nineties when I was working there as a trainee. Steven Keuning and colleagues developed an environmental accounting framework which they called a National Accounting Matrix including Environmental Accounts (NAMEA).

My first official job at Statistics Netherlands was to provide the NAMEA with real numbers. Obviously this work was carried out in close co-operation with colleagues from the environmental statistics department. The first pilot results presented in 1993 contained rather old data but nevertheless reached the headlines of many newspapers in the Netherlands. It was not shown before that in the Netherlands a larger part of environmental pressures was generated in only a restricted number of relatively small industries in terms of value added and employment. It was very challenging to explain to a wide audience what we had done and what messages may be derived from it.

Eurostat, the statistical office of the European Community, got interested in the NAMEA as well and organised a number of workshops to investigate the possibilities of implementing NAMEAs in other member states. The first workshop was held in 1995 at Statistics Netherlands in Voorburg and its organisation together with my colleagues Peter Bosch and Leon Tromp was a great pleasure. It became clear that for a large number of member states the possibilities of compiling NAMEAs for air emissions were quite good. So far, Eurostat has released two NAMEA publications with estimates of most member states. Generally the working programme initiated by Eurostat and carried out in close co-operation with Planistat has very much taken forward the development of environmental accounts in Europe.

In later years the London Group on environmental accounting became responsible for the revision of the 1993 United Nations interim manual on Integrated Environmental and Economic Accounting (SEEA). This revision was found necessary to keep up with the wide range of environmental practices up to date. Over several years, the revision took much effort from a lot of people including myself and this ultimately resulted in a statistical manual of almost the size of the 1993 System of National Accounts. This shows that environmental accounting comprises a very broad and dynamic field of statistics with a great policy interest that is sometimes subject to strong differences in views.

The last four years have been challenging to say the least. Not only did I have to combine writing a thesis with a rather busy job. Also in this period our daughter Kira and our son Gijs were born. Their liveliness and distaste for sleeping made these four years demanding but nevertheless very enjoyable. Much like training for a marathon, writing a thesis is a very selfish business. Without the help and support of my wife Jolanda, it simply would have been impossible to finish this thesis in four years time. I owe her a lot.

There are several other people who contributed to this thesis. First of all I would like to thank Steven Keuning for his contributions to much of the original material referred to in this thesis. He has been the initiator of environmental accounting at the national accounts department of Statistics Netherlands. Despite the sometimes passionate internal debates at Statistics Netherlands about matters of environmental accounting, I have appreciated very much my contacts with Bart de Boer from the environmental statistics department which have always been pleasant and helpful. I am also obliged to Henk Verduin who developed the energy accounts required to compile the air emission accounts according to the national accounts resident principle. Further I would like to thank Ole Gravgård and Anton Steurer for the many stimulating discussions we had in the course of the SEEA revision. In many ways the drafting of the SEEA handbook has been a learning experience.

Many others such as Jan van Dalen, Hendrik Jan Dijkerman, Marieke Gorree, Bas Leurs, Johan van Rooijen, Bas Schoorlemmer, Reinoud Segers, Marret Smekens and Monique Voogt, contributed to the development of the NAMEA at Statistics Netherlands and their contributions are gratefully acknowledged. I am also grateful to Brugt Kazemier, Winfried Ypma and Kees Zeelenberg for allowing me to spend some of my working time on this thesis and for providing me with valuable comments on several chapters.

Last but not least, I would like to thank Bert Steenge for his coherent supervision and for the many inspiring discussions we have had over the last couple of years which made the frequent journeys to Enschede worthwhile.

Chapter 1. Introduction

1.1 Background

Economic growth, measured by the volume increase in national income, does not represent an increase in welfare per se. Many determinants of welfare remain uncovered in an income measure representing the free disposable sum of money received by all economic agents in an economy. In economic theory, it is generally acknowledged that utility is also derived from non-priced amenities such as leisure and a well-preserved natural environment.

Yet, economic growth is still commonly regarded as being synonymous with an increase in welfare. This illustrates that national accountants have an obligation to present indicators like gross domestic product and net national income in the right, and perhaps a more modest, perspective. One logical way of doing so is to systematically supplement the national accounts with indicators covering a wide range of welfare aspects. Obviously, such extensions are only fruitful when the usefulness of the present national accounts indicators is accepted in their own right.

An example from the Netherlands may be illustrative here. Statistics Netherlands has developed a range of modular extensions of the national accounts, an approach that builds on Keuning's (1996) notion of a so-called System of Economic and Social Accounting Matrices and Extensions (SESAME). SESAME is an extended national accounting system that contains various modules from which a set of core economic, social and environmental indicators is being derived. These kinds of extensions are also discussed in chapter XXI of the System of National Accounts (SNA-1993, Commission of the European Communities *et al.*, 1993) on satellite analysis and accounts. Satellite accounting broadens the scope of the national accounts in specific fields of interest without overburdening the core framework. Satellite accounts may address various welfare related issues such as the environment, household production of non-market services but also issues related to specific economic sectors or activities such as transport and tourism.

This thesis is mainly concerned with those extensions of the national accounts dealing with the environment. This field of extensions is generally referred to as environmental accounting. The recently compiled handbook on Integrated Environmental and Economic Accounting (SEEA-2003, Commission of the European Communities *et al.*, 2003) provides a virtually complete overview of environmental accounting methods. The need for environmental accounting can be formulated as follows. The unfavourable environmental consequences of continuing economic expansion have brought about awareness that economic growth must be bounded by additional policy constrains. Although most policy agendas these days address simultaneously a wide range of economic, environmental and social goals, economic growth is still conceived as being socially desirable as a way to increase purchasing power but also as a way to create new jobs and to abate social exclusion. Quite illustrative in this context is the recently formulated 'Lisbon Strategy' that aims at transforming the European Community into the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion.

Opting for a wide notion of prosperity uncovers various limitations of the SNA-1993. The SNA is principally based on the systematic recording of transactions such as product sales and purchases, the payments and receipts of transactions such as wages, dividends and taxes, and so on. The balance sheet embedded in the SNA reflects the wealth of the nation at certain moments in time in terms of (net) ownership of financial and non-financial assets. In other words, the SNA provides a complete and systematic description of the money dimension of a macroeconomic system. Each recorded money receipt principally coincides with the recording of a money outlay and the accounting system guarantees the systematic reconciliation of current transactions, financial transactions and balance sheets. However, the insurmountable consequence of this main focus on measuring factual money flows and stocks is obviously the underexposure of the non-priced determinants of welfare.

Markets may fail to safeguard a desirable allocation of environmental resources. The unilateral use of an environmental asset by one agent may eliminate other use options without the consent of those being harmed. Also, these unilateral actions may be taken without appraising private benefits against foregone social benefits. A classic example is the use of a river as a sink that destroys its functioning as a source for drinking water. An uncompensated loss in welfare of one agent caused by another is usually referred to in an economic context as a negative externality. In view of this, the SNA-1993 explicitly acknowledges that not all economic flows are transactions (*cf.* §2.26). As a consequence of a main focus on market transactions, the SNA principally excludes economic flows related to either positive or negative externalities.

Environmental problems also give rise to intergenerational welfare consequences. Current environmental deterioration is likely to restrict the available amount of environmental services at the disposal of future generations. Issues such as climate change, losses in biodiversity and the depletion of crucial natural resources such as fresh water and energy indicate that environmental degradation possibly interferes with the existence of life on earth. The importance of sustainability was emphasised by the World Commission on Environment and Development in 1987 by stating that the needs of the present should be met without compromising the ability of future generations to meet their own needs. Translated into economic terms, the issue of environmental sustainability could be formulated as "how should we treat natural environments in order that they can play their part in sustaining the economy as a source of improved standard of living?" (Pearce & Turner, 1990, p. 43).

Pearce & Turner (1990) indicate that there are no straightforward rules for sustaining an economy. First of all, they emphasise that 'standard of living' cannot be something single-valued like real income per capita. Instead, standard of living comprises a set of different components such as the utility derived from real income, education, health status and spiritual wellbeing. In other words, measuring economic progress in terms of social welfare is a multidimensional phenomenon and assessing the parameters of a social welfare function can only be subject to policy evaluation. Secondly, the extent to which the functions of nature must be preserved for future generations depends, among other things, on the irreversibility of environmental deterioration, the degree of substitutability of man-made and natural capital, changes in preferences and the technical state that will be at their disposal.

The notion of natural capital, being the accessible reservoir of functions provided by nature, is connected to two conflicting sustainability perceptions. A 'weak' sustainability concept does not consider natural capital to be very different from man-made capital. Also, a weak sustainability perception presumes that all relevant environmental functions are principally assessable in money values. Subsequently, environmental capital comprises a regular part of a nation's capital portfolio that includes, in addition to natural capital, other categories such as produced capital and human capital. According to mainstream economic theory, all these capital categories are allocated with the ultimate purpose of optimising social welfare (*cf.* Solow, 1993).

Proponents of a 'strong' sustainability concept consider at least certain environmental functions as critical for the existence of life on earth (*cf.* Victor, 1991). These critical components of natural capital, *i.e.* the life supporting functions, are expected to lack any manufactured substitutes. Ekins (2001) advocates a sustainability concept that focuses on the maintenance of these crucial environmental functions. He argues that there are cases in which trade-offs between produced and environmental capital are justified. However, "the loss of natural capital to date, combined with ignorance about the importance what remains, together with threshold effects and irreversibilities that make unwelcome changes impossible both to predict and undo, argue for caution" (Ekins, 2001, p.104).

Opting for a strong or weak sustainability perspective largely determines the kind of statistics or accounting approaches that are put forward to measure trends in sustainability. The weak sustainability perspective is related to a strong believe in the optimal functioning of markets. Money values of produced and environmental assets are considered to solidly reflect their scarcity and hence their mutual substitutability. In contrast, a strong sustainability concept poses absolute restrictions upon the allowable levels of environmental deterioration and as such the money valuation of environmental assets is considered with respect to these critical functions pointless and not useful.

1.2 The scope of national accounting

The standardisation of the national accounts methods strongly evolved over the period after the Second World War. An important milestone is without doubt the SNA-1993 as the first really universal standard on national accounting concepts (*cf.* Bos, 2003, p.19). From an environmental point of view, the 1993 version of the SNA contains a number of improvements compared to its predecessor, the SNA-1968 (United Nations, 1968). The SNA-1993 provides much more guidance to the representation of balance sheets and the coverage of those environmental assets subject to ownership and with clearly observable market values. Examples of environmental assets covered in the SNA-1993 are land, certain water deposits, mineral deposits and non-cultivated biological resources. However, many other environmental assets, those without clearly defined ownership and observable market values, remain unrecorded in the SNA-1993 balance sheet. Yet, these assets can be highly significant from a welfare perspective, for example with respect to the, already referred to, fundamental life support functions.

As already briefly mentioned, the SEEA-2003 presents a broad range of possible modifications and extensions of the national accounts. In this way, the handbook is a good reflection of an ongoing debate leading to many alternative environmental accounting and indicator proposals. In the past, the SNA has proven to be a powerful statistical tool for mainstream macroeconomic policy analysis. Environmental accounting explores directions in which this 'systems approach' can be expanded towards environmental-economic policy issues. Such expansions may for example comprise an extended representation of balance sheets or supplementary accounts for measuring the environmental interactions of production and consumption activities. The first research question raised in this thesis is:

1. *What specific goals are pursued by various environmental accounting methods?*

With respect to national accounting, the development of environmental accounts has anticipated roughly to two points of criticism. The *first* one refers to the feasibility and desirability of everlasting economic growth. This debate has a long tradition. In the beginning of the nineteenth century, Ricardo already concluded that due to decreasing productivity of additional inferior land, economic growth would ultimately lead to stagnation. In the second half of the former century, several authors such as Mishan (1967), Georgescu-Roegen (1971), Meadows *et al.* (1973), Hueting (1980) and Daly (1992) have been questioning the feasibility or desirability of continuing economic growth. Their shared point of concern is that the goods and services provided by the natural environment are subject to absolute biophysical constrains. And without technical change, these constrains will inevitably bind economic expansion at some point in time. The scenarios analysed in the world model developed by Duchin & Lange (1994) indicate that world-wide environmentally sound economic development requires significant changes that go far beyond technical improvements.

One important conclusion that can be drawn from empirical research on the environmental consequences of economic growth is that environmental deterioration is not a one-dimensional phenomenon. While most post-industrialised economies achieved in recent years substantial reductions in several kinds of pollution outputs and improvements in air and water quality, there are still several environmental concerns that are persistently connected to economic growth. A well observed example of the latter category is fossil energy consumption and the concomitant emission of greenhouse gases. Obviously, it is important to reflect with the help of statistics and accounts on these diverging trends. Yet, identifying these diverging patterns in environmental deterioration may be in conflict with a frequently expressed desire to provide condensed and (over)simplified overviews of environmental impacts, *e.g.* by way of environmental indices or other types of aggregates. The construction of meaningful aggregates has received a lot of attention in environmental accounting. Generally, one of the analytical strengths of accounting is providing, in a consistent way, information at various levels of detail.

Its principle focus on market transactions and market valued assets implies that the SNA provides only little information about the environmental dimension of economic performance. Measuring environmental-economic interactions requires first of all insight into the physical and spatial characteristics of the economic system. Much of this thesis deals with how the SNA framework can be applied to account for the physical dimension of economic performance or the systematic mapping of the environmental pressures of economic activities. Enhancing the comparability of physical and monetary information supports the statistical basis for constructing various kinds of environmental-economic performance indicators. These indicators are for example helpful in illustrating the influence of various changes in the economic system on various environmental pressures. However, the possibilities of doing so depends on the extent to which national accounts definitions and classifications are applicable to a wide range of non-monetary statistics, reflecting the physical and spatial characteristics of the economy.

One important feature in this context is the ability of environmental accounting frameworks to express the influence of economic structures on environmental indicators. The explanatory power of environmental indicators is greatly improved when these are represented in relation to the specific set of consumption and production activities represented by an economy. In this way, accounting systems help to indicate whether structural changes in post-industrialised economies truly contribute to trends in dematerialization or instead to the casting out of polluting industries, which continue to serve the domestic market from other parts of the world.

Summarising, the SNA framework has several beneficial characteristics that potentially support an integrated assessment of environmental-economic performance with the help of a national accounts based recording of environmental pressures. Most chapters in this thesis examine the strengths and weaknesses of such an extended national accounts oriented information system. This examination entails the following research questions:

2. *What kind of indicators is particularly useful in recording environmental-economic dependencies?*
3. *What accounting structure serves most appropriately such an integrated environmental–economic information system?*
4. *What are the strengths and weaknesses of a national accounts oriented representation of environmental statistics?*

Obviously, the credibility of environmental extensions, rather than modifications, stands or falls with the credibility of the SNA. This brings us to the second point of criticism. The measurement of income, wealth and changes therein (*i.e.* economic growth) in the SNA have been subject to substantial debate. This debate started with the rejection by Mishan (1967), Nordhaus & Tobin (1972) and many others of gross domestic product as a measure of welfare. As already mentioned, welfare, or the standard of living, is a multidimensional phenomenon, partly determined by non-economic factors such as accidents and natural disasters, partly by factors that are less easily expressed in terms of money income. The SNA considers gross domestic product (GDP) strictly as a measure of production: "GDP is a measure of production. The level of production is important because it largely determines how much a country can afford to consume and it also affects the level of employment" (SNA-1993, §1.69).

Even in this capacity, the indicator is subject to rather pragmatic boundaries. Quite illustrative in this context is the exclusion of the own account production of services by households. Several of these services do not fundamentally differ from corresponding market activities e.g. transportation, preparing meals, childcare. However, the justification of imputing market values for household production is generally difficult to assess. Also, an extension of the production boundary with household production disturbs well established notions as employment and unemployment.

From an environmental perspective, a major point of discussion has been how, and to what extent, domestic product and national income figures should reflect the depletion and degradation of environmental assets. Intuitively, this need can be formulated as follows. When production leads to severe environmental decline, gross domestic product no longer measures "how much a country can afford to consume", certainly not when losses in environmental assets today restrict production and consumption opportunities tomorrow. However, the wide range of different adjustments proposed by several authors indicates that deficiencies are apparently less clear then intuitively conceived.

Although gross domestic product or national income will never be able to serve as comprehensive measures of welfare, it is obviously legitimised to modify the SNA accounting conventions when these unnecessarily lead to distorted views on developments in production and welfare. These changes may for example concern the imputation of the costs of environmental losses. However, proposed changes may have their consequences in other directions and therefore the pro's and con's of these modifications have to be carefully analysed. This leads to the following research question:

5. *Which national accounting conventions contribute to a distorted view of environmental-economic dependencies and what are the system-wide consequences of possible modifications in these accounting conventions?*

In this context, it is important to keep in mind the purpose of accounting as the structured ex-post observation of factual events. Although, the recording of observable transactions is a leading principle in the national accounts, so-called imputations are sometimes made to account for e.g. the rents of owner-occupied dwellings or banking services that are not directly observable. The imputation of environmental costs cannot be rejected by arguing that the recording of environmental costs does not follow the observation of factual events. Environmental damages may concern real economic flows. However, the uncertainties about their manifestation imply that the imputation of environmental costs may be of a different magnitude compared to the imputations that are currently being made in the SNA.

1.3 Structure of this thesis

Chapter 2 opens with exploring the scope of national accounting from an environmental welfare perspective. An improved representation of environmental costs in the national accounts is being discussed in relation to possible modifications of three rudimentary national accounting concepts, *i.e.* exchange values, the production boundary and the asset boundary. Further, in this chapter an overview is given of the most important characteristics of two main environmental accounting approaches: cause-oriented accounting versus effect-oriented accounting.

Chapter 3 reviews physical flow accounting as a fundamental way of extending the SNA scope from a cause-oriented perspective. This chapter includes a methodological overview of different physical flow accounting approaches together with the indicators they embody. This discussion also addresses the kinds of flows that should be identified by environmental pressure indicators. Chapter 3 further elaborates on the significance of national accounting concepts in physical flow accounting, for example with respect to a consistent attribution of environmental pressures to economic activities.

The economic significance of cause-oriented accounting increases when physical flow accounts are made compatible to the monetary information in the national accounts on production and consumption. A so-called National Accounting Matrix including Environmental Accounts (NAMEA) facilitates this compatibility. The structuring of non-monetary data on environmental pressures, *i.e.* the environmental requirements of production and consumption activities, within a national accounts framework is the key subject of *chapters 4 and 5*.

Chapter 6 discusses the applicability of the NAMEA to a wider spectrum of environmental requirements including for example water use, land use and the dispersion of toxic matter. The chapter reviews the strengths and weaknesses of recording these various kinds of environmental pressures in a national accounting context. Especially the spatial characteristics of different environmental pressures are taken into consideration.

In *chapter 7*, the NAMEA indicators are extended by two sets of interdependent indicators: the 'environmental balance of trade' and the 'environmental consumption'. Both indicators bring about a shift in focus from a production perspective to a consumption perspective. Both perspectives provide alternative ways to look at the environmental performance of an economy. The production perspective follows the 'direct' recording of environmental requirements as statistically observed at the production process level. The product use or consumption perspective results from a reallocation of directly observed environmental requirements to product outputs and subsequently to the final users of products in an economy: consumers.

With the help of structural decomposition analysis, *chapter 8* illustrates the use of NAMEA time series in the inter-temporal analysis of environmental pressure indicators. Structural decomposition analysis decomposes the periodic changes in environmental pressures according to a number of economic driving forces, e.g. changes in eco-intensities at the level of industries or households, changes in the production structure, shifts in consumer demand and, of course, economic growth. Also, this chapter includes a discussion about the conceptual backgrounds of structural decomposition analysis.

Finally, *chapter 9* sums up the main conclusions of this thesis and winds up with a number of directions in which future developments in environmental accounting are being considered most promising.

Chapter 2. The national accounts and the environment

2.1 Introduction

When looking at the SNA-1993 from a welfare perspective, the system's scope is restricted due to its principle focus on directly observable market transactions. Environmental accounting attempts to widen the scope of national accounting by taking into consideration in various ways the environmental repercussions of production and consumption. This chapter discusses the strengths and weaknesses in doing so.

In this context, it is important to keep in mind the general goals of national accounting. The SNA-1993 serves as an interface between statistical observation and empirical analysis. Accounting contributes to the structuring of statistics in order to improve their accessibility to specific analytical purposes. These purposes may vary from a condensed review of economic progress to more advanced analytical uses. The accounts are only able to provide a reasonable representation of factual events when they do not depend too heavily on analytical interpretations and expectations. Obviously, this neutrality is not achievable in absolute terms. The SNA relies on theoretical concepts such as production, income and consumption and their reconsideration may turn out necessary at the moment they become obsolete for the majority of analytical objectives at present. Yet, the introduction of analytical constructs should be considered carefully. Accounting should facilitate debates and not settle them. A descriptive, and perhaps a somewhat conservative, interpretation of accounting is taken as a point of reference in the appraisal of environmental accounting approaches in this chapter.

The strengths and weaknesses of calculating environmentally adjusted national accounts figures are very well documented in a methodological research funded by the European Communities (*cf*. Brouwer & O'Connor, 1997). This research became in later years known as the 'Greenstamp' project. Conclusions drawn by the Greenstamp project about the conceptual soundness and scope of various accounting methods are much in line with the conclusions presented in this chapter. This chapter particularly addresses the extent to which environmental adjustments can be reconciled with basic SNA concepts dealing with valuation, production and ownership. Furthermore, pragmatic choices are usually unavoidable when translating economic reality into workable and internationally harmonised accounting concepts. In addition to conceptual soundness, the practical implications of environmental adjustments are also addressed in this chapter.

The following section contains a brief overview of the development of the SNA. In section 2.3 three rudimentary SNA-1993 national accounts concepts are introduced:

exchange values, the production boundary and the asset boundary. Especially their role in establishing economic-environmental relationships in the system will be discussed. This section also discusses accounting recommendations that may follow from economic theory on measuring social welfare. Section 2.4 discusses the extent to which environmental pressure-state relationships can be translated into accounting identities. Section 2.5 distinguishes two main directions in which environmental accounts have been developed: cause-oriented accounting versus effect-oriented accounting. Section 2.6 winds up with conclusions.

2.2 *The development of the SNA*

Before discussing it's relationships to environmental concerns, this chapter continues first with a brief historic overview of the SNA. This section largely originates from Bos (2003) who provides a concise overview of developments in national accounting over time.

The first national accounts estimates date back to those of Petty and King for England and of Boisguillebert and Vauban for France in the second half of the seventieth century. The policy goals of these estimates, as mentioned by Petty, were to assess the financial health of the State and to estimate the feasibility of possible tax increases needed to finance the war. One century later, Quesnay published his 'Tableau Économique' with the purpose of providing an overview picture of all transactions between the main groupings of actors, *e.g.* farmers, landlords and artisans, in the economy. Quesnay's system can be interpreted as a forerunner of the input-output table much later developed by Leontief.

The pioneering work of Clark and Kuznets in the first half of the twentieth century very much influenced the worldwide calculations of national income. Their work has also been relevant in the context of environmental accounting. Clark already discussed a possible 'deduction for any demonstrable exhaustion of natural resources' from national income (*cf*. Bos, 2003, p.12) while the 'Kuznets curve', visualising the macroeconomic relationship between economic growth and income distribution, was later introduced in empirical research on the relationship between economic growth and environmental pressures (*cf*. De Bruyn, 1999). The introduction of input-output analysis by Leontief (1936) is another major national accounts development with clear applications in the field of environmental accounting. Input-output systems have been used extensively in analysing substance and energy flows in the economic system.

Bos (2003, p.17) refers to the post Second World War period as 'the area of the international guidelines'. In this period three major steps can be distinguished in the development of the SNA:

- the SNA-1953 (United Nations, 1953) and preceding guidelines of the United Nations and OEEC (*i.e.* the precursor of the OECD);
- the SNA-1968 (United Nations, 1968) and the European guidelines of 1970;

– the SNA-1993 (Commission of the European Communities *et al.*, 1993) and the European System of Accounts ESA-1995 (Eurostat, 1996).

The first generation of national accounts was published under the direction of Stone. The OEEC guidelines preceding the SNA-1953 manual were to be used in the planning of the Marshall aid. This system was very simple in structure, anticipating the limited data sources in most OEEC countries at that time. A second revised system was published by the United Nations in 1968. Stone was again one of the main authors. This system was a few years later followed by the first European System of Accounts, which was quite similar to the SNA-1968, however with a specific focus on European circumstances. The SNA-1993 can be considered as truly the first universal set of national accounting standards jointly published by the Commission of the European Communities, the International Monetary Fund, the Organisation for Economic Co-operation and Development, the United Nations and the World Bank. The SNA-1993 is harmonised with the European System of Accounts (ESA-1995), however the latter being more precise and specific due to its legal status enforced by Council Regulation (Council of the European Union, 1996). Within the European Community the national accounts play an important administrative role, for example in determining part of the own resources of the EU, and in providing the entrance criteria for the monetary union.
From an environmental point of view, the most important innovations in the most recent national accounting guidelines, the SNA-1993, compared to its precursors are the following:

– Balance sheets have not been included until the SNA-1993 and the ESA-1995. In addition to fixed or produced assets (*e.g.* buildings, machinery) and financial assets, balance sheets may also take record of a range of natural assets such as land and mineral deposits. The other changes in asset accounts cover both holding gains and losses and changes in the volume of assets that are unrelated to economic transactions, *e.g.* environmental damages (resource depletion) or damages due to earthquakes and floods.
– The presentation of supply-use and input-output tables is much more operational compared to the SNA-1986 and the ESA-1970. The SNA-1993 explicitly recommends that the statistical supply-use tables should serve as the foundation from which the analytical input-output tables are constructed.
– The SNA-1993 contains a chapter on so-called satellite accounts which is to be supplemented by handbooks on *e.g.* on environmental accounting (cf. Commission of the European Communities *et al.*, 2003). Such a building block system may expand the analytical scope of the national accounts without overburdening the system with different (conflicting) concepts.
– The SNA-1993 contains a chapter on a Social Accounting Matrices. Matrix presentations provide a direct link to macroeconomic modelling. As shown in this thesis, matrix presentations of the national accounts are also useful in environmental accounting.

– Finally, the SNA-1993 (*cf*. chapter I, section J) explicitly acknowledges that national income is not, or at least a very partial, welfare indicator.

The system of national accounts is a multipurpose system designed for economic analysis and policy. Especially, the creation of the European Monetary Union has brought about an increasing policy interest in national accounts data on *e.g.* economic growth, government deficit and debt. As a consequence, the harmonisation of economic growth estimates between EU member states have been enforced by additional regulations. In other words, in Europe the use of national accounts data at present seems to be dominated by administrative and monetary policy uses. However, the national accounts and satellite accounts may also play a supporting role in the harmonisation and analytical use of other EU policy indicators as for example introduced in the context of the Lisbon Strategy or the Sustainability Strategy. Despite many recent and promising developments in the field of social and environmental accounting, the role of national accounts frameworks in these latter policy strategies has not (yet) been explored.

2.3 SNA boundaries

2.3.1 Valuation

The SNA presents economic statistics in a format useful for purposes of monitoring, economic analysis and decision-making. The system measures values at which products, labour or assets are exchanged or else could be exchanged for money. The use of exchange values in the system logically follows from the system's principle reliance on the recording of statistically observable events. From an environmental point of view, this valuation principle is rather restrictive since it leaves most goods and services provided by the natural environment priceless. This sub-section discusses the possibility and usefulness of introducing additional valuation methods in economic accounting.

The common sense behind market valuation in the SNA is explained as follows. "The System does not attempt to determine the utility of the flows and stocks which come within its scope. Rather, it measures the current exchange value of the entries in the accounts in money terms, *i.e.*, the values at which goods and other assets, services, labour or the provision of capital are in fact exchanged or else could be exchanged for cash (currency or transferable deposits)" (SNA-1993, §3.70).

Part of the production recorded in the SNA concerns so-called non-market production of the government and the non-profit institutions serving households. The value of non-market output is by convention determined by the sum of production costs. One could argue that this recording also follows observable events in the sense that collective consumption is principally produced without generating profits. However, the measurement of non-market output at production costs, *e.g.* healthcare, defence, environmental protection services, does necessarily reflect the social welfare derived from it.

The current exchange value imposes an overall consistency to the system in a sense that transactions in cash are systematically counterbalanced by the financial flows recorded in the system. So, the accounting consistency of the system is clearly served by the use of current exchange values. However, an accounting system that is principally restricted to market observations leaves inevitably uncovered the various non-priced welfare determinants such as leisure and environmental amenities. At the same time, the private costs of production as reflected by market prices may be less than their social costs due to the existence of negative externalities such as pollution. These social costs are not recorded in the system.

The balance sheet in the national accounts includes several environmental assets such as mineral deposits, timber and fish stocks that are only infrequently exchanged on markets. The exchange values of the raw materials derived from these assets are usually used to determine asset values. Under the condition of constant extraction costs, no technical progress and optimal resource exploitation, Hotelling (1931) explains that the unit price of a non-renewable natural resource contains a resource rent reflecting the value of a marginal resource unit with respect to its future extraction. The Hotelling rule indicates that the resource rent increases over time at a rate equal to the time preference of money, *i.e.* the discount rate. This supposes firstly that resource prices fully reflect the opportunity costs of future uses and secondly that the value of natural assets is directly determined by the resource rent times its volume.

In the real world, the validity of the Hotelling rule is uncertain given for example the volatile market price trends of most raw materials. This complicates resource rent estimations and subsequently the valuation of exhaustible natural assets. Resource rents are not directly observable but are instead usually approximated by the difference between the value of extracted resources and extraction costs including the user costs of produced capital. In practice, the only way to approximate the value of non-renewable assets is to determine the discounted present value of the expected future rents generated from the asset's exploitation. This implies that assumptions are unavoidable with regard to future price developments, extraction rates, extraction costs and discount rates in order to determine the net present value of a natural resource's future earnings.

The SNA-1993 does not strongly support the use of net present values in the system. "Although this method is theoretically entirely justified, it is not generally recommended since it involves many assumptions and as a consequence the outcomes are highly speculative" (§3.75). One important obstacle in estimating net present values is that they unavoidably reflect the accountant's views on the expected scarcity of natural resources in the future. This makes the results less indisputable in policy debates about sustainable resource exploitation. Net present valuation introduces several uncertainties in the accounts with respect to future

events and should therefore preferably be accompanied by sensitivity analyses with respect to the assumptions on which these estimates rely.
Net present values are only applicable to assets that generate goods or services with clear market values. Many environmental assets generate services that are not exchangeable and market observations are basically irrelevant when determining the value of various life support functions. It is in many cases infeasible to establish absolute values for ecosystems or life support systems. However, in and outside the context of environmental accounting, attempts have been made to value environmental amenities or damages on the basis of *indirect market values*, *i.e.* that part of the exchange value of a product that is associated with an environmental amenity or the decline in the exchange value of a product associated with an environmental burden, or *non-market valuation* methods such as contingent valuation (willingness to pay or willingness to accept measures).
O'Connor & Steurer (2001) evaluate the applicability of monetary valuation along two dimensions. Firstly, the larger the spatial scale and the longer the temporal scale of ecosystem changes, the more problematic becomes the assessment of the welfare effects that are at stake. For example, the future consequences of world-wide environmental problems like climate change are uncertain and may vary substantially between different regions. Again, in many cases, welfare effects can only be assessed on the basis of rather uncertain expectations.
Secondly, the value of nature is partly socially or morally motivated. A good example is the social desire to preserve certain habitats or species. Maintaining the bio-diversity of our planet is not necessarily an issue of preserving use values but equally an issue of fairness and existence (e)valuation. Although some may reject the attachment of money values on moral grounds, even the preservation of habitats and species is undoubtedly subject to economic decision making. However, strong ethical believes about nature preservation seriously disturbs valuation possibilities. For example, there is empirical evidence that certain individuals totally refuse to trade-off losses in environmental quality against income (*cf.* Spash & Hanley, 1995). This implies that, for these environmental assets, no finite money values will ever be found.
Generally, contingent valuation methods, as frequently used in cost-benefit analysis, are most successful in cases of relatively small, non-catastrophic, changes in the state of environmental assets (*cf.* Shechter, 2000). The willingness of members of a society to pay for environmental amenities and indirectly observed environmental values may indicate the size of some of society's preferences and concerns. However, one important precondition underlying non-market valuation is that individuals posses all relevant information on the environmental impacts and repercussions of the appraised project. This implies indeed that environmental concerns evolving on wide spatial and periodic scales are expected to be less easily captured in money terms, especially when interregional and intergenerational fairness issues are at stake.

The ultimate question is of course in what ways alternative valuation methods may genuinely help to inform the public. Referring to cost-benefit analysis, Nyborg (2000, p.394) answers this question as follows. "Monetary valuation is obviously useful when the goal of a cost-benefit analysis is to provide a final ranking of policy alternatives. However, a very common goal of economic analysis is to *provide background information for a public debate*. The latter aim differs from the former in a fundamental way – while a final ranking requires that the policy maker's normative views are taken into account (...) democratic debate requires, instead, that citizens have access to factual information which can, as far as possible, be distinguished from normative judgement."

Quite obviously, one of the main primary goals of environmental accounting, as part of the official statistics programs of statistical offices, is the provision of background information for public debates. While cost-benefit analysis may assess the values connected to presupposed environmental use options, accounting cannot rely on such presumptions. Even more strongly than economic analysis, environmental accounting should give citizens access to factual information which should, as far as possible, be distinguished from normative judgement. Only on the basis of this information, citizens are able to express their values. This is why a rather prudent accounting perspective is taken as a point of reference in this thesis.

2.3.2 *Production; reconsidering output*

The production account represents a fundamental part of national accounting. This account explains how inputs, or the means of production, are allocated to outputs. Obviously, it is necessary to specify what is meant by inputs and outputs to make a production account operational. Therefore, the demarcation of the output of goods and services, *i.e.* the production boundary, is given extensive attention in the SNA. The balancing item in the production account is value added. Gross value added is defined as the value of output less the value of intermediate consumption. Net value added excludes in addition to intermediate consumption the consumption of fixed capital.

In general terms, the SNA-1993 defines production "as an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital and goods and services to produce outputs of goods and services" (§6.15). A purely natural process without human involvement, such as the unmanaged growth of fish stocks, is not considered production in the SNA sense.

The system distinguishes between produced and non-produced assets. Produced assets are created by way of capital formation. The appearance of non-produced assets is considered to be unrelated to human controlled production processes. They include naturally occurring assets such as land, uncultivated forests and deposits of minerals. An important consequence of this distinction is that the consumption of non-produced assets is not shown as part of the costs of production. As a result, net domestic product includes the depletion or degradation of natural resources.

The distinction between produced and non-produced assets is principally eliminated in extended net national income measures as defined in neo-classical growth models as for example developed by Weitzman (1976), Hartwick (1990) and Mäler (1991). These models illustrate at a conceptual level the restrictions of the national accounts from a welfare perspective by extending the concept of national income with all welfare related elements of consumption and capital formation. "A more comprehensive consumption concept, which actually reflects consumer preferences, may not only include goods and services; it is also likely to include other 'utilities' such as leisure and environmental quality. Similarly, net investments should reflect all capital formation undertaken by society and not just changes in the stock of physical capital" (Aronsson, 1999, p.564).

Weitzman shows that, with a stationary technology and an economy that follows an optimal path, the utility value of an extended national income is proportional to the present value of future utility. And in such a world of perfect foresight, future utility is fully reflected by presently observable variables. The approximation of the corresponding welfare measure by way of an extended national income concept would in addition to conventional consumption and net investment for example include the value of leisure time (*i.e.* leisure time × real wage rate) and the utility of pollution (for example measured by the willingness to pay for small improvements in environmental quality, *i.e.* lower pollution stocks). In these models, the accumulation of pollution in the natural environment is being regarded as the net (negative) investment in environmental capital. In other words, the level of environmental quality is an integral part of the production decision and subsequently the welfare optimisation of the single representative economic agent as defined in the model. Periodic decisions about production (present and future consumption), labour input (leisure) and the release of pollutants (present and future consumption of environmental amenities) are simultaneously based on the inter-temporal utility function of one representative consumer. As a consequence, presently observed asset prices fully reflect present and future utility derived from assets.

This extended income measure closely complies to the income concept introduced by Hicks, *i.e.* "... the maximum amount the individual can spend this week, and still expect to be able to spend the same amount in each ensuing week" (Hicks, 1939, p.174). In addition to consumption, this income measure takes record of all changes in assets within a (re)defined asset boundary. Hicksian income is often addressed as the principle notion of a sustainable income.

A somewhat counterintuitive conclusion that can be derived from these models is that the need for environmental accounts is only due to the incompleteness of the SNA-1993. Weizman's model does not acknowledge the existence of environmental problems. One would expect that the need for environmental accounting arises in the first place as a consequence of the existence of environmental concerns. This is why governments all over the world have been formulating environmental and sustainability policies. The fact that several environmental assets are being depleted or being damaged in an undesirable way for societies implies that these assets are apparently not under the control of one optimising agent.

Although, these models clearly conceptualise the directions in which the present national accounts could be expanded towards a more comprehensive welfare framework, their accounting implications are not always straightforward.

In the real world, it is evidently clear that pollution levels are not necessarily the outcome of an intended evaluation of social costs and benefits. [1)] In a decentralised economy with imperfect pollution control, there is no longer a simple connection between the present value of future utility and the utility value of green national income as defined in neo-classical growth models (*cf*. Aronsson, 1999, p.573). This means that policy evaluations are unavoidable in assessing the social costs and benefits of environmental deterioration, also on behalf of future generations. In many cases, these values cannot be statistically observed and subsequently introduced in a descriptive set of accounts. Therefore, there is a strong case to restrict the production boundary in the SNA to those outputs that can be valued according to reasonably representative exchange values. In the context of national accounting, it should be acknowledged that welfare measurement requires in addition to national income supplementary indicators based on similar statistical principles concerning their descriptiveness.

In other words, the substantial difficulties related to incorporating environmental costs in the national accounts demands for alternative, or supplementary, accounting approaches. This demand is also emphasised by the rather simplistic one dimensional relationship established in these models between pollution accumulation and utility. In many cases, the ultimate occurrence of environmental damages follows dynamic processes involving a variety of environmental pressures. Cause-effect relationships are often hard to assess for individual pressures but also for individual damages, implying that in many cases an environmentally extended national income is simply infeasible. As illustrated in the subsequent chapters of this thesis, instead of extending the national accounts with highly uncertain imputations, an alternative way of extending the national accounts is by constructing supplementary sets of non-monetary (physical) accounts. These supplementary accounts leave the production account and the subdivision between produced and non-produced assets largely unchanged, but at least help to explain, based on factually observed information, how economic activities interact with the environment. This approach acknowledges that pollution is not necessarily the intended outcome of the optimal use of environmental assets.

2.3.3 Production; reconsidering costs

Another conclusion that can be derived form neo-classical growth models is that pollution control will be introduced until their marginal costs equal the marginal social costs of pollution. Hamilton & Ward (1998, p.350) conclude that “in order to arrive at a greener income measure, abatement expenditures should be subtracted from GDP – they (*i.e.* environmental abatement expenditure) become, in effect, intermediate consumption. Of course, most abatement expenditures are already treated as intermediate consumption in the national accounts. Therefore it is only expenditures on pollution abatement in final demand that need to be deducted in measuring green national income".

Many others (*cf.* Hueting, 1980, Daly, 1989) have advocated the deduction of environmental protection expenditure, or even the repercussion costs of environmental deterioration (*e.g.* health expenditure, government clean-up actions), from final demand, and thus gross domestic product, as a way to obtain a more welfare oriented national income measure. Steurer *et al.* (1998) show that in most industrial countries environmental protection expenditure equals about one to two percent of gross domestic product. This would suggest that the deduction of environmental protection expenditure is of a somewhat limited significance.

Social preferences regarding the state of the environment may change in the course of economic development. The inverted U-shaped relationship over time between certain pollutant outputs and per capita income may indicate that preferences for certain aspects of environmental quality increase as income rises (De Bruyn, 1999, p.83-84). This would imply that the consumption of environmental protection services is, at least for certain environmental concerns, truly welfare enhancing.

However, more importantly, the demarcation of intermediate and final consumption expenditure in the SNA is not based on such a welfare criterion. Consumption is defined and measured quite independently from any utility that households may, or may not, derive from it. Intermediate consumption simply represents the value of goods and services used in production while final consumption is supposed to satisfy directly individual or public needs. The SNA-1993 uses an activity-based demarcation: production versus consumption. A reconsideration of this demarcation on the basis of welfare principles requires a moral evaluation of economic transactions which may give rise to reconsidering a much wider range of consumption categories that are generally regarded as 'regrettable necessities', *e.g.* defence, justice, healthcare.

On the other hand, the discussion on the recording of environmental protection expenditure shows that the representation of households and household consumption requires reconsideration in environmental accounting. Following the SNA-1993, it is insufficient to regard households in a rather passive way as the final users of goods and services. Households usually generate a substantial share of the total pollution output in an economy and environmental accounts should explain how this pollution relates to different kinds of consumer activities. Environmental accounting should make clear how environmental protection measures and related expenditure may result in changing household pollution patterns similarly to the recording of production activities. The importance of household lifestyles in addition to production technologies in measuring and analysing the main causes of environmental degradation is also emphasised in Duchin's (1998) work on structural economics.

In the context of environmental accounting, it is very important to represent households in a similar way as the government: simultaneously as producers and final consumers. Conceptually, this implies that household activities become part of the production account. The notion of household production is for example established in the context of own-account household production accounting (*cf*. Fitzgerald *et al*., 1996). This type of satellite accounting has been developed to expand the rather narrow production boundary in the SNA-1993. In a similar way, in environmental accounting, household production functions should be defined homogeneously with respect to their corresponding environmental requirements. The destination of household production is logically final consumption expenditure.

Conceptually, an increase of environmental protection expenditure per money unit of household own-account output does not increase (the volume of) household output. [2)] In other words, the introduction of own-account household production functions follows, with respect to most environmental protection expenditure of households, the accounting recommendations of Hamilton & Ward and others.

It must be acknowledged that this 'intermediate' recording of environmental protection expenditure by households is not comparable to the treatment of most environmental protection expenditure by the government. In many cases, the government is the principal producer of public environmental protection services, *e.g*. waste collection and treatment, sanitary services, cleaning of pavements and oil spills. As far as the consumption of these services cannot be attributed to individual industries or households, their destination will by convention be final government consumption. Since there is no further process of production in which such services are consumed, there is simply no reasonable way imaginable how this expenditure could be recorded as intermediate consumption. This means that the output of these services will inevitably contribute to domestic product and their volume growth will contribute to economic growth. However, the contribution to social welfare of public environmental protection expenditure is in the first place measured by the reductions in environmental pressures or damages these measures bring about. One of the main goals of environmental accounting is to visualise these environmental benefits of environmental protection measures.

2.3.4 Assets

The SNA-1993 defines assets as "entities over which ownership rights are enforced by institutional units, individually or collectively, and from which economic benefits may be derived by their owners by holding them, or using them, over a period of time" (§10.2 and §10.3). In comparison to the 1968 version, the SNA-1993 (*cf*. Annex 1, §64) includes much more guidance to the representation of balance sheets and consequently the coverage of assets. The SNA-1993 distinguishes two types of natural assets. Assets which growth is the result of human cultivation are treated as produced assets. All other natural assets over which ownership rights are enforced and from which economic benefits may be derived, are treated as non-produced assets. Examples are land, subsoil assets, non-cultivated biological resources and water resources.

From an environmental point of view, it is useful to extend the notion of assets at least at a conceptual level (*cf*. SEEA-2003, chapter 7). Environmental functions and their decline may not only include the depletion of natural assets subject to ownership but also a much wider range of ecological functions. Therefore, the SNA 'ownership' and 'economic benefit' may be too narrow from an environmental perspective. Environmental accounting may focus on assets omitting clearly defined ownership rights, *e.g.* international fishing waters, clean air, and assets without direct use values *e.g.* global climate regulation, ecosystems.

In addition, the spatial boundaries of a *national* accounting perspective may be too restricted as well. The SNA-1993 defines the territory of an economy as "the geographical territory administered by a government within which persons, goods, and capital circulate freely" (§14.9). These territorial boundaries are applicable to the SNA type of locally bounded environmental assets but are irrelevant for those assets or environmental systems with a much broader or even a global appearances.

Although it is acknowledged that "even measuring the services by ecosystems is difficult and the measurement of the basic stock even more so" (§7.73), the environmental asset classification in SEEA-2003 includes ecosystems. The functions supported by ecosystems may vary from the provision of various biological resources to the support of biodiversity, the regulation of water systems and the preservation of soils. The entanglement of ecosystem functions and the omission of a uniform unit of measurement clearly complicate the representation of ecosystems in national accounts type of balance sheets. This does not imply that there are no other statistical tools available to account for ecosystems and bio-diversity. However, such accounting frameworks are less related to the SNA and for example more geographically oriented (*cf*. Rademacher, 1998 and Stott & Haines-Young, 1998).

2.4. *Accounting relationships*

The previous section discussed the strengths and weaknesses of three rather crucial national accounting conventions: exchange values, the production boundary and the asset boundary. The main conclusion that can be drawn from this evaluation is that limitations only to some degree concern the SNA. Generally, limitations are much more related to economic accounting as a descriptive statistical tool. Environmental losses are only to a some extent assessable in monetary terms, especially when these values are socially or morally motivated or when the nature of environmental functions are complex and uncertainties about their human induced deterioration are high.

This section discusses how the underlying cause-effect relationships of environmental resource depletion and degradation may possibly be represented in environmental accounting. Environmental indicators have been categorised according to those addressing environmental pressures, *e.g.* resource use, pollution, and those measuring (changes in) the environmental state *e.g.* resource stocks, environmental quality (*cf.* OECD, 2000). Ideally, and in analogy with mainstream economic accounting, environmental accounting should preferably provide a fully interconnected representation of flows or environmental pressures and changes in stocks or environmental state. Clearly, the complexities of pressure-state interactions by large determine their accountability. For this purpose, it is useful to distinguish between the depletion of natural resources and the degradation of the environment resulting from pollution.

2.4.1 Natural resources

Natural resources usually refer to those assets with quantitative use functions. Depletion comprises the loss in value of a natural resource resulting from its exploitation. Examples of natural resources are subsoil assets, biological resources, soils and water resources such as groundwater deposits and aquifers. Natural resources provide direct inputs into consumption or production processes. Another important characteristic of a natural resource is the presence of ownership. Natural resources with clearly defined economic use functions are usually subject to legal ownership of either private entities or the government. In the latter case, the use of the resource by private entities is often contractually arranged and the government will usually appropriate a share of the resource rent through taxes, royalties or licences. [3)]

Subsoil assets

Subsoil assets are pre-existing natural deposits of fossil fuels, metallic and non-metallic minerals. In strict physical terms, for subsoil assets, there usually exits a direct or linear relationship between extractions and deposit changes. In addition to extractions, physical changes in stocks may also result from new findings and reassessments of current deposits due to technical improvements. In economic terms, the quantitative changes in subsoil assets are additionally affected by changing resource prices and exploration and exploitation costs. Although mineral exploration contributes to the identification of new subsoil assets and subsequently their accessibility, the asset itself is not subject to human creation. Therefore, in the SNA-1993 a mineral deposit is considered as a non-produced asset. Mineral exploration expenditure is recorded as gross fixed capital formation of an intangible asset that represents the value of knowledge on the location and size of mineral deposits.

The recording of depletion in the national accounts has been subject to ongoing debate and has resulted in various alternative recording proposals to the current SNA-1993 recording of depletion outside the production account but instead in the other changes in assets account. Depletion usually refers to the decrease in value of a natural resource as a result of its exploitation. A Eurostat (2000a, p.32) publication on subsoil asset accounting and the SEEA-2003 (§10.30) define depletion as the resource rent minus the opportunity costs of capital invested in the natural resource. This latter component unavoidably shows up when the value of a mineral deposit is approximated by the net present value of current and future resource rents. Although the SEEA-2003 seems to present these as two separate things (*cf.* §10.26 and §10.30), the income element of the resource rent as determined by El Serafy's (1989) user cost method completely corresponds to the opportunity costs of capital. [4)]

Value added, as defined in the production account of the SNA includes in principle the depletion of natural resources. Most economists acknowledge that the depletion of a natural resource is not income. Depletion reduces the asset's future income generation capacity and as such there seems to be an analogy of natural resource depletion with the depreciation of produced capital. A possible representation of depletion in the production account has been subject to ongoing debate. This can be illustrated by two almost opposite accounting propositions: one of Vanoli (1995) and another one of Landefeld & Howell (1998). Both propositions are briefly discussed below to illustrate the complexities of a satisfying recording of depletion in the SNA.

Vanoli (1995, p.128) proposes to exclude the entire resource rent, including the income component, from the output of mining industries. Alternatively, he recommends recording the resource rent as a withdrawal from inventories. In this way, the subsoil assets are represented in the production account as strictly non-produced. Since the resource rent is totally withdrawn from value added, this recording method ignores the fact that countries endowed with substantial mineral deposits will be able to generate higher incomes compared to similar countries without these natural endowments. This distortion could be avoided by valuing withdrawals from inventories with only the depletion element of the resource rent.

Vanoli explains that a rather problematic consequence of his proposal concerns the fact "that certain flows are no longer income flows to be recorded in the current accounts, they now must be recorded as capital transfers or in a way which is similar to capital transfers" (p.129). He indicates that all property income and taxes related to depletion should be treated as capital flows as well. Otherwise, the net saving of mining industries would be seriously distorted. This creates several practical problems and removes the national accounts away from business accounting and fiscal reality. Van den Berg & Van de Ven (2001) show that the government appropriation of the resource rent may concern only to some extent specific taxes on production but more generally the total tax regime imposed on mining companies, including general profit taxes, *i.e.* taxes on income. The subdivision of these taxes between current and capital flows seems somewhat arbitrary.

Totally contrary to Vanoli's proposition, Landefeld & Howell (1998, p.119) regard subsoil assets as being produced. They recommend the recording of depletion as consumption of fixed capital and discoveries subsequently as gross fixed capital formation. They argue that, if domestic product and income is reduced by depletion, new discoveries should symmetrically add to domestic product and income. This proposition is in line with the Hicksian income concept discussed above. However, somewhat counterintuitive, this environmental adjustment or 'greening of' net national income may lead, on average, to upward adjustments as long as new discoveries surpass extractions. The Landefeld & Howell proposal will by definition lead to upward adjustments of gross income.

There is a strong case to continue to consider subsoil deposits as non-produced assets provided by the natural environment. Although mineral exploration contributes to reassessing the total availability of mineral deposits, one could argue that exploration does not genuinely lead to the creation of a new asset. Upward appraisals of mineral reserves frequently occur without additional exploration efforts. On the other hand, when natural resources become scarcer, exploration costs are expected to rise per unit of newly discovered mineral deposits. This makes these additional natural resource deposits more and more the outcome of human endeavours.

Both alternatives do not seem to provide entirely satisfying alternatives to the current SNA-1993 guidelines. The SEEA-2003 records depletion as an supplementary entry in an 'extended 'generation of income account (*cf.* Box 10.5). This solution logically follows the fact that the resource rent can only be approximated in this account as the residual item that results after subtracting the services from produced capital and self-employed labour from gross operating surplus. In this way, domestic product and national income can be defined gross and net of depletion, analogously to the gross and net recording of consumption of fixed capital in value added, national income and saving. [5)]

However, this does not solve one of the issues raised by Vanoli. In many cases, substantial shares of the resource rent are appropriated by the government by way of special tax regimes imposed on mining corporations. As a consequence, the depletion adjusted net savings of mining industries will on average be small or negative. It seems rather odd to adjust the savings of mining companies for depletion while most of the resource rent is actually being appropriated by the government. This appropriation indicates *de facto* a shared ownership of the natural resource between the mining industry and the government. In fact, in many countries the government is the principal owner of natural resources. One way to overcome this distorted representation of depletion adjusted net savings is to acknowledge this shared ownership by introducing a financial asset in the balance sheet of the government and a corresponding financial liability in the balance sheet of the extractor (*cf.* Eurostat, 2000a, Annex 5). As a result, part of the appropriated resource rent is recorded as a repayment of the liability which does not influence the net saving of the mining corporations. However, as mentioned above, this requires a range of rather artificial rearrangements of transactions in the accounts including taxes.

Biological assets
Biological resources include timber, fish stocks and other species with direct use benefits. Biological resources are principally renewable as long as regeneration of the resource catches up with the pace of extractions. This makes the measurement of stock-flow interactions, and more specifically the depletion, of biological resources less univocal compared to mineral resources. The SNA-1993 subdivides biological resources into cultivated and non-cultivated resources. Cultivated natural resources are under direct human control, responsibility and management, *e.g.* fishponds, cattle stock and timber plantations. Non-cultivated assets in the SNA sense are equally liable to ownership but their natural growth or regeneration is considered outside direct human management and control. In the SNA growth in cultivated resources is regarded as production while their harvesting and sales are recorded as changes in inventories. The harvesting of non-cultivated assets is part of production while growth in natural assets is recorded as other change in assets in the balance sheets.

The borderline between cultivated and non-cultivated assets is in many cases unclear. The timber stock contained by virgin forests is typically considered to be a non-produced asset while a (partly) replanted forest may be, or may not be, regarded as being produced. This may lead to substantial differences in the way these resources show up in the accounts. Since the sustainable management of natural resources becomes more and more a point of concern, one may argue whether the difference between produced and non-produced biological assets should be maintained. The rising scarcity of many natural resources implies that the unconditional harvesting of biological resources is increasingly becoming an obsolete way of production. As a consequence, an increasing range of assets falls under the management and control of institutional units since it is likely that the sustainable exploitation of biological resources inhabited by ecosystems will require additional efforts and costs. As such, it seems logical to reconsider also those natural resources that are principally supported by natural ecosystems as being produced in the SNA sense.

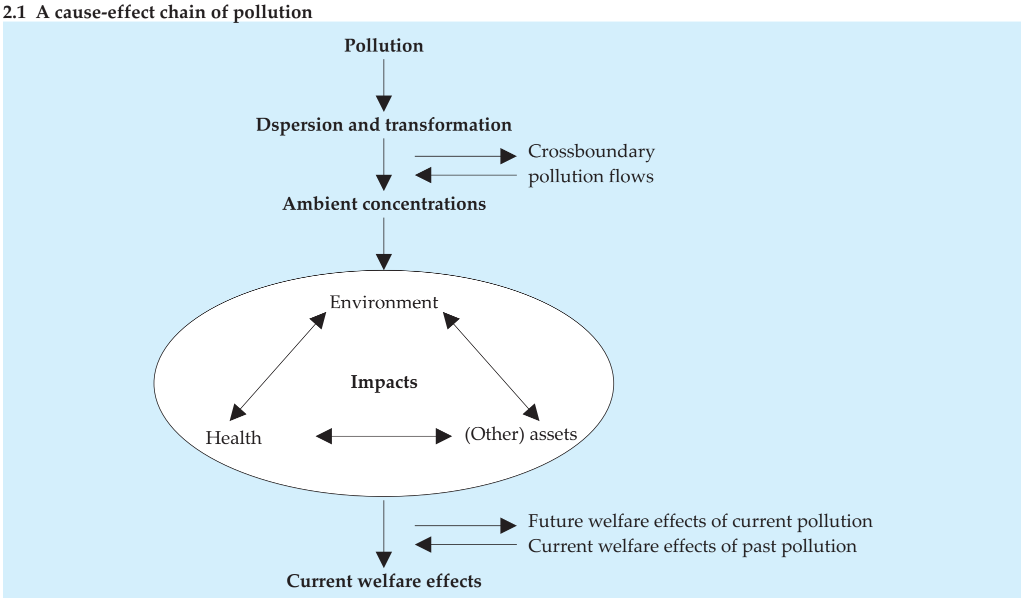
2.4.2 Degradation

Degradation usually refers to the detrimental effects of pollution, landscape interventions and hydrological alterations. Environmental degradation often coincides with the existence of negative environmental externalities. Environmental degradation often brings about uncompensated welfare transfers between agents. This is why degradation fundamentally differs from natural resource depletion. Although degradation may affect assets with clearly established ownership rights such as buildings or biological resources, it more generally affects a much wider range of ecological assets, *e.g.* climate regulation, solar ultra-violet radiation protection, biodiversity, clean air and water.

Especially with regard to the degradation of life support functions, cause-effect chains are often complex and subject to uncertainty. Figure 2.1 presents a schematic overview of a cause-effect chain in the case of pollution. Emissions from production and consumption processes will disperse in the environment and increase pollution concentrations in air, water or soil. The dispersion of pollutants may exceed the boundaries of these three environmental domains and possible transformations of substances within these environmental domains will additionally determine the potential consequences of pollution. For example, under the influence of solar radiation, emissions of nitrogen oxides and volatile organic compounds may contribute to the formation of ozone pollution (*e.g.* smog). This illustrates that variable natural conditions are mutually decisive with respect to the threshold levels beyond which effects will occur.

The impacts of pollution may include damages to human health, ecosystems and assets in the SNA sense. Impacts often occur with a delay over time. In the case of so-called 'stock' pollution, effects will only occur after certain threshold concentration levels have been exceeded. A clear example of stock pollution is the accumulation of greenhouse gases in the atmosphere. Changes in climate change increase the risk of abrupt changes in ecosystems, which may affect their functioning, biodiversity and productivity. Subsequently, this may have various repercussions to mankind, directly through the emergence of extreme weather conditions, *e.g.* floods and storms, or indirectly through changes in agricultural production systems and changing conditions in water reserves and air quality (*cf.* IPCC, 2001). In other words, the deterioration of one asset or ecological function may have a sequence of subsequent repercussions.

2.1 A cause-effect chain of pollution



Especially damages to ecosystems are often characterised by non-linear cause-effect relationships. Pollution may increase the vulnerability of ecosystems without direct notable changes. The actual collapse of ecosystems is often brought about by relatively small disturbances (*cf*. Perrings *et al*., 1995 or Scheffer *et al*., 2001). This implies that the ecological consequences of current economic activities are hard to predict in advance. Also, the actual contribution of individual pressures to the decline of ecosystems is very difficult to address. In conclusion, the coverage in economic accounts is most easy for those degradation issues with direct or linear cause-effect relationships with modest disruptions in space and time and with clearly identifiable repercussions. In addition, monetary assessments of repercussions are most easily established for those assets generating goods or services with observable exchange values.

Table 2.1
Conceptual representation of degradation within an extended SNA context

In the case of an environmental externality (*x*) generated by producer (*a*) affecting consumer (*b*):	
Production account:	The extended value added of producer (*a*) includes the environmental loss or negative externality (*x*)
In case of **non-recurrent** repercussions:	
Income distribution account:	This account includes an income transfer of consumer (*b*) to producer (*a*) representing the value of the environmental externality (*x*). Extended disposable income of consumer (*b*) is reduced by the value of externality (*x*). Consumption is adjusted accordingly. Disposable income of producer (*a*) does noet change.
In the case of **recurrent** repercussions:	
Capital account:	This account includes a capital transfer of consumer (*b*) to producer (*a*) representing the value of environmental externality (*x*). Extended changes in net worth of consumer (*b*) are reduced by tha value of externality (*x*). Changes in net worth of producer (*a*) do not change.
Income distribution account:	In subsequent periods extended disposable income of consumer (*b*) will be reduced due to the future repercussions of externality (*x*). Consumption is adjusted accordingly.

Table 2.1 presents an accounting scheme showing an example of how, at a conceptual level, degradation could be recorded in an environmentally extended SNA. The table illustrates the case of an environmental damage (*x*) generated by producer (*a*) that affects consumer (*b*). One could imagine that when production contributes to environmental degradation, the concomitant (expected) welfare loss could be reflected by a negative element in the income generation account, leading to an extended or environmentally adjusted domestic product concept. In other words, the value added of producer (*a*) is diminished by the welfare loss resulting from externality (*x*). When this externality represents a nonrecurring effect (*e.g.*

noise, nuisance) the affected agent (*b*) suffers a welfare loss represented by an income transfer in kind from agent (*b*) to agent (*a*). Consumer (*b*) gives up part of his welfare on behalf of producer (*a*). As a consequence, extended disposable income (and consumption) of consumer (*b*) is reduced while the disposable income of producer (*a*) is on balance not affected. In case of recurrent repercussions evolving over longer periods of time, the externality represents also a capital transfer in kind. This recurrent loss will reduce the extended disposable income (and consumption) of consumer (*b*) in subsequent years.

This accounting scheme reveals the following complications. Firstly, environmental degradation is often accompanied with current or capital transfers. Those agents causing an environmental damage are not necessarily the agents suffering from the concomitant losses in welfare. These transfers remain principally uncovered in the 'single optimising agent' models discussed earlier. However, the national accounts distinguish several types of actors *e.g.* corporations, households, government bodies, and the incorporation of environmental damages in the national accounts requires that these transfers between agents should be accounted for.

Secondly, recurrent losses in assets can only be reflected in an extended national income figure when these assets are part of the accounts in the first place. This obstacle becomes particularly apparent when regarding the pollution damages to human health. Health threats are often considered as one of the most acute dangers of environmental degradation (*cf.* Howarth *et al.*, 2001 and Markandya, 2000), especially in developing countries (*cf.* McGranahan & Murray, 1999). However, human health is not represented as an individual asset in the SNA-1993. Although increasing per capita health expenditure in many countries is likely to have positive health effects, the national accounts do not show these improvements as such. Nordhaus & Kokkelenberg (1999, p.148) conclude that reflecting the negative impacts of pollution on human health in national income accounting is misleading and only becomes meaningful at the moment all positive and negative changes in the health state of a population are systematically taken into consideration, for example in a system of health accounts.

In conclusion, partial environmental adjustments in national income are rather meaningless when the implications of these adjustments for the complete accounting system are not carefully reconsidered. The analytical strength of indicators derived from the national accounts is that they are embedded in an information system. Extended income or welfare measures that are not really defined within an accounting framework omits this analytical strength and may be internally incoherent.

2.5. *Two accounting propositions*

One could identify the following two supplementary, but sometimes loosely related, accounting perspectives: cause-oriented accounting and effect-oriented accounting. The first accounting approach specifically addresses the human related causes of environmental deterioration. The second accounting perspective aims at quantifying the actual depletion or deterioration of environmental assets. Due to various complications earlier discussed in this chapter, environmental accounts are often not able to facilitate an integrated representation of both the causes and effects of environmental degradation. This is why both accounting approaches are not always fully interconnected. The main characteristics of cause- and effect-oriented accounting are summarised below.

2.5.1 *Cause-oriented accounting*

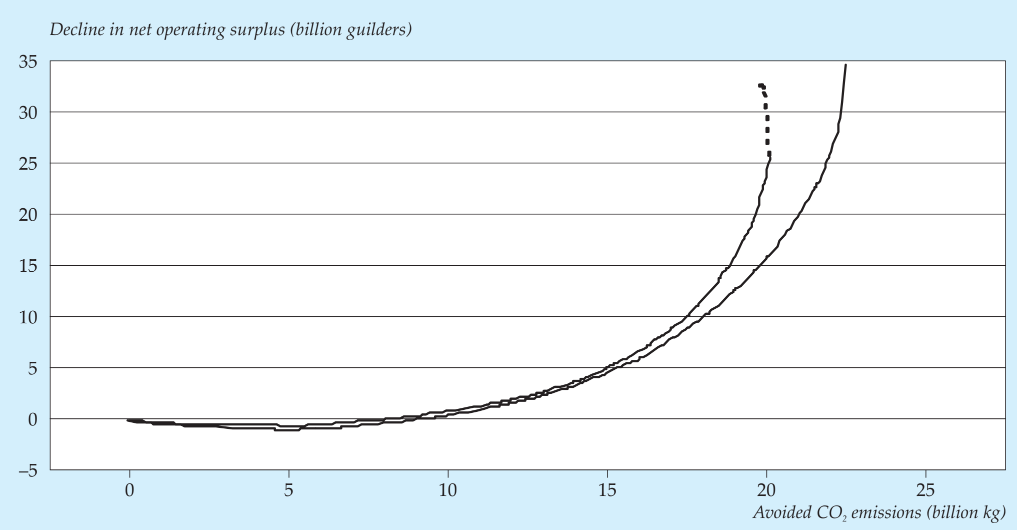
Cause-oriented accounting focuses on the determinants of environmental deterioration. These determinants are for example represented by natural resource inputs, occupation of space and the output of residuals, noise, stench and radiation. The recording of these environmental requirements is generally not part of the SNA-1993. The most obvious way to track down these environmental requirements is by way of physical flow accounting. The introduction of physical flow accounts in a national accounting context is extensively discussed in the subsequent chapters of this thesis. One important point of concern addressed in this chapter is that cause-oriented accounting should not be restricted to producers only since the environmental requirements of households are usually not negligible.

One specific analytical goal of cause-oriented accounting is the combined representation of environmental and economic performance indicators. These indicators allow for analysing, in various levels of detail, the interactions between economic developments and environmental pressures. For example, cause-oriented accounting is specifically useful as the statistical framework in cost-effectiveness studies of pollution control policies. Cause-oriented valuation was in the interim SEEA-1993 introduced as maintenance costing. Maintenance costs where defined as "... the additional imputed costs that would have been incurred if the domestic economic activities (...) had been modified or their impacts mitigated in such a way as not to have impaired the long-term quantitative and qualitative levels of the domestic and worldwide natural environment." (United Nations, 1993, p.105).

Generally, a maintenance cost concept measures the hypothetical costs of pollution reduction, or reductions in other environmental requirements, to certain predefined levels. In the SEEA-1993, it is recommended to simply subtract the microeconomic costs from value added. In this way, these costs are translated into a macro context in terms of foregone valued added or domestic product. However, from a macro-economic perspective such calculations are not very meaningful since environmental protection expenditure will irrevocably trigger production and pollution in other industries that are producing environmental protection equipment.

This is illustrated by figure 2.2 representing two avoidance cost curves as compiled by De Haan (1997). The curves range the cost-effectiveness of CO_2 abatement measures as derived from Blok (1991). In figure 2.2, the expected costs of these, not yet implemented energy saving measures, are translated into intermediate consumption, compensation of employees and consumption of fixed capital, which

2.2 Differences between the direct and total cost-effectiveness of carbon dioxide (CO_2) pollution abatement in the Netherlands (reference year 1990)



Source: De Haan (1997, p.106)

together reflect the initial decrease in operating surpluses at the industry branch level. Cost reductions resulting from energy saving are taken into consideration as well. The first part of both curves shows that, to a limited extent, pollution prevention or energy saving pays. For the cheapest measures the elimination of CO_2 leads to an increase in net operating surplus due to the direct benefits from energy saving. However, beyond a reduction of approximately ten billion-kg CO_2 (about 5% of the total CO_2 emission in the Netherlands in 1997), costs start to rise progressively.

The lower curve reflects only the direct costs at the industry level. The upper curve reflects an input-output model estimation of both direct and indirect effects. The indirect effects include the backward linked effects on operating surpluses and CO_2 emissions of all industries in the economy. Indirect pollution effects are dominated by the capital requirements of pollution abatement measures. For almost all measures the cost-effectiveness for the whole economy is lower than the direct cost-effectiveness for individual industries. This is caused by relatively less beneficial CO_2 pollution-operating surplus ratios in the capital producing industries. At the range of 20 kiloton abated CO_2, the indirect increase in CO_2 emissions from additional capital requirements exceeds the reduction of CO_2 that results directly from the pollution abatement measure. There appears to be an absolute limit to the amount of CO_2 that can be abated by implementing additional technical measures. The substantial capital requirements may ultimately counterbalance the directly abated emissions, resulting to a net increase of CO_2 emissions for the economy as a whole. In other words, it makes a difference whether cost projections are being made for an individual firm or for the whole economy. As illustrated by figure 2.2, for the whole economy a cost-effectiveness analysis needs to be established in terms of macroeconomic indicator projections based on consistent economy-wide modelling analyses. Only a model approach enables us to detect the economy-wide implications of additional environmental protection measures.

In general, a cost-effectiveness analysis comprises a hypothetical reflection of macroeconomic indicators (*e.g*. domestic product, consumption) in case an economy would have followed a specified set of environmental standards. Although, cause-oriented environmental accounting may play a significant role in the development of pollution reduction strategies, accounting itself will not provide ultimate answers on the expected costs borne of meeting these predefined targets. Typically, such an analysis can only be carried out on the basis of comparative static or dynamic scenario modelling.

O'Connor (2001) explains that one application of cost-effectiveness analysis at the macroeconomic level could lead to a particular conception of an environmentally-adjusted domestic product which he calls a 'greened-economy' gross domestic product. One basic feature of this approach is that adjustments in the economy are being considered rather than adjustments in accounting conventions. This approach does not try to evaluate the welfare contributions of the natural environment. Instead, the cost-effectiveness analysis can only be conducted after environmental standards have been established first.

De Boer *et al*. (1994) illustrate some of the principle features of a 'greened-economy' gross domestic product. They use a linear-programming model based on the Dutch NAMEA to estimate a net domestic product in case policy targets, as formulated in the Dutch national environmental policy plan, would have been met. More recently, a similar but more advanced, general equilibrium model is developed by Verbruggen (2000) and colleagues to estimate a sustainable national income according to the theoretical findings of Hueting (1980) and the sustainability standards as developed by Hueting & De Boer (2001). Hueting (1980, p.165) indicates that environmentally adjusted national income measures should not replace, but instead, be introduced alongside the calculation of the regular unadjusted national income figures. In this way, a comparison of both measures visualises the 'sustainability gap' between current income and income at a sustainable level.

One may conclude that maintenance cost accounting, or more generally, the cost-effectiveness analysis of environmental performance improvements, can only be the outcome of economic modelling. Cause-oriented environmental accounting as discussed in this thesis contributes to these kinds of modelling exercises as the underlying framework. In addition to future oriented scenario modelling, cause-oriented accounting may also serve as a backward monitoring system for reviewing past and present environmental-economic performance. This latter use of cause-oriented accounting is illustrated in later chapters of this thesis.

2.5.2 *Effect-oriented accounting*

Effect-oriented accounting focuses on the impacts of environmental depletion and to some extent deterioration. This accounting perspective allows for detecting developments in the state of environmental assets and is particularly useful for those countries with strong economic dependencies on the exploitation of natural resources. Especially in developing countries, the exploitation of natural resources is often a key source of income. Natural resource accounts have been developed by Repetto *et al.* (1987, 1989) to indicate that many developing countries are boosting economic growth by rapidly depleting their natural capital. Clearly, this way of economic growth is likely to be unsustainable.

Natural resource accounts may be structured in accordance with a national accounts balance sheet. As mentioned earlier, a range of natural assets are already included in the SNA-1993 balance sheet. As such, the SNA balance sheet is capable of providing an overview of changes in wealth of both produced assets and those non-produced environmental assets that are included within the SNA asset boundary. A rather complete balance sheet is for example being compiled for Australia by the Australian Bureau of Statistics (*cf.* ABS, 2002). These accounts show that the share of environmental assets in total wealth increased in the period 1993 to 2001 from 31.1% to 33.5% (*cf.* p.3). Much of this increase was due to rising prices. This indicates that holding gains and losses may substantially influence the annual changes in natural wealth of a country. Holding gains and losses are amplified by the volatile world market prices of many natural resources.

Another illustrative application of effect-oriented accounting is given by Lange *et al.* (2003). They use both physical and money measures to reflect the wealth of natural resources such as fish stocks, mineral assets, water and forests in a number of southern African countries. They use total per capita wealth estimates in constant prices to indicate to what extent the depletion of natural assets is offset by compensating increases in produced capital. This weak sustainability principle of non-declining total wealth estimates at all times is also known as the so-called Hartwick rule. Hartwick (1977) shows this condition must be fulfilled to sustain welfare over time. Two important preconditions of such a sustainability indicator is that firstly the balance sheet should take record of all forms of capital including ecological and social capital and secondly that appropriate prices are found to value each of these capital components.

Natural resource management is also evaluated by Lange *et al.* (2003) by analysing the appropriation of resource revenues by governments. The more governments gain from natural resource exploitation, the more these funds can potentially be used for investment in, for example, human capital via health and education programmes. In the context of water resource management, they also look at water use efficiency rates by economic activity. In this way, they manage to establish a bridge between cause-oriented and effect-oriented accounting. It is not surprising that physical indicators (*e.g.* value added per square meter water consumption) and not monetary ones are introduced in the accounts to measure resource efficiencies.

As mentioned before, such direct linkage between resource consumption and changes in natural assets is most easily established for natural resources but less easily for pollution related forms of environmental degradation. An integrated flow-stock water accounting system for the Netherlands is also presented in chapter 6 of this thesis.

Another indicator derived from effect-oriented accounting is the genuine savings rate published by the World Bank (1997) for a range of countries. Instead of absolute wealth measures, this indicator reflects the *annual changes* in wealth. Asset changes taken into consideration are those of produced assets, human capital (*i.e.* education expenditure as a proxy for investment in human capital), natural resources and environmental degradation of carbon dioxide pollution. Again, this indicator builds on the Hartwick weak sustainability criterion of non-declining wealth, or non-negative 'extended' net saving rates at all times. Substantial negative savings especially show up for those countries with relatively high natural resource depletion rates that are unable to reinvest resource rents in other forms of capital. As such, this indicator may give important signals to those countries experiencing a rapidly declining environmental capital base.

However, there are also some important deficiencies in the way this indicator has been put into practice. Firstly, indeed one could argue that education expenditure contributes to human capital and should therefore be recorded as gross fixed capital formation instead of final consumption expenditure. The latter recording method complies with current SNA-1993 recommendations. However, the upward effect of alternative recording on net saving should be counterbalanced by the negative effect of human capital depreciation, *e.g.* human capital losses due to ageing and retirement, in order to make this saving measure really 'genuine'. Another problem concerns the representation of environmental degradation, *i.e.* global warming as a result of carbon dioxide pollution. This is motivated by Hamilton & Clemens (2000, p.342) as follows. "Global damages are charged to emitting countries on the assumption that the property right to a clean environment lies with the pollutee". One may argue whether accounting should rely on such disputable assumptions that are not necessarily put on record with present observation or expectation. It is questionable whether countries that have had very high carbon dioxide pollution records over the last hundred years will be ever held responsible for the resulting global damages. In addition, it seems morally questionable whether developing countries should be held responsible for the very moderate levels of carbon dioxide emissions they have been emitting up to date. Global warming pollution abatement is not only a matter of absolute pollution cutbacks. It is also an issue of fairly distributing pollution quotas among countries. This latter concern is at present not very well reflected in the genuine saving indicator. A truly genuine saving measure should be restricted to the effect-oriented perspective without raising liability issues. Indeed, the expected impacts from global warming are difficult to assess at present and will substantially differ between different world regions. This acknowledges the limitations of a genuine saving indicator and to certain extent also its use as a sustainability device.

2.6 *Concluding remarks*

The strengths and weaknesses of both cause-oriented and effect-oriented accounting are summarised in table 2.2. Although this thesis mainly deals with cause-oriented accounting, it must be acknowledged that both accounting perspectives are principally complementary in scope. The exchange in experiences from both accounting perspectives is likely to be beneficial for a general understanding of the welfare consequences of environmental deterioration. Without a clear notion of environmental damages and the way they occur, cause-oriented accounting and cost-effectiveness analysis are principally meaningless.

Table 2.2
Overview of accounting characteristics

Cause-oriented accounting:	Effect-oriented accounting:
– Pressure related	– Impact related
– Production approach: Extended description of production and consumption processes	– Capital approach: Extended description of assets and changes therein
– Physical flow accounting	– Balance sheet accounting
– Cost-effectiveness analysis	– Damage analysis
– Specifically suitable for addressing the driving forces of depletion and degradation in physical terms	– Specifically suitable for addressing natural resource depletion in monetary terms

One important reason why this thesis has a main focus on cause-oriented accounting is that degradation issues have been dominating environmental policy in the Netherlands. Also much emphasis has been given to improving environmental performance of the Dutch economy. This brings logically into the picture a cause-oriented environmental accounting approach. One important related issue in this context is also the cross-boundary displacement of degradation effects. In addition to cross-boundary pollution flows, these environmental effects may also comprise foreign natural resource dependencies and other cross-boundary transfers of environmental losses via international commodity trade. Chapter 7 shows how cause-oriented accounting helps to address these international trade related displacements of environmental burdens.

Notes

1) Similarly, the existence of involuntary unemployment indicates that labour supply is not necessarily the outcome of weighting marginal utility of consumption against the marginal utility of leisure.

2) This boils down to the question whether the environmental improvements of household activities should be reflected as a quality increase in volume measures.

3) Van den Berg & Van de Ven (2001) show that, in the case of the Netherlands, the government approximately appropriates the total resource rent of natural gas extractions. They argue that a government appropriation method is a valid alternative to determine the resource rent. However, this method requires a careful analysis of the tax regimes applied to the mining industries under review and may lead to different results between countries.

4) The Eurostat publication refers to the opportunity costs of capital as "revaluation due to time passing" while in §10.26 of the SEEA-2003, this part of the resource rent is called the "income element". Following the notation in the SEEA-2003, El Serafy (1989) defines the income element X by way of the net present value (NPV) of an infinite income stream that equals the value of the natural resource deposit RV at time (t): $NPV(X)t = RVt = Xt/r$, where r denotes the interest rate that is assumed constant over time. This shows that the income element Xt equals the opportunity costs of capital, *i.e.* $Xt = rRVt$.

5) In relation to the forthcoming SNA revision scheduled for 2008, the Canberra II Group on capital measurement recommends such a breakdown of the income generation account in order to explicitly account for capital services inputs. Such a breakdown would at the same time lead to the explicit recording of resource rents in the income generation account.

Chapter 3. A review of physical flow accounting methods

3.1 Introduction

Understanding the interrelationships between the natural environment and the economic system is not possible without understanding their physical and spatial characteristics. This proposition equally applies to the economic analysis of these interrelationships. Material and energy exchanges with the environment are fundamental to the operation of an economy. All production and consumption processes and commodity transactions coincide one way or another with the use of materials, energy and space. Simultaneously, material and energy consumption and the occupation of space are of the most important determinants of environmental degradation and subsequently the losses in environmental use functions. Prior to any environmental damage and remedy assessment in terms of money, the causes and consequences of environmental degradation have to be observed and understood in physical terms.

Physical flow accounting generally refers to the systematic identification of material or energy flows through the economic system. In many cases, specific attention in physical flow accounting is given to the material exchanges between the economy and the environment (*e.g.* natural resource inputs, waste outputs). As such, physical flow accounting provides a description of the physical characteristics of production and consumption processes, sometimes referred to as the process of social or industrial metabolism. [1] One of the key goals of physical flow accounting is to trace down and analyse the environmental impacts of production and consumption processes throughout the economic system.

Physical flow accounting differs fundamentally from the volume measurement of product transactions and GDP as the weighted sum of all final product deliveries in an economy. Volume (change) measures in standard national accounting are used to determine real economic growth figures corrected for price changes. They are based on the quantity and quality of the use service provided by goods and services expressed in any relevant unit. As explained by Ayres & Kneese (1969, p.284), "... standard economic theory is in reality concerned with services. Material objects are merely the vehicles which carry some of these services ...". Physical flow accounting, on the other hand, specifically addresses the 'vehicles' underlying product transactions. It is the material composition or energy content of products that is subject to physical flow accounting. Also, physical flow accounts may take record of non-priced material flows such as resource inputs and residual outputs.

This chapter discusses the scope and purposes of physical flow accounting methods. Further, this chapter indicates how the SNA-1993 may contribute to the structuring of physical flow accounts. Prior to this review of physical flow accounting methods, this section continues with an introduction of the main principles of accounting as a statistical tool.

As already addressed in chapter 2, accounting is conceived as a tool for structuring statistics in order to improve their accessibility to specific analytical purposes. The SNA-1993 (§3.2) discusses two general characteristics that are valid for accounting in a broader sense, also in relation to physical flow accounting. Firstly, stocks and flows are exhaustively described within the boundaries defined. Secondly, the same set of concepts, definitions and classifications is applied throughout the accounting framework.

Generally, accounting depends on a wide range of statistical techniques to adjust and to supplement various types of, usually imperfect or incomplete, data sources into a system wise description of reality. The system's boundaries determine what is included and what is left out. The accounting identities guarantee the exhaustiveness of the accounts within these predefined boundaries. Like models, accounting usually provides an abstracted, and therefore a partial representation, of reality. A good understanding of the accounts requires a good understanding of its systems boundaries.

Accounting systems are able to provide simultaneously information on various levels of detail. In this capacity, accounts are sometimes referred to as 'information pyramids'. On the highest level of aggregation, accounts provide the so-called accounting aggregates or indicators with a clear scorekeeping function. [2)] On more detailed levels, accounts may provide the information systems and analytical frameworks required for research and policy assessment. Indicators and information systems serve different kinds of users. Indicators support policy target setting, monitoring and informing society while the underlying information systems provide the statistical tools for analysis. A consistent linking-up of information systems and indicators, as foreseen by accounting frameworks, undoubtedly improves the communication between these different stakeholders.

The SEEA-2003 illustrates, in much more detail compared to the interim version of 1993, how the national accounts framework may contribute to physical flow accounting. One major attraction of a national accounts oriented approach is the direct comparability with monetary information on for example production and consumption. This subsequently leads to a data framework that supports integrated environmental-economic policy assessment. The physical oriented indicators embedded in these systems directly comply with environmental performance related policy targets that are usually formulated in physical terms. In this respect, the extension of the national accounts with physically oriented performance indicators anticipates quite well to key policy questions related to the issue of 'decoupling' or the de-linking of increasing environmental pressures from economic growth. A strong increase in natural resource productivity is considered an important precondition for sustainable development (*cf.* Hinterberger & Schmidt-Bleek, 1999).

The next section provides an overview of developments in physical accounting with an emphasis on methods applied to the meso (industry branch) and macro level. The subsequent section compares three main types of macro oriented accounting approaches. In addition to accounting structures, this section also discusses the accounting aggregates or indicators they may represent. Section 3.4 further elaborates on the role of the SNA-1993 in physical flow accounting. The final section of this chapter winds up with conclusions.

3.2 A brief methodological review

In the first half of the 20th century, most economists regarded pollution as small scale market failures with limited repercussions. Standard economic theory states that welfare of all agents in an economy can be improved by environmental policies with the aim to 'internalise' these market imperfections. This can be achieved by either imposing a Pigouvian tax on the originators of the externality (Pigou, 1920) or by assigning property rights to environmental assets and the services they provide (Coase, 1960). In this way, the scarcity of environmental amenities becomes part of the market system.

In the second half of the 20th century, environmental pollution problems intensified and there emerged awareness that the depletion of natural resources might eventually stop economic growth. [3)] This amplification of environmental concerns contributed to alternative ways of looking at the operation of economic systems. In addition to labour and capital, the environment was much more acknowledged as an equally crucial production factor. As a result, more attention was given to the physical operation of the economic system. The representation of the economic system, mainly focussing on the circular flow of income, was found to be too restricted from an environmental perspective (*cf.* Ayres, 1998). This restricted scope is equally present in the SNA-1993 where the 'income generation – income distribution – income expenditure' cycle is the leading principle of the current accounts. No attention is given in the SNA to the physical characteristics of the production-consumption system.

Ayres & Kneese (1969) took a far more reaching position by considering pollution and material consumption as a fundamental and indissoluble concern of the operation of economies. They acknowledged that, from a physical perspective, the production-consumption system is not closed but continuously interacting with the environment. The material balance principle is fundamental in the Ayres-Kneese model. Matter or energy is neither created nor destroyed in the course of production and consumption. This implies that "in an economy which is closed (no imports or exports) and where there is no accumulation of stocks (plant, equipment, inventories, consumer durables or residential buildings), the amount of residuals inserted into the environment must be approximately equal to the weight of basic fuels, food, and raw materials entering the processing and production system, plus oxygen taken from the atmosphere" (Ayres & Kneese, 1969, p.284). In other words, the material balance principle provides an interconnected view on natural resource inputs and waste outputs. More or less each accounting identity that defines the structure of a physical flow account is based on the material balance principle.

The omission of physical entities in economic analysis was at that time also addressed by Georgescu-Roegen (1971) when recognising the thermodynamic constraints to production and consumption. In this respect, Georgescu-Roegen considered the second law of thermodynamics, or entropy law, of a much greater environmental concern than the first law on the preservation of matter. The entropy law determines the direction in which energy conversion can take place. Entropy refers to the amount of unusable energy. The second law explains that in a closed system entropy cannot be decreased and is likely to increase. The practical implication of the entropy law with respect to the irreversible depletion of fossil fuel deposits is indisputable. However, the relevance of the entropy law to material conversion and depletion, as equally put forward by Georgescu-Roegen, is controversial; especially his claim that closed material cycles within the economic system (*i.e.* 100% material recycling) is by definition impossible due to material dissipation. Although the entropy law is clearly useful in the efficiency analysis of energy systems, its more general relevance with respect to environmental accounting is less clear and not further explored here.

In the same period of time, several attempts were made to apply the Leontief input-output framework to integrated economic and environmental analysis. Perhaps the most comprehensive frameworks were introduced by Daly (1968) and Isard (1969). Both authors used the input-output framework to account for the physical flows running between the economic system and the environment. In addition to that, both authors provided, at least conceptually, full-fledged input-output matrices for the non-human ecological system. However, both authors did not convincingly show the general feasibility and usefulness of this latter extension. It is hard to believe that a larger part of the environmental pressure-repercussion interactions can be expressed in terms of fixed coefficient input-output relationships. The multidimensional appearances of ecosystems, the existence of thresholds and transfers of burdens over time and space severely complicates such a representation of ecological production functions.

The founding father of input-output analysis, Leontief (1970) introduced the analysis of pollution abatement in open input-output models. In his model, pollution is represented as the by-products, expressed in physical terms, of regular production activities. He further extended the input-output framework with additional, net yet implemented, pollution treatment activities. The underlying data-system of his model augments the standard input-output system with pollution output coefficients of the regular industries and pollution input coefficients of the 'anti-pollution' industry. This analytical model can be used to estimate the economy-wide volume and price effects of alternative pollution control techniques. The hypothetical nature of the model is illustrated by the fact that abatement techniques, environmental constraints and cost allocation schemes are added to the standard Leontief model. This complicates the interpretation of Leontief's model in various ways (*cf.* Steenge, 1978, 1997, 1999 and 2002).

A more descriptive approach is followed by Victor (1972). The data structure underlying Victor's model combines physical data on 'ecological commodities' (i.e. unexploited raw materials and waste products discharged to the environment) with the monetary data represented by a system of supply and use matrices. This 'hybrid' accounting structure is somewhat similar to the framework introduced by Leontief. [4)] One important difference however is the data structure proposed by Victor which is entirely restricted to the recording of factual events. In addition, Victor's accounting structure maintains a clear distinction between unexploited raw material inputs and waste outputs. Raw material inputs are shown as material transfers from the environment to the economic system while waste outputs are reversibly shown as transfers from the economic system to the environment.

The accounting structure underlying Victor's model (*cf.* table 4, p.56) could be regarded as a prototype of the National Accounting Matrix including Environmental Accounts (NAMEA) later developed by De Haan & Keuning (1996). Both systems are characterised by a hybrid structure, representing simultaneously the physical as well as monetary dimension of economic processes. There are also some important differences. Victor exclusively focuses on the ecological commodities of industries, ignoring households. Further, the supply-use tables provide only a partial picture of the economic system while the national accounting matrix presented in the NAMEA represents the complete system of current accounts.

In recent years, NAMEA type of accounting systems have been established on the basis of supply-use tables, input-output tables or full-fledged national accounting matrices. Supply-use tables are a set of rectangular (of the order $m \times n$) tables, presenting the supply and use of products (m) by industries (n). The supply table includes in an additional column entry the foreign supply of products on the domestic market, i.e. import. The use table includes additional entries for final demand, that is, consumption, gross fixed capital formation and export.

Square ($m \times m$) input-output tables have a more analytical nature. Input-output tables directly connect the intermediate product requirements to product outputs. These 'product-by-product' relationships are rarely subject to direct statistical observation. Instead, homogenous input-output tables have to be derived from supply and use matrices (*cf.* Konijn, 1994 and Konijn & Steenge, 1995). [5)] Both accounting frameworks may be augmented with entries describing in physical terms the direct material exchanges of production activities with the environment.

The national accounting matrix represents the principle framework of the Dutch NAMEA as presented in chapters 4 and 5. In addition to a set of supply and use tables, this matrix potentially contains a complete system of national accounts. The national accounting matrix could be regarded as an extended closed input-output system, incorporating the complete circular flow of income; from production, income generation, income distribution to income expenditure. The role of the national accounting matrix in the NAMEA is further discussed in chapters 4 and 5. However, as not yet many countries are representing their national accounts in a matrix format, the Eurostat (1999, 2001a) NAMEA publications take the supply-use system as the main framework. [6)]

Supply-use and input-output tables are also being used, for example by Konijn *et al.* (1997), Gravgård (1999), Muukkonen (2000), Stahmer (2000) and Hoekstra (2003), to provide a physical representation of commodity flows throughout the economy. Instead of, or in addition to, natural resource inputs and waste outputs, these accounts describe physical flows within the economic system. Usually these accounts focus on specific 'bulk' flows such as fossil fuels, wood products and pulp, nutrients or metals. One key feature of this type of physical flow accounting is the mapping of complete material chains throughout the economic system, possibly with the inclusion of recycling and waste generation. This approach may serve as a tool for measuring trends in 'dematerialization' (or re-materialization), *i.e.* material use per unit of product or service. A review of 'dematerialization' indicators is given by De Bruyn *et al.* (2003). They conclude that dematerialization policies are only meaningful when they are able to address specific environmental concerns such as energy efficiency improvements or particular environmental burdens. They consider aggregate flow measures as less meaningful indicators, particularly when they do not address specific environmental concerns.

Apart from national accounts oriented approaches, other kinds of frameworks have been developed that deal with the physical characteristics of economic systems. [7)] One major family of approaches is the framework of economy-wide material flow accounts developed for example by Steurer (1992), Adriaanse *et al.* (1997) and Matthews *et al.* (2000). This macro-oriented approach is purely restricted to all material exchanges of the socio-economic system expressed by their weight *i.e.* kilograms. The material flows addressed in economy-wide material flow accounting include firstly the material exchanges between the economic system and the natural environment and secondly the material exchanges between economies via imports and exports.

Apart from macro or meso oriented approaches, physical flow accounting is also carried out on more detailed levels. In this context, an overview and comparison of three frequently applied analytical approaches is given by Bouman *et al.* (2000): substance flow analysis, lifecycle assessment and partial equilibrium modelling.

Substance flow analysis usually focuses on those types of substances that are of particular environmental concern *e.g.* specific heavy metals or nutrients (*cf.* Van der Voet, 1996) and may be used to analyse the consequences of alternative production techniques, product designs or consumer behaviour. The mathematical characteristics of substance flow analysis are quite similar to those found in input-output analysis. However, the scope of substance flow analysis may differ. For example, substance flow accounts may also address stocks and flows within the environmental domain (so-called fate modelling) in order to deal with relevant environmental circumstances when assessing impacts. Substance flow analysis does not necessarily follow national account classifications or definitions and may also be applied on regional levels. The construction of a system of substance flow accounts is a fundamental step in substance flow analysis. Within the borders of a predefined system, various data sources are being integrated on the basis of material balance identities. This allows for a consistency check of the various data sources but also for the identification of unexpected emissions flows or stockpiles within the economic system. As shown in chapter 6 of this thesis, the emission accounts for nutrients in the Dutch NAMEA are derived from substance flow accounts.

Lifecycle assessments are used to determine the environmental consequences of a product from cradle to grave. Lifecycle assessment analysis specifically focuses on the comparison of alternative products or design of products that provide a similar kind of use service. In that sense, the use function of a product, and not the product itself, is the key object of the analysis. This implies that, in addition to the recording of factual events, also the corresponding market volumes and the concomitant environmental impacts of product alternatives must be assessed. Lifecycle assessments are usually partial in scope. For example, the product system taken into consideration will inevitably contain shortcuts ignoring those processes of minor significance. Also, the environmental impacts related to capital requirements of products that occurred at the stage of capital formation are usually not included. According to Lenzen (2000), these truncation effects can be substantial and he therefore recommends input-output models as a way to overcome the distortions resulting from short cuts.

At the process level, material balance identities for individual substances, or for groupings of materials, may contribute to a consistent description of all related environmental impacts of the product system. In other words, the description of processes in lifecycle assessment ideally requires an accounting approach. However, the data requirements may be overwhelming. Lifecycle assessment usually encompasses an wide range of environmental impacts. The environmental theme oriented indicators as proposed by Van den Berg *et al.* (1995, p.31) to compare in a condensed way different kinds of environmental impacts are quite similar to those applied in the Dutch NAMEA.

Partial equilibrium models describe the outcome of one market or a restricted range of markets on the basis of behavioural relationships of producers and consumers. This allows for the explicit modelling of price and substitution effects of product alternatives and the analysis of economic instruments such as taxes on environmentally harmful products and subsidies on environmentally beneficially ones. Material balance identities may be used to safeguard a consistent representation of the physical dimension of these models. These identities contribute to a consistent representation of environmental impacts coinciding with different market projections. Yet, a realistic representation of market behaviour into physical flow analysis increases model complexity and requires inevitably a substantial amount of information.

Although Bouman *et al.* do not discuss data issues at large, it is beyond doubt that the gathering and systematic ordering of data, resemble a fundamental step in each of these methods. One may also conclude that the accounting wise structuring of data according to accounting identities forms in each example at least some part of the physical flow analysis. The main conclusion Bouman *et al.* arrive at is that the three methods should be considered as supplementary rather than complementary. Substance flow analysis helps to identify those flows of key policy concern. Lifecycle assessment serves the evaluation of product alternatives with the most beneficial set of environmental impacts while partial equilibrium modelling may be conducted to assess social optimum economic policy measures.

3.3 A review of physical accounting methods

3.3.1 Introduction

This section continues the discussion of physical flow accounting approaches applied to the national or industry branch level. Features addressed in this section are the scope of accounting frameworks and the indicators they may provide. Accounting scope refers to the boundaries and structure of the various accounting propositions. The discussion on indicators deals with issues such as aggregation methods and indicator boundaries.

This chapter mainly discusses accounting methods dealing with the recording of physical flows within the economic system and between the economic system and the environment. Throughout this thesis, much attention is given to the direct recording principle and the recording of environmental requirements. Both notions are further explained below.

Direct recording is here defined as the representation of physical flows at the level of those processes or activities as factually observed. The direct recording principle is an important precondition for an account to function as a descriptive information system. Only the direct recording principle guarantees an exhaustive representation of physical flows of all activities that together make up the entire economy. However, direct recording does not necessarily indicate causalities or responsibilities. For example, energy saving of consumers will indirectly reduce the pollution generated by electricity producers. Chapter 7 introduces the notion of *indirect* environmental effects to analyse these interactions or dependencies between economic activities. Chapter 7 shows that physical flow accounting based on the direct recording principle is an important precondition for the systematic reallocation of environmental requirements to the ultimate commodity users in an economy: consumers.

Environmental requirements are here defined as the physical and non-physical or spatial requirements of production and consumption that are directly derived from the environment. Environmental requirements are the use services provided by the environment in contrast to the use services provided by purchased products or manmade capital. From a physical perspective, environmental requirements roughly consist of the environmental source functions, i.e. natural resource inputs, and sink functions, *i.e.* residual outputs. The interrelationships between natural processes and human activities or needs are referred to by Hueting (1980) and De Groot (1992) as environmental functions. De Groot (1992, p.7) divides these interrelationships into two main categories: physiological needs, *e.g.* oxygen, water, food, energy, and psychological needs, *i.e.* the environmental contributions to spiritual wellbeing and recreational services. Environmental requirements particularly refer to the physiological functions of nature.

3.3.2 *Accounting scope*

As mentioned in the former section, most physical flow accounts are one way or another based on the material balance principle. This principle implies that, for a predefined system, the balance of material inputs and outputs measured in mass terms equals its net material accumulation. As shown in this subsection, this identity has similarities with the accounting identities underlying supply-use and input-output tables. This makes these tables suitable for monetary as well as for physical representations.

The scope of various accounting systems that are being applied at the national economy level can be illustrated by way of three main categories of accounting schemes. Obviously, combined or partial applications of these frameworks are equally possible and are found in the literature.

Economy-wide material flow accounting

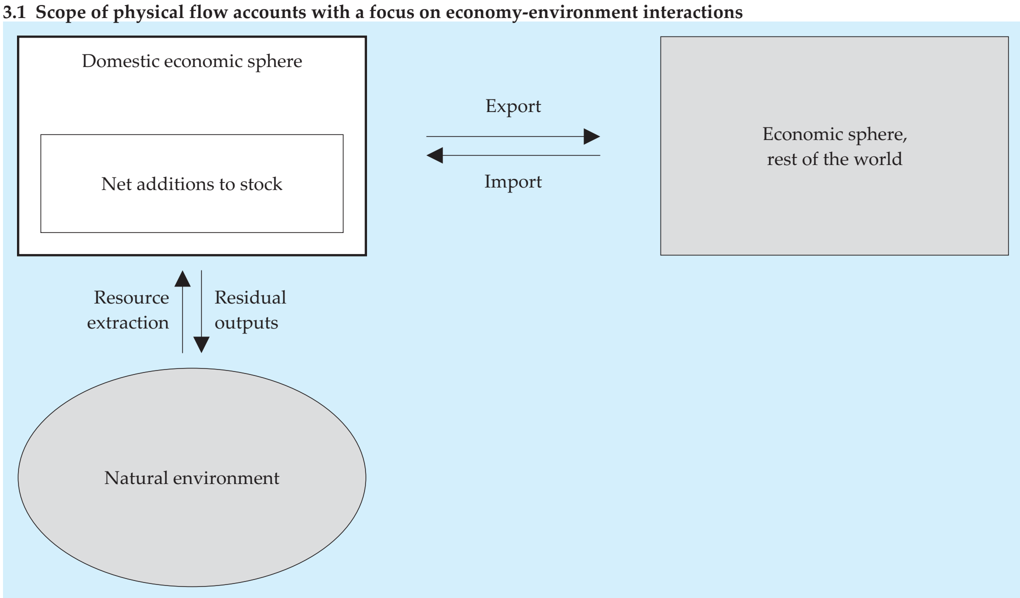
Economy-wide material flow accounting as carried out by Steurer (1992), Adriaanse *et al.* (1997) and Matthews *et al.* (2000), and as reviewed in a Eurostat (2001b) methodological guide, is mainly restricted to firstly the direct environmental-economic material exchanges and secondly the material inputs and outputs of an economy via imports and exports. In this approach, all flows are accounting for in mass terms, *i.e.* kilograms.

The net balance of both material flow categories together determines the net additions to stock in the (domestic) economic sphere. Flows within the economic sphere are not being described and the economic system itself remains principally a black box. The underlying 'input = output' accounting identity of economy-wide material flow accounting can be summarised as follows.

natural resource extraction + import = residual output + export + net additions to stock in the economic sphere (3.1)

Figure 3.1 illustrates this accounting identity (3.1). The arrows in this figure identify the material flows represented in the accounts. The bold framed box indicates the

3.1 Scope of physical flow accounts with a focus on economy-environment interactions



accounting system's scope. The grey parts indicate areas that are not specifically covered. Resource extractions and residual outputs include the direct interactions with the environment. Imports and exports represent the material exchanges with the rest of the world. In figure 3.1 the environmental consequences of international trade are not further taken into consideration. Adriaanse *et al.* (1997) introduces for this purpose the notions of indirect and hidden flows to reveal some of these import related environmental impacts. Also trade related indirect effects are being discussed in chapter 7.

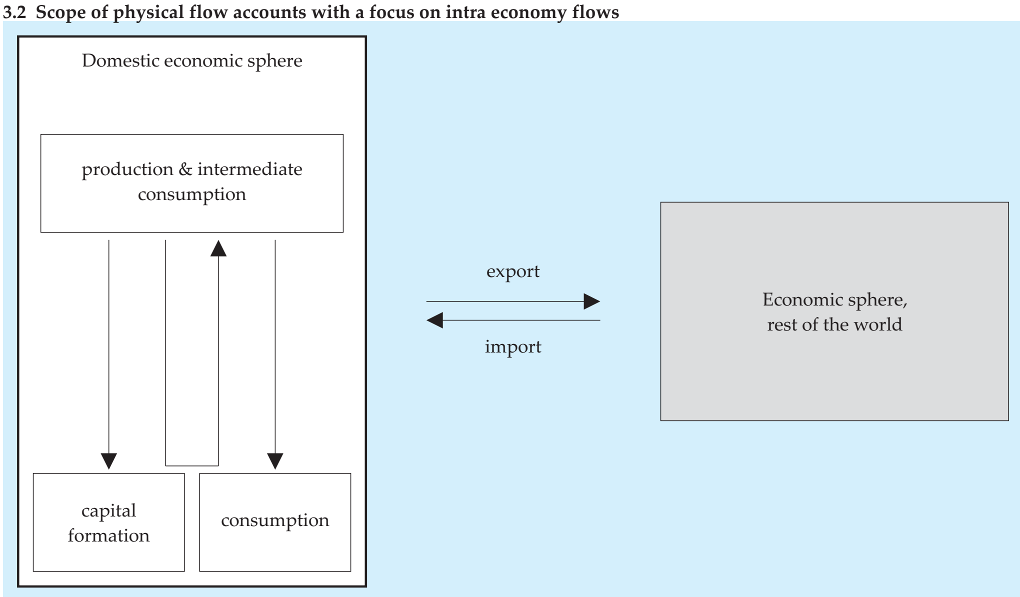
Physical supply-use and input-output tables

As already mentioned, examples of physical flow accounting with a focus on product flows are presented by Konijn *et al.* (1997) and Hoekstra (2003) for the Netherlands, Gravgård (1999) for Danmark, Muukkonen (2000) for Finland, with special reference to forestry accounting, and Stahmer (2000) for Germany. These national accounts based approaches are constructed by decomposing specific commodity transactions in supply-use tables into two separate matrices, one matrix representing the underlying physical quantities and another one containing the concomitant average prices of each matrix entry.

This approach results in a description of specific material flow chains within the economic system, such as those related to the manufacturing of *e.g.* plastics, metals, energy, paper. These accounts show how primary inputs such as ore, timber, sand or biological resources are transformed in several production processes into secondary and higher order products. Following the ‘supply-use’ accounting identity underlying supply-use matrices, suppliers and users are consistently identified for each product group.

domestic production + import = intermediate consumption + household and government consumption + gross fixed capital formation + inventory changes + export (3.2)

3.2 Scope of physical flow accounts with a focus on intra economy flows



The supply-use accounting identity (3.2) explains that, following *ex-post* accounting practice, the origin and destination of product flows must be equal by definition. This identity holds both for the monetary and physical dimension of product transactions. The accounting scheme, as represented by figure 3.2, is perhaps most frequently applied to energy accounting. Such accounts are for example required in the compilation of air emission accounts. For this purpose, it is also necessary to divide the fossil energy inputs in the use matrix between those related to combustion processes and those related to transformation processes such as petrochemical production.

Similarly to monetary supply and use tables, physical supply and use tables can be translated into symmetric or square input-output tables. In fact, Konijn *et al.* (1997), Gravgård (1999), Stahmer (2000) and Hoekstra (2003) all compiled, in addition to physical supply and use tables, square physical input-output tables. Other examples of physical input-output table compilations are those of Mäenpää (2002) for Finland and Moriguchi (2002) for Japan.

Accounting identity (3.2) does also apply to the representation of physical flows in input-output tables. In supply-use tables, identity (3.2) structures the rows or product entries of both tables: total product supply represented by the row totals of the supply table (domestic production + import) equals total product use represented by the row totals of the use table (intermediate consumption + household and government consumption + gross fixed capital formation + inventory changes + export). In input-output tables, the industry dimension is eliminated by merging together the supply-use framework into one single product by product table. Identity (3.2) structures an input-output table as follows: the row totals represent simultaneously the domestic product output together with their uses reflected column wise (intermediate consumption + household and government consumption + gross fixed capital formation + inventory changes + export – import).
Quite similar to monetary input-output tables, physical input-output tables may serve various analytical purposes. An overview of environmental applications is for example given by Duchin & Steenge (1999). Applications frequently found in the literature are:

– *impact analyses:* analysing changes in primary inputs such as labour, capital and environmental requirements as a result of shifts in final demand, *e.g.* consumption, export;
– *attributing primary inputs to final products:* measuring economy-wide the total amount of primary inputs required for one unit of final output. This type of analysis is further illustrated in chapter 7 of this thesis;
– *structural decomposition analysis:* tracing down changes in primary inputs as a result of shifts in the economic structure through time, *i.e.* shifts in final demand as well as shifts in the production structure of an economy. This type of analysis is further illustrated in chapter 8 of this thesis.

When compiling physical supply and use tables or input-output tables, it is certainly not necessary to provide a full overview of all physical flows in the economy. Instead, these tables may also focus on specific physical flows that are of particular environmental concern, *e.g.* energy, heavy metals, paper, plastics. Combined physical and monetary input-output tables may be used to conduct the kinds of analyses mentioned above. Such 'hybrid-unit product flow' input-output tables are for example discussed by Miller & Blair (1985, chapter 6), Konijn *et al.* (1997) as well as in chapter 6 of this thesis in the context of energy input-output analysis. The adjective hybrid is used here somewhat differently from the hybrid tables as discussed above in the context of the NAMEA.
The accounting schemes presented in figures 3.1 and 3.2 are supplementary in scope. The first scheme represents the environmental-economic interactions while the second scheme keeps track of material flows within the economic sphere. Rademacher & Stahmer (1998) and Gravgård (1999) have compiled complete physical flow accounts simultaneously based on both accounting identities. The input-output identity only holds when, for each individual production activity

represented in the accounts, all material inflows and outflows are systematically traced down. The balance between these material inflows and outflows is made up by the 'net material accumulation'. Obviously, this further extends, but also increases the complexity, of the accounting system. For example, all commodities must be included, also those with rather unclear and heterogeneous material compositions. Also, the product descriptions in regular supply and use tables do not necessarily take record of all recycling flows. Further, sales, purchases and disposals of tangible capital goods must be taken into consideration as well.

NAMEA

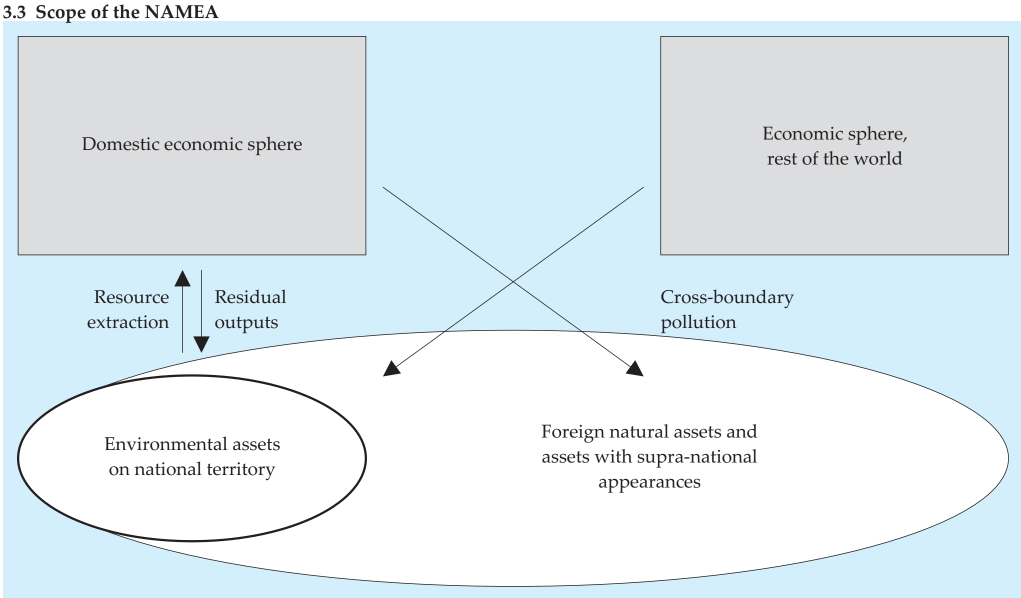
The substances account of the NAMEA, as presented in chapter 5 (*cf.* tables 5.1 and 5.3) follows an accounting scheme that maintains a strict borderline between economy and environment. Similarly to the firstly presented accounting scheme, the NAMEA primarily focuses on the material transfers from and to the natural environment. Physical flows connected to commodity transactions, as followed in the second approach, do not enter the NAMEA substances account. From an environmental perspective, the NAMEA systematically exposes the national accounts system's boundaries and the physical flow accounts logically expand these boundaries. The primary goal of the NAMEA is extending the national accounting system in the Leontief or Victor tradition, allowing for similar analytical advantages.

The physical flow accounts in the NAMEA are somewhat reversed in scope compared to the firstly presented accounting framework. The first accounting scheme determines the material accumulation in the economic sphere. The NAMEA determines for specific substances their material accumulation in the environment. The primary goal of the NAMEA is to provide a systematic representation of those environmental interactions that are particularly relevant from an environmental perspective.

The natural environment perspective is further emphasised by the recording of cross-boundary residual flows in the NAMEA. Cross-boundary residual flows firstly result from airborne pollution transfers such as acid rain and pollution transferred via river systems. Secondly, cross-boundary residual flows may result from the cross-border transportation of solid waste. Thirdly, cross-boundary pollution is also brought about by internationally operating economic activities such as transport and tourism. Cross-boundary residual flows create a gap between the sum of environmental threats caused by a national economy and the environmental threats exposed to (all ownership of) all residential agents. For example, the acid rain problem has shown that damages to environmental assets (lakes, forests) are often only to a limited extent related to domestically originating acid pollution. Similarly, access to clean water bodies in downstream countries may be influenced by polluting activities in upstream countries.

The recording of cross-boundary pollution helps to determine the accumulation of certain pollution and waste types within specified territorial boarders. Conceptually, this accumulation may be determined for the national territory, specific regions or specific environmental domains such as land and water bodies. Obviously, this accumulation is irrelevant for pollutants contributing to global environmental problems such as greenhouse gas pollution and emissions contributing to ozone layer depletion.

3.3 Scope of the NAMEA



The two accounting identities, underlying the physical flow accounts in the NAMEA, refer to natural resource inputs (3.3) and to residual outputs (3.4).

extraction (–) + net balance of other changes in natural resources =
net change in natural resources (3.3)

net domestic output of residuals + net balance of cross-boundary residual flows =
accumulation of residuals on national territory (3.4)

Identity (3.3) explains the difference between the opening and closing stocks of natural resources in physical terms and corresponds to the changes in the volume of non-produced natural assets in the SNA-1993 (*cf.* §12.10). The net balance of other changes referred to in the left hand side of this identity includes for example the economic appearance of new deposits due to successful mineral exploration or the natural growth of non-cultivated biological resources but also accidental losses.
The accumulation of residuals on national territory is determined by the sum of the net domestic output of residuals and the net balance of cross-boundary residual flows. The net domestic output of residuals is determined by the gross output of

residuals minus residual re-absorption into the economic sphere, *e.g.* pollution treatment, waste recycling and incineration.

A numerical example of accounting identity (3.4) is presented in table 3.1. This table shows how cross boundary pollution transfers make of the difference between the (net) environmental pressure of the domestic economy and the environmental pressure exposed to national territory.

Table 3.1
The origin and destination of pollution in the Netherlands, 1997

	NO_x	SO_2	NH_3	P	N
	mln kg				
Origin of pollution					
Emission by residents	701	236	188	100	1 034
From the rest of the world	101	82	22	15	325
Non-residents in the Netherlands	41	12	–	–	11
Transfer by surface water or air	60	70	22	15	313
Total, origin	801	319	210	115	1 359
Destination of pollution					
Absorption by producers (recycling, waste water treatment)				21	118
To the rest of the world	694	223	34	16	504
Residents in the rest of the world	282	131	–	–	79
Transfer by surface water or air	412	92	34	16	425
Accumulation of pollution in the Netherlands					
Acidification	108	96	176		
Eutrophication				77	738
Total, destination	801	319	210	115	1 359

Source: Statistics Netherlands (2000).

In conclusion, the three accounting schemes presented here are complementary in scope. Controversies in physical flow accounting are perhaps less related to contradicting accounting frameworks but much more to the indicators they may provide and the way these indicators should be understood. Several accounting aggregates or indicators derived from physical flow accounts are discussed below.

3.3.3 *Accounting aggregates and indicators*

The construction of environmental indicators is largely motivated by the need for 'simple to understand' information on environmental concerns. Environmental policy may address a variety of environmental problems and the gathering of relevant information may equally comprise a wide range of data. Indicators may contribute to the provision of condensed and comprehensible information accessible to a wider public. Indicators usually serve as a means for target setting and scorekeeping allowing for sound comparisons over time and between countries. Obviously, a balance must be found between simplification on the one hand and objectivity and scientific accountability on the other. The temptation to include a host of different indicators into a single 'all-embracing' index may ultimately lead to a rather pointless figure. The conceptual underpinnings of a number of environmental indicator proposals are discussed below. Firstly, attention is given to the role of weighting as a way to construct indicators on higher levels of aggregation. Secondly, the discussion addresses the scope of indicators, or kind of flows that are presented by various indicators. Specific attention is given to the role of accounting as a way to safeguard indicator transparency and consistency.

Weighting

A variety of frameworks and indicators in physical as well as in monetary terms have been developed in relation to environmental concerns and sustainable development. Some of these examples are unrelated to accounting frameworks. Typical examples of these kind of indicators are the Human Development Indices that are annually published by the United Nations for a wide range of countries (*cf.* United Nations, 2002) and the Index of Sustainable Welfare developed by Daly & Cobb (1989). Although, the underlying determinants of these indicators are expelled, their policy relevance is less clear. Indices typically lack an underlying information system and therefore they do not provide any information about the interrelationships of the variables they represent. Indices are therefore to some extent footloose information devices.

The weighting schemes underlying aggregated indexes are another point of concern. For example, Neumayer (2000b) shows that the choice of weights attached to determinants such as natural resource depletion and income distribution, in the Index of Sustainable Welfare influences substantially the development of this indicator over time. He also puts into question the transparency of this indicator by showing that weights are quite differently interpreted and used in various country estimates.

Jesinghaus (1999) applies an expert assessment, or Delphi type of weighting procedure, in the construction of one aggregated environmental pressure index. The expert assessment foresees, firstly in the selection of environmental problems to be covered in the index, and secondly, in an evaluation of their importance. One can dispute the legitimacy of expert evaluations in this context. Expert knowledge is obviously essential in a general understanding of the consequences of particular environmental problems. However, there is no reason why experts are legitimised, more than others, to assess the social preferences connected to various environmental concerns. Such an assessment is typically the principal responsibility of a democratic decision making process. Statistics and science should primarily provide the factual information on which policy decision-making can rely.

Another aggregated indicator that relies on a method of weighting is the Ecological Footprint indicator, developed by Wackernagel & Rees (1996). Van den Bergh & Verbruggen (1999, p.63) explain the substantial amount public attention this indicator receives by "the fact that all human exploitation of resources and environment is reduced to a single dimension, namely land and water area needed for its support". The Ecological Footprint is calculated as the total sum of land appropriated by a certain amount of consumption. This consumption package may refer to individuals, communities, countries or even the entire world. Consumption is subdivided into different consumption categories and each category has its own land requirement. These land requirements represent together the weighting scheme underlying the Ecological Footprint.

Yet, the translation of a wide range of environmental impacts into land requirements, as applied in this indicator, is debatable. For example, the land requirement proposed in relation to the emission of greenhouse gases is estimated by the required land surface covered with trees, which serves as a carbon sink in order to compensate for carbon emissions. Van den Bergh & Verbruggen (p.65) emphasise the arbitrariness of this land requirement estimation by stating that "CO_2 assimilation by forests is one of many options to compensate for CO_2 emissions, and indeed a very land-intensive one". The land requirement conversion factors do not necessarily reflect the relative social preferences of the environmental concerns included in the Footprint.

A literally 'weighting method' is followed by Adriaanse *et al.* (1997) in the construction of the total material flow accounts and corresponding indicators such as the Direct Material Input and Total Material Requirement. The Direct Material Input of a national economy includes the total sum in mass terms of all input flows represented in figure 3.1, *i.e.* the direct material extractions from nature and commodity imports. The Total Material Requirement contains in addition indirect and hidden flows.

The Direct Material Input indicator results from the straightforward aggregation of material inputs. Their aggregation is facilitated by a uniform accounting unit applied to all flows in the accounts, being their weight measured in kilograms. Obviously, this aggregation ignores the particular environmental characteristics of different kinds of physical flows included in the accounts. Therefore, a one-dimensional representation of a multidimensional appearance of environmental concerns has its limitations and may easily lead to oversimplification.

This oversimplification is carried forward by the "Factor 10" policy goal advocated by Hinterberger & Schmidt-Bleek (1999, p.53–54): "... global material flows per year should be reduced by about 50% over the next 30–50 years. To allow economies which today use much fewer resources than others still to grow, we suggest a factor of ten reduction for industrialised economies".

The legitimacy of this policy goal is not straightforward. Surely, the total economy wide mass throughput is directly related to a variety of environmental impacts, from the depletion of natural resources to the various environmental degradation problems. Yet, it is debatable whether reducing the total mass input of economies will lead to a cost-effective reduction of environmental problems. For example, Steurer (1996, p.219) illustrates that the most toxic substances are often the smallest in mass terms. At the same time, the tiniest and nastiest toxic flows, such as heavy metals, are easily lost in the margins of error of these aggregated measures. In other words, physical flow accounting should track down physical flows according to their environmental policy relevance. A Factor 10 policy goal ignores the fact that the type of flow matters.

Therefore, a summation of the material inputs of an economy on the basis of quantities or kilograms, as reflected in the Total Material Requirement indicator, is less informative. These aggregated representations of material flows in physical quantities will usually not take into consideration the wide range of environmental concerns that coincides with these flows. The manufacturing of imported commodities requires a range of environmental requirements that are not particularly shown by the physical import flow itself. This issue is further taken up in chapter 7.

In conclusion, besides the logic of quantities as put forward by the material balance principle, physical flow accounting equally has a quality dimension. Obviously, a common unit of account contributes to accounting consistency. However, introducing a wider range of accounting units may indicate some of the specific environmental characteristics of different kinds of material flows. Such a multidimensional approach is followed in the NAMEA as developed by De Haan & Keuning (1996) and presented in chapter 5. Matthews *et al.* (2000, p.38) equally recommend such an approach in order to put more emphasis to the environmental impacts that may be addressed in economy wide material flow accounting.

Accounting units, other than mass or volume related units, may indicate certain quality aspects of physical flows in relation to specific environmental problems. For example, potential environmental stress equivalents may indicate the average expected contribution of an individual pollutant to a particular environmental problem. These equivalents can be used for weighting and aggregating a wider range of substances into one environmental pressure indicator. Adriaanse (1993) firstly introduced the systematic compilation of so-called 'environmental theme indicators'. These themes correspond to the key environmental problem fields that have been identified in the Dutch national environmental policy plans. Examples of environmental theme oriented stress equivalents are:

– the conversion of greenhouse gas pollutants into CO_2-equivalents;
– the conversion of halogenated hydrocarbons contributing to ozone layer depletion into CFC-11 equivalents;
– the conversion of sulphur, nitrogen oxides and ammonia into acidification equivalents, *i.e.* H+ moles;
– the conversion of nitrogen and phosphor pollution into nutrient equivalents, based on the ratio in which both nutrients appear under undisturbed natural conditions;

– the conversion of toxic pollutants on the basis of predicted no-effect concentrations in ecosystems or acceptable daily human intakes.

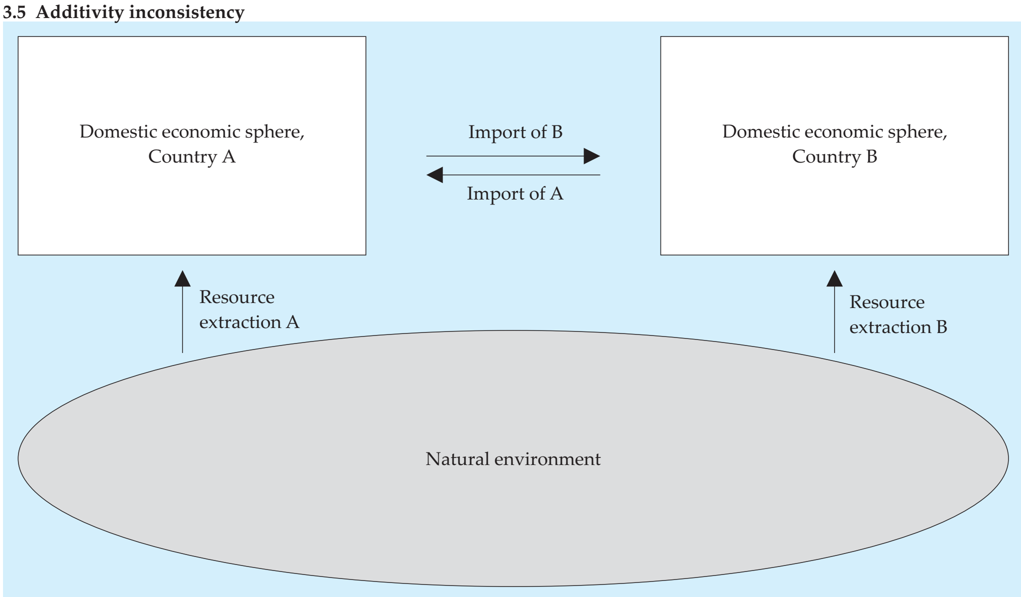
These conversion factors are also presented in the SEEA-2003 manual (*cf.* table 4.10). Theme indicators are compiled on the basis of the mechanisms by which particular pollutants contribute to ecological damages. The applied conversion factors make use of scientific knowledge on cause-effect relationships. A theme-oriented weighting of substances, or any other non-physical environmental requirement, relies without any doubt on various assumptions. The occurrence of impacts usually depends on various additional factors. As a result, the individual contributions of different pressures may show non-linear patterns that are not reflected by the linear conversion factors used in the theme indicators. However, these assumptions are considered less rigorous than other weighting methods discussed here. Theme indicators explicitly underline the multiple character of environmental degradation. The evaluation of these various concerns is explicitly acknowledged as a policy assignment. Any each higher level aggregation method of environmental pressures, including valuation, equally depends, implicitly or explicitly, on assumptions on how pressures relate to impacts. On top of that, any additional aggregation procedure can only be based on revealed social preferences.
Environmental theme indicators contribute to a condensed representation of environmental impacts without the necessity of severe oversimplification. It must be emphasised that the theme indicators reflect the *potential* stress on the environment. Combinations of various stresses as well as spatial and timing conditions will usually together determine the factual environmental consequences of pressures represented by the various theme-indicators. The construction of environmental theme indicators is further discussed in chapter 6.

Indicator scope

Like accounting systems, indicators are defined by system boundaries. These boundaries determine the *content* as well as the *scope* of the flow or stock represented by an indicator. The demarcation of indicators within accounting frameworks has the advantage of transparency. Accounting identities explicitly exhibit the boundaries of indicators embedded in the accounts. In other words, the common sense behind the accounts and indicators are simultaneously revealed.
A sound comparison of environmental and economic indicators requires consistency in both sets of measures. This is not straightforward. National pollution estimates usually rely on emission inventories that are bounded by territorial principles. The economic indicators in the national accounts are based on the *resident* principle, *i.e.* all agents that take part of an economy of a specified region or country. This difference in scope, which may disturb a consistent comparison of economic growth (*i.e.* the volume increase in GDP) with periodic changes in pollution, is further discussed and illustrated in the following section.

As already mentioned, the Ecological Footprint reflects the total space requirements of consumption. However, the aggregation of space is not based on the summation of factually observed space requirements. Instead the indicator projects the total amount of space required to permanently sustain a certain consumption pattern. As such, the Ecological Footprint tries to answer a rather hypothetical question: "What would be the total amount of space required to permanently sustain a certain consumption pattern?" [8] This question implies a hypothetical imputation of land requirements. For example, the total Ecological Footprint of the world will exceed the world surface at the moment that worldwide consumption reaches unsustainable levels.
Both examples illustrate that a sound indicator interpretation requires a transparent representation of its system boundaries.

3.5 Additivity inconsistency

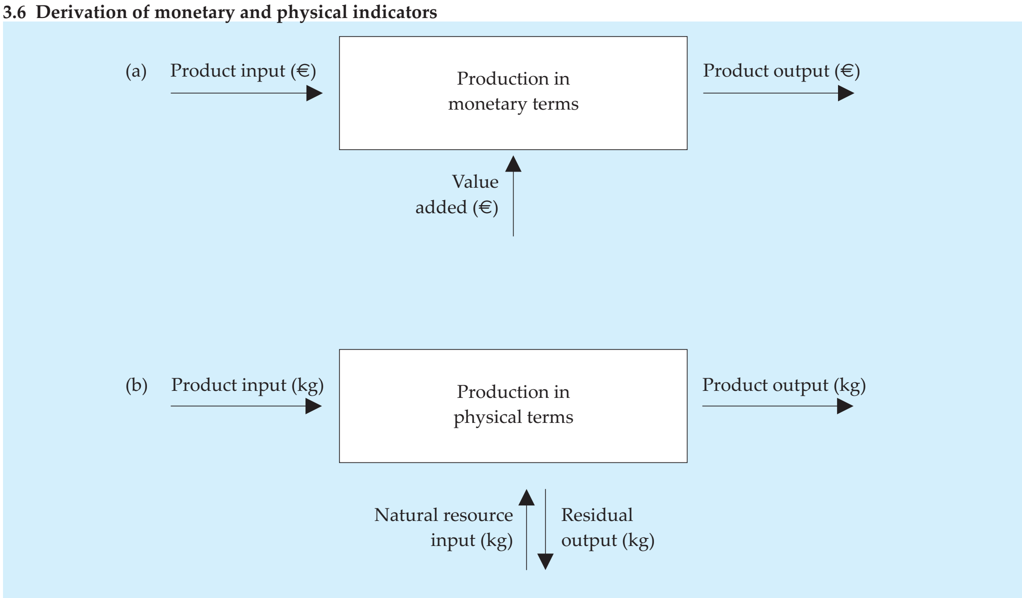


Another important characteristic of indicators is their *additivity*. Additivity contributes to the consistent summation of indicators over time and space. Additivity problems are illustrated by the Direct Material Input indicator as introduced by Adriaanse *et al.* (1997). As earlier mentioned, this indicator sums up all material inputs of an economy. [9] Figure 3.5 represents a world divided by two countries *A* and *B*. This figure shows that adding up the Direct Material Inputs over countries *A* and *B* leads to double counting since the mutual import flows should be refrained from the 'worldwide' Direct Material Input. As such, this indicator is wrongly recommended as an indicator that ". . . complements monetary measures of a nation's economic activity such as GDP", (Adriaanse *et al.*, 1997, p.8) since gross domestic product consistently adds up over different countries. This problem is also acknowledged in the Eurostat methodological guide (2001b, ch.4).

The key goal of combined monetary and physical flow accounting is obviously integrated environmental-economic performance monitoring. One of the main key policy questions underlying this performance monitoring concerns the extent to which economic growth may coincide with reducing levels of environmental deterioration. The national accounts provide in this context at the macro and meso level several relevant economic growth measures, *e.g.* gross or net domestic product, value added at industry level and household consumption expenditure preferable with a breakdown to household activities.

National accounts oriented physical flow accounts supplement these mainstream economic measures with their corresponding physical counterparts. The Journal of Industrial Ecology has published a range of articles discussing the kind of indicators that should be used to show trends in de- or re-materialization (*cf.* Reijnders, 1998, Cleveland & Ruth, 1999, Lifset, 2000 and Klein, 2001). In many cases, trends in dematerialization have been analysed on the basis of material throughput indicators. A repeating point of criticism found with these indicators is the indistinctness of the environmental threats they are supposed to represent. This is especially the case when using indicators addressing bulk material throughputs in the economic system. Cleveland & Ruth (1999, p.41) refer to various authors who use material input measures as proxies for environmental impacts, assuming that " . . . a decrease in the amount of material – measured in tons – that is extracted, fabricated and consumed will decrease the amount of waste material released to the environment".

3.6 Derivation of monetary and physical indicators



Especially on higher levels of aggregation, material throughput measures inevitably suffer from double counting. It is because of this reason that in national accounting, aggregated figures like total output (*i.e.* the sum value of production in the domestic economy) and intermediate consumption (*i.e.* the sum value of all goods and services used in the course of production) are equally of limited economic relevance. They do not serve as meaningful economic indicators. It is the *balance* between output and intermediate consumption that determines the value added of individual production activities. The total sum of value added equals to gross domestic product, one of the main indicators included in the SNA.

In a similar way, indicators can be derived from system of physical flow accounts. The value added of an economic activity is determined by the value of product outputs minus the value of product inputs. Similarly, the difference between the total product outflow and product inflow in mass terms equals the balance of natural resource extraction and residual disposals. This analogy is shown in figure 3.6. This figure shows that the meaningful indicators physical flow accounts should put forward are either addressing natural resource inputs directly withdrawn from the natural environment or the direct residual outputs. Both types of material exchanges ultimately determine the state of the natural environment.

This does certainly not imply that material throughputs are irrelevant. Product flows within the economic system determine the product chains in an economy. As already mentioned, these chains logically connect natural resource inputs to residual outputs that occur at different stages in the production-consumption system.

In conclusion, the leading principles of the indicators embedded in the physical flow accounts of the NAMEA are the following:

- They are descriptive in nature and based on the direct recording principle;
- They address those physical flows that are particularly relevant from an environmental perspective and may also address environmental requirements unrelated to physical flows *e.g.* noise, space, radiation;
- They are consistently connected to the production and consumption activities of an economy as defined within the national accounts. In this way, the accounts provide a consistent basis for comparable environmental and economic indicators;
- They are additive;
- With respect to the indicator scope, they address either natural resource inputs or residual outputs but not throughputs or product flows.

3.4 The role of the national accounts

3.4.1 Introduction

This section discusses the structuring of physical flow accounts according to national accounting principles. The former section already addressed the use of input-output tables and supply-use tables in physical flow accounting. These tables are a well established part of the SNA framework. This section discusses how national accounts definitions help to define the e*conomic sphere* and the *national* economy. Both concepts play an important role in the construction of physical flow accounts based on national accounting conventions. Consistency between physical flow accounts and the national accounts guarantees not only a consistent comparison of environmental burdens to economic benefits (or environmental benefits to economic costs) but also a consistent demarcation of the environmental burdens of the economic systems of individual countries.

3.4.2 The economic sphere

The accounting schemes presented in the former section illustrate that a transparent and systematic description of all direct human interactions with the environment requires a subdivision between the *economic sphere* and the *environment*. The national accounts provide a coherent basis for such a separation.

From a national accounts perspective, the economic sphere is logically defined as all physical flows and stocks coinciding with commodity transactions and manmade or produced assets. The environment is logically defined as all other biotic and abiotic appearances that are outside the economic sphere. Produced assets (buildings, infrastructures, machinery equipment etc.) are part of the economic sphere while non-produced assets are considered elements of the environment.

Intuitively, a separation between the natural environmental and the economic sphere may seem artificial. From a spatial perspective it is clearly impossible to divide the world into an economic sphere and the environment since both are spatially entwined. However, it is possible to divide up all physical and biotic transformation processes in this way. From a national accounting point of view, production and consumption processes are the two main processes that make up the economic sphere. All other physical and biotic processes are supposed to be part of the natural environment.

The demarcation between the economic sphere and the environmental is accompanied by the following sub-categorisation of material and energy flows connected to consumption and production.

Products refer to material flows within the economic sphere. Products are the output of production as defined in the SNA-1993 (*cf.* §2.49). Products are exchanged and consumed. It should be noticed that the Central Product Classification (CPC) has primarily been developed for economic analysis and that supplementary classifications may be required in relation to the physical and environmental characteristics of product flows.

Natural resources (renewable and non-renewable) refer to the full set of physical inputs directly withdrawn from the natural environment. At the moment raw materials, extracted from nature, are sold on markets, they have entered the economic sphere as products in the same way as processed resources or other products. Natural resources may include a wide range of material inputs varying from mineral deposits to the nitrogen or oxygen inputs in combustion processes. [10)]Principally, a natural resource input may or may not coincide with the depletion of a scarce natural resource.

Residuals refer to the total set of unwanted outputs from production and consumption processes. Residual outputs differ from product outputs since they omit market values. Products become residuals at the moment they loose their economic value. One could even argue that residuals have a negative price since often they bear removal or disposal costs. Residuals also include so-called 'dissipative' losses from car brakes and tyres, abrasions from roads, zinc from rain collection systems on roofs as well as 'deliberate disposals' of products *e.g.* fertilisers and pesticides in agricultural production.

Like products, residuals may be transferred within the economic sphere as a result of recycling or waste(water) collection and treatment activities. Waste treatment usually results in the replacement or transformation of residuals with the purpose of diminishing their environmental impacts. In cases were secondary outputs such as metal scrap are sold at significant prices, these outputs are classified as products (*cf.* CPC-39) and not as residuals. Those residuals that are not re-absorbed by the economic sphere will be transferred from the economic sphere back into the natural environment. This re-absorption of residuals also contributes to possible residual stock building within the economic sphere.

A strict demarcation between the environment and the economic sphere is often less easily made in the case of agricultural and forestry production. Agricultural and forestry production largely result from biological processes in direct interaction with the natural environment. From a material balance perspective, the material exchanges with the natural environment of agricultural production processes often exceed by far those inputs and outputs regulated by mankind. As a result, the recording of material exchanges in relation to agricultural should be established on practical grounds.

3.4.3 The national economy

The SNA demarcates the national economy from other economies, *i.e.* 'the rest of the world', by the following two concepts.

Economic territory

The SNA-1993 (§14.9) defines the economic territory of a country as "the geographical territory administered by a government within which persons, goods, and capital circulate freely. All land and structures within the economic territory is deemed to be sufficient in itself for the owner to have a centre of economic interest in that country".

In other words, the owner of land and structures on the economic territory is by definition regarded as a resident entity. Although, many environmental assets are not subject to ownership in the SNA sense, when they appear on economic territory, one could argue that these are subject to the management responsibility of resident units. The management of supra-territorial environmental assets or functions such as fish stocks in international waters, ozone layer and global climate regulation can only be subject to multilateral arrangements.

Resident criterion
The national economy is defined in terms of economic activities under the control of resident units. Units may include persons or groups of persons such as households, legal and social entities. A resident unit belongs to the national economy, in which it has a centre of economic interest, that is, "when it engages for an extended period (one year or more being taken as a practical guideline) in economic activities on this territory" (SNA-1993, §14.12). So, the concept of residence is not based on national or legal criteria.
Having a centre of interest does not mean that all economic activities of resident units will by definition be carried out on national territory. Certain production or consumption activities carried out by resident units, including their environmental consequences, may appear outside national territory. This is specifically relevant for (international) transportation and tourism. Both may contribute to the deterioration of the environment in foreign country area.
The economic territory provides the boundary for national environmental assets while the resident criterion provides the boundary for national economic activities and their environmental requirements. Both perspectives are presented in an interconnected way in table 3.1 by the recording of cross-boundary pollution flows. The table shows that these flows may create a substantial discrepancy between the caused and borne environmental burdens on a national level.

3.4.4 *The resident principle* [11)]

Data on air and water emissions and solid waste are often compiled by so-called emission or waste inventories. The classification of pollution sources applied in these inventories usually differs from those applied in the national accounts. At the same time, emission inventories often include emission sources within the boundaries of a specified region while a national accounts based demarcation of emission sources can only be established on the basis of the resident principle. As indicated before, this difference in scope results from the existence of internationally operating economic activities such as transport and tourism.
The national accounts follow clear guidelines on how costs and revenues should be allocated consistently to individual economies. The resident principle guarantees that macroeconomic indicators such as Domestic Product and National Income are comparable between countries and can be summated straightforwardly over countries. According to the SNA-1993 (*cf.* §14.25), internationally operating activities, *e.g.* shipping, road and air transport, mineral exploitation, should be attributed to the economy of residence of the operator. This accounting principle is equally useful in the recording of pollution or waste generated by an economy.

However, the resident principle is not always followed in the international guidelines on pollution statistics.
For example, the International Panel on Climate Change (IPCC, 1995) provides instructions for the determination and reporting of greenhouse gas emissions by individual countries. These emission data are subsequently used in the international co-ordination of climate policies. According to these IPPC regulations, bunkering, or the fuel inputs of international aviation and shipping, must be separately reported from other fuel consumption in a country. As a result, the emissions from international transport are not subject to the emission reduction agreements as laid down in the Kyoto protocol. In case of the Netherlands, this concerns a substantial share in the total greenhouse gas pollution. In 1998, from a total of 203 billion kilogram of carbon dioxide (CO_2), approximately 28 billion kilogram was emitted outside the borders of the Netherlands. Another disadvantage of the IPCC-regulation is obviously its incomparability to macroeconomic indicators like Gross Domestic Product and employment.
In the Netherlands, a number of different definitions are applied to carbon dioxide emission estimates as monitored and reported by Statistics Netherlands (2000) and the Government Institute for the Environment and Public Health (RIVM, 1999). These deviations are completely resulting from differences in definitions and do not result from discrepancies in statistical observation. These differences in definitions are further illustrated below including their specific purposes and (dis)advantages.

Table 3.2
Differences in carbon dioxide (CO_2) emission totals in the Netherlands

		1995	1996	1997	1998	1997	1998
		billion kg				*%-annnual change*	
1.	Total, IPCC (Kyoto-protocol)	177	185	183	183	–0,8	–0,6
2.	Temperature correction	3	–5	3	3		
3.	Total, Environmental report (RIVM) = 1 + 2	180	180	186	186	2,8	0,2
4.	Emissions connected to short term carbon cycles	4	5	4	4		
5.	Statistical differences and adjustments for mobile sources	2	3	6	4		
6.	Potential CO_2 (-)	3	3	2	3		
7.	Total emissions in the Nederlands (CBS) = 3 – 2 + 4 – 5 – 6	177	184	179	181	–2,6	0,7
8.	Residents in the rest of the world	23	23	25	26		
9.	Non-residents in the Netherlands	4	3	3	3		
10.	Total emissions by residents, NAMEA (CBS) = 7 + 8 – 9	196	204	201	203	–1,8	1,2

Data in this table are based on the Emission Register 1999.
Change rates cannot always be derived from the presented data due to rounding.

Source: De Haan & Verduin (2000).

Table 3.2 provides an overview of a number of different carbon dioxide estimates for the Netherlands in the period 1995–1998. The first one refers to the IPCC estimate, the second one refers to the total carbon dioxide emission as presented in the annual environmental reports of the RIVM (1999) and the third contains the actual emissions as published in the national accounts of the Netherlands (Statistics Netherlands, 2000). The CBS emission figures refer to emissions generated on Dutch territory and the emissions generated by Dutch residents. Only the latter is directly comparable to the macroeconomic indicators as defined in the national accounts.
As already mentioned, the emission reductions agreed upon in Kyoto are based on IPCC regulations concerning the reporting of greenhouse gas emissions. The short-term circulation of carbon, such as the combustion of wood and biochemical processes, is not taken into account since theses cycles are not supposed to lead to a structural increase in greenhouse gas concentrations in the atmosphere. Pollution generation by traffic is calculated on the basis of domestic fuel purchases, disregarding the nationality of the user or the location of the actual use and the corresponding emissions of pollutants. Besides, bunkering is reported separately. Together with the estimates of individual countries, this bunkering provides a global wide coverage of carbon dioxide emissions. However, the Kyoto agreements only refer to the emission totals of individual countries excluding international bunkering.
Probably the most important advantage of the IPCC definition is its rather straightforward application to particular countries or regions. Although individual countries are obliged to report on the international bunkers, a disadvantage of the IPCC regulation is undoubtedly that these corresponding emissions are not attributed to individual countries and are excluded from their Kyoto targets.
The carbon dioxide emission figure annually published by the RIVM (1999) corresponds to the IPCC total, adjusted for changes in the average temperature in one year to another. In this way, the consumption of fuel is adjusted for a relatively cold or a warm winter in order to reveal structural developments in greenhouse gas emissions. Similarly to the IPCC, the RIVM figure does not include special arrangements for the international bunkers.
Statistics Netherlands publishes annually the *actual* emission of carbon dioxide. Moving away from IPCC regulations, the actual emissions from traffic and other mobile sources are recorded regardless the location of fuel purchases. Also, no corrections are made for annual changes in temperatures. When, on average, a year with high temperatures is followed by a year with low temperatures, the actual emission (as well as the IPCC) figure shows a decline while the RIVM estimate may show an increase. This is illustrated in Table 3.2 by the differences in annual change rates for 1997.
Besides the actual emissions on Dutch territory, the estimates of Statistics Netherlands also include those presented in the NAMEA. The total difference in pollution generated on Dutch territory and emissions caused by all activities that belong to the Dutch economy is determined by pollution caused by residents in the

rest of the world (row 8 in table 3.2) minus pollution caused by non-residents in the Netherlands (9). The table shows that, on balance, the national accounts based estimate is 19 to 23 kiloton higher than the territorial based estimate.
The estimation of pollution according to the resident principle as applied in the NAMEA has at least two advantages. Firstly, this estimate results in an exhaustive world-wide emission total that can be completely allocated to (the economies of) individual countries, taking fully into account emissions from international transport. The carbon dioxide emission of residential transport activities is remarkably higher than the emission of these type of activities on Dutch territory. In 1998, approximately 13% of all carbon dioxide emissions where generated outside the borders of the Netherlands. The greater part of this cross-boundary pollution was caused by aviation and shipping. With respect to aviation, the emission on Dutch territory only includes landing and take-off cycles. Yet, most pollution is generated during the cruise of the flight. A similar situation exists in the case of international shipping where only small amounts of the total pollution are generated on domestic territory.
A second advantage of the resident criterion is the consistent comparability of the environmental and economic performance of countries also on the level of various production and consumption activities in an economy. This comparison is further discussed in subsequent chapters.

3.5 *Conclusions*

Physical flow accounting is an rudimentary step in understanding the inter-relationships between the natural environment and the economic system. Yet, it must be acknowledged that some environmental requirements are unrelated to physical environmental-economic exchanges. This chapter shows that various accounting frameworks can be applied. The three frameworks presented here are quite complementary in scope. This is also very well illustrated by chapter 3 of the SEEA-2003 handbook on environmental accounting. Controversies in physical flow accounting arise together with the indicators that have been put forward. In attempts to arrive at aggregated figures, disputable weighting methods are being applied together with inconsistencies in indicator scope. Physical flow accounting should acknowledge the fact that physical flows are connected to a variety of different environmental problems. Aggregation over environmental problems can only be based on welfare theoretic grounds. In chapter 2 it was explained that such an evaluation easily surpasses the scope of accounting as considered here.
This chapter illustrates the benefits of physical flow accounting according to national accounts principles. Firstly, national accounts guidelines contribute to a sound attribution of pollution to individual economies. Secondly, this delineation contributes to a sound comparability of national accounts indicators and environmental pressure indicators. The representation of physical flow accounts in

a national accounts framework illustrates the economic relevance and dependencies on material exchanges. The NAMEA systematically records physical flows in connection to economic transactions as presented in the national accounts. This linkage guarantees a consistent comparison of environmental burdens to economic benefits, or environmental benefits to economic costs. The characteristics and benefits of the NAMEA as a comprehensive accounting framework that aims at measuring environmental-economic performance on the meso and macro level are illustrated in subsequent chapters.

Notes

1) The mapping and analysis of industrial metabolism processes is the main subject of the Journal of Industrial Ecology.

2) In the national accounts, most indicators are embedded as balancing items in the sequence of accounts. The presentation of balancing items in the accounts is discussed in chapter 4.

3) Almost two centuries before, Malthus and Ricardo already addressed the possible restrictions imposed by nature on the economic system. In the twentieth century it was especially Meadows *et al*. (1973) who advocated that the absolute limits to crucial environmental resource stocks would eventually put a stop to economic expansion.

4) The adjective 'hybrid' is also being used in connection to those input-output tables in which one group of commodities, representing specific material flows such as energy, steel or plastics, is denominated in physical units while all other commodities are accounted for in money units. This type of hybrid input-output tables is for example discussed by Miller & Blair (1985, chapter 6) in the context of energy input-output analysis and in as well as in chapter 6 of this thesis.

5) One of the key issues in compiling square input-output matrices is the distribution of joined inputs to product outputs in cases of multiple product outputs.

6) Figure 1.1 in the 1999 Eurostat NAMEA publication shows many similarities with the table 4 of Victor (1972).

7) A rather complete overview of these accounting approaches is for example given by Daniels (2002).

8) In fact, the Ecological Footprint should be carried out on the basis of a reverse optimisation as conducted by De Boer *et al.* (1994) in answering the question: "What would have been GDP in a sustainable environment?" Given that the sustainable limits to the environment could be fully (and meaningfully) expressed in terms of land use requirements, the Ecological Footprint should minimise the total land required to sustain at least consumption level c_o. Reformulated in terms of a footprint indicator, De Boer *et al.* maximises consumption (≈GDP) subject to the restriction that land use will not exceed a sustainable level p_o. Instead of land use, De Boer *et al.* use a range of environmental pressure indicators and related policy standards.

[9] The Total Material Requirement indicator introduced by Adriaanse *et al*. (1997) includes in addition to the Direct Material Input indicator the hidden flows resulting from excavation and ore processing in mining operations and soil erosion in agriculture.

[10] The SEEA-2003 labels this latter group as 'ecosystem' inputs.

[11] This paragraph is based on De Haan & Verduin (2000).

Chapter 4. Origin of the NAMEA

4.1 Introduction

This chapter discusses the development of the National Accounting Matrix including Environmental Accounts (NAMEA), starting with its conceptual design by De Boo *et al*. (1991) and Keuning (1993), and ending with the main characteristics of its current presence. While several features of its first design changed in the course of its implementation, the essence of the NAMEA approach did not change. The NAMEA has been developed to systematically supplement the national accounts with environmental statistics. Its hybrid accounting structure, *i.e.* the combined presentation of physical and monetary accounts, indicates that in the NAMEA environmental imputations in the core national accounts framework are avoided. Money (e)valuation of environmental damages, including the calculation of shadow prices, is explicitly considered as one out of several analytical applications of the NAMEA.

This chapter also compares the first NAMEA design with the interim version of the System of Environmental and Economic Accounts (SEEA-1993) published by the United Nations (1993). Both frameworks were developed in the beginning of the nineties and have served widely as reference accounting models. Their conceptual designs were much broader than their applications up to date. For example, both systems were developed with the intention to provide (complete) descriptions of the changes in environmental assets resulting from human action. Obviously, it is quite useful to evaluate how more than ten years of accounting practice has tested the validity of these, and other, features of both systems.

An illustrative impression is given by the revised SEEA-2003. One of the main goals of the SEEA update is to provide a comprehensive reflection of present environmental accounting practises. As such, it is not surprising that the SEEA-2003 contains a somewhat looser representation of various accounting modules compared to its predecessor by putting much less emphasis on an integrated representation of all environmental phenomena in one single accounting body.

The NAMEA is presented in a matrix format that follows Keuning's (1991) design of a National Accounting Matrix (NAM) that corresponds to the basic concepts of the SNA-1993. A National Accounting Matrix (NAM) reconciles two important subsystems of the SNA, *i.e.* the supply-use tables and the institutional sector accounts, into one accounting body. Matrix representations of the national accounts are found in the SNA-1993, the ESA-95 and the SEEA-2003. Before, discussing the main features of the NAMEA, the main features of the NAM are discussed first.

Also, this chapter briefly discusses linkages to social accounting and the combined use of NAMEAs and Social Accounting Matrices (SAMs) in this context. The SAM extends the NAM with more detailed statistics on the compensation of employees, classified by the type of employees (*e.g.* gender, educational attainment) and income distribution related transactions at the level of different household groups. [1)]

4.2 *The National Accounting Matrix (NAM)*

4.2.1 Supply-use and institutional sector accounts

The SNA-1993 basically consists of two supplementary accounting frameworks: the institutional sector accounts (including the balance sheet) and the supply and use tables.

In the national accounts, institutional sectors are used for the classification of so-called institutional units. Institutional units are supposed to be capable of conducting all sorts of transactions, owning (financial) assets and incurring liabilities. In other words, for an institutional unit, it is principally feasible and meaningful, both from an economic and legal viewpoint, to compile a complete set of accounts (*cf*. SNA-1993, §4.3). The five main institutional sectors the SNA distinguishes are:

– non-financial corporations;
– financial corporations;
– general government;
– non-profit institutions serving households;
– households.

The institutional sector accounts provide a complete picture of all sorts of transactions in the economy, *i.e.* production, income generation, income distribution, consumption, capital and financial transactions. Capital and financial transactions are presented in the so-called accumulation accounts. These accounts are concerned with the recording of changes in the value of financial and non-financial assets and changes in liabilities.

Finally, the balance sheet measures the total value of assets and liabilities of all resident institutional units. The total value of assets minus liabilities equals to the 'net worth', *i.e.* the total wealth of an institutional unit, sector or the total economy at a certain point in time. The current accounts logically explain all changes in assets and liabilities in the accounting period as reflected by the differences in the opening and closing balance sheets.

It may be useful to describe institutional units in their role of producers by way of smaller more homogenous units, the so-called establishments. Single, especially large, corporations may be engaged simultaneously in various kinds of productive activities. The nature of these activities may be quite relevant from various analytical points of view, for example in relation to employment issues, productivity analysis and environmental concerns. The main characteristics to classify establishments are summed up in §5.4 of the SNA-1993:

– type of goods and services produced as output;
– type of inputs used or consumed;
– technique of production employed;
– ways in which the outputs are used.

The main selection criterion underlying the International Standard Industrial Classification of All Economic Activities (ISIC, Rev.3) is the nature of the principle product output of establishments. Although establishments are independently operating production units, from other, *e.g.* a legal or financial point of view, they are an indissoluble part of the corporation, institution or household to which they belong.

The SNA-1993 introduces the supply-use tables and input-output tables to facilitate the economy-wide analysis of product transactions and production processes. The SNA-1993 recommends that supply-use tables are the principal accounts from which the more analytically oriented input-output tables are being derived. [2)] In most countries, supply-use tables also serve as the co-ordinating framework for consistency checking and the subsequent balancing of *e.g.* industrial surveys, labour surveys, household budget surveys and foreign trade statistics.

A fundamental part of the supply-use tables is the goods and services account, *i.e.* the *row entries* in these tables. The Central Product Classification is recommended by the SNA-1993 for the classification of product groups presented in the goods and services account. As discussed in chapter 3, the supply-use identity (3.2) in these tables, identifies that, for each product group represented in the rows, domestic output plus import, *i.e.* the row totals in the supply table, equals by definition the sum of intermediate consumption of industries, final consumption of households and government, export, fixed capital formation and inventory changes, *i.e.* the row totals in the use table.

Establishments, grouped by industry branch, are represented as *column entries* in the supply-use tables, as the (domestic) suppliers and (intermediate) consumers of products in the supply and use tables respectively. At the industry level, the balance between product supply and intermediate consumption is made up by (gross) value added. As a result, for each industry, total output or product supply equals by definition the sum of all uses, *i.e.* intermediate consumption plus gross value added. This equality represents the input-output or column identity in the supply-use system.

The use table includes row entries representing the value added by industry. The value added sub-matrix in the use table has a breakdown of transactions as presented in the income generation account:
– compensation of employees;
– taxes less subsidies on production;
– consumption of fixed capital;
– net operating surplus.

4.2.2 *Main properties of the NAM*

The NAM reconciles the supply-use tables (or input-output tables) with the institutional sector accounts. While the supply-use tables provide in detail information on product transactions between industries and final demand categories, *e.g.* consumption, capital formation export, other types of transactions are represented at the level of institutional sectors. In other words, the NAM introduces to most appropriate units, establishments versus institutional units, at different stages in the sequence of accounts.

Supply-use matrices do not show how generated income, *e.g.* wages, profits, interest payments, dividends, is distributed to the various agents in the economy. Also, supply-use tables do not show how these agents subsequently expend their received income. This is why supply-use or input-output models are sometimes referred to as 'open models'. Contrary to open models and concomitant accounting frameworks, the NAM provides an interconnected picture of the so-called 'circular flow of income' by the simultaneous recording of production, income generation, income distribution and income expenditure in an economy. The capital account in the NAM connects saving, or that part of current income that is not consumed, to the (net) capital formation and inventory changes. In other words, in a closed economy without interactions with the rest of the world, income received is *ex-post* by definition equal to income expensed.

Each account in the NAM is represented by a row and a corresponding column in the matrix. The row entries of an account represents the resources side (*i.e.* receipts) of the account, the column represents the uses (*i.e.* outlays). The consistency of each account, *i.e.* 'resources = uses', is indicated by the identical corresponding row and column sums in the NAM.

Each entry or cell in the NAM automatically relates outlays to receipts. This is not necessarily the case in a system of institution sector accounts as represented by the traditional 'T-accounts'. T-accounts systematically sum-up all resources and uses at the level of individual institutional sectors. Yet, T-accounts do not necessarily match the outlay of one unit to the corresponding receipt of another unit. This is typically established in an accounting matrix in which each entry identifies simultaneously the paying and receiving party of a transaction or groupings of transactions.

Similarly to the regular T-accounts set-up, in most accounts the total difference between resources and uses is reflected by a closing balancing item presented at the uses side of the account, *i.e.* as a column entry. The subsequent account in the system is opened with this balancing item on the resources side, *i.e.* as a row entry. The balancing items in the NAM link-up the sequence of accounts by their single-entry recording as a use in the column and as a resource in the row of the subsequent account.

This interconnected representation of transactions and balancing items makes the NAM quite useful for macroeconomic modelling purposes. This is one of the reasons why SAMs, which are based on a national accounts matrix presentation, have been developed in the first place (*cf.* Pyatt & Round, 1977). There are several other properties of the NAM that support certain analytical uses of national accounting statistics, specifically in relation to satellite accounting: [3)]

- An aggregate NAM provides a 'bird's eye view' on the national accounts including a sequential overview of balancing items *e.g.* domestic product, national income, disposable income, savings. Each entry in the aggregate matrix represents the grand total of the underlying sub-matrix, showing the different transactors or transaction types involved.
- The national accounts system is principally a three dimensional information system. The accounts simultaneously distinguish the paying actor, the receiving actor and the nature of all transactions included.4) The NAM, as well as the regular T-accounts, are necessarily two-dimensional reflections of a three-dimensional information system. Yet, the NAM is flexible in the combination of classifications it may adopt *i.e.*:
  - receiving actor × transaction type;
  - transaction type × paying actor;
  - receiving actor × paying actor.

  Clearly, in a two-dimensional table, a selection of two dimensions in one account automatically excludes the presentation of a third dimension. This restriction can be bypassed by introducing in the matrix separate accounts for specific types of transactions. In the Dutch NAMEA, presented in chapter 5, all (environmental) taxes and subsidies are separately presented in one specific taxes and subsidies account. In this way, this transaction type is explicitly represented in the accounting matrix. However, this recording diverges from standard national accounting practice and may affect the balancing items in the system.
- The NAM allows for using different (combinations of) classifications at various stages in the sequence of accounts. As mentioned, the production account may be shown in terms of product groups and industries while income distribution transactions are shown at the level of institutional sectors. The level of detail may also vary, for example in accordance with the level of detail at which (reliable) information for each of these accounts can be provided.
- The NAM is especially successful in representing certain phenomena in the context of the entire economic system.

In conclusion, several properties of the NAM make this representation format useful for satellite accounting purposes. The NAM is most suitably applied in those satellite accounts for which it is important to maintain a full overview of the economic system. Clearly, there are several satellite accounts imaginable for which partial expansions or adjustments in the national accounts are sufficient to meet certain analytical requirements. Partial systems often have the convenience of simplicity. In the context of satellite accounting, the NAM framework forces to take into consideration the system wide consequences of all changes in accounting conventions one wishes to make.

The following subsection discusses the accounts of the NAM on the basis of a bird eye's view: an aggregate NAM for the Netherlands in 1997. This matrix largely follows the SNA-1993 accounting conventions. The next chapter discusses the modifications needed to expand the NAM to a NAMEA. Both tables 4.1 and 5.1 in this thesis are derived from the definitive 1997 national accounts estimates (*cf*. Statistics Netherlands, 2000).

4.2.3 *An overview of a NAM for the Netherlands*

Table 4.1 shows an aggregate NAM for the Netherlands in 1997. Each entry in the table is denominated in million guilders. Each account in the table provides the aggregate for the total economy. More detail can be provided according to the classifications indicated between brackets, *i.e.* product groups, industries, institutional sectors and financial assets. Cells containing balancing items are shown in grey.

Table 4.1
An aggregate NAM (in million guilders), 1997

ACCOUNT *(classification)*		Goods and services *(product-groups)*	Production *(industries)*	Generation of of income *(value added categories)*	Allocation of primary income *(sectors)*
		1	2	3	4
Goods and services *(product groups)*	1	Trade and transport margins –	Intermediate consumption 706 672		
Production *(industries)*	2	Output at basic prices 1 364 227			
Generation of income *(value added categories)*	3		Net value added at basic prices 547 733	VAT not handed over to the government 1 354	
Allocation of primary income *(sectors)*	4	Taxes less subsidies on products 71 538		Net national generated income at basic prices 548 803	Property income 236 095
Secondary distribution of income *(sectors)*	5				Net national income at market prices 633 843
Use of disposable income *(sectors)*	6				
Capital *(sectors)*	7		Consumption of fixed capital 109 822		
Financial *(financial assets)*	8				
Rest of the world, current	9	Imports (cif) and taxes less subsidies on products to r.o.w 411 322		Compensation of employees and other taxes less subsidies on production to r.o.w. 217	Property income to r.o.w. 65 183
Rest of the world, capital	10				
TOTAL		1 847 087	1 364 227	550 374	935 121

* Including statistical differences.

Source: Statistics Netherlands (2000).

The first account in table 4.1 shows the supply (column 1) and use (row 1) of goods and services in the economy. Products sales and product purchases, measured at purchasers' prices, are equal by definition and this is reflected by equal row and column totals (total product supply and use equals 1,847,087 million guilders). The total supply of goods and services in the economy consists of domestic output (cell 2,1) and imports (9,1). The underlying sub-matrices of both cells represent together the (transformed) supply table, *i.e.* the total commodity supply by domestic industries and the rest of the world. The total use of goods and services consists of intermediate consumption, final consumption, gross fixed capital formation, changes in inventories and exports. Output is recorded in basic prices while all uses are recorded in purchasers' prices. Differences between total supply in basic prices and total use in purchasers' prices are made up by trade and transport margins (1,1) and taxes less subsidies on products (4,1). Cell (1,1) is empty by definition since the

	Secondary distribution of income *(sectors)*	Use of disposable income *(sectors)*	Capital *(sectors)*	Financial *(financial assets)*	Rest of the world, current	Rest of the world, capital	TOTAL
	5	6	7	8	9	10	
		Final consumption 532 009	Gross capital formation and inventory changes 158 514		Exports (fob) 449 892		1 847 087
							1 364 227
					Compensation of employees from r.o.w. 1 287		550 374
			VAT on land 1 297		Property income 77 388		935 121
	Current transfers 627 508				Current transfers from r.o.w. 8 031		1 269 382
	Net disposable income 627 605						627 605
		Net saving 95 595		Net incurrence of liabilities* 406 740		Capital transfers from r.o.w. 2 427	614 584
			Net acquisition of financial assets 449 180			Net lending of the r.o.w. –42 440	406 740
	Current transfers ro r.o.w. 14 270						490 992
			Capital transfers to r.o.w. 5 593		Current external balance –45 606		–40 013
	1 269 382	627 604	614 584	406 740	490 992	–40 013	

underlying sub-matrix shows the reallocation of trade and transport margins from their producers (–) to the products to which these margins are related (+).
Account 2 represents the production account at the level of industry branches. The account defines the balancing item net value added (3,2) as the difference between domestic output on the one hand and intermediate consumption plus consumption of fixed capital on the other hand. Net value added is presented in the income generation account, classified by value added categories *i.e.* compensation of employees, net operating surplus and other taxes less subsidies on production. Consumption of fixed capital is directly presented in the row of the capital account (7,2).
Account 3 is also used for the recording of compensation of employees paid to (9,3), and received from (3,9), the rest of the word. Cell (9,3) also includes other taxes less subsidies on production paid to the rest of the world. As a consequence, the generation of income account is closed by a balancing item that is, strictly speaking, not found in the standard system of national accounts: 'net national generated income'. This balancing item contains total income earned by resident institutional units as a result of being engaged in production (*cf.* SNA-1993, §20.55). Net national generated income is the intermediate balancing item that emerges logically from the reconciliation of the supply-use tables and institutional sector accounts in a NAM or SAM.
The allocation of primary income account (4) opens with net generated income and subsequently records all property income transfers between institutional sectors (4,4) including property income received from (4,9), and paid to (9,4), the rest of the world. Property income consists of interest, distributed income of corporations (*e.g.* dividends) and rents. Net generated income at basic prices plus taxes less subsidies on production plus property income received minus property income paid results in 'net national income at market prices'.
The secondary distribution of income account (5) adds to national income at market prices the balance of income transfers received and paid. This account also records income transfers paid to (9,5), and received from (5,9), the rest of the world. This subsequently results in the balancing item 'net disposable income' (6,5). Income transfers exist of taxes on income and wealth, social contributions and benefits and other current transfers. The use of disposable income account (6) subsequently defines 'net saving' (7,6) as the difference between disposable income and final consumption (1,6).
The financial accounts (8) in the NAM, classified according to financial asset types, determines 'net lending of the rest of the world' to the domestic economy. Net lending is the balance between the net acquisition of financial assets minus the net incurrence of liabilities. In the case of the Netherlands, this balancing item is negative, indicating a net borrowing of all Dutch residents to the rest of the world.
The rest of the world account in the NAM consists of a current (9) and a capital account (10). Both accounts omit a further breakdown. This account is used in the NAM to show, for of the (other) accounts (1-8), the transactions of resident entities

with the rest of the world, *e.g.* commodity transactions, wages, property income, income transfers, capital transfers. The current rest of the world account balances all current receipts (row 9) with current outlays (column 9). The negative sign of the 'current external balance' indicates a deficit from the perspective of the rest of the world and a surplus from the perspective of the Netherlands. Finally, the rest of the world capital account records, in addition to the current account surplus, the capital transfers going to (10,7), and received from (7,10), the rest of the world. These may for example exist of capital taxes and investment grants. The resulting balancing item that emerges in conjunction with the financial account, is 'net lending to the rest of the world'.

4.2.4 *The use of the NAM in environmental accounting*

In conclusion, the NAM provides a complete and coherent picture of the economy. It allows for flexibility in the level of detail at which various parts of the accounts are presented and also for the introduction of various sets of classifications at different places in the system without loosing its internal consistency. The NAM also helps to identify, or to single out, specific transaction types or economic activities, that are of particular analytical interest, in connection to the other economic transactions or activities represented in the system.

The expansion of a NAM into a SAM illustrates how the analytical capacity of the national accounts is enhanced in the direction of (un)employment and income distribution related issues. Keuning (1996) illustrates that such an expansion is not necessarily restricted to adding more detail but may also comprise a range of supplementary tables leading to what he calls a 'System of Economic and Social Accounting Matrices and Extensions' (SESAME). This system contains, in addition to a SAM, various sets of non-monetary data, covering for example information on the size and composition of the population, household groups and the labour force. As the founding father of Social Accounting Matrices, Stone has done a lot of pioneering work in this field, resulting for example in a national accounts linked System of Social and Demographic Statistics (United Nations, 1975).

Similarly, the NAM may also be used as the principal framework for a system integrated environmental-economic accounts, leading to the NAMEA. Matrix presentations are also introduced in the SEEA-2003 (*cf*. table 6.8, Commission of the European Communities *et al*., 2003). The transformation of the NAM into a NAMEA basically contains two steps. Firstly, modifications in the ordering of transactions may help to identify those transactions or actors that are typically relevant from an environmental viewpoint. Examples in this context are the representation of household activities and related pollution, the explicit recording of environmental protection expenditure and environmental taxes and subsidies. Such modifications of the NAM are discussed in the subsequent chapter.

Secondly, the scope of the NAM is enhanced by additional accounts recording the environmental-economic relationships. Generally, these relationships are not subject to market transactions as presented in standard national accounting. The argumentation of such an extension is given in chapter 3. The systematic recording of (physical) economic-environmental interactions in connection to the national accounts leads a economy-wide environmental-economic performance monitoring system. This approach results to *supplementing* national accounts indicators such as domestic product, national income, government surplus/deficit, trade balance, with environmental performance indicators rather than the *modification* of national accounts based indicators.

As such, NAM(EA) based analysis may portray an economy-wide view on various integrated environmental-economic policy scenarios. Like SAMs, NAMEAs may be used as the underlying databases of macroeconomic models. One key necessity of such a database is its representation of the complete circular flow of income in the economy. These model outcomes are usually the projection of a NAMEA reflecting a hypothetical policy scenario. For example, comparative static analyses may indicate what gross domestic product and other national accounts indicators may look like when the policy targets for certain environmental pressures would be met. In the Netherlands, such NAMEA based models have for example been developed by De Boer *et al*. (1994), Komen (2000) and Verbruggen (2000). As discussed in chapter 2, the modelling of environmentally adjusted national income figures is referred to by O'Connor (2001) as the 'Greened Economy' gross domestic product approach. From an accounting point of view, this approach does not require the modification of national accounting conventions but instead a supplementary set of environmental accounts and indicators which facilitate their representation in macroeconomic models.

4.3 The NAMEA as introduced by De Boo et al.

The NAMEA, as firstly presented by De Boo *et al.* (1991), provides a pragmatic way to direct the national accounts towards environmental concerns. They sketch the conceptual design of a national accounts module that ". . . should provide information, step by step, on the human-induced flows of matter, species and energy (commodity flows), as well as on the resulting effects on the environment (changes in ecosystems), and on the nuisance experienced by the population, thus linking economy, environment and society" (De Boo *et al*., 1991, p.3). They advocate the NAMEA in its capacity to provide a complete and systematic account of all environmental changes caused by production and consumption processes in a way that is explicitly linked to the SNA framework.

The main objectives of the NAMEA as presented by De Boo *et al*. are ". . . to sketch the trade-offs between the objective of environmental sustainability and other macro-economic policy objectives." This led them ". . . to pay much attention to the *linkage* of indicators of environmental change no only to GDP-growth, but also to other important policy objectives like income distribution, balance of payments equilibrium etc." (p.4, emphasis on linkage added). They argue that the NAMEA should also provide basic material for designing performance indicators on the relationships between production and environment, addressing for example developments in energy or environmental efficiencies.

According to De Boo *et al*. the transformation of the NAM into a NAMEA contains the following steps:

– recording the environmental changes stemming from economic activities in the period of observation, encompassing the elements 'net pollution' and 'net depletion';
– recording the actual costs and benefits of environmental prevention and protection and the recording of non-restored damages.

Although no argumentation is given why, stock accounts are completely ignored. Chapter XX of the SNA-1993 (*cf.* table 20.7) shows that, conceptually, there is no restriction of representing balance sheets in a NAM framework.

The NAM used by De Boo *et al.* builds on the SNA-1993 and is a slightly extended version of the NAM presented in table 4.1. Their table has a complete set of accumulation accounts, including the 'other changes in assets' that are due neither to transactions between institutional units, as recorded in the capital and financial accounts, nor to holding gains and losses. Examples of other changes in assets are the natural growth of non-cultivated biological resources, depletion of natural assets and catastrophic losses. In this way, their NAM gives a full record of all changes in assets and liabilities.

De Boo *et al.* extend this NAM with two additional environmental accounts: one for the recording of environmental *agents* and another one for the recording of changes in environmental *assets*. The first account registers extractions and emissions of all kinds of agents from and to the environment. In other parts of this thesis, the more general name of 'environmental requirement' is used to indicate all sorts of environmental-economic dependencies. The environmental assets account is introduced to show the effects of resource depletion and pollution accumulation on environmental assets and ecosystems. As such, this account is meant to provide a general description of changes in the environmental state. Both accounts are expressed in non-monetary units. The other accounts in the NAMEA, represented by the NAM, are denominated in money terms.

The two environmental accounts in the NAMEA, as introduced by De Boo *et al*., are defined on the basis of the following accounting identities discussed in the following subsections.

4.3.1 *Agents account: the representation of natural resources*

The agents account presents the depletion of natural resources with the help of the following accounting identity (*cf*. p.21).

extraction + net losses due to natural causes = referable damage of owned assets due to environmental effects + net depletion of not owned environmental assets (4.1)

The extraction of natural resources is recorded at the intersection of the agents account with the production account. In this way, resource extractions are recorded in connection to the corresponding mining industries that are responsible for their extraction.

The 'net losses due to natural causes' include positive changes, for example the natural growth of non-cultivated biological resources, and negative changes apart from extractions such as catastrophic losses.

The representation of natural resources is somewhat being complicated by the fact that all changes in natural resources that are subject to ownership are already recorded in the other changes in (non-produced) assets account of the NAM. The entry 'referable damage of owned assets due to environmental effects' is used to account, in physical terms, for the environmental pressures leading to value losses of assets subject to ownership. This entry also includes in physical terms the extraction of natural resources. As a result, equation (4.1) includes two 'physical' depletion items: one for owned assets and another one for assets not subject to ownership. [5)]

The NAMEA presentation of the De Boo *et al.* records the depletion of natural assets subject to ownership twice: firstly, in the other changes in assets account in money terms and secondly, in the environmental agents account in physical terms. De Boo *et al.* show that this double recording is eliminated when the extraction of natural resources in the agents account is given a money value. In this way, depletion is no longer recorded as an other change in asset but instead as a cost of production. This alternative recording decreases all balancing items throughout the sequence of accounts, from 'value added' to 'changes in net worth do to saving and capital transfers'.

4.3.2 *Agents without a capital character*

Agents without a capital character or with non-recurrent repercussions do not accumulate but only have immediate impacts. Repercussions will stop at the moment the dispersion of these agents stops. Examples of such agents are the nuisance from stench and noise. In the first NAMEA design, these agents are presented according to the following accounting identity.

'free' emissions by production + 'free' emissions by consumption =
current consumption of pollutants (4.2)

With the prefix 'free' the authors indicate that the emissions are recorded without a money value. The non-recurrent effects of these emissions are recorded in terms of consumption of pollutants. As far as equation (4.2) refers to physical pollution, it must be notified that this equation does not follow the material balance principle. It is unlikely that all emissions with non-recurrent impacts are physically consumed by those affected. Instead, agents without a capital character enter the environment where they subsequently alter the environmental state on an impermanent basis.

As a result, equation (4.2) mixes up agent flows with their impacts. There is not necessarily a one-to-one relationship between the dispersion of these emissions and their nonrecurring impacts.
In physical terms, the recording of these agents could be rephrased as follows.

'free' emissions by production + 'free' emissions by consumption = dispersion of pollutants (or agents) without a capital character (4.2)

The common sense behind equation (4.2) is that these agents lead tot immediate welfare effects that negatively influence consumption as defined in an extended national accounting framework. In value terms, this recording is in line with the welfare extensions of the national accounts as discussed in chapter 2. However, an environmentally extended consumption concept is unavoidably tied to an extended income concept. In the NAMEA presentation of De Boo *et al.*, it remains unclear how the income of households is being adjusted by the immediate welfare effects of pollution without a capital character. As shown in subsection 4.3.4, they suggest such a symmetric adjustment of income and consumption when recording the repercussions from recurrent environmental degradation.

4.3.3 Agents with a capital character

Agents with a capital character accumulate in the environment with long lasting repercussions. These agents are also referred to as stock pollutants. Agents with a capital character are represented in the agents account on the basis of the following accounting identity.

'free' emissions by production + 'free' emissions by consumption + 'free' emissions from abroad = 'free' emissions to abroad + referable damage of owned assets due to environmental effects + immission into ecosystems (4.3)

This accounting identity is almost identical to identity (3.4) presented in chapter 3 and is used in the annually published Dutch NAMEA for those pollutants for which it is relevant to determine their accumulation on the domestic economic territory. There is however one exception: equation (4.3) also includes the entry 'referable damage of owned assets due to environmental effects' to reflect pollution related damages of assets that are included in the national accounts balance sheet. As already discussed, this item mixes up the recording of (physical) flows with their repercussions. Only for a restricted set of pollutants, it is meaningful to record the physical accumulation of agents in assets that are represented in the national accounts balance sheet. An example is the contamination of crops. In all other cases, effects will result via indirect cause-effect relationships which should be recorded as the consequential changes in ecosystems.

4.3.4 *National ecosystems*

In addition to an account for agents, the NAMEA presented by De Boo *et al*. also add to the NAM an environmental account for changes in environmental assets or national ecosystems that are not subject to ownership. The authors present the following accounting identity to structure this account (*cf.* p.22).

(–) current effects of past disposals + natural cleansing + (–) immission =
(–) current effects of past disposals + non-referable degradation + net depletion
+ (–) changes in worth of ecosystems (4.4)

Equation (4.4) mixes up three dimensions: the accumulation of physical flows in the natural environment, the concomitant changes in ecosystems and the repercussions that follow from ecosystem changes. The minus signs indicate a negative welfare effect.
Firstly, equation (4.4) represents the net depletion of (not owned) natural resources and the net accumulation of pollution. These items are denominated in the corresponding units as found in the agents account.
Secondly, the ecosystems account also present net depletion and net immission in terms of their effects on ecosystem assets. In case of natural resource depletion, this effect is simply a decline in the physical availability of the asset, most likely denominated in the same unit in which their extraction and (other) losses are recorded in the agents account.
In the case of degradation the relationship between pollution immission and asset degradation is less easily spelled out. The authors recommend a subdivision of the immision (agents × ecosystems) sub-matrix into cause and effect matrices. They acknowledge the complexities of monitoring the dispersion patterns of agents and their subsequent accumulation in various ecosystems. They also acknowledge the complexities of assigning the changes in ecosystems to the accumulation of individual agents.
Another complexity of this account, not mentioned by De Boo *et al*., is that certain ecosystems and related damages may exceed the borders of individual countries. For global warming or ozone layer depletion, it seems only feasible to account for the contributions to these global environmental problems of individual economies. The appearance of the concomitant environmental assets, *i.e.* global climate regulation and the ozone layer, in an national accounts balance sheet is simply infeasible.
Thirdly, the entries on 'current effects of past disposals' in equation (4.4) reflect the repercussions of environmental degradation to society.
In conclusion, equation (4.4) can be unravelled by the following two equations. With respect to changes in ecosystems, equation (4.4) encloses the following identity.

natural cleansing – (impacts of) immission – non-referable degradation – net depletion =
changes in worth of ecosystems (4.4')

Natural cleansing could encompass the biodegradability of agents in which case this entry would preferably be represented in the agents account, leading to a reduced immission total. In case natural cleansing addresses the (permanent) accumulation of pollutants below threshold levels or the natural recovery of ecosystems, it would probably be appropriate to introduce this item in identity (4.4'). It must be noticed that an aggregate presentation of the changes in worth of ecosystems can only be given on the basis of damage valuation.
The second identity addresses the repercussions of environmental deterioration.

current effects (on extended disposable income) of past disposals =
current effects (on extended consumption) of past disposals (4.4'')

De Boo *et al.*, firstly present the current effects of past disposals in the secondary distribution of income account were an attached damage value would lower disposable income. Current effects of past disposals are subsequently recorded in the use of income account, showing the negative adjustments of an environmental extended consumption concept in cases for which the corresponding values are being observed.

4.4 A comparison with the SEEA-1993

The goals of the SEEA-1993, as formulated in the 1993 United Nations manual (1993), are quite similar to those set out by De Boo *et al*.. The SEEA has been developed with the aim of providing a picture of the interrelationships between the natural environmental and the economy that is both comprehensive and consistent. The first SEEA tried to synthesise the various environmental accounting approaches, present at the time of its development, in one common framework.
The basic framework of the SEEA basically comprises a (product × industry) use table supplemented by balance sheets for non-financial assets. Other parts of the national accounts, such as institutional sector accounts, are not included. As such, the SEEA-1993 mainly focuses on goods and services transactions, production processes and (environmental) assets. This basic table is subsequently extended in various SEEA versions.
Version 2 adds more detail to environmental protection activities and concomitant services and contains a detailed breakdown of assets including an explicit representation of non-produced natural assets and of assets connected to the production of environmental protection services. No adjustments in accounting conventions are made at this stage. Only more detail is added.
Version 3 supplements the SEEA matrix with accounts on physical flows and stocks. The physical flow accounts include those for products (*i.e.* produced materials), natural resources and residuals. The physical accounts are set up in a supply-use format based on the material balance principle. For each of these three physical flow

types, origin of flows equals by definition their destination. For residuals, cross-boundary flows to the rest of the world are recorded. However, pollution flows received from the rest of the world are ignored (*cf*. §211). This implies that these residual accounts do not record the accumulation of residuals on domestic territory and is therefore somewhat disconnected from the asset account presented in the SEEA-2003. The input-output identity is applied at the level of processes where a distinction is being made between current and capital related flows.

Version 4 of the SEEA-1993 deals with the imputation of environmental costs and the subsequent estimation of an environmentally adjusted product or, for short, an 'eco domestic product'. Three different approaches are being discussed. The first valuation approach concerns an adjustment in gross domestic product for the depletion of natural resources. The second approach addresses the maintenance costs method discussed in chapter 2 of this thesis. The third approach concerns contingent valuation as a way of determining the environmental costs borne in an economy. Contingent valuation is not strongly recommended in the SEEA-1993 (*cf*. §321).

Other extensions discussed in the SEEA-1993 handbook are the expansion of the production boundary, firstly with regard to household activities, secondly, with regard to the environment as a producer of outputs such as disposal services, productive services of land and consumer services.

One clear attraction of the SEEA-1993 framework is its simplicity. The main focus of this system is on production, commodity transactions and assets. Other accounts and balancing items of the SNA are ignored. At the same time, quite some emphasis is put on the compilation of an eco domestic product from either a costs-borne perspective, based on contingent valuation, or a costs-caused perspective, based on maintenance costing. It is surprising that the consequences of these adjustments on other balancing items in the system, such as disposable income and saving are not discussed at all. For example, it is not at all straightforward how the imputation of maintenance costs should affect the disposable incomes of institutional sectors in an economy. In many cases, it is simply not true that the disposable incomes of agents are affected by the pollution they generate. Indeed, in many cases they have a 'free' permission to pollute without any financial consequences.

Reversibly, the attribution of environmental damages to their originators, when following an eco domestic product concept based on damage valuation, is not straightforward either. At least at a conceptual level, the original design of the NAMEA shows that the recording of transfers are essential in bridging the causes and impacts of environmental degradation. Also, the concept NAMEA shows that the recording of transfers requires a complete representation of the national accounts. Further, the SEEA-1993 does not differentiate pollution with current repercussions from those with non-current repercussions. As such, no notification is given of the current damages resulting from environmental degradation in the past. Similarly, the consequences of cross-boundary pollution transfers are not addressed.

The NAMEA allows for representing environmental information at the most obvious locations in system of national accounts. A complete overview of the system, as provided by a NAM, is in this respect useful. Also, the recording of agents or substances in accordance with their origin or destination provides a transparent presentation of (gross) emissions, waste absorption due to treatment and the recording of cross-boundary flows. The NAMEA is more complete in its capability of representing environmental expenditure accounts, particularly environmental taxes and subsidies, compared to the SEEA-1993 table. It is not surprising that the revised SEEA-2003 puts much more emphasis on matrix representations at various parts of the system.

Generally, the NAMEA follows a more prudent or descriptive approach compared to the SEEA-1993. In the NAMEA, maintenance costing is explicitly considered the realm of accounting based model applications. The NAMEA has been used in this way in several models. An explicitly formulated model based on the NAMEA is much better capable of consistently indicating the adjustments in the sequence of balancing items resulting from 'what-if' scenarios. The NAM specifies the economy-wide monetary relationships that are required in such models.

4.5 *Putting the NAMEA into practice*

This section takes stock of differences in goals and means between the conceptual design of the NAMEA and its practical use at present.

De Haan *et al.* (1994) firstly applied the NAMEA concept with the main objective "to present an common framework for monitoring and analysing environmental and economic policies" (p.1). Their NAMEA contains accounts for five categories of environmental pressures: greenhouse effect, ozone layer depletion, acidification, eutrophication (*i.e.* nutrient overburden) and solid waste. Neither changes in ecosystems, nor the repercussions of environmental deterioration are included in this NAMEA. In the first and subsequent Dutch national environmental policy plans (*cf*. VROM, 1989, 1993, 1998) these pressures are being confronted with policy targets for predefined years. Obviously, this enhances the policy relevance of the pressure indicators presented in this NAMEA.

The representation of a restricted set of pressure indicators was accomplished by the introduction of so-called 'environmental theme' indicators in the NAMEA as developed by Adriaanse (1993). Instead of attributing agents to changes in environmental assets, this NAMEA alternatively allocates agents to the environmental themes. The environmental theme indicators establish a linkage between agents (*e.g.* pollutants) and the environmental problems to which they are expected to contribute. As such, the environmental themes provide a transparent presentation of a restricted set of aggregated environmental pressure indicators, which help to evaluate the environmental performance of an economy. The presentation at the industry level of traditional national accounts indicators on *e.g.* value added and employment together with these five environmental pressure indicators received a substantial amount of public attention. This indicator profile shows that the larger part of environmental pressures is concentrated in only a limited number of industries such as agriculture, petroleum and chemical industries which are at the same time industries with relatively small shares in employment and value added.

De Haan & Keuning (1996) extend this NAMEA with accounts for environmental taxes and environmental protection expenditures. This version approximately corresponds to the NAMEA set-up as annually compiled and published by Statistics Netherlands (2000).

In recent years, a lot of experience has been gained with NAMEA type of 'hybrid' accounting approaches. The journal "Structural Change and Economic Dynamics" (1999) issued a special number on the NAMEA including contributions from Japan, Germany, Netherlands and Sweden. In the European Community, the development of the NAMEA has been stimulated by an official communication in December 1994 of the Commission of the European Communities to the European Council and the European Parliament on "Directions for the EU on Environmental Indicators and Green National Accounting". In this communication, the NAMEA is recommended as an example of how a European System of Integrated Economic and Environmental Indices should be structured. This recommendation is subsequently carried forward by Eurostat, the statistical office of the European Communities, which has resulted in two NAMEA publications (Eurostat, 1999, 2001a), containing the NAMEAs for air emissions of most EU member states. In addition, Hass *et al.* (2000) provide a detailed overview and comparison of the NAMEAs for Denmark, Finland, Norway and Sweden. So far, most NAMEA examples are concentrated on the recording of pollution and waste.

The main characteristics of the NAMEA, as being compiled up to date, could be summarised as follows. Firstly, the NAMEA maintains a strict borderline between the economic sphere and the natural environment, established by monetary accounts on the one hand and accounts denominated in the most relevant physical units on the other. The non-monetary accounts show the environmental requirements of an economy, which are not subject to market transactions and which are for that reason not included in the core national accounts. Similarly, the physical flows underlying commodity transactions do not enter the accounts for environmental requirements. From an environmental perspective, the NAMEA table clearly exposes the SNA boundaries and the non-monetary accounts clearly expand these boundaries. The NAM systematically traces down the points of connection of environmental information to the system of national accounts.

Secondly, the NAMEA maintains a clear distinction between physical inputs (extraction of resources) on the one hand and outputs (emission of pollutants) on the other. Hellsten *et al.* (1999) argue that from a welfare perspective both types of environmental requirements can be explained as an economic use of natural resources: either as a source or as a sink. This principle is also in line with the

SEEA-1993 and the Leontief model (1970) in which pollution is indeed recorded as a primary input similarly to labour and capital.

By following the direction of flows, the substances account in the Dutch NAMEA systematically express the origin and destination of substance flows, from and to the economic system. This approach takes explicitly record of residual flows that re-enter the economic sphere due to recycling waste collection and incineration activities, *e.g.* solid waste and wastewater. In addition, this recording enables a logical representation of cross-boundary pollution transfers. In total, the substances account in the Dutch NAMEA systematically explains the difference between on the one hand, the *net* amount of environmental pressure originating from the domestic economy, and on the other hand, the amount of environmental pressure that potentially threatens all property of residential entities including produced assets, their health status and the national ecological heritage.

Thirdly, most NAMEAs contain environmental themes account in which substances are grouped together and aggregated in accordance to the type of environmental pressure to which they are expected to contribute. In this way, a wide range of substances are represented by only a limited number of aggregated theme indicators on the basis of weighting methods to be further discussed in chapter 6. Some theme indicators correspond to nationally or locally bounded environmental problems, reflecting in addition to the net pressure resulting from domestic activities, the net pressure exposed to a country's territory. For environmental problems on a global scale, *i.e.* greenhouse effect and ozone layer depletion, the indicators only review the domestic contribution to these global problems.

Fourthly, the NAMEA provides an institutional representation of the economy and its relationship with the environment. This implies that economic activities together with their environmental requirements are defined and subsequently recorded according to statistically observable units, *i.e.* the so-called establishments classified according to the International Standard Industrial Classification (ISIC). As in economic accounting, environmental accounting preferably relies on totally homogeneous units, that is, an activity entirely designated to the output of one single product. Only for these homogeneous units, the environmental requirements entirely refer to one single product output. However, establishments as observed in reality will usually make use of ancillary production, such as own account power generation, or will have secondary output, which may complicate the allocation of environmental requirements to product outputs. Also, it is clear that both ancillary and secondary production may complicate the comparison of eco-performance of industries between countries (*cf*. Hass *et al*., 2000). However, before constructing accounts on the basis of homogeneous units, inputs and outputs have to be consistently recorded first at the level of statistically observable units.

Finally, the NAMEA also records the direct environmental requirements of government and household activities. By convention, public consumption equals government production and their environmental requirements are thus recorded in accordance to government production in the production account. In the NAMEA, a supplementary household production account is required to take record in a similar way of the direct environmental requirements of households at the level of various household activities.

4.6 The social dimension of environmental accounting

Sustainable development could be visualised as the multidimensional portfolio management of produced capital, environmental capital, human capital (*e.g.* health, human skills, knowledge) and social capital (*e.g.* institutional arrangements, social cohesion). This implies that environmental policy strategies should not be developed in isolation from economic and social policy.

However, quantifying all these capital categories in statistical terms is not straightforward. For example, as with environmental capital, it is unlikely that all relevant aspects of social capital can be described and quantified in terms of national accounts balance sheet entries. This means that other statistical tools are needed to describe certain relevant interactions between the different dimensions of sustainability. In this respect, SAMs may be helpful. As mentioned, a SAM enhances the social dimension of national accounting in the following two ways:

- The compensation of employees by industry is shown in much more detail, usually by a breakdown according to gender, educational attainment or profession;
- The household sector is presented in much more detail with the help of a sub-categorisation of the household sector according to, firstly main income received, *e.g.* compensation of employees, mixed income, income transfers, and secondly, household composition. Keuning & De Ruijter (1988) recommend to define household groups in such a way that they are recognisable for policy purposes over longer periods of time. As such, they consider a categorisation on the basis of income levels or main sources of income only in many cases inadequate.

In a SAM employed persons are represented as units who receive compensation of employees (or mixed income) as shown in the generation of income account and who contributes as a household member to the income received by the household sector as recorded in the primary distribution of income account. In other words, the SAM integrates labour market and income distribution statistics within a national accounts framework.

Since the national accounting matrix resembles the basic framework of both the NAMEA and the SAM, both information systems are principally compatible. Merging the SAM and NAMEA in a so-called SAMEA (Keuning & Timmerman, 1995) or an Extended SAM (ESAM, Alarcón *et al.*, 2000) provides a statistical framework that may help to detect employment and income distribution effects of environmental policy. For example, Resosudarmo & Thorbecke (1997) construct for this purpose an environmentally extended SAM to analyse human health problems and income distribution effects of pesticides reduction programs in Indonesia.

In addition to linking employment and income distribution related issues, SAMs may also support the environmental assessment of differences in consumer behaviour or life style patterns. Differences in life styles are reflected by the variation in consumption expenditure found at the level of different household groups represented in a SAM. SAMs may help to detect shifts in consumption expenditure resulting from economic development and demographic changes. This environmental assessment may also take into consideration the environmental requirements of consumer goods at the stage of their production. The estimation of such 'environmental consumption' indicators are discussed in chapter 7. Adaptations in consumer lifestyles have been addressed as being important in improving environmental performance of the economy (*cf*. Slob *et al*., 1996). As indicated by Duchin (1998), just as producers decide among different technologies, households play an important role in making choices among alternative life styles. In emphasising the role of structural economics in analysing the economic driving forces underlying environmental concerns, Duchin represents a conceptual framework for analysing relations among the economy, society and the physical environmental (*cf*. figure 3.1, p.56) that corresponds closely to the NAMEA and the SAMEA of Keuning & Timmerman.

Notes

1) A recently compiled handbook by the Leadership Group SAM (2003) provides a complete review of SAMs and their uses.

2) The transformation of supply-use matrices to square input-output tables is in detail discussed by Konijn (1994).

3) A similar list of properties can also be found in the SAM handbook (Leadership Group SAM, 2003, p.15).

4) One could argue that the ordering of transactions, as determined by the accounting structure, adds a fourth dimension.

5) For a clearer presentation, both balancing items are here presented on the right-hand side of the equation.

Chapter 5. The Dutch NAMEA [1)]

5.1 Introduction

This chapter presents the NAMEA as in recent years published in the Dutch national accounts (*cf*. Statistics Netherlands, 2000). Table 5.1 provides an overview of an aggregate NAMEA for the Netherlands in 1997. All entries in the first 10 accounts, *i.e*. rows and columns, are denominated in million guilders. These first 10 accounts contain a somewhat modified version of the NAM presented in table 4.1 of chapter 4. These adjustments are required to expand the NAM with environmental accounts including an explicit representation of environmentally related transactions in the NAM.

Most accounts in the matrix can be represented in more detail according to the classifications indicated between brackets. As discussed in chapter 4, the NAM provides the possibility of using different (combinations of) classifications at various stages in the sequence of accounts. These classifications may address either activities/actors or transaction types. The following classifications are used in the NAMEA as presented in table 5.1:

– goods and services account (*1*): product groups (*transactions*);
– consumption account (*2*): household activities or functions (*actors*);
– production account (*3*): industries (*actors*);
– generation of income account (*4*): value added categories (*transactions*);
– the combined distribution and use of income account (*5*): institutional sectors (*actors*);
– taxes and subsidies account (*8*): tax and subsidy categories (*transactions*).

Those accounts in the NAM containing less relevant information from an environmental perspective are presented by one single (row) entry, *e.g*. the capital (*6*) and financial account (*7*). All transactions with the rest of the world are represented by two separate accounts, one for current (*9*) and one for capital transactions (*10*).

The NAMEA presented in table 5.1 supplements the NAM with two accounts, describing the economy-environment interactions: a substances account (*11*) and an environmental themes account (*12*). All environmental requirements presented in these accounts refer to substance flows. The recording of other types of environmental requirements in the NAMEA is discussed in chapter 6.

Contrary to the first ten accounts representing in the NAM, these two accounts contain statistics denominated in non-monetary units. Obviously currency units and other units are not added up. Row and column totals of the accounts 1–10 only include the sum of entries in the first ten columns and rows respectively. The row and column totals of accounts (*11*) and (*12*) logically add up all entries in the substances or theme accounts respectively. The different nature of monetary and non-monetary accounts is emphasised by the, row-wise, higher positioning of entries in accounts (*11*) and (*12*), in contrast to the monetary entries in the first 10 columns, and by the, column-wise, left-side positioning of entries in the accounts (*11*) and (*12*) in contrast to the first ten rows of the NAMEA.

5.2 *An overview of accounts*

The goods and services accounts (*1*) and the production account (*3*) in the NAMEA present together the supply-use tables. In the NAMEA, the supply table is presented in transposed order. Industries are reflected in the rows while product groups are presented column-wise. The first row and column in table 5.1 represent together the goods and services account, classified by product groups. The goods and services account in the NAMEA corresponds largely to the goods and services account in the NAM presented in the former chapter. Differences between the supply of goods and services in basic prices, and their use in purchasers' prices are bridged by the trade and transport margins in sub-matrix (*1,1*) and taxes minus subsidies on products presented in sub-matrix (*8,1*).

The supply and use of environmental protection services are separately reflected in account (*1a*). The corresponding output in basic prices is shown in entry (*3,1a*) of the supply matrix. The use of environmental protection services consists of consumption by households (*1a,2*), intermediate consumption (*1a,3*) and government consumption (*1a,5*). Since not all environmental protection services, recorded here, fall inside the SNA production boundary, total output in the NAMEA is slightly increased compared to total output as recorded in the NAM presented in chapter 4. A more detailed discussion of the recording of environmental protection expenditure in the NAMEA is given in section 5.4.

The second account presents the consumption of households by function. This is a modification of the NAM as presented in chapter 4. Conceptually, in these accounts households are reflected as the own-account producers of services such as preparing meals, transport services and cleaning. In full-fledged household production accounts (*cf*. Fitzgerald *et al*., 1996) the corresponding production costs principally consist of current consumption expenditure, the imputed costs of labour and the depreciation of consumer durables. In the context of the NAMEA, functions are used to connect consumption expenditure to the direct environmental requirements of households, presented in sub-matrix (*2,11*), to which they relate. In the NAMEA, as annually compiled by Statistics Netherlands, this account distinguishes only two different functions: own-account transportation services and the sum of all other household functions. The classification of household consumption by functions is further discussed in subsection 5.3.2.

The production account (*3*) shows the domestic output of goods and services in the row (*3,1*) and intermediate consumption (*1,3*) and net value added excluding the

Table 5.1
An aggregate NAMEA (account 1–10 in million guilders) for the Netherlands, 1997

ACCOUNT (classification)		Goods and services (productgroups)		Consumption (functions)	Production (industries)	Generation of of income (value added) categories)	Distribution of income and consumption (sectors)	Capital	Taxes (types)			Rest of the world, current	Rest of the world, capital
		1a	1b	2	3	4	5	6	8a	8b		9	10
Goods and services (product groups)		Trade and transport margins		Consumption households	Intermediate consumption		Consumption government	Gross capital formation				Exports (fob)	
Environmental protection	1a			2 004	13 178		1 573						
Other goods and services	1b	–	–	361 598	697 691		166 834	158 514				449 892	
Consumption of households (functions)	2						Consumption households 363 602						
Production (industries)	3	Output at basic prices 16 214	1 352 210										
Generation of income (value added categories)	4				Net value added excluding other taxes less subsidies on production 547 282				VAT not handed over to the government	1 354		Compensation of employees from r.o.w. 1 287	
Distribution of income and consumption (sectors)	5					Net national generated income excluding other taxes less subsidies on production[2] 548 465	Property income and current transfers 699 026		Taxes less subsidies 11 536	153 041		Property income and current transfers from r.o.w. 83 738	
Capital	6				Consumption of fixed capital 109 822		Net saving 95 595						Capital transfers from r.o.w. 2 427
Financial balance	7							National net lending (+) or net borrowing (–) 42 440					Net lending of the r.o.w. –42 440
Taxes (types)		Taxes less subsidies on products			Other taxes less subsidies on production		Current taxes on income and wealth	VAT on land				Current taxes on income and other taxes less subsidies from r.o.w.	
Environmental taxes	8a	177	8 099		1 056		2 204						
Other taxes minus subsidies	8b	364	67 941		–605		87 847	1 297				1 681	
Rest of the world, current	9	Imports (cif)	406 279			Compensation of employees to r.o.w. 1 458	Property income and current transfers to r.o.w. 79 125		Current taxes on income and other taxes less subsidies to r.o.w.	4 130			
Rest of the world, capital	10							Capital transfers to r.o.w. 5 593				Current external balance –45 606	
Substances, destination[1]					Absorption or extraction by producers							Cross-boundary transfers to r.o.w.	
CO_2	11a												
N_2O	11b												
CH_4	11c												
CFC's and halons	11d												
NO_X	11e											694	
SO_2	11f											223	
NH_3	11g											34	
P	11h				21							16	
N	11i				118							504	
Solid waste	11j				4 460							.	
Natural gas	11k				2 541								
Crude oil	11l				88								
Environmental themes								Environmental indicators					
Global warming (CO_2-*equivalents*)	12a							246 780					
Ozonelayer depletion (*CFK11-equivalents*)	12b							931					
Acidification (*Acid Equivalents*)	12c							157					
Eutrophication (*Nutrient equivalents*)	12d							1 512					
Solid waste (*million kg*)	12e							10 710					
Natural resource depletion Fossil energy (*peta joules*)	12f							985					
TOTAL		16 755	1 834 529	363 602	1 368 424	549 923	1 495 806	207 844	11 536	158 525		490 992	–40 013

ACCOUNT (classification)		Substances, origin[1]												Accumulation of substances to the environment	Environmental themes						TOTAL
		CO_2	N_2O	CH_4	CFC's and halons	NO_X	SO_2	NH_3	P	N	Solid waste	Natural gas	Crude Oil		Global warming	Ozonelayer depletion	Acidification	Eutrophication	Solid waste	Natural resource depletion fossil energy	
		11a	11b	11c	11d	11e	11f	11g	11h	11i	11j	11k	11l	12	12a	12b	12c	12d	12e	12f	
Environmental protection	1a																				16 755
Other goods and services	1b																				1 834 529
Consumption of households (functions)	2	Emissions by consumers 36 790	4	21	45	109	2	7	9	115	5 120										363 602
Production (industries)	3	Emissions by producers 163 270	69	619	803	591	234	181	84	903	10 050										1 368 424
Generation of income (value added categories)	4																				549 923
Distribution of income and consumption (sectors)	5																				1 495 806
Capital	6	Other domestic emissions and changes of natural resources 960	–	464	33	–	–	–	7	16	–	3 364	250								207 844
Financial balance	7																				–
Environmental taxes	8a																				11 536
Other taxes minus subsidies	8b																				158 525
Rest of the world, current	9	Cross-boundary transfers from r.o.w.				101	82	22	15	325	.										490 992
Rest of the world, capital	10																				–40 013
Substances, destination[1]														Contribution to environmental themes							
CO_2	11a													201 020	201 020						201 020
N_2O	11b													73	22 580						73
CH_4	11c													1 104	23 180						1 104
CFC's and halons	11d													881		931					881
NO_X	11e													108			23				802
SO_2	11f													96			30				319
NH_3	11g													176			103				210
P	11h													77				775			115
N	11i													738				738			1 359
Solid waste	11j													10 710					10 710		15 170
Natural gas	11k													823						823	3 364
Crude oil	11l													162						162	250
Global warming (CO_2-*equivalents*)	12a																				246 780
Ozonelayer depletion (*CFK11-equivalents*)	12b																				931
Acidification (*Acid Equivalents*)	12c																				157
Eutrophication (*Nutrient equivalents*)	12d																				1 512
Solid waste (*million kg*)	12e																				10 710
Natural resource depletion Fossil energy (*peta joules*)	12f																				985
TOTAL		201 020	73	1 104	881	801	319	210	115	1 359	15 170	3 364	250		246 780	931	157	1 512	10 710	985	

[1] CFCs and halons in 1,000 kg, gas en oil in petajoules, other substances in million kg.
[2] Including VAT not handed over to de government.

Source: Statistics Netherlands (2000).

other taxes less subsidies on production (*4,3*) in the column. The row of this account also records, in quantities, the output of pollutants from production at the intersection of the substances account (*3,11*).

In addition to intermediate consumption and net value added, the column of the production accounts also contains entries for consumption of fixed capital (*6,3*) and the other taxes less subsidies on production at its intersection with the separate taxes and subsidies account (*8,3*). On a more detailed level, this sub-matrix thus reveals which types of (environmental) taxes and subsidies are paid, respectively received by which industry. At the intersection of the substances account, the column of account (*3*) also contains the material inputs in non-monetary units. Examples presented in this table are extractions of natural gas and crude oil (*11k,3* and *11l,3*) and the re-absorption of nutrients and waste due the collection and treatment of waste water and solid waste (*11h,3-11j,3*).

The balancing item in the generation of income account (*4*), net national generated income (*5,4*), represents all income generated by national production factors including the net balance of compensation of employees received from (*5,9*), and paid to (*9,5*) the rest of the world. This income is allocated to the various institutional sectors in the economy presented in account (*5*). This balancing item also includes value added tax not handed over to the government (*4,8b*). The net generation of income equally excludes other taxes less subsidies on production, the latter being separately presented in the tax account (*8,3*). In other words, the introduction of a taxes account leads to a modification of the balancing item net value added at basic prices as defined in the SNA-1993.

The fifth account represents the (re-)distribution of income and its use for consumption and saving. This account combines all transactions presented in the accounts 4 to 6 of the NAM presented in table 4.1. The entries (*5,5*), (*9,5*) and (*5,9*) in the income distribution and use account include property income transfers, social contributions, social benefits and all other current transfers between institutional sectors and the rest of the world. Matrix (*5,8*) allocates all tax receipts less paid subsidies to the government sector. This condensed presentation of income redistribution transactions and consumption by institutional sectors results directly in the balancing item net national saving (*6,5*).

The sixth account represents the capital account in which net national saving and the balance of capital transfers are allocated to gross capital formation (including inventory changes) and acquisitions less disposals of non-produced non-financial assets, the balancing item (*7,6*) being net lending (+) or net borrowing (–). Vector (*6,11*) in the capital account records a number of substance flows and changes in assets that are not directly referable to *current* consumption or production such as leakage of pollutants, particularly methane, from landfills. [2)] On the one hand, this vector contains, all other changes, not due to extraction, in natural resources such as additions to proven reserves of natural resources (*6,11k-11l*).

The seventh account does not contain a full financial account but only presents the financial balance of the total economy with the rest of the world. Total net lending of all resident entities to the rest of the world equals by definition the total net borrowing of the rest of the world from domestic entities. This explains the absence of an (empty) column (*7*).

The eighth account shows all taxes and subsidies (–) by the type of tax and subsidy and by incidence. This separate presentation of taxes clearly differs from standard national accounting practice and the NAM presented in chapter 4. A detailed explanation of this account is given in subsection 5.4.2.

Accounts (*9*) and (*10*) sum-up all current and capital transactions with the rest of the world. Current transactions consists of imports and exports, property income, income transfers and the cross-boundary substance transfers from (*9,11*) and to (*11,9*) the rest of the world. Data on cross-boundary solid waste transportation are not presented due to lack of data.

The substances account (*11*) provides information on the physical exchanges between the economy and the natural environment. The column of account (*11*) shows the origin of substances while the columns represent their destination. This account incorporates the following three accounting identities.

For residuals contributing to environmental degradation on a global scale (*11a-11d*):

Gross output of residuals from households (2,11), producers (3,11) and other sources (6,11) – re-absorption of residuals by producers (11,3) = net output of residuals (11,12) (5.1)

For residuals contributing to environmental degradation on a regional scale (*11e-11j*):

Gross output of residuals from households (2,11), producers (3,11) and other sources (6,11) + cross-boundary inflows (9,11) – re-absorption of residuals by producers (11,3) – cross-boundary outflows (11,9) = net accumulation of residuals in the (domestic) natural environment (11,12) (5.2)

For natural resources (*11k-11l*):

Total extractions by producers (11,3) – other changes in natural resources (6,11) = net change in natural resources (11,12) (5.3)

In conclusion, for residuals account (*11*) explains the difference between the gross and net output of residuals and subsequently defines the accumulation of pollutants on domestic territory. For natural resources, account (*11*) defines the net change in natural resources.

Table 5.2 is a restructured version of table 3.1 in chapter 3 and quantifies the difference between two indicators represented in the substance flow accounts: ‘net emissions by residents’ and ‘net accumulation on domestic territory’. The difference

Table 5.2
Acid and nutrient emission aggregates in the Dutch NAMEA, 1997

	NO_x	SO_2	NH_3	P	N	Acid-eq.	Nutrient-eq.
	1	2	3	4	5	*f(1–3)* [1]	*f(4–5)* [2]
	mln kg					*acid-eq.*	*nutrient-eq.*
Emissions by households	109	2	7	9	115	29	202
Emissions by producers	591	234	181	84	903	309	1 748
Emissions by other sources	–	–	–	7	16	–	82
Gross emissions by residents	701	236	188	100	1 034	338	2 032
Absorption by produces (–)	–	–	–	21	118	–	331
(I) Net emissions by residents	**701**	**236**	**188**	**78**	**917**	**338**	**1 701**
Emission transfers from ROW	101	82	22	15	325	61	475
Emission transfers to ROW (–)	694	223	34	16	504	242	664
(II) Net accumulation on national territory	**108**	**96**	**176**	**77**	**738**	**157**	**1 512**

[1] $= 0.022 \times NO_X + 0.031 \times SO_2 + 0.059 \times NH_3$.
[2] $= 10 \times P + 1 \times N$.

Source: Statistics Netherlands (2000).

between these two indicators is made up by cross-boundary pollution transfers. Table 3.1 shows that these transfers exist of two components: emissions transferred via international operating economic activities and emissions transferred via environmental media (air, water). These transfers are particularly relevant for those substances that accumulate on a regional scale in the natural environment. Examples of such pollutants, presented in table 5.2, are acid precursors and nutrients.

Natural resource extraction and pollution reflect two different ways in which the economic system makes use of the environment. In the substance account, resource extractions are recorded as inputs while emissions of pollutants are recorded as (unwanted) outputs As such, the NAMEA follows the direction in which these flows enter either the economy sphere (*i.e.* natural resource inputs and re-absorption of residuals) or the natural environment (residual outputs). This way of recording is consistent with thermodynamic principles but not necessarily in conflict with economic principles. Model based estimates of shadow prices, for residual outputs, will show up with negative signs in the column of account (*11*). Similarly, natural resource rents will be reflected with a positive sign in the row of account (*11*). In this way, the effect of both sets of prices will run through the balancing items in the NAMEA in a similar way, *i.e.* as the costs of using the environment.

The environmental themes account (*12*) reflects a number of key environmental policy concerns in the Netherlands: global warming, ozone layer depletion, acidification, eutrophication, solid waste, and natural resource depletion. The column totals of account (*11*) are grouped together by theme and subsequently converted into theme-related units in the interior of sub-matrix (*11,12*). This conversion facilitates, for each environmental theme, the aggregation over substances presented in columns (*12a-12f*). The weights attached to each substance reflect a pollutant's potential contribution to the environmental problem concerned.

Account (*12*) subsequently yields six environmental pressure indicators presented in vector (*12,6*). The first two indicators, those referring to greenhouse effect and ozone layer depletion, express the contribution of the Dutch economy to these global environmental concerns. The other theme-indicators refer to the total accumulation of pollution or the depletion of natural resources on Dutch territory. As shown in table 5.2, these theme indicators can also be used to concisely review an economy's net residual outputs.

In conclusion, the aggregate NAMEA in table 5.1 logically extends the standard set of macroeconomic indicators such as net domestic product, net saving and current external balance, with six environment performance indicators.

5.3 *Substance flow account*

The tables 5.3a and 5.3b provide a detailed presentation of the substances flow account (*11*) of the NAMEA presented in table 5.1. The table shows how the physical inputs and outputs of an economy are systematically connected to specific accounts and economic activities as defined in the NAMEA. In the tables 5.3a and 5.3b different units of account are used for different types of substances, such as million kilograms for high volume pollutants, *e.g.* carbon dioxide (CO_2) and nitrogen oxides (NO_X), thousand kilograms for small quantity pollutants, *e.g.* (CFCs and halons) and energy content (peta joules) for the fossil mineral resources.

This section discusses various parts of account (*11*) in more detail, starting with the outputs and inputs of production, then consumption and finally capital related flows.

5.3.1 *Production*

The production account in the NAMEA presents the requirements of production not only in terms of production costs, *e.g.* intermediate consumption, compensation of employees, consumption of fixed capital and taxes on production, but also in terms of environmental requirements. The latter remain non-priced and are being presented in quantities only.

One important precondition for such an extended production account is a consistent timing in the recording of both transactions and environmental requirements. Generally, the SNA-1993 recommends the *accrual* recording of transactions in the system including output and intermediate consumption. Accrual recording means that transactions are recorded at the time economic value is created, transformed,

Table 5.3a
Detailed presentation of the origin of substance flows in the NAMEA of 1997 (account 11, column)

	CO_2	N_2O	CH_4
	11a	11b	11c
	mln kg		
Emission by consumers	36 790	3.53	21.17
Own-account transport	15 640	3.32	3.99
Other household funtions	21 150	0.21	17.18
Emission by producers	163 270	69.32	618.58
Agriculture and forestry	9 230	26.32	448.95
Fishing	3 760	0.88	0.13
Crude petroleum and natural gas production	1 820	0.01	157.57
Other mining and quarrying	250	0.02	0.08
Manufacture of food products, beverages and tobacco	4 520	0.07	0.34
Manufacture of textile and leather products	420	0.01	0.05
Manufacture of paper and paper products	1 930	0.01	0.08
Publishing and printing	310	0.02	0.04
Manufacture of petroleum products	11 200	0.07	0.60
Manufacture of chemical products	22 470	35.06	3.11
Manufacture of rubber and plastic products	250	0.01	0.04
Manufacture of basic metals	8 870	0.01	0.09
Manufacture of fabricated metal products	530	0.03	0.04
Manufacture of machinery n.e.c.	380	0.02	0.04
Manufacture of electrical equipment	1 140	0.01	0.11
Manufacture of transport equipment	170	0.01	0.07
Recycling industries	370	–	–
Manufacture of wood and wood products	80	0.01	0.01
Manufacture of construction materials	3 150	0.02	0.29
Other manufacturing	300	0.02	0.03
Electricity supply	44 400	0.35	1.23
Gas and water supply	50	–	1.95
Construction	1 910	0.40	0.25
Trade and repair of motor vehicles	660	0.04	0.02
Wholesale trade	1 890	0.30	0.13
Retail trade, repair (excl. motor vehicles), hotels and resaurants	2 280	0.04	0.02
Land transport	7 560	1.83	0.44
Water transport	6 440	1.51	0.24
Air transport	10 290	0.06	0.11
Supporting transport activities	390	0.05	0.03
Financial, business services and communication	4 030	0.58	0.50
Public administration and social security	2 710	0.32	0.12
Education	870	0.04	0.12
Health and social work activities	1 730	0.43	0.22
Sewage and refuse disposal services	5 590	0.72	1.40
Other services	1 320	0.07	0.11
Other domestic origin	960	–	464.06
Waste dumping sites	960	–	464.06
Transport differences			
Gross emission by residents	201 020	72.85	1 103.81
From the rest of the world			
Non-residents in the Netherlands			
Transfer by surface water or air			
Other changes of natural resources			
Total = NAMEA Colomn total 11	201 020	72.85	1 103.81

Source: Statistics Netherlands (2000).

CFCs and halons	NO_x	SO_2	NH_3	P	N	Solid Waste	Natural gas	Crude oil
11d	11e	11f	11g	11h	11i	11j	11k	11l
1 000 kg	*mln kg*						*peta joules*	
45	109.42	2.05	6.77	8.64	115.44	5 120		
–	87.61	1.52	–	–	25.50	70		
45	21.81	0.53	6.77	8.64	89.94	5 050		
803	591.09	234.08	180.89	84.49	903.37	10 050		
5	32.51	1.75	176.50	53.01	612.79	860		
–	77.31	63.11	–	–	19.81	110		
–	3.20	0.17	–	–	1.17	100		
–	1.00	0.35	0.15	–	0.50	90		
20	6.99	0.48	0.23	2.54	15.46	460		
–	0.58	0.01	0.01	0.03	1.95	50		
–	2.18	0.08	0.10	0.82	4.33	360		
–	1.07	0.03	–	–	0.41	90		
–	15.53	52.14	0.02	0.01	5.99	70		
231	27.65	12.22	2.77	7.51	19.37	1 980		
–	0.41	0.01	–	0.02	0.27	90		
–	9.35	10.09	0.07	0.17	3.98	110		
–	1.42	0.04	–	0.02	1.33	80		
–	1.03	0.03	–	0.07	0.90	80		
–	1.79	0.35	0.01	0.02	1.10	90		
1	0.44	0.02	–	–	0.86	70		
78	0.15	–	–	–	0.00	740		
–	0.34	0.01	–	–	1.13	40		
–	11.93	3.85	0.50	0.05	5.84	180		
–	0.61	0.04	–	–	1.34	120		
–	44.33	12.46	–	0.03	21.81	50		
–	0.15	0.02	–	–	0.03	30		
225	21.38	1.44	–	2.95	8.83	1 330		
–	1.85	0.06	–	–	0.99	100		
6	12.30	0.33	–	0.04	4.22	170		
11	2.73	0.06	–	0.01	1.51	140		
–	87.62	2.31	–	–	27.62	90		
–	129.32	57.95	–	–	35.46	610		
–	38.63	0.85	–	–	9.82	20		
1	3.84	0.27	–	–	1.45	50		
–	20.46	0.67	0.53	–	8.56	510		
–	21.88	11.39	–	–	6.22	180		
–	1.37	0.01	–	–	0.44	70		
–	2.03	0.39	–	–	0.62	130		
225	4.87	1.05	0.02	17.21	76.26	740		
–	2.82	0.04	–	–	1.00	60		
33	0.31	0.02	–	6.62	15.66	.		
33	0.31	0.02	–	.	.	.		
				6.62	15.66			
881	700.82	236.15	187.66	99.75	1 034.47	15 170		
	100.81	82.40	22.10	15.00	324.65	.		
	41.01	12.00	–	–	11.25	.		
	59.80	70.40	22.10	15.00	313.41	.		
							3 364	250
881	801.63	318.54	209.76	114.75	1 359.12	15 170	3 364	250

Table 5.3b
Detailed presentation of the destination of substance flows in the NAMEA of 1997 (account 11, row)

	CO_2	N_2O	CH_4
	11a	11b	11c
	mln kg		
Absorption by producers			
Agriculture			
Crude petroleum and natural gas production			
Construction			
Sewage and refuse disposal services			
To the rest of the world			
Residents in the rest of the world			
Transfer by surface water or air			
Contribution to environmental themes			
Greenhouse effect	201 020	72.85	1 103.81
Ozonelayer depletion			
Acidification			
Eutrophication			
Waste			
Waste water			
Changes in natural resources			
Total = NAMEA row total 11	201 020	72.85	1 103.81

Source: Statistics Netherlands (2000).

exchanged, transferred or extinguished. Ownership is entered when ownership passes, services are recorded when provided, output at the time products are created and intermediate consumption when materials and supplies are being used (*cf.* §3.94).

The direct recording of physical flows, as discussed in chapter 3, and the accrual recording of economic transactions together guarantee a consistent timing in the recording of both the physical and monetary dimension of the NAMEA. So, the production account provides a direct comparison between monetary and physical entries. In this way, several environmental performance indicators can be derived from the accounts such as 'eco-productivity', 'eco-efficiency', or its inversion, eco-intensity measures:

- eco-productivity of industry (j) with respect to environmental requirement (p) = y_j / e_j^p
- eco-intensity of industry (j) with respect to environmental requirement (p) = e_j^p / x_j

whereby the variables:

CFCs and halons	NO_x	SO_2	NH_3	P	N	Solid Waste	Natural gas	Crude oil
11d	11e	11f	11g	11h	11i	11j	11k	11l
1 000 kg	*mln kg*						*peta joules*	
				21.27	117.91	4 460	2 541	88
				1.09	5.41	–	–	–
				–	–	–	2 541	88
				3.00	3.00	–	–	–
				17.18	109.50	4 460	–	–
	693.99	222.85	34.00	16.00	503.72	.		
	282.31	130.70	–	–	79.20	.		
	411.68	92.15	34.00	16.00	424.51			
881.40								
	107.64	95.70	175.76					
				77.47	737.50			
						10 710		
							823	162
881.40	801.63	318.54	209.76	114.75	1 359.12	15 170	3 364	250

y_j denotes the valued added of industry (j);
x_j denotes the production value of industry (j);
e_j^p denotes the environmental requirement (p) of industry (j).

Eco-productivity is thus defined as the sum of value added generated per unit of environmental requirement. Eco-intensity is defined as the total amount of environmental requirements per money unit of output. The periodic changes of both indicators visualise either the extent to which economies or individual industries are able to increase their value added per unit of environmental requirement or to reduce the amount of environmental requirements per money unit of output. Environmental policies often address the strategy of 'de-coupling' as a way to simultaneously improve environmental and economic performance. Overviews of the literature on research on de-coupling trends and strategies are for example given by De Bruyn (1999) and Cleveland & Ruth (1999).
Both indicators introduced above are useful in detecting de-coupling trends at the national and industry level. Eco-intensity coefficients are frequently used in environmental-economic (input-output) modelling. Both eco-intensity and eco-productivity measures play an important role in the structural decomposition

analyses presented in chapter 8 of this thesis. Decomposition models are helpful in detecting the driving forces behind periodic changes in the environmental requirements of an economy. In fact, the structural decomposition analyses presented in chapter 8 illustrate the influence of changes in eco-intensities at the industry level and structural changes (*i.e.* industry composition changes and demand shift changes) on eco-productivity.

The eco-productivity figures presented in table 5.4 refer to total production related carbon dioxide (CO_2) and acid pollution in the Netherlands. Carbon dioxide pollution shows a weak de-coupling trend. This implies that, while eco-productivity rises over time, production related carbon dioxide emissions show an increase well. The on average decline in acid pollution over time indicates an absolute de-coupling of this environmental pressure from economic growth.

In addition to the gross output of residuals presented in the column, the row entries of the substances account (*11*) also records a number of inputs. These physical inputs of production (and possibly consumption) consist either of natural resource extractions or the re-absorption of residuals. Both input categories are represented as the absorption of substances by producers (*11,3*) in table 5.1. The majority of natural resources directly withdrawn from the natural environment are usually reserved to a minority of activities such as agriculture, mining and to some extent manufacturing. As soon as a natural resource is extracted, its further allocation will be foreseen by markets and the concomitant product exchanges between economic agents will appear in the NAMEA as product transactions, recorded in currency units. Several direct environmental inputs are found in a majority of activities such as the oxygen required in combustion processes and direct water extractions for

Table 5.4
Eco-productvity measures for the Netherlands with respect to carbon dioxide (CO_2) and acid pollution

	1995	1996	1997	1998	1998
					index 1995 = 100
GDP at market prices (million guilders) in constant (1997) prices	687 873	708 510	735 433	765 586	111.3
Pollution from production					
CO_2 in mln kg	158 210	163 360	163 270	166 050	105.0
Acid-equivalents[1)]	311.5	314.6	309.3	303.6	97.5
Eco-productivity measured in 1997 prices					
GDP / CO_2	4.3	4.3	4.5	4.6	106.0
GDP / Acid-equivalents (× 1 000)	2.2	2.3	2.4	2.5	114.2

[1)] = $0.022 \times NO_X + 0.031 \times SO_2 + 0.059 \times NH_3$.

Source: GDP figures are calculated with the help of growth figures from the 1999 national accounts publication, Statistics Netherlands (2000, table H3).
Emissions are from the NAMEA database constructed for the structural decomposition analyses presented in chapter 8 of this thesis.

cooling purposes and processing. However, these inputs do not necessarily relate to natural resource depletion.
Sub-matrix (*11,3*) of the NAMEA also includes the residual inputs that result from either waste(water) treatment or recycling activities. One could argue that concomitant residual inputs such as recycled waste in fact do not leave the economic sphere since often they are directly transferred from one economic agent to another. However, this is only a matter of definition. In the NAMEA, the economic sphere is defined as all material flows represented by product transactions. Subsequently, the substance flow accounts logically extent the supply and use tables with material exchanges that do not coincide with product transactions. Therefore, recycled materials with a zero market value are principally presented in the substances account and not in the goods and services account.
So, by definition residual flows are excluded from the economic sphere. As soon as a (recycled) substance flow has a positive market value, its transfer will be recorded as a market transaction in the supply-use tables of national accounts. As mentioned in the introduction of this chapter, reversibly the NAMEA table does not account for the physical flows that coincide with product transactions in the economic sphere. Yet, the physical flow accounts of a NAMEA are often constructed based on the physical flow data underlying product transactions. The most obvious example in this respect are the energy accounts which are an fundamental part of the accounts for air emissions. Also the substances accounts for nutrients in the NAMEA are derived from economy-wide substance flow accounts. This is the only way to safeguard a consistent presentation of nutrient exchanges interfering with all domains of the natural environment (*e.g.* air, water, soil).
In addition, a consistent timing in the recording of economic transactions and substance flows requires that special attention is given to those waste and pollution flows connected to the demolition and disposal of worn out buildings, machinery and other capital. This issue is further discussed in subsection 5.3.3.

5.3.2 *Consumption*

As illustrated in table 5.3a, the Dutch NAMEA presents the residual outputs from household activities by two separate entries:
– own account transportation;
– other household functions.

In the NAMEA, these so-called consumption functions are used for a consistent reconciliation of consumption expenditure and the direct environmental requirements of households. The consumption function describes a specific use or a consumer need that is satisfied by a specified set of consumer goods and services. One could argue that these sets of consumption expenditure represent the intermediate requirements of the own-account production of household services. As earlier mentioned, household production functions have been introduced in household production accounts with the purpose of extending the rather narrow production

boundary in the SNA. The consumption functions in the NAMEA could be regarded as the output generated by a specific set of consumption inputs and environmental requirements.
Quit similar to the eco-intensity measures for production, eco-intensity measures can be derived from the NAMEA at the level of household functions. Eco-intensity ratios for households are illustrated in chapter 8 and are determined as follows.

– eco-intensity of households with respect to household function (*k*) and environmental requirement $(p) = e_k^p / c_k$

whereby the variables:

e_k^p denotes the environmental requirement (*p*) of household activity (*k*);
c_k denotes the consumption value of household function (*k*).

The classification of individual consumption by purpose (COICOP), as presented in SNA-1993 (*cf*. §18.1 and table 18.1) seems to provide a logical starting point for the construction of consumption functions in a NAMEA. Classification of individual consumption by purpose is applicable to both individual consumption expenditure as well as actual individual consumption (*cf*. §18.7). The latter includes social transfers in kind from government to households such as education and health services that directly benefit (the members of) individual households.
However, there are some essential differences between COICOP and the representation of household consumption according to functions. Firstly, the individual consumption expenditure concept is the one and only consumption concept applicable in relation to the description of household production functions. Secondly, COICOP does not genuinely specify consumption expenditure according the own account output of household services. For example, purchases on 'Food' (COICOP - 1.1), 'Beverages' (1.2) and 'Tobacco' (1.3) are together defined as a separate individual purpose. Yet, from a household production perspective, it is necessary to bundle together all inputs required for the *preparation* of meals including energy and water demands and the services provided by food processing equipment. Yet, consumption of 'Electricity, gas and other fuels' (3.4) is presented in COICOP as a separate purpose. Obviously, energy consumption does not have a purpose on its own but supports various functions such as housing, cooking, recreation, communication etc. The allocation of fuel consumption to specific purposes is especially relevant for the concomitant estimation of air emissions according to functions.
Another issue in the description of household functions is the use of consumer durables. COICOP allocates all consumption expenditure to purposes disregarding the fact that consumer durables often serve a certain consumption purpose for longer periods of time. From a household production perspective, it seems reasonable

to consider consumer durables as assets, which services should be addressed to specific functions and properly distributed over time.

The recording of consumption expenditure on environmental protection needs some further reconsideration as well. One option is to group together environmental protection expenditure as an additional consumption purpose. [3] This recording shows the overall significance of consumption on behalf of the environment. Indeed, a similar categorisation is recommended in the Classification of the Functions of the Government (SNA-1993, COFOG-07.3; Sanitary affairs and services including pollution abatement and control, p.599).

Yet, as earlier discussed in chapter 2, another possibility is to record environmental protection expenditure in connection to those functions to which these protection expenditures specifically relate. For example, the extra costs of motor cars fitted with catalytic converters could be expressed in relation to own account transportation. This alternative recording directly relates environmental protection expenditure to the environmental requirements of households that are supposed to be abated. As such, the accounts facilitate, at least conceptually, the cost-effectiveness analysis of consumption related environmental protection expenditure.

Ready made services such as public transport services, restaurant services, are unrelated to own-account household production and their consumption is subsequently refrained from any direct environmental impacts at the household level. This equally holds for government consumption that is attributed to individual households by social transfers in kind. Their direct environmental requirements are recorded at the stage of their production. The measurement of direct and indirect (*i.e.* at the stage of their production) environmental requirements of consumption is being discussed in chapter 7.

5.3.3 Recording of stock related flows

There are various obstacles that obfuscate the allocation of residual outputs to current production and consumption. Sometimes, statistical observation simply falls short. For example, in many cases information is not available to determine the origin of wastewater and the pollution it contains from pavements collected in sewage systems. In other cases there are conceptual restraints. Demolition waste or the disposal of worn out machinery and consumer durables result from the transformation of assets into residuals. Principally, these residual outputs include the transfer of stocks from the economic sphere to the natural environment. Clearly, it is inconsistent to attribute the disposal of capital items to current production or consumption activities. In this respect, there is an analogy with the differences in treatment of fixed capital formation and consumption of fixed capital in the national accounts. Consistent cost accounting requires the allocation of capital costs over its entire service life. Depreciation, or in SNA terminology, consumption of fixed capital, represents the periodic loss in asset values due to its use in production.

One could equally argue that physical flow accounting based on national accounting principles requires a re-allocation of the disposal of an asset over its entire lifetime. Similarly, consumption of fixed capital does not reflect the factual, but instead imputed, payments for capital losses due to its use. Both types of imputation are quite similar in terms of speculation and arbitrariness. For example, both imputations depend on an expected service life of the asset. However, one serious consequence of such an imputation in the physical flows accounts is that it is in conflict with the mass balance principle.

An alternative recording recommended in the SEEA-2003 (*cf.* §3.98) is to introduce a separate account for capital related flows in a system of physical flows accounts. In such a capital account, capital formation, or stock building, is recorded separately from the recording of current flows in connection to production and consumption processes. In this way, the disposal of assets is not part of the current residual outputs of industries. In theory, for households, a distinction should be made in the monetary as well as the physical accounts, between current and capital expenditure and related physical inputs and outputs. Yet, such refinements have yet not been made in the NAMEA presented here.

Another issue related to the recording of stocks are the emissions from landfills. The solid waste indicator as presented in element (*12e,6*: 10710 million kg) of the NAMEA in table 5.1 addresses the total amount of waste disposed on landfills or elsewhere. This amount of solid waste is considered to be transferred from the economic sphere to the natural environment. Subsequently, vector (*6,11*) includes the emissions resulting from landfills. However, conceptually these emissions should not be regarded as economic-environmental material transfers since the Dutch NAMEA considers the appearance of landfills outside the economic sphere. This minor inconsistency is introduced on practical grounds. Firstly, the reduction of solid waste storage in landfills has been a specifically addressed policy goal in the Netherlands, and it seems for that reason relevant to explicitly address the accumulation of waste on landfills in the environmental performance indicators of the NAMEA. Secondly, it should be acknowledged that emissions from landfills are part of the human induced environmental burdens which can be considerable. For example, table 5.1 shows that for methane (CH_4), entry (*6,11c*), emissions from landfills represent more than 40% of the total emission in the Netherlands.

A conceptually correct recording of solid waste would be to include waste stored on human controlled landfills (similarly as incinerated waste) as a re-absorption of waste by the sewage and refuse disposal services industries (*i.e.* entry *11j,3* in table 5.1). As a result, the emissions from the human controlled storage of waste would become part of the emission outputs of the sewage and refuse disposal services industries and only the *uncontrolled* dumping of waste would be reflected in the NAMEA indicator (*12e,6*).

5.4 *Environment related transactions*

The NAM in the NAMEA is adjusted in several ways to accommodate an explicit representation of environment related transactions. The presentation of environmental expenditure in combination with substance flow accounts in a NAMEA may enhance the analytical use of environmental expenditure accounts. The NAMEA helps to visualise the environmental gains (and losses) of environmental protection expenditure. This is especially the case for the main producers of environmental protection services such as sewage and refuse disposal services. In the NAMEA, solid waste inputs are recorded as the environmental services in quantitative terms, provided by this industry. Also, the side effects, *e.g.* air emission outputs, of waste incineration (and wastewater treatment) are shown in relation to the producers of sewage and refuse disposal services.

Environmental expenditure data in the NAMEA includes firstly environmental protection expenditure by households and industries and secondly environmental taxes. Eurostat (1994) has published a system of environmental expenditure accounts with the purpose of tracing the monetary flows linked to environmental protection and expressing the impact of environmental protection to the economic system. The recording of environmental protection services in the NAMEA is largely consistent with this Eurostat system and the accounts for environmental products and activities as presented in the SEEA-2003 (*cf*. chapter 5).

However, the tax account in the NAMEA, has a somewhat different objective compared to the Eurostat accounting system. The latter system categorises environmental taxes earmarked for the financing of environmental protection measures. In this way the Eurostat system aims at quantifying how national environmental protection expenditure is ultimately financed by the various institutional sectors in the economy. In the NAMEA the recording of environmental taxes serves a different purpose, namely showing to what extent the total tax system in the economy is directed at environmental harmful products or activities. Therefore, the tax base represents the key principle for the demarcation of environmental taxes in the NAMEA, disregarding whether or not a tax is earmarked for environmental (financing) purposes. This delineation is in line with the directives developed by the OECD (1997) for the purpose of international comparisons.

5.4.1 *Environmental protection expenditure*

The NAMEA distinguishes the following four types of environmental protection services:

- market services;
- non-market services;
- garbage collection and disposal fees;
- internal services.

Table 5.5a
Supply of environmental protection services in the Dutch NAMEA, 1997

	Sewage and refuse disposal services	General government	Other industries	Total, basic prices	Taxes less subsidies on production	Total, purchasers' prices
	million gld					
Market services	5 072	–	311	5 383	453	5 836
Non-market service	4 474	–	–	4 474	88	4 562
Refuse collection and disposal fees	–	2 160	–	2 160	–	2 160
Internal services	4 170	27	–	4 197	–	4 197
Total	13 716	2 187	311	16 214	541	16 755

Source: Detailed NAMEA-1997 table, Statistics Netherlands.

Table 5.5b
Use of environmental protection services in the Dutch NAMEA, 1997

	Sewage and refuse disposal services	General govern-ment	Other industries	Con-sumption households	Con-sumption government	Total, purchasers' prices
	million gld					
Market services	2 109	1 822	1 755	150	–	5 836
Non-market service	7	1 998	984	–	1 573	4 562
Refuse collection and disposal fees	2	6	298	1 854	–	2 160
Internal services	–	27	4 170	–	–	4 197
Total	2 118	3 853	7 207	2 004	1 573	16 755

Source: Detailed NAMEA-1997 table, Statistics Netherlands.

A detailed overview of the supply and use of these services, as represented in the 1997 NAMEA, is provided in the tables 5.5a and 5.5b. Market services, presented in the first rows of these tables, are exchanged at market prices and predominantly supplied by market producers. Non-market services are provided by government units and are valued at the sum of production costs, *i.e.* intermediate consumption, compensation of employees, consumption of fixed capital and other taxes on production less other subsidies on production.

The ESA-1995 (*cf.* §4.23 and §4.80d) explicitly recommends that in the national accounts waste collection and disposal fees must be recorded as the purchase of a service provided. In the Dutch supply and use table, these fee payments are subsequently represented as a separate product group supplied by the general government. In this way, the government is represented in the accounts as the intermediary between the providers of refuse collection and incineration services and the fee payers. Therefore, the production value of these refuse collection and disposal fees should not be interpreted as an actual additional output of environmental protection services. Other environmental charges such as water sewage and purification charges are still recorded as taxes on income (households) or on production (enterprises).

Ancillary environmental protection services, such as pollution control or waste(water) treatment, are produced in many industries. These ancillary activities include all expenditure with the main objective of protecting the environment. In the SNA-1993 (§5.41), ". . . a productive activity is described as ancillary when its sole function is to produce one or more common types of services for intermediate consumption within the same enterprise. (. . .) Neither the inputs into, nor the outputs from, ancillary activities are recorded separately from the others consumed by the principal or secondary activities."

Contrary to this SNA convention, the NAMEA explicitly records the internal output of en vironmental protection services separately from all other output. This recording raises total domestic output as shown in the NAM, sub-matrix (2,1) in table 4.1 of chapter 4, with the amount of 4197 million guilders, measured in basic prices. For each individual industry in the NAMEA, the ancillary output of environmental protection services equals its intermediate consumption of these services. In other words, intermediate consumption is equally increased with the amount of 4197 million guilders. As a result, this recording does neither alter value added nor any other balancing item in the NAM. The ancillary output of environmental protection services is valued at the sum of production costs.

Defining the internal environmental protection of public administration (*i.e.* NACE-code 75) is less straightforward. According to the functional classification of government expenditure, government consumption directed at environmental management and control equalled 2303 million guilders in 1997 (*cf*. Statistics Netherlands, 2000, table D3.3, p.166). This consumption is not meant to diminish the environmental burdens of the production of government administration services. It merely represents government outlays on environmental management on behalf of the entire society. In the Dutch NAMEA for 1997, only 27 million guilders (*cf*. table 5.5b) of government expenditure on the cleaning of military drilling grounds is identified as purely internal environmental services related to government production.

5.4.2 *Environmental taxes*

The NAMEA in table 5.1 includes a specific 'taxes and subsidies' account (8). In the standard national accounts, taxes and subsidies are recorded at different locations throughout the system:

- Taxes and subsidies on products (Goods and services account, Allocation of primary income account);

Table 5.6
The taxes and subsidies account in the Dutch NAMEA 1997

	Products (8,1)			Production (8,3)	Income (8,5)			Total
	Energy	Vehicles	Other		Corporations	Households	Rest of the world	
	million gld							
1. Taxes on products	17 908	6 701	59 686					84 295
Value added tax (VAT)	4 396	1 963	44 139					50 498
Import duties (to the EU)	33	196	2 814					3 043
Excise duties	10 466	–	4 790					15 256
Specific environmental taxes	3 013	4 542	721					8 276
Levies on groundwater extraction	–	–	331					331
Taxes on passenger cars and motorcycles	–	4 542	–					4 542
Fuel tax	1 219	–	213					1 432
Refusal tax	–	–	177					177
Energy levy	1 794		–					1 794
Other	–	–	7 222					7 222
2. Other taxes on production (producers)								
Taxes on income and wealth (households)				7 593		9 660		17 253
Real estate tax				3 247		1 328		4 575
Motor vehicle tax (incl. Eurovignet)				1 182		3 993		5 175
Specific environmental taxes				1 056		2 204		3 260
Sewerage charges				230		920		1 150
Levies on water pollution				760		1 284		2 044
Other environmental taxes				66		–		66
Other				2 108		2 135		4 243
3. (other) Taxes on income and wealth					32 674	47 717	1 681	82 072
4. Total subsidies			–7 714	–7 142				–14 856

Source: Detailed NAMEA-1997 table, Statistics Netherlands.

- Other taxes or subsidies on production (Production account, Allocation of primary income account);
- Current taxes on income, wealth etc. (Secondary distribution of income account);
- Capital taxes and investment grants (Capital account).

The taxes and subsidies account in the NAMEA separates the taxes and subsidies from other transaction types in the corresponding accounts and classifies them by type of tax or subsidy. In the NAMEA, this account is obviously used to provide an overview of environmental taxes. As mentioned, in the NAMEA the tax incidence depicts the principal demarcation criterion of the environmental taxes.
Table 5.6 provides a more detailed picture of three sub-matrices in the taxes and subsidies account of the NAMEA: taxes (minus subsidies) on products (8,1), other taxes on production (8,3) and taxes on income and wealth (8,5). The table shows that, for corporations, certain taxes may be recorded as a tax on production, while for households, these taxes are recorded as taxes on income. This is typically the case

for specific environmental taxes such as sewerage charges and levies on water pollution. A tax account may bring these tax outlays together in one account, providing a logical overview of similar kinds of tax payments by producers and consumers.

Table 5.6 includes the product taxes levied on energy use and car sales. The table shows that almost 70% of all excise duties are levied on energy, *e.g.* car fuel, electricity and other energy commodities. Almost 30% of all product taxes are levied on either energy or vehicles while these commodities constitute together only 10% of total supply. One may conclude that in the Netherlands product taxes are dominantly levied on products with relatively high negative environmental impacts. For the other tax categories, the shares in environmental taxes are far less significant.

Capital transfers are not represented in Table 5.6. These transfers include capital taxes, *e.g.* non-periodic current taxes on wealth paid by households to general government (2096 million guilders in 1997). Other relevant capital transfers are the investment grants for environmental protection related capital formation, which amounts to 34 million guilders in 1997.

5.5 The 1997 NAMEA and the 1993 SNA

Chapter XIX in the SNA-1993 on applications (*cf.* §19.4) explains that, in response to various analytical needs, a certain level of flexibility is gained by putting different priorities to various parts of the accounts and by differences in frequencies at which they are being compiled. Also, differences in the level of detail in classifications may highlight the most significant parts of the system from certain analytical viewpoints. Almost all differences found in the NAM of the NAMEA in table 5.1 compared to standard SNA practice, *i.e.* the NAM presented in chapter 4, concern a re-ordering of transactions with the aim of, firstly, accommodating a consistent connection of the substances accounts and, secondly, improving the representation of environmentally related expenditure. This section sums up all differences between the NAM presented in chapter 4 and the corresponding accounts in the NAMEA, presented in this chapter. It must be emphasised that table 5.1 is certainly not the only possible presentation format of a NAMEA. Depending on uses and data availability, alternative formats are imaginable. As mentioned earlier, many NAMEAs developed in other countries are being compiled on the basis of an extended supply-use table.

- The recording of 'internal' environmental protection services as output is an extension of the standard SNA-1993 production account that is beyond a flexible implementation of SNA guidelines.
- Another deviation from regular national accounting practice is the presentation of final consumption expenditure in account (2) according to functions, particularly since these functions are not according to COICOP.

– Net national generated income (*5,4*) is a balancing item that is only presented in the SNA-1993 in the context of national accounts matrix representations (*cf*. chapter XX).
– The introduction of a separate tax accounts implies that the income generation account does no longer include other taxes less subsidies on production. This leads to modifications in two balancing items. Net value added in account (*4,3*) and net national generated income (*5,4*) are both excluding the other taxes less subsidies on production. Value added without other taxes less subsidies on production is formerly known as value added at factor cost which is a concept no longer used in the SNA-1993 (*cf*. §6.229).

All remaining differences in accounts 1–10 of table 5.1 compared to table 4.1 result from the more condensed presentation of those accounts that currently do not add specific environmental information. However, this condensed presentation leaves the complete system's representation in tact.
Finally, the other changes in assets accounts and the balance sheets are neither included in table 4.1 nor in table 5.1. As discussed in chapter 4, conceptually, there is no obstacle to include both set of accounts in a NAM or NAMEA. Clearly, balance sheets play an important role in environmental accounting. They may give an overview of the wealth represented by natural resources at specific points in time. Yet, this wealth perspective differs from the perspective of the NAMEA as presented here: *i.e*. an cause-oriented accounting framework that provides an overview of environmental-economic performance at the level of industries and household activities.

Notes

1) The NAMEA as presented in this chapter originates from De Haan, Keuning & Bosch (1994) and De Haan & Keuning (1996).
2) Principally, this account should also be used for recording the disposal of worn out capital such as demolition waste. This recording is currently not followed in the Dutch NAMEA. Stock related issues are discussed in the following section.
3) This recording is originally recommended by De Haan & Keuning (1996, p.133).

Chapter 6. The environmental requirements of an economy

6.1 Introduction

The former chapter illustrated how a set of substance flow accounts in the NAMEA logically extents the scope of the national accounts as presented by a NAM. Although most NAMEAs compiled so far mainly focus on air emissions (*cf*. Eurostat, 1999, 2001a), the environmental requirements of an economy may include a much broader range of human induced disturbances of the natural environment. This chapter discusses the strengths and weaknesses of representing, in the NAMEA framework, a wide range of environmental requirements.

Many environmental disturbances are related to material economic-environmental exchanges. This is why physical flow accounting receives a substantial amount of attention in this thesis. There are at least two principles to evaluate the exhaustiveness of physical environmental-economic exchanges: from a *material balance* perspective, or alternatively, from an *environmental impact* perspective.

Physical flow accounting can be constructed on the basis of an univocal and exhaustive representation of material inputs, throughputs and outputs. The material balance principle is particularly helpful in establishing an exhaustive economy-wide representation of physical flows. As the material balance principle explains that 'what comes in must get out', this approach safeguards a consistent representation of material or energy inputs, outputs and accumulation of stocks.

Alternatively, the exhaustiveness of physical flow accounts can also be evaluated with regard to the kinds of environmental threats or themes to be accommodated in the accounts. Following such a perspective, the categorisation primarily addresses the range of expected environmental impacts to which substance flows are expected to contribute. Theoretically, each interaction with the environment that interferes one way or another with other use functions of the natural environment should be taken into consideration. [1)] In practice the selection of environmental requirements will most logically follow from those environmental concerns addressed in environmental policy. Accounts that are exhaustive from a total material balance point of view are not necessarily complete from an impact perspective. Those (toxic) flows that are highly relevant from an environmental impact point of view may be insignificantly small from an economy wide material flow perspective. This means that the recording of these tiny but harmful flows in the accounts requires specific attention.

This chapter discusses the capability of the NAMEA to address those environmental themes that have been subject to national environmental policy in the Netherlands.

This appraisal should indicate to what extent the NAMEA, or more generally a national accounts based environmental accounting framework, is capable of representing those pressures that have been assigned as relevant environmental threats in environmental policy.

This chapter provides a case-by-case evaluation and is not necessarily in all respects representative for the environmental concerns in other countries. Beforehand, there are some conceptual considerations that should not be left unnoticed when reviewing the scope of the NAMEA. These are addressed in section 6.2 and refer to restrictions that are a priori expected to be present in a *national* and *annually* oriented accounting system. Section 6.3 discusses the strengths and weaknesses of the environmental themes approach. This section also addresses the assumptions underlying an aggregated thematic presentation of environmental pressures based on weighting. Section 6.4 discusses the statistical sources and methods used in the construction of these environmental accounts. Section 6.5 winds up with conclusions.

6.2 Space and time

Cause-effect interactions are often characterised by differences in space and time. Therefore, the recording of environmental threats on a regional or local level in a *national* accounting context requires specific attention. For example, space use becomes only a point of concern at the moment it starts to delimit freedom of movement to others or starts to become a threat to valuable ecosystems. Similarly, regional circumstances will often to a some degree determine the environmental impacts of certain pressures. Therefore, the location of a pollution source is in many cases relevant from an environmental impact perspective and a straightforwardly aggregate emission total of a particular pollutant for the complete economy may therefore in some cases be of limited significance.

Similarly, annual accounting may complicate the recording of environmental problems that follow periodic or seasonal patterns. For example, water scarcity in arid areas will usually be most severe in dry seasons and so the environmental impacts of water extractions will differ within the period of one year. The consequences of polluting river basins may equally depend on seasonal patterns in running water. The occurrence of considerable periodic fluctuations may limit the significance of straightforwardly aggregated emission totals over the period of one year in an annual accounting system.

Also, the accumulation of emissions in the environment with recurrent effects, the so-called 'stock pollutants', may affect the environment over long periods of time. This implies that current emissions of these pollutants, *i.e.* the additions to stock, only fragmentally express the burden exposed to the environment. Equally, landscape alterations due to agriculture or mining operations may continue to cause negative impacts long after these activities have ceased their operations. The current recording of environmental requirements, as provided by a NAMEA, will therefore not necessarily represent the total sum of human exposed pressures faced at certain moments in time.

Therefore, representing the environmental requirements of a total economy on an annual basis is bounded by certain limitations. These limitations can be explicitly acknowledged by emphasising that the scope of the accounts are delimited to recording the *potential* impacts of current activities, disregarding these divergences over time and space on actual outcomes. However, especially for those environmental concerns in which specific local conditions play a significant role, this may still lead to unsatisfying pressure indicators and alternative approaches have to be reconsidered. A certain level of pragmatism is unavoidable when appraising in general terms the overall environmental performance of an economy on the meso and macro level.

6.3 A thematic presentation of environmental requirements

6.3.1 Introduction

Table 6.1 is an attempt to categorise environmental pressures. This thematic presentation of environmental pressures is broadly derived from the Dutch Environmental Policy Plans (*cf*. VROM, 1989, 1993, 1998). Dutch policy addresses roughly the following environmental pressures: climate change, ozone layer depletion, acidification (and other large scale air pollution), eutrophication, dispersion of toxic substances, noise nuisance, solid waste, dehydration of soils and natural resource depletion. These environmental concerns are in a similar way monitored in the annual state of the environment reports of the Dutch Government Institute for Public Health and the Environment (*cf*. RIVM, 2002).

As mentioned, a representation of environmental pressures without any reference to the consequential environmental damages or repercussions is not very satisfying. The environmental themes reflect the mechanisms by which specific sets of pressures are connected to certain types of environment threats. These may vary in scale from changes in global climate systems to human health threats and damages to ecosystems and species. In Dutch environmental policy, environmental themes are used in the formulation of policy goals with respect to the maximum allowable environmental pressures at the national level or at sector levels. Generally, one may assume that these maximum levels reflect the reductions in environmental pressures required to obtain the socially desired improvements in the environmental state.

As explained in chapter 3, the weight or caloric content of a physical flow does not necessarily indicate its significance from an environmental impact perspective. Since the substance flow accounts in the NAMEA mainly focus on those flows that are relevant from an environmental policy perspective, they are not necessarily exhaustive from a material balance perspective: less relevant flows may be ignored.

Table 6.1
The theme-oriented representation of environmental requirements

Environmental requirements	Accumulation	Repercussions
Greenhouse gases	Atmosphere	Ecosystem damages *(losses in biodiversity)*, human health threats, losses in produced capital
Ozone layer depletion percursors	Atmosphere	
Acid percursors *(acidification)*	Surface water, soils	
Nutrients *(eutrophication)*	Surface water, soils, human intake	
Toxic agents *(dispersion of toxic agents)*	Surface water, soils, air, human intake	
Noice, stench	(..)	
Solid waste	Land(fills)	
(..)	Land and waterbody alterations	
Natural resources (including land)	Deposits *(net extraction i.e. de-accumulation)*	Natural resource depletion

From a material balance point of view, the NAMEA categorisation of environmental requirements may sometimes even show overlaps. For example, nitrogen flows embodied in the acid precursor nitrogen oxide (NO_X) may also be singled out as nitrogen (N) in the substance flow accounts in showing at the same time this acid precursor's potential contribution to the nutrient overburden. Also, there may be a necessity to include environmental requirements that are totally unrelated to physical flows. Such a multidimensional representation of environmental requirements underlines the multidimensional existence of environmental problems.
The environmental theme indicators, as firstly presented by Adriaanse (1993), are introduced in the NAMEA to provide a condensed presentation of environmental requirements. Adriaanse illustrates how conversion factors can be used to determine the potential contribution of individual substances to specific environmental pressures. For certain pressures, these conversion factors are internationally used, for example in the monitoring of greenhouse gas emissions or emissions contributing to ozone layer depletion. The SEEA-2003 also contains an overview of environmental themes related conversion factors (*cf*. §4.94–4.98 and table 4.10).
Subsequently, in the NAMEA these pressure indicators are consistently represented in a national accounts framework. The most straightforward indicator reviews derived from the NAMEA are the so-called environmental-economic profiles as for example presented by De Haan (1999), Hellsen *et al*., (1999) and Eurostat (1999). The main purpose of these profiles is providing a condensed and comparable

Table 6.2
Environmental-economic profiles based on net emissions, the Netherlands, 1997

	Gross value added, basic prices	Employ-ment	Con-sumption house-holds	Green-house gases	Acidi-fication	Eutro-phication	Solid waste
	(guilders)	(fulltime-eq.)	(guilders)	(CO_2–eq. 1))	(Acid-eq. 2))	(N-eq. 3))	(kg)
	%-shares						
Total				100	100	100	100
Households				15.5	8.5	11.9	47.8
Production				80.1	91.5	83.3	52.2
Other sources				4.3	–	4.8	–
Households			100	100	100	100	100
Own transport			7.6	43.7	68.8	12.6	1.4
Other household functions			92.4	56.3	31.2	87.4	98.6
Production	100	100		100	100	100	100
Agriculture, forestry and fishing	3.1	3.9		15.6	48.0	80.9	17.4
Mining and quarrying	2.9	0.1		0.1	0.1	0.0	1.6
Manufacturing	17.1	14.1		36.6	14.7	12.5	84.3
Electricity, gas and water supply	1.7	0.5		22.6	4.4	1.6	1.4
Construction	5.4	6.2		1.0	1.7	0.4	23.8
Trade, hotels and restaurants	14.8	20.0		2.5	1.2	0.5	7.3
Transport and commmunication	7.4	5.4		13.0	24.6	5.2	13.8
Financial and business activities	24.8	18.3		2.1	1.6	0.6	9.1
General government	11.7	10.8		1.9	2.8	0.5	4.5
Environmental services	0.6	0.3		3.0	0.5	–2.3	–66.5
Care and other service activities	10.5	20.2		1.6	0.4	0.1	3.4

1) $= CO_2 + 310 \times N_2O + 21 \times CH_4$.
2) $= 0.022 \times NO_X + 0.031 \times SO_2 + 0.059 \times NH_3$.
3) $=10 \times P + N$.

Source: Derived from Statistics Netherlands (2000).

review of economic and environmental performance indicators by economic activity (industries and households). The profiles may either show the shares of industries and households in both sets of indicators or indicator changes over time (*cf*. De Haan & Keuning, 1996). Chapter 8 of this thesis specifically deals with analysing and representing NAMEA indicators in a dynamic context.

The environmental-economic profile presented in table 6.2 reviews the contribution shares of industries and households in a selection of economic and environmental indicators. Firstly, a comparison is made between production, consumption and other sources (*i.e.* emissions from landfills and other unidentified sources). Secondly, an overview is given of the household functions 'transport' and 'other functions'. While household consumption expenditure on own account transport represents only a modest share of total household consumption, the transport related air emission totals are quite substantial. Thirdly, a separate economic-environmental profile is presented for the manufacturing industries. At first sight, these profiles may look astonishing by showing highly unequal contributions of environmental and economic indicators by industries. A similar picture derived from the first pilot NAMEA reached the headlines of the Dutch newspapers (*cf.* De Volkskrant, 1993). Agriculture, manufacturing and transport portray one end of the spectrum with relatively high environmental requirements but relatively low labour and capital requirements and therefore small shares in value added. Services industries show the opposite picture. These results largely reflect the highly diverging primary input mixtures between the various industries in an economy.

Besides primary production factors, industry branches also rely on intermediate requirements. Intermediate product flows depict the mutual dependencies of industries. Generally, the production of one industry is not possible without the production of intermediate requirements of other industries. This implies that the pollution in one industry may be triggered by the demand of intermediate requirements from other industries. One way to analyse these interdependencies is to shift the focus from production, or activity oriented *accounting*, towards products, or product chain related *analysis*. Such a shift in focus is the main subject of chapter 7.

Table 6.2 emphasises the importance of evaluating environmental-economic performance on the basis of information on the economic structure (*cf*. De Haan, 2002). An appraisal of environmental-economic performance indicators on the macro level may be distorted by differences in the industry composition between economies. Environmental performance does not only refer to what is being produced but, perhaps more importantly, the kind of production technologies that are being applied. This implies that a sound international benchmarking can only be based on indicators that allow for breakdowns at an industry branch level.

The indicators presented in table 6.2 refer to net emissions. As such, the environmental services industry contributes on balance negatively to eutrophication and solid waste. These negative contributions result from reduced nutrient concentrations in wastewater (*i.e.* denitridication) as a consequence of water treatment and from solid waste incineration.

The following sub-sections discuss the composition of environmental theme-indicators.

6.3.2 *Global warming*

Increasing concentrations of greenhouse gases in the atmosphere are expected to lead to an on average rise of temperatures on the earth's surface and subsequently to the global wide disturbance of climate systems. The repercussions of global warming are diverse, *e.g.* extreme weather conditions, damages to ecosystems and water cycles, increased risks of floods. Also, repercussions are expected to differ between regions. Greenhouse gas emissions accumulate in the global atmosphere leading everywhere to almost similar increases in greenhouse gas concentrations. Most greenhouse gases will remain in the atmosphere over longer periods of time, giving them the characteristics of stock pollutants.

This global dispersion pattern of greenhouse gas emissions makes the location of pollution sources irrelevant with respect to expected effects. This characteristic provides global warming an almost 'ideal' coverage in the NAMEA. Each emission source contributes similarly to global warming and a national emission aggregate of greenhouse gases genuinely reflects a nation's contribution to this global problem. As discussed in chapter 3, the national accounting principles underlying the NAMEA contribute to a systematic and consistent allocation of all greenhouse gas emissions to individual countries, including those from international transport. Principally, this is a much more satisfying basis for international emission reduction agreements compared to the current IPCC greenhouse gas inventory.

Due to the continuing human induced accumulation of greenhouse gases in the atmosphere, the timing of greenhouse gas emissions is also quite irrelevant with respect to expected repercussions. This is why Neumayer (2000a) advocates the accountability of historically accumulated greenhouse gas emissions by nations as a point of departure in multilateral emission reduction agreements.

So-called 'global warming potentials' are applied in the NAMEA to convert individual greenhouse gases into carbon dioxide (CO_2) equivalents, resulting to an aggregated theme indicator for global warming. global warming potentials have been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas (*cf.* IPCC, 1995). Carbon dioxide is used as the reference gas (weight 1) while the global warming potential of methane (CH_4) equals 21 and that of laughing gas (N_2O) 310. While principally any time horizon could be taken in which the expected presence of a particular greenhouse gas is estimated, the period taken by the IPCC is a hundred years.

There is a range of global warming substances that also contribute to ozone layer depletion such as chlorofluorocarbons (CFCs, HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). These substances may directly or indirectly contribute to global warming as well. Direct effects occur when the gas itself is a greenhouse gas. Indirect effects occur when chemical transformations of the original gas produce a gas or several gases that contribute to global warming.

For substances that both contribute to global warming and ozone layer depletion, there are two sources from which global warming potentials can be derived. Firstly, the numbers according to IPCC guidelines are used in the negotiations for the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC) refer to these numbers. Secondly, the numbers from the World Meteorological Organization's Global Ozone Research and Monitoring Project (1998, Table 10-8) represent an assessment of the global warming potentials of a broader range of compounds by leading international experts in atmospheric sciences.

6.3.3 *Ozone layer depletion*

The depletion of the ozone layer in the stratosphere leads to increasing levels of ultraviolet radiation at the world's surface. This leads to various ecological and health threats such as skin cancer. The contribution of substances such as chlorofluorocarbons (CFCs) and halons to the depletion of stratospheric ozone follows a multistage pattern. These rather stable substances are able to accumulate in the stratosphere. Subject to intense ultraviolet light, these substances start to break down, release chlorine or bromine atoms, which then deplete ozone. Similarly to global warming, one may assume that the location of emission sources is largely irrelevant with respect to the expected effects. This provides the recording of ozone layer depletion precursors in the NAMEA a similar 'ideal' status as greenhouse gas emissions. The so-called 'ozone depletion potentials' are used in the NAMEA to construct the corresponding theme indicator. These ozone depletion potentials can be derived from the World Meteorological Organization (1998, table 11-1).

6.3.4 *Acidification*

Acidification is caused by the deposition of sulphur oxides (SO_2), nitrogen oxides (NO_X) and ammonia (NH_3) in soil and surface water. Continuing accumulation of these substances will ultimately increase the acidity of soils, leading to ecological damage. The spatial scale of acidification usually exceeds the borders of countries. Acid precursors and other 'large scale' air pollutants such as ozone and fine particles have in common that they are subject to large distant air born transportation. Table 3.1 shows that cross-boundary pollution flows of acid precursors can be quite substantial. The foreign contribution to acid depositions on Dutch territory amounts to approximately 50% of the total (RIVM & Statistics Netherlands, 1999, p.110). At the same time, the cross-boundary transfers of acid emissions by Dutch residents outside the borders of the Netherlands are substantial as well.

The critical loads of so-called potential acid may vary substantially between regions and ecosystems (RIVM & Statistics Netherlands, 1999). Similarly, the deposition of acid precursors may vary between regions as well, depending on various conditions such as the presence of vegetation. For example, in the Netherlands the highest acid concentrations are found in forest regions with intensive husbandry farming (*cf.* RIVM & Statistics Netherlands, 1999, p.111). In some cases, the ecosystems in these regions are highly sensitive to acid depositions. This means that acid pollution reduction schemes, aiming at a cost-effective reduction of the expected damages from acidification, needs to take into consideration the location of emissions sources.

In Dutch environmental policy, targets have been formulated for individual acid precursors as well as for depositions. Data on acid depositions and concomitant critical loads are expressed in terms of potential acid (RIVM & Statistics Netherlands, 2001, p. 238). Potential acid is defined as the maximum amount of acid generated from by NO_X, SO_2 and NH_3 pollution in soils or surface water. An acid equivalent corresponds to 32 g (0.5 mol) SO_2, 46 g (1 mol) NO_2 or 17 g (1 mol) NH_3 (Schneider & Bresser, 1988). These potential acid conversion factors are applied in the NAMEA in constructing a theme indicator for acidification. This macro indicator does not take into consideration actual acid conversions, the location of pollution sources, nor differences in acid sensitivities of ecosystems in different regions.

6.3.5 *Eutrophication*

Eutrophication is to a large extent a problem connected to agriculture, caused by the excessive accumulation of nutrients from manure and fertilisers in soils and subsequently in groundwater and surface water. Nutrient pollution is a serious environmental problem in the Netherlands where the large and intensive husbandry sector relies substantially on fodder imports. The international trade of fodder embodies substantial nutrient transfers, creating at the same time nutrient deficits in exporting countries and surpluses in importing countries. In addition, the acid precursors, nitrogen oxides and ammonia may also contribute to the overburden of nutrients in the environment.

This overburden leads to various repercussions such as the degradation of water resources including groundwater and surface water deposits. Eutrophication also poses a threat to aquatic and terrestrial ecosystems. Together with the lowering of groundwater tables and acidification, eutrophication is considered as one of the three major environmental threats to nature in the Netherlands (Roos, *et al.*, 2000).

The spatial scale of eutrophication is somewhat similar to acidification. For example, both themes are characterised by a large-scale pollutant accumulation in surface water and soil and by considerable cross-boundary pollution flows. The representation of this theme in a national accounting context has therefore strengths and flaws comparable to acidification: spatial variations in emissions, depositions and ecosystem sensitivities are principally ignored. Only a regional breakdown of the accounts will be able to support the analysis of optimal pollution schemes by taking into consideration the spatial variation in emission sources under the restriction of spatially differentiated maximum critical loads (*cf.* Erisman *et al.*, 1996).

So-called eutrophication equivalents are used to provide an aggregated review of nutrient pressures (1 eutrophication equivalent equals 1 kg P or 10 kg N per annum, *cf.* RIVM & Statistics Netherlands, 2001, p.252). These equivalents are based on the average appearance of nitrogen and phosphorus in ecosystems under natural conditions.

6.3.6 *Dispersion of toxic substances* [2)]

The dispersion of toxic substances resembles a wide range of substances, *e.g.* carbon monoxide, nitrogen oxides, various organic compounds, radioactive matter, heavy metals and pesticides. The toxicity characteristics are better revealed for individual substances than for these categories of substances since within these categories, the toxicity characteristics of substances may vary substantially. So-called 'acceptable daily intakes' and 'predicted no effect levels' are used in life cycle assessments

Table 6.3
Profiles for the despersion of toxic substances on net emissions, the Netherlands, 1997

	Aquatic ecosystems	Terrestrial ecosystems	Human health
	%		
Total	100	100	100
Households	5.2	0.2	27.5
Production	94.8	99.3	72.3
Other sources	–	0.5	0.1
Households	100	100	100
Own transport	11.1	2.5	48.6
Other household functions	88.9	97.5	51.4
Production	100	100	100
Agriculture, forestry and fishing	91.2	99.1	19.8
Mining and quarrying	–	–	0.4
Manufacturing	3.7	0.1	54.0
Electricity, gas and water supply	–	–	0.9
Construction	0.5	–	3.1
Trade, hotels and restaurants	2.9	0.2	8.5
Transport and commmunication	2.9	0.1	8.0
Financial and business activities	0.5	0.1	1.5
General government	1.1	0.2	1.1
Environmental services	–3.0	–	2.0
Care and other service activities	0.5	0.2	0.7

Indicators are based on the 'equivalence factor method' and include the so-called priority substances selected by the Ministry of the Environment (cf. VROM, 1994), pesticides and radioactive substances. See also Gorree (1998, Annex 2) for the compete overview of substances included in these indicators.

Source: derived from Gorree (1998, table 3.4).

to express the potential threats from individual pollutants to human health and ecosystems respectively (Guinée *et. al.*, 1996). Acceptable daily intake is the maximum exposure level to humans below which no health effects are expected. No-effect levels refer to the maximum pollutant concentration levels for the various environmental domains (air, water, soil) below which no damages to ecosystems are expected.

The logical consequence of using no-effect levels to weight toxic pollution is that differences in weighing schemes with respect to ecosystems and human health will inevitably result in different indicators. Table 6.3, derived from Gorree (1998), reflects the substantial differences in no-effect levels of individual substances with respect to aquatic ecosystems, terrestrial ecosystems and human health. As a result, the shares of different industries in the concomitant dispersion of toxic substances indicators vary substantially. For example, between these three indicators, contributions of agriculture (*e.g.* pesticides) vary from 20% up to 99%.

Unlike the weighing methods discussed so far, no-effect levels resemble pollution concentration *targets*. These targets follow a strong sustainability principle, *i.e.* no allowance for any damage. This principle does not necessarily coincide with environmental quality conditions or health risks that are being considered acceptable to society. On the other hand, the no-effect levels seem to provide a rather logical basis for comparing the toxicity potentials of individual pollutants.
The name '*dispersion* of toxic substances' indicates that the transportation of toxic matter in different environmental compartments plays an important role in the ultimate ambient pollution concentrations. Non-degradable pollutants will be dispersed over longer periods of time and subsequently over larger distances compared to less persistent substances. Modern pesticides will usually degrade rather quickly while heavy metals do not degrade at all. The period of time over which a pollutant remains in the environment contributes to expected ambient concentration after its release. Ideally, the conversion factors required to reformulate no-effect concentration levels to pollution targets in a macroeconomic accounting context should be based on:

- the volume (land areas, water volume, number of humans) that is affected after the pollutant has been fully dispersed;
- the duration of the pollutant's presence;
- the contribution of other pollution sources to ambient concentrations.

A mutual comparison of the toxicity characteristics of individual pollutants depends on the time span over which related hazards are taken into consideration. A NAMEA without regional breakdown does not take into consideration the specific local conditions (*e.g.* environmental conditions, the presence of other pollution sources, of individual emission sources (height of chimneys) and multi-substance toxicity. This simplification coincides with the scope of life cycle assessment (Guinée *et al*., 1996) in providing a general evaluation of the average environmental impacts of products regardless the locations of their production, consumption or disposal. The equivalence factor weighing method underlying the indicators presented in table 6.3 is based on a dispersion model with a continental scale and an infinite time horizon.
Segers *et al*. (2000) explain that such a large-scale model as applied in life cycle assessment neglects local circumstances and the emergence of short term and local peaks in concentration levels. For example, local high-level concentrations of pesticides may cause severe environmental damage in rather short periods of time. These problems may not show up at all in large-scale equilibrium dispersion models. Wesseling & Bovenkamp (1997) have tried to overcome the deficiency of neglecting specific regional conditions by formulating regional emission targets derived from regionally dispersion patterns and concomitant no-effect concentrations. However, they ignore the combined effects of a multitude of emission sources concentrated in one area. One may conclude that the construction of a toxic dispersion indicator, based on a regional bottom-up approach, as recommended by

Wesseling & Bovenkamp, is highly data demanding and easily leads to increasing indicator murkiness. So far, no satisfying solutions have been found to overcome the problems of oversimplification resulting from the equivalence factor weighing method as applied by Gorree.

Pressure indicators addressing the health threats from noise nuisance may review the number of people that are affected by certain predefined levels of noise (*cf*. Adriaanse, 1993). Such an indicator has so far not been subject to research at Statistics Netherlands.

6.3.7 Natural resource depletion

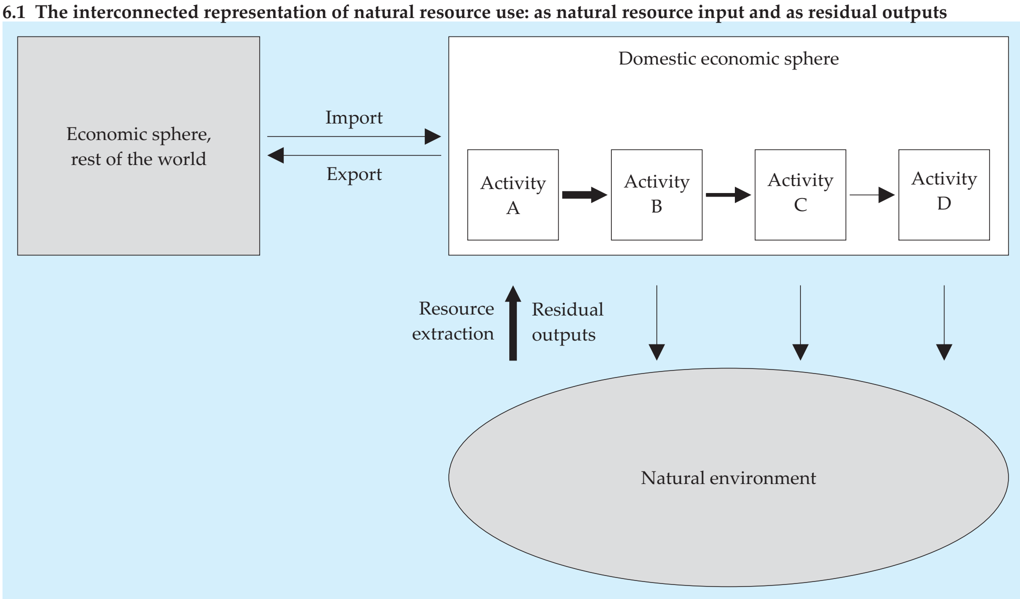
A balance sheet may provide a systematic review of natural resource stocks and their periodic changes. Balance sheets may be compiled in physical or money terms. As such, a balance sheet may provide a condensed or aggregated overview of the net worth of natural resource deposits for which money valuation is feasible. The periodic changes in the worth of natural resources will include in addition to volume changes entries for the effects of resource price changes or holding gains and losses.

Physical flow accounts may subsequently address the economy wide resource dependencies of individual production or consumption activities. Both types of accounting frameworks, balance sheets and physical flow accounts, are complementary in scope, in a similar way as the integrated recording of money flows and stocks in the SNA-1993. As discussed in chapter 2, for many environmental degradation issues such a fully integrated flow-stock accounting approach is less easily established.

There are various ways to indicate the natural resources dependencies of an economy in physical flow accounting. The most straightforward option is to record the input of natural resources directly in connection to the mining activities responsible for their extraction. This is how natural gas and crude oil extractions and all other changes in these natural assets are currently being represented in the Dutch NAMEA (*cf*. table 5.1, accounts *11k* and *11l*). The corresponding indicator in the NAMEA, presented in entry (*12f,6*), shows how new findings and the other changes in natural resources match up with extractions.

Usually, the exploitation of natural resources is under the responsibility of only a limited number of industries *e.g.* agriculture and fishing, mining and quarrying and perhaps a few manufacturing industries. As such, this recording does not very well illustrate how other parts of the economic system depend on natural resources. After extraction, most natural resources or raw materials are allocated via markets and subsequently used as the intermediate inputs in the manufacturing of products. The sequential transformation of materials in product chains may be traced down in physical supply-use or input-output tables. As explained in chapter 3, these types of tables are particularly useful for analysing the subsequent material transformations in product chains.

6.1 The interconnected representation of natural resource use: as natural resource input and as residual outputs



The economic use of natural resources can be expressed in at least three interconnected ways. A direct resource input indicator identifies its use in terms of extraction. This perspective is particularly relevant for countries with a strong economic dependence on natural resource deposits. At the moment a natural resource is withdrawn from nature, its economic use starts. In many cases, a natural resource is transformed into products. The use of a natural resource ends at the moment the product embodying the natural resource looses its use value and becomes waste. Residual outputs indicate the disuse or disposal of a natural resource. For example, carbon dioxide and other emissions from fuel combustion represent the disposal of residuals originating from oil and gas deposits. The material balance between resource inputs and residual outputs is visualised by figure 6.1. Throughout the product chain, natural resources are transformed into residuals. Without material accumulation in the economic sphere, the mass sum of natural resource inputs and imports equals the mass sum of residual outputs and exports. This identity corresponds to identity (3.1) discussed in chapter 3.

A third perspective is that of the consumer. Consumers in an economy are in fact the ultimate users of natural resources since the ultimate goal of production, and the use of natural resources in the course of production, is the satisfaction of consumer needs. Consumption is the final step of the product chain in the economic sphere. Input-output tables are helpful in analysing the economy-wide total amount of natural resources required for the production of one money unit of consumer product. In fact, all natural resource inputs can ultimately be appointed to one or various consumer product(s).

Table 6.4a
An example of a simple input-output table in money units

	Crude oil	Electricity	Fuel	Cars	Final demand	Total supply
	€					
Crude oil	–	500	500	–	–	1 000
Electricity	250	550	–	250	1 250	2 300
Fuel	250	125	125	250	1 250	2 000
Cars	–	–	–	–	2 000	2 000
Value added	500	1 125	1 375	1 500		4 500
Total use	1 000	2 300	2 000	2 000	4 500	

Table 6.4b
An example of a simple input-output table in peta joules (PJ)

	Crude oil	Electricity	Fuel	Cars	Final demand	**Energy losses (II)**	Total supply
	PJ						
Crude oil	–	44	44	–	–	**7**	95
Electricity	2	7	–	2	33	**10**	54
Fuel	5	3	3	5	28	**3**	47
Cars						**7**	7
Final demand						**61**	61
Energy extraction (I)	**88**	**–**	**–**	**–**	**–**		**88**
Total use	95	54	47	7	61	**88**	

Table 6.4c
An example of a hybrid input-output system in energy and money units

	Crude oil	Electricity	Fuel	Cars	Final demand	Total supply
Crude oil (PJ)	–	44	44	–	–	88
Electricity (PJ)	2	7	–	2	33	44
Fuel (PJ)	5	3	3	5	28	44
Cars (€)	–	–	–	–	2 000	2 000

Table 6.4d
The Leontief inverse of the hybrid input-output system presented in table 6.4c

	Crude oil	Electricity	Fuel	Cars
	PJ/PJ			*PJ/€*
Crude oil	1.099	1.402	1.179	0.004
Electricity	0.030	1.227	0.032	0.001
Fuel	0.069	0.175	1.147	0.003
	€/PJ			*€/€*
Cars	0.000	0.000	0.000	1.000

The construction of these three indicators is illustrated by way of a numerical example. The tables showed here largely originate from Miller & Blair (1985, p.104-108). The first table (6.4a) shows a fairly standard input-output table in money units of an economy existing of three energy industries and one car industry. For simplicity reasons, the economy represented by this input-output table is totally autarkic and does neither have imports nor exports. All required crude oil is entirely extracted from domestic natural resource deposits. This crude oil is supplied in equal portions to the electricity and the fuel industry. Both fuel and electricity are used as intermediate and final consumption. Cars are supposed to be used only for final consumption.

The following table (6.4b) is an input-output table in energy units, *i.e.* peta joules (*PJ*). This physical input-output table is only constructed for the three energy industries. The car industry is not included. Further, this table includes an entry representing the amount of fossil energy extracted from nature. Only for illustrative purposes, the total amount of crude oil extraction is set equal to the total amount of crude oil extracted in the Netherlands in 1997, *cf*. table 5.1, (*11l,3*). There is no other similarity of these tables with the Dutch NAMEA as presented in this table.

Table 6.4b contains two out of three indicators referred to above. This table presents a closed energy input-output system with the environment presented in an additional account. This account, recording the environmental-economic exchanges, shows in its row the total extraction of crude oil (I) by the corresponding mining activity: 88 peta joules. The subsequent energy losses (II) are presented in the column of this account. The energy loss of an individual industry is defined as the balance between the sum of energy inputs (= column total: total use) minus the total supply of energy via products. Obviously, the car industry and final demand (consumption) do not supply energy, so their net energy use equals by definition their total sum of energy inputs. Table 6.4b shows that total extraction equals the

sum of economy wide energy losses. This is true by definition as long as there are no energy exchanges between other economies and there is no stockpiling of energy carriers in the economic sphere.
Finally, the third indicator, the final consumption perspective, can only be derived from an input-output calculation. This perspective is the main topic of chapter 7 in this thesis.3) For illustrative purposes, the allocation of energy use to consumption is already briefly discussed here by showing how the indicators (I) and (II) relate to the attribution of energy to consumption, *i.e.* indicator (III). A hybrid input-output table can be constructed to analyse the accumulated energy demand of consumers. Such a hybrid input-output table is shown in table 6.4c. This table consists of the first three rows (*i.e.* crude oil, electricity, fuel) of the physical input-output table (6.4b), excluding the entries for energy losses, and the fourth row (cars) of the input-output table in money terms (6.4a). Wilting (1996) and Konijn *et al*. (1997) developed for the case of the Netherlands similar types of hybrid energy input-output systems.
A hybrid input-output table has largely the same properties as a regular table expressed in money terms. In fact, the technical coefficients in a Leontief type of production function, as derived from input-output tables, are physically in nature by expressing the total amount of a product *i* required to produce one unit of product *j* (*cf*. Leontief, 1966). Principally, this implies that each row in an input-output table can be denominated in the most appropriate accounting unit, *e.g.* barrels of crude oil, kilowatt-hour, number of cars. Table 6.4c has only two dimensions: peta joules for the three energy industries and money units for the car industry.
Table 6.4c can be used to compile a Leontief model for estimating the total energy requirements of final consumption. The first step contains the construction of a matrix with input-output coefficients. If matrix **Z** represents the industry by industry intermediate requirements, then the matrix **A** containing the technical, or input-output, coefficients can be determined as follows:

$$\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1} \qquad (6.1)$$

Matrix **Z** denotes the matrix with intermediate requirements. In our example, **Z** is a square 4 × 4 matrix. Vector **x** denotes the row sum of industry outputs, *i.e.* total supply in table 6.4c. Matrix denotes the inverse of the diagonal matrix of vector **x**. Matrix **A** contains the technical coefficients: [4)]

For $i,j = \{1,2,3\}$, $a_{i,j}$ represents the direct energy input from industry *i* required for one energy unit of output of industry *j*.
For $i = \{1,2,3\}$, $a_{i,4}$ represents the energy input from industry *i* required for one money unit of output of the car industry (*4*).
For $j = \{1,2,3\}$, $a_{4,j}$ represents the money input from the car industry required for one energy unit of output of industry (*j*). In our example $a_{4,j} = 0$ for al values of *j*.
Finally, $a_{4,4}$ represents the direct sum of money units of cars, required for the production of one money unit of cars. In our example $a_{4,4} = 0$.

The Leontief model can now be formulated as follows.

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \qquad (6.2)$$

y denotes the hybrid final demand vector, *i.e.* the fifth column in table 6.4c. Equation (6.2.) explains that, for each industry, total output equals the sum of intermediate deliveries plus final demand. With the help of the Leontief inverse, output **x** can be expressed as a function of final demand **y**.

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \qquad (6.3)$$

I denotes the identity matrix and the matrix $(\mathbf{I}–\mathbf{A})^{-1}$ denotes the Leontief inverse. In addition to the *direct* technical coefficients presented by **A**, the Leontief inverse contains the economy-wide or *total* requirements. Element $\alpha_{i,j}$ of $(\mathbf{I}–\mathbf{A})^{-1}$ denotes the total amount of output of industry *i* required for one unit of (final) output of industry *j*. Table 6.4d presents the Leontief inverse in our example. The first row of the Leontief inverse is particularly interesting when analysing the economy wide natural resource requirements. The crude oil industry is mainly concerned with the extraction of crude oil from the natural environment. Its production in physical terms equals the total extracted amount of crude oil (*i.e.* 88 peta joules). The elements in the first row of the Leontief inverse, $\{\alpha_{1,1} \ldots \alpha_{1,4}\}$, show the total amount of crude oil required for one unit output of crude oil, electricity, fuel and cars respectively. In our numerical example, the total economy wide use of crude oil can be calculated by multiplying these total requirement coefficients with the corresponding elements of **y**: $1.099\times0 + 1.402\times33 + 1.179\times28 + 0.004\times2000 = 88$ peta joule. Since the primary energy source, crude oil, is entirely converted into secondary energy products before this energy source is further used in the economy, the sum of the

Table 6.5
Three types of indicators reflecting the economic use of natural resources

	Natural resource inputs	Residual outputs (energy losses)	Consumption (accumulated use)
	I.	II.	III.
	PJ		
Crude oil	88	7	(–)
Electricity	–	10	(46)
Fuel	–	3	(33)
Cars	–	7	(9)
Final demand	–	61	88
Total	88	88	88

two total secondary energy requirements equals the total crude oil requirements, *i.e.* $\alpha_{1,j} = \alpha_{2,j} + \alpha_{3,j}$. [5)]
Table 6.5 summarises the three categories of indicators, showing at various stages the natural resource uses throughout the economy. In the closed model presented in our example, the total sum of each indicator adds up to the same total of 88 peta joules. On the macro level, the three indicators are identical and this illustrates the material/energy balance principle underlying this set of indicators. As will be shown in the next chapter, the existence of imports and exports may cause substantial gaps between these indicators on the macro level. However, these indicators lead to differences at the industry level. For the consumption related indicator (III), the industrial breakdown is shown between brackets. These elements reflect the individual terms in the above presented calculation. For example, for electricity the corresponding element equals 1.402×33 = 46 peta joules. This implies that in our example, 33 peta joules of final electricity consumption require 46 peta joules of crude oil.
The accumulated energy use, or the consumption indicator III, is in our example calculated by attributing energy inputs to final demand. Indicator III, can also be estimated by accumulating to final demand the concomitant resource losses or residual outputs, *i.e.* indicator II. In the hybrid input-output system presented above, the outputs of mining industries and natural resource processing industries are presented in energy units while the output of the car industry is denominated in money terms. The output vector **x** can be subdivided into two sub-vectors **x*** and $\mathbf{x}^{€}$ in such a way that

$$\mathbf{x} = \mathbf{x}^* + \mathbf{x}^{€} \tag{6.4}$$

The physical entries of **x** are included in **x*** while all other entries in **x*** are zero. Similarly, all money entries of **x** are represented in $\mathbf{x}^{€}$ while all other entries in $\mathbf{x}^{€}$ are zero. The following material balance identity holds between the natural resource inputs by industries, presented by vector $\mathbf{v}_{\mathbf{I}}$ and the concomitant residual outputs presented be vector $\mathbf{v}_{\mathbf{II}}$.

$$\mathbf{v}_{\mathbf{I}} + \mathbf{A}'\mathbf{x}^* = \mathbf{x}^* + \mathbf{v}_{\mathbf{II}} \tag{6.5}$$

Identity (6.5) explains that, for each industry, primary natural resource inputs + secondary resource (product) inputs equal secondary resource (product) outputs plus residual outputs (or energy losses). Matrix **A′** is the transposed matrix of **A**.
The resource input-oriented estimation of the consumption indicator $\mathbf{v}_{\mathbf{III}}$ can be formulated as follows:

$$\mathbf{v}_{\mathbf{III}}' = \mathbf{e}_{\mathbf{I}}'(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}} \tag{6.6}$$

where the *resource input* coefficient vector is calculated as follows:

$$\mathbf{e}_{\mathrm{I}} = \hat{\mathbf{x}}^{-1}\mathbf{v}_{\mathrm{I}}$$

Vector $\mathbf{v}_{\mathrm{III}}$ shows the accumulated resource requirements of the final deliveries by industries. Pre-multiplication of equation (6.5) with leads to the following expression.

$$\mathbf{e}_{\mathrm{I}} = \hat{\mathbf{x}}^{-1}(\mathbf{I} - \mathbf{A}')\mathbf{x}^{*} + \mathbf{e}_{\mathrm{II}} \quad (6.7)$$

where the *residual output* coefficient vector is defined as follows:

$$\mathbf{e}_{\mathrm{II}} = \hat{\mathbf{x}}^{-1}\mathbf{v}_{\mathrm{II}}$$

The final demand vector **y** can be subdivided into two sub-vectors **y*** and $\mathbf{y}^{€}$ in such a way that

$$\mathbf{y} = \mathbf{y}^{*} + \mathbf{y}^{€} \quad (6.8)$$

The physical entries of **y** are included in **y*** while all other entries in **y*** are zero. Similarly, all money entries of **y** are represented in $\mathbf{y}^{€}$ while all other entries in $\mathbf{y}^{€}$ are zero. Then, substitution of equation (6.7) into (6.6) results in the following expression:

$$\begin{aligned} \mathbf{v}_{\mathrm{III}}' &= \mathbf{x}^{*}'(\mathbf{I} - \mathbf{A}')'\hat{\mathbf{x}}^{-1}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}} + \mathbf{e}_{\mathrm{II}}'(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}} \\ &= \mathbf{y}^{*}' + \mathbf{e}_{\mathrm{II}}'(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}} \end{aligned} \quad (6.9)$$

A comparison of the equations (6.6) and (6.9) shows that the resource requirements of final products, *i.e.* indicator $\mathbf{v}_{\mathrm{III}}$, can be calculated from either the perspective of natural resource inputs or residual outputs. However, the output oriented approach omits the actual natural resource content of final demand, *i.e.* **y***. This component must be added in order to arrive at $\mathbf{v}_{\mathrm{III}}$.

This similarity implies that the distinction between natural resource inputs and the concomitant waste outputs is not so obvious in a sense that each side reflects one end of a natural resource's use in an economic system. Output oriented indicators, that are dominating the Dutch NAMEA at present, do not necessarily neglect natural resource related issues. For example, the above-presented set of indicators illustrate that the carbon dioxide emission account may serve as a fossil energy resource use indicator that can be applied to estimate the fossil energy intensities of final products.

It is possible that atmospheric carbon dioxide accumulation turns out to be a more restrictive environmental threat than the world-wide depletion of fossil fuel deposits. Intuitively, one may argue that the choice of an input- or output-oriented indicator depends on the kind of environmental problem one wants to address. On the other hand, the energy example shows that both problems are totally interconnected. Resource inputs and the concomitant waste outputs are the *two* interconnected angles of the industrial metabolism.

6.3.8 *Water use*

An essential natural resource with a multiple range of use functions is water. De Haan (1998) addressed several environmental issues related to water in a specially developed National Accounting Matrix including Water Accounts (NAMWA) for 1991. The NAMWA provides a statistical framework that aims at facilitating integrated economic and environmental policies with special reference to fresh water management. This system of water accounts is discussed in the following section and contains features such as quantitative and qualitative (*i.e.* water pollution) water use, depletion of fresh water deposits and an explicit representation in the accounts of water management activities.

In co-operation with the Dutch National Institute for Integrated Water Management (RIZA), Statistics Netherlands recently updated the NAMWA for the period 1996 – 1999. These NAMWA's contain a regional subdivision according to four major river basins in the Netherlands, *i.e.* Rhine, Meuse, Scheldt and Ems. The results and policy needs of the NAMWA are discussed by Van der Stegen (2003) and Brouwer *et al*. (2003). One of the policy uses addressed by Brouwer *et al.* is the monitoring of policy and management responses to various kinds of environmental pressures on Dutch fresh water bodies. The NAMWA also serves as a data delivery system for the European Water Framework Directive. Finally, the NAMWA is used for collecting information about the production costs of water related services such as waste water treatment and the supply of drinking water and the recovery of these costs through *e.g*. sales and the tax system.

6.3.9 *Land use*

Due to lacking concepts and missing data (*cf*. Krack-Roberg & Schäfer, 1997) land use accounting has received up till now limited attention. Yet, land or space clearly is a scarce environmental requirement in a densely populated area like the Netherlands, where the optimal allocation of land often dominates policy debates on spatial planning and new infrastructure. Leurs & Van Dalen (1998) developed a preliminary environmental theme indicator for land use in the Dutch NAMEA with the main objective of illustrating the occupation of space by economic activity.

The main focus of the NAMEA is providing an overall economic picture. Each environmental indicator is represented by one uniform classification of economic activities. This enhances a comprehensive review of different types of environmental requirements, allowing for a general review of environmental-economic performance as for example presented in table 6.2.

There are a number of conceptual obstacles that obfuscate a satisfying representation of land use in the NAMEA. Land is usually not very homogeneous and different kinds of land use functions require different kinds of land categories. The competition between different land use functions is not easily quantified in an activity based accounting framework. Certain use functions may coexist harmoniously while other functions totally exclude any other possible land use. Ideally, land use accounting should be able to address the competition as well as the co-existence of different use functions.

The assignment of land to specific purposes largely determines the quality of ecosystems it may be able to support. In other words, land use, land coverage and the functioning of terrestrial or aquatic ecosystems are highly entangled. Although land is principally included as an asset in the SNA balance sheet, land prices or rents will usually provide very limited, if any, information about the intrinsic ecological values of land. Land use accounting may be helpful to reveal these non-market related functions.

In this context the principles by which Leurs & Van Dalen determine land use by economic activity are not entirely satisfying. They classify the total available land surface according to use functions from which information on land use by economic activity is subsequently derived. In this way, all available land is fully allocated to economic activities, recreation and nature preservation. Yet, a NAMEA indicator should preferably be constructed on the basis of the *actual* occupation of space by individual economic activities rather than on the basis of *potential* uses as derived from a functional land use classification.

Land use scarcity results from direct competition between different activities or use functions. Although a NAMEA may provide information on the claims laid by different economic actors on *e.g.* occupied land or the total areas disturbed by stench or noise, the resulting conflicts between different users or use functions (recreation, natural preservation) remain largely unidentified. Therefore, supplementary to activity oriented land use indicators, land use, land coverage and ecosystem accounts based on geo-referencing or geographical information systems seem to be highly effective in linking information on (changes in) land use to information on land cover and ecosystem characteristics (*cf.* Rademacher, 1998 and Stott & Haines-Young, 1998). Clearly, geographic-oriented accounts are generally less related to the national accounts. However, the earlier referred at regional breakdown of the NAMWA according to different rivers basins in the Netherlands illustrates that junctions of both accounting perspectives are feasible and useful.

6.4 Statistical issues

6.4.1 Air emissions

Measured in metric tonnes, emissions from combustion are usually the most substantial residual outputs of an economy and this is equally the case for the Dutch economy (*cf.* Matthews *et al*., 2000, p.98-100). The larger part of these air emissions consists of carbon dioxide (CO_2). Other example of combustion related emissions are carbon monoxide (CO), nitrogen oxides (NO_X), sulphur dioxide (SO_2), methane

(CH_4) and non-methane volatile organic compounds (NMVOC). In addition to air emissions from combustion processes there exists a variety of other processes that generate air emissions of less significance in terms of weight but not necessarily in terms of environmental impacts.

As discussed in chapter 3, air emissions in the NAMEA are recorded according to the resident principle. For stationary emission sources the resident principle will generally converge with the emission data as recorded in emission inventories. However, for mobile sources such as those related to traffic, air and water transport, substantial differences may occur. Table 6.6 shows the reconciliation of the emissions to air by Dutch residents to air pollution emitted on Dutch territory. Regular emission inventories usually follow a territorial demarcation of pollution sources but this is inconsistent with the national accounts boundaries of for example production and consumption (*cf*. chapter 3, par. 3.4).

In other words, a special point of concern in constructing environmental accounts based on national accounting principles is the estimation of air emissions from mobile sources. In case of stationary pollution sources, business registers are usually helpful in identifying their relation to industries. For mobile sources these allocations are not always that easily made. In case of pollution from shipping or aviation, the corresponding industries are usefully rather straightforwardly identified. Road transport services are often carried out as an ancillary activity in a wide range of industries. Car registers may be used to identify the ownership of vehicles, however, passenger cars may be company owned but privately used and vice versa. Additional information on propellant purchases found in the supply-use tables may be helpful in allocating pollution to the economic activities.

Table 6.6
A bridge table for air emissions: from residents to territory, the Netherlands, 1997

		CO_2	N_2O	CH_4	NO_x	SO_2
		mln kg				
Emissions by resident	1	201 020	73	1 104	701	236
Residents in the rest of the world, of wich	2	24 980	3	1	282	131
Transport by road	2a	4 990	1	1	50	1
Air transport (incl. defence activities)	2b	10 530	–	–	39	1
Water transport	2c	9 460	2	–	193	129
Non-residents in the Netherlands, of which	3	2 850	1	–	41	12
Transport by road	3a	1 040	–	–	9	–
Air transport	3b	270	–	–	1	–
Water transport	3c	1 540	–	–	31	12
Emissions in the Netherlands	4=1–2+3	178 890	70	1 103	460	117

Source: Statistics Netherlands (2000).

Table 6.7
Emission sources included in the Dutch NAMEA, 1997

	CO_2		NO_X		SO_2	
	mln kg	%-shares	mln kg	%-shares	mln kg	%-shares
Combustion of fossil fuels, stationary sources	112 800	56.1	123.5	17.6	67.2	28.4
Combustion of fossil fuels, mobile sources	56 160	27.9	540.9	77.1	141.4	59.9
Combustion of wood	1 050	0.5	16.8	2.4	0.5	0.2
Waste cobustion and landfills	4 250	2.1	9.3	1.3	1.2	0.5
Other industrial processes	26 760	13.3	10.7	1.5	26.0	11.0
Total	201 020	100	701.3	100	236.2	100

Source: Statistics Netherlands (2000) and supplementary calculations based on the Emission Register 2000 Database.

In the Dutch economy, emissions from international transport activities are quite substantial. As shown in table 6.6, from a total of 201 million kiloton carbon dioxide in 1997, Dutch residents emitted almost 25 million kiloton outside the borders of the Netherlands. This shows that transportation is a rather significant economic activity in the Dutch economy. Table 6.7 also underlines the importance of transportation activities in the Dutch economy. Almost 28% of all emissions by Dutch residents in 1997 is transport related. In the period 1995–1999, carbon dioxide emissions from stationary source decreased by 1% while emissions from mobile sources increased with 11,5%. So in recent years, transport related emissions have substantially increased while other emissions almost stabilised. This emphasises the importance of addressing emissions from international transportation in international agreements on climate change. This is presently not the case. The NAMEA provides the appropriate framework to overcome this deficiency in the international regulation of greenhouse gas reductions.

Besides a sound delineation of economic activities represented in the accounts, a confinement of pollution sources is equally required. Table 6.7 reviews for three pollutants, CO_2, NO_X and SO_2, the emission sources included in the NAMEA as annually published by Statistics Netherlands. The Dutch NAMEA aims at providing a complete coverage of *actual* emissions which means that emissions are recorded were and when they factually occur. For example, the actual emissions from waste incineration are recorded in connection to the activity waste treatment. As a logical consequence, *potential* CO_2 or the embodiment of carbon in plastics, as included in the IPCC estimate, *cf.* table 3.2, is not followed in the emission account of the NAMEA.

The actual emissions in the NAMEA include those related to so-called short-term carbon cycles (*e.g.* wood and waste combustion). These sources are without doubt relevant for pollutants such as NO_X and SO_2. With respect to CO_2, it can be argued that, contrary to fossil fuel combustion, emissions from short-term carbon cycles do not contribute to a structural increase in atmospheric greenhouse gas concentrations. This is why the IPCC regulation ignores these emissions. On the other hand, short-term carbon cycles are considered relevant for carbon sequestration as an option to diminish the concentration of greenhouse gases in the atmosphere. In this respect, if carbon sequestration is considered a valid abatement option in international greenhouse pollution abatement agreements, there seems to be no reason why emissions from short-terms cycles should be ignored in emission accounting.

In conclusion, potential carbon dioxide emissions as included in the IPCC estimates are inconsistent with the principles of actual and accrual accounting and are therefore excluded from the NAMEA. Instead, the environmental accounts in the NAMEA record emissions when and where they occur in reality for example at the stage of waste plastic incineration instead of at the stage of plastic production. The internal consistency of the accounts is improved by a uniform coverage of emission sources for all pollutants.

There are however a number of minor exceptions in this respect. The Dutch emission register as well as the NAMEA includes methane (CH_4) and ammonia (NH_3) emissions from husbandry which are rather significant. However, CO_2 emissions from husbandry are excluded. Similarly excluded are all air emissions from human fermentation. Yet, the NAMEA includes pollution from cigarette smoking.

Table 6.8
A condensed substance flow account for nitrogen in the Netherlands, 1995

Origin		**Destination**	
	mln kg (N)		*mln kg (N)*
Economic sphere			
Import of products	1 244	Export of products	2 724
Absorption (from the environment)		Gross emission	
N_2	2 719	N_2	33
Other compounds	117	Other compounds	1 050
		Net additions to stocks	**273**
Total origin	4 080	Total destination	4 080
Natural environment			
Gross emission (exluding N_2)	1 050	Absorption (exluding N_2)	117
Cross-boundary pollution from the rest of the world	322	Cross-boundary pollution to the rest of the world	542
		Net accumulation in the natural environment	**713**
Total origin	1 372	Total destination	1 372

Source: derived from Fong (1997a). Data on air emissions and cross-boundary pollution flows are based on revised calculations.

6.4.2 *Nutrients*

The most important pollutants contributing to eutrophication in the Netherlands are phosphates, nitrates and a number of air pollutants such as ammonia (NH_3) and nitrogen oxides (NO_X). Economy-wide substance flow accounts, as compiled in the Netherlands by Fong (1997a), are helpful in determining the nitrogen or phosphorus contents of a range of relevant substances. In these accounts, all nutrient flows are expressed either in kilograms nitrogen (N) or kilograms phosphorus (P). In the Dutch NAMEA, these substance accounts are translated into activity-oriented nitrogen and phosphate accounts with a strict focus on nutrient exchanges of the economic sphere with the natural environment.

Table 6.8 summarises the substance flow account for nitrogen as compiled by Fong. However, different from Fong's presentation, table 6.8 provides an overview of nutrient flows from two perspectives: the economic sphere and the natural environment. This subdivision is crucial in the construction of NAMEA-type of nitrogen and phosphorus accounts. Regarding the economic sphere, table 6.8 categorises the origin and destination of nitrogen flows along the lines of the first input-output accounting identity (3.1) presented in chapter 3. The balancing item 'net additions to stock' largely corresponds to inventory changes in nitrogen containing compounds like fertilisers and changes in the biomass tied up in the economic sphere, *e.g.* fodder, food products, livestock. This aggregate is, at least partially, compiled as a balancing item and Fong indicates (*cf.* figure 3.1, p.21) that statistical errors are reflected in this estimate as well.

Table 6.9
A condensed substance flow account for phosphorus in the Netherlands, 1995

Origin		**Destination**	
	mln kg (P)		*mln kg (P)*
Economic sphere			
Import of products	573	Export of products	449
Absorption (from the environment)	22	Gross emission	112
		Net additions to stocks	**34**
Total origin	595	Total destination	595
Natural environment			
Gross emission	112	Absorption	22
Cross-boundary pollution from the rest of the world	14	Cross-boundary pollution to the rest of the world	20
		Net accumulation in the natural environment	**84**
Total origin	126	Total destination	126

Source: derived from Fong (1997b). Data on cross-boundary polution have been modified.

The second half of table 6.8 refers to the origin and destination of nitrogen flows in relation to the natural environment as far as Dutch territory is concerned. This scheme follows the structure of NAMEA substance account. However, there is one important difference. The NAMEA account deliberately ignores pure nitrogen (N_2) flows. As one of the major constituents of the atmosphere, N_2 emissions are totally irrelevant from an environmental perspective. Similarly, N_2 inputs in combustion processes are not represented as natural resource inputs and the breakdown of nitrates in wastewater into pure nitrogen (N_2), *i.e.* de-nitrification resulting from wastewater treatment, shows up in the NAMEA nitrogen account as a 'net environmental benefit' or the net cleansing of harmful nutrient compounds.

Table 6.9 reviews the substance flow account for phosphorus. Again, the lower part of this table summarises the accounting structure followed in the NAMEA. The set-up of the phosphorus account is perhaps somewhat simpler since, unlike nitrogen, air emissions do not play a significant role here. Also unlike nitrogen, wastewater treatment does, on balance, not contribute to a reduced accumulation of (potentially harmful) phosphor compounds in the natural environment. Table 6.9 shows that for sewage and refuse disposal services the gross emissions and absorption of phosphorus compounds are approximately equal. Wastewater treatment may result in lower phosphate concentrations in surface water but the residues of this process, *e.g.* sewage sludge, will fully contain these phosphate loads.

6.4.3 *Solid waste*

Solid waste generally refers to those materials, packages and products at the end of their life cycle when they have lost their use value. Solid waste is quite difficult to grasp in one univocal classification (*cf.* Eurostat, 2000b) since a range of different dimensions are usually relevant in their statistical representation. The solid waste account in the NAMEA mainly focuses on the treatment and storage problems connected to (regular non-toxic) solid waste in the Netherlands.

Solid waste may contribute to a range of environmental problems and therefore the *composition* of waste is usually very relevant. Waste may be toxic, may contain nutrients and may require financial means, space and other environmental requirements for their transportation, treatment and storage. Other themes in the NAMEA may single out some of these 'quality aspects' of waste.

Conceptually, the waste account in the NAMEA illustrates the 'physical' significance of solid waste related services such as recycling, trade in waste collection and treatment services. The NAMEA systematically brings together the monetary and non-monetary inputs and outputs of these activities. The main services provided by these activities are to some extent revealed by the payment of the services provided but equally by their physical appearance, *i.e.* the transportation, storage and transformation of waste.

Regarding the delineation of solid waste, one may conclude that the concept of waste can be extended almost infinitely when each material movement is ultimately defined as a waste. Especially, excavations and material movements in mining and construction operations may expand the notion of waste enormously. In the Netherlands a substantial amount of waste results from dredging, required to maintain entrance of shipping to inland water bodies. Unfortunately, this dredging sludge is often polluted and this restricts its use for agricultural or other purposes. At the same time, this pollution makes the treatment of dredging sludge quite expensive. The waste account in the Dutch NAMEA does not include these movements of matter. Instead, the waste account is basically restricted to those waste flows directly resulting from either production or consumption activities. The destination of the recorded waste flows in the NAMEA could be categorised as follows:

– direct discharges to nature or (controlled) land fills;
– internal processing or external recycling;
– treatment or incineration.

Table 6.10
Waste categories represented in the Dutch NAMEA, 1997

	Gross waste	Recycled or internally processed	Net waste
	1.	2.	3. = (1–2)
	mln kg		
Domestic waste	6 210	2 860	3 350
Domestic waste, coarse	1 640	920	720
Pavement cleaning (municipalities)	1 000	–	1 000
Offices, shops and services	2 660	930	1 740
Process waste from manufacturing	8 510	6 870	1 650
Process independent waste from industrial processes	480	80	400
Grossing up of industrial waste for smaller firms	340	–	340
Toxic waste	1 280	140	1 140
Slags from powerplants	1 370	1 370	–
Construction and demolition waste	16 100	14 930	1 170
Agricultural waste	2 200	1 400	800
Specific waste from hospitals	10	–	10
Car wrecks	260	180	80
Car tyres	90	70	20
Shipping waste	720	–	720
Waste oil	60	50	10
Cleaning grit	60	40	20
Phosphor plaster	1 500	–	1 500
Sewage sludge [1)]	560	110	450
Slags from waste incineration	1 110	1 060	50
Total	46 160	31 010	15 170

[1)] Dry weight.

Source: Statistics Netherlands solid waste NAMEA database. Compilations are partly based on surveys carried out by Statistics Netherlands, and RIVM reportings (PRIAF monitoring).

Internally processed waste is by convention excluded from the NAMEA. The NAMEA system does not keep record of waste flows within establishments. Principally, recycling and waste incineration are recorded as the waste inputs of the corresponding industries. One could argue that at least certain landfills are fully under human control and that waste stored in these landfills should be regarded as waste reabsorbed in the economic sphere. The consequence of this recording would be that emissions from landfills should be attributed to the corresponding waste management industry since this recording defines landfills as a stock of residuals controlled within the economic sphere. Currently, the Dutch NAMEA does not distinct between direct waste discharges to the environmental and storage of waste in controlled landfills. The current waste indicator in the NAMEA reflects the annual amount of waste that has to be stored regardless its precise destination.

An overview of waste categories covered in the NAMEA is presented in table 6.10. The current presentation of solid waste in the NAMEA is still somewhat incomplete and unsatisfactory. Firstly, a clear distinction between internal processing and recycling is at present not being made. Secondly, the destination of recycled waste has not (yet) been identified on the basis of current waste surveying. Different from other substances, the emission matrices in the NAMEA, *cf.* entries (*2,11j*) and (*3,11j*) in table 5.1, record from sheer necessity the *net* output of waste instead of gross waste output and the destination of recycled waste is unfortunately not explicitly recorded as the re-absorption of waste in sub-matrix (*11j,3*). Yet, incinerated waste is specifically addressed as the waste inputs of sewage and waste disposal industries. Finally, the cross-boundary flows of waste are currently not presented due to lacking information.

Table 6.11
Oil and gas reserves in the Netherlands

	1995	1996	1997
	peta joule		
Natural gas			
Opening stock	62 129	60 673	60 008
Extraction (–)	2 537	2 868	2 541
Other volume changes	1 081	2 203	3 364
Closing stock	60 673	60 008	60 831
Crude oil			
Opening stock	2 010	1 795	1 974
Extraction (–)	116	95	88
Other volume changes	–99	274	250
Closing stock	1 795	1 974	2 136

Source: derived from annual mineral exploration reports of the Dutch Ministry of Economic Affairs.

6.4.4 *Natural resources*

The Dutch NAMEA summarises the annual changes in natural gas and crude oil deposits in the Netherlands. Oil and gas extractions are shown in entry (*11k–11l,3*) of the NAMEA as presented in table 5.1. Other changes in these mineral deposits are presented in entry (*6,11k–11l*). Table 6.11 presents a balance sheet presenting the expected oil and gas reserves over the period 1995–1997 in the Netherlands, again denominated in peta joules. Balance sheets in money values for these mineral reserves in the Netherlands have been compiled by Van den Berg & Van de Ven (2001).

6.4.5 *Land use*

The land use indicator as compiled by Leurs & Van Dalen (1998) allocates the total land surface of the Netherlands, approximately 41 thousand square km, to different economic activities as represented by the NAMEA. In order to provide a general indication of land occupied by economic activity, multiple uses of land are

Table 6.12
The conversion of land use by purpose to economic activtities, the Netherlands, 1993

	Agri-culture	Forests	Built-up areas	Traffic	Recrea-tion	Natural areas	Other land use	Water bodies	Total
	km²								
Consumers									
Own transport	–	–	–	502	–	–	–	–	502
Recreational use	–	311	–	50	448	–	–	679	1 488
Producers									
Agriculture and forestry	22 771	1 212	–	109	47	–	–	–	24 139
Fishing	–	–	–	2	–	–	–	1 182	1 184
Mining	–	–	68	1	–	–	–	–	69
Manufactoring	–	–	141	38	–	–	–	–	179
Electricity, gas and water supply	–	–	48	1	–	–	–	12	61
Construction	–	–	20	53	–	–	–	–	73
Wholesale and retail trade and Hotels and resaurants	–	–	119	33	187	–	–	–	339
Land transport	–	–	49	306	–	–	–	–	355
Water transport	–	–	5	94	–	–	–	2 087	2 186
Air transport	–	–	18	54	–	–	–	–	72
Supporting transport activities	–	–	20	1	–	–	–	–	21
Housing	–	–	2 168	–	–	–	–	–	2 168
Business services	–	–	77	31	–	–	–	–	108
Other services n.e.c.	–	62	362	55	128	–	38	–	645
Other uses									
Landfills	–	–	–	–	–	–	31	–	31
Nature	984	1 523	–	–	–	1 409	–	3 187	7 103
No direct use	–	–	–	–	–	–	305	–	305
Total	23 755	3 108	3 095	1 330	810	1 409	374	7 147	41 028

Source: Leurs & van Dalen (1998).

proportionally allocated to different economic activities. The results of this land use indicator are summarised in table 6.12. The table shows how Dutch territory classified by purpose is converted into a general NAMEA activity classification. The data on land use by function originates from a land use survey (Statistics Netherlands, 1997).

The allocation ratios, required to divide multiple uses of land by specific activities, are sometimes difficult to assess. It seems reasonable to allocate traffic supporting infrastructure to various economic activities on the basis of their transport performances, *e.g.* kilometres driven. Less obvious is the allocation of water bodies to use functions *e.g.* transportation, fisheries, nature preservation and recreation. Recreational uses of natural areas have not been taken into consideration.

The full allocation of the surface of the Netherlands to economic activities and nature, as illustrated by table 6.12, overstates space used by water-related activities. One could hardly imagine that a share of approximately 55% of all water bodies is actually occupied by production or consumption activities. At the same time, water bodies cannot support non-water related use functions

An opposite bias probably occurs in other transportation. For example, the side effects of aviation will delimit other uses of land in extension to land directly occupied by airports. Similarly, road infrastructure usually encloses much more space than the actual surface occupied by roads, pavements etc. The encapsulation of natural area by transport infrastructure is a specific point of concern with respect to maintaining ecological functions and environmental quality. This concern is not really taken into consideration in the land use indicator presented in table 6.12.

Leurs & Van Dalen provide a regional breakdown between three separate regions. Especially, the differences in space use intensities between the conurbation of Western Holland, including the main urban areas Amsterdam, Rotterdam, The Hague and Utrecht, and the other parts of the Netherlands are without doubt significant.

6.4.6 *Water use* [6)]

Besides the so-called 'in-situ' uses of water bodies discussed in the former subsection, water resembles in a much broader way an important natural resource. This subsection shortly reviews a NAMEA specially constructed for water related issues, *i.e.* a National Accounting Matrix including Water Accounts (NAMWA).

The substance flow accounts in the NAMWA-1991 cover both the quantitative and qualitative aspects of water resources in the Netherlands. One substance flow account in the NAMWA records the quantitative use of fresh water, *e.g.* water extraction by economic activities. In this account, the total sum of human extractions is brought in relation to the total natural annual water supply. Since one of the most important tasks of the so-called 'polder boards' in the Netherlands is the prevention of floods, one might conclude that the natural water supply is abundant and indeed at some cases redundant.

However, in many parts of the Netherlands the excessive exploitation of groundwater is severely damaging local ecosystems. Therefore, these quantitative water accounts are subdivided into separate accounts for groundwater and surface water. While the physical accounts provide additional information on produced tap water as well, *cf.* tables 6.14a and 6.14b, the NAMWA itself only provides data on the supply and use of tap water in the goods and services account, following the NAMEA accounting conventions discussed in section 4.5 of chapter 4.
Pollution negatively influences the quality, and therefore the potential uses, of groundwater and surface water. Therefore, the emissions of phosphates, nitrates, biological oxygen demand and heavy metals to surface water are recorded in a second set of substances accounts. The NAMWA shows that cross-boundary pollution flows play again a dominant role in the case of surface water pollution. Since the Netherlands is situated around the Rhine and Meuse delta, the pollution accounts in the NAMWA (*cf.* De Haan, 1998, table 3, p.12) show substantial loads of heavy metals, originating from Germany, France and Belgium, entering the Netherlands via these rivers. The same holds for nutrients as accounted for in the regularly published Dutch NAMEAs. So, domestic economic activities only partly determine the water quality of Dutch water bodies.
A third set of accounts in the NAMWA addresses water management related environmental protection expenditure and systemises those economic transactions that are relevant from a water management perspective, including for example an explicit presentation of wastewater treatment and water regulation activities and specific taxes on water extraction and pollution.
This subsection only discusses the quantitative water accounts in the NAMWA since only this set of account differs conceptually from the regular NAMEA table presented in chapter 5. Water is a renewable resource and the total available amount of water depends on specific local conditions, seasonal patterns as well as technical and economic conditions. The total water quantities that are transported via natural water cycles are usually immense in relation to the small amounts of water that are actually used by mankind. However, much of this water is not available to men due to technical and economic restrictions. Also, water scarcity usually arises in specific arid areas or at those moments in time when water needs are often the highest. Theoretically, a proper concept of water availability should take into account exploitation restrictions, timeliness and location of water resources.
A water resource can be seen as a ‘renewable-renewable’ resource. Not only will the natural water cycle guarantee a recurrent annual supply of fresh water by precipitation and inflow via rivers, Also each withdrawal of water is eventually followed by a similar amount of water output (discharge or evaporation). Whether these discharges can be added to the total amount of available water depends, among other things, on evaporation and the amount of pollution added to water discharges.
Therefore, water extraction or other uses in the upstream regions of a watershed may restrict or even fully eliminate other uses downstream. A number of rivers in

the world have almost disappeared by the time they enter the coastal zones, due to dams, large-scale irrigation works or other artificial water transportation systems. The NAMWA shows that the rivers Rhine and Meuse have already been substantially polluted at the moment their water supply enters the borders of the Netherlands. It is only at considerable costs that water from the Meuse river can be used for the provision of tap water.

So, it appears to be rather difficult to determine a set of objective criteria defining that part of the natural water flow potentially available to society. One may conclude that the concept of social water availability seems to be an issue of water management, rather than a concept that can be usefully followed in an accounting system. The optimal allocation of water resources and subsequently the social water availability can only be determined by specifying the property rights of all potential users possibly including the water requirements of precious ecosystems.

Despite these difficulties, a pragmatic solution is found in the Eurostat/OECD questionnaire on the State of the Environment (section F: inland waters). In this questionnaire, the renewable water resource is simply defined as the water quantity available each year as a result of the movement of water in the hydrological cycle and covers water in aquifers and in surface waters. More specifically, the renewable water resource in any year is defined as the net result of annual precipitation minus evapo-transpiration plus annual inflow by rivers and underground flows into a country. The technical, managerial or economic feasibility of exploitation is ignored in this definition.

Table 6.13
Renewable water resources in the Netherlands, 1991

	Fresh water
	mln m^3
Origin	
Water inflows via rivers from neighbouring counties	63 127
Precipitation	27 296
Total	90 423
Destination	
Water outflows of surface waters to open sea	67 672
(Natural) evapo-transpiration1	22 851
Changes in stock	–100
Total	90 423

Source: De Haan (1998).

Table 6.13 provides a rough overview of the fresh water cycle in the Netherlands in 1991. Due to lack of data, it is assumed that the inflow of groundwater from abroad equals the corresponding outflow. In this way, both flows can be ignored on balance. The average annual groundwater inflow is estimated to be approximately 6,800 km^3. While the net foreign inflow of groundwater is postulated to zero, this inflow must have been fed by precipitation and surface water in the Netherlands. Table 6.13 also shows a decline in groundwater stock of 100 million m^3. This estimation is based on an average annual lowering of the groundwater table of one centimetre over the last 25 years. Actual year to year changes in the groundwater table may show divergent patterns.

The tables 6.14a and 6.14b supplement the quantitative water resource accounts by presenting water use by economic activities. The use of water is presented for three different water categories. All categories refer to fresh water, so brackish and marine water are excluded.

The origin of water resources, reviewed in table 6.14a, is subdivided by two separate sources. The first category represents water supply by economic activities, such as the supply of tap water but also water discharges to surface water. Equally, the effluent water of wastewater treatment plants is also presented as a supply of surface water by sewage and refuse disposal services. Surface water discharges by the water boards as the result of the artificial lowering of the groundwater table are recorded in a similar way (see also the corresponding withdrawal of groundwater by water boards in table 6.14b). Surface water regulation by the water boards, *i.e.* pumping water from one water body to another, is consolidated.

Due to lack of data, other discharges are not shown by economic activity and the accounts therefore do not show the actual net use of water by economic activity. Theoretically, this net use must correspond to the total sum of human induced evapo-transpiration, *i.e.* the accounts only take record of water in liquid form. Alternatively, it is assumed that all water extraction is fully recharged and therefore no distinction is being made between natural and human induced evaporation. Water supply by nature determines the last two entries in table 6.14a, *i.e.* the water inflow by rivers and precipitation.

From the total fresh water consumption of 11 km^3, approximately 6 km^3 was used for cooling. Although all three water categories are used for cooling purposes, surface water is in this respect by far the most important source (*cf.* Statistics Netherlands, 1994). Another 1.5 km^3 of salt water is used in 1991 for cooling purposes as well. Other destinations of fresh water flows presented in table 6.14b are evapo- transpiration and the water outflow into open sea.

The net change in stock represents the annual quantitative decline in groundwater availability. The total inflow of surface water is supposed to equal total outflow and no changes in stock of surface water are included in table 6.14b. In other words, in the Netherlands, only groundwater deposits are subject to depletion.

Table 6.14a
Water extraction in the NAMWA 1991; origin of water

	Tap water	Ground-water	Surface water	Total
	mln m^3			
Supply of tapwater and discharges by producers				
Water supply	1 278			1 278
Environmental cleansing and sanitary services			1 642	1 642
Water boards			100	100
Discharges by other economic activities			8 130	8 130
Other origins				
Water inflows via rivers from neighbouring counties and precipitation		5 800	84 623	90 423
Total, origin	1 278	5 800	94 495	101 573

Source: De Haan (1998).

Table 6.14b
Water extraction in the NAMWA 1991; destination of water

	Tap water	Ground-water	Surface water	Total
	mln m^3			
Use by consumers				
Own transport	–	–	–	–
Other consumption	704	–	–	704
Use by producers				
Agriculture and forestry	100	130	200	430
Mining and quarrying	1	–	–	1
Manufacture of food, beverages and tobacco	34	77	94	204
Manufacture of textile leather products	4	5	4	12
Manufacture of wood and woodproducts	2	–	–	2
Paper, printing and publishing industry	13	32	58	102
Manufacture of petroleum products	27	0	3	30
Manufacture of chemical products	36	43	849	928
Manufacture of rubber and plastic products	2	15	2	19
Manufacture of Construction materials	5	14	157	177
Manufacture of basic metals	41	7	3	50
Manufacture of fabricated metal products	22	5	2	29
Other manufacturing	27	7	3	37
Electricity and gas	5	2	5 143	5 150
Water supply	1	842	435	1 278
Construction	5	–	–	5
Transport and storage	9	–	–	9
Sewage and refuse disposal services	12	–	1 642	1 654
Water boards	–	100	–	100
Other services	230	–	–	230
Other destinations				
Water outflows of surface water to open sea and evapo-transpiration	–	4 621	85 902	90 523
Net changes in stocks	–	–100	–	–100
Total, destination	1 278	5 800	94 495	101 573

Source: De Haan (1998).

6.5 Conclusions

The NAMEA aims at providing a consistent overview of the direct environmental dependencies of production and consumption processes. On important characteristic of the pressure indicators presented in the NAMEA is their completeness in terms of source coverage. Only in this way, the NAMEA system is able to deliver environmental indicators that are genuinely supplementary to the national accounts.

The environmental themes, represented in the NAMEA, are deliberately untied from a total material balance set-up. For example, different accounting units may be introduced in the substances accounts to indicate the kind of pressures various substance flow outputs are expected to contribute. In some cases one particular substance flow may contribute to more than one type of environmental damage and this will be illustrated by the NAMEA indicators if necessary or possible.

Finally, a national accounting perspective fits adequately well with those environmental requirements causing expected impacts on a global or a continental scale. However, a national accounting approach less easily pertains to environmental pressures with local impacts influenced by local conditions.

Notes

1) De Groot (1992, Table 2.0-1, p.15) identifies in total 37 functions of nature which he subdivides into four main categories: regulation functions (maintaining the physiological cycles in ecosystems), carrier functions (providing space and substrate), production functions (*e.g.* natural resources in the strict sense) and information functions (non-physical amenities).

2) This section refers to research carried out by Gorree (1998) and Segers *et al.* (2000).

3) Vringer & Blok (1995) and Wilting (1996) provide detailed analyses of the total energy requirements of household consumption.

4) Throughout this thesis, bold capital characters are used to denote matrices, bold regular characters are used to denote vectors and italic regular characters are used to denote scalars.

5) The production sum in quantities of the crude oil industry equals exactly the direct extracted amount of energy from the environment, *i.e.* 88 peta joules. In reality, some energy may get lost in the course of oil extraction, *e.g.* due to oil spills. Pre-multiplication with an energy loss coefficient in equation (6.3) may be required to keep record of these energy losses.

6) This section summarises De Haan (1998).

Chapter 7. Indirect environmental requirements: the domestic consumption perspective

7.1 Introduction

In chapter 3 the direct recording principle is defined as the representation of physical flows at the level of processes or activities as factually observed. Direct recording results from immediate statistical observation and is an important precondition for a physical flow accounting system to function as a descriptive multipurpose information system.

The direct recording principle does not necessarily coincide with identifying causalities or responsibilities. For example, in the case of fuel desulphurisation, the decline in sulphur emissions does not result from modifications in the emission source itself but instead from the adjusted composition of its fuel inputs. Reversibly, energy saving measures adopted by electricity consumers will lead to pollution reductions at the level of electricity producers. Both examples show that additional information is often needed to detect these causalities. This detection starts however with a systematic recording of facts as for example accommodated by a NAMEA.

Another clear limitation of the direct recording principle is that environmental requirements indirectly displaced via commodity transactions remain unnoticed. The policy relevance of analysing these indirect environmental requirements is diverse. For example, indirect effects are relevant in analysing interdependencies between industries. Indicator reviews straightforwardly based on a direct recording principle will neglect these interdependencies.

The analysis of complete product chains, as for example pursued in life cycle assessments, represents an example of cross-section environmental performance evaluation. In life cycle assessments, it is not the production processes but the product outputs that are the key objects of analysis. As such, the environmental requirements, observed at the production process level, have to be reallocated to their outputs. Yet, the direct recording of environmental requirements at the process or activity level resembles the indispensable statistical basis of such a shift in focus.

Trade related environmental impacts are another example showing the policy relevance of analysing indirect effects. Trade liberalisation and the opening of domestic markets will usually increase the share of foreign supply in domestic commodity consumption. It will force the economies of countries to specialise according to their comparative advantages. As a result, the product composition of domestic output will increasingly differ from the product composition of domestic consumption. These increasing trade dependencies will more and more contribute to the international displacement of environmental impacts.

The environmental consequences of trade liberalisation are subject to ongoing debate. The Ecological Footprint indicator reflects perhaps a most radical viewpoint in case an ecological footprint deficit is by definition regarded as undesirable (*cf.* Wackernagel & Silverstein, 2000). Such a deficit results when the consumed environmental requirements in one region exceeds the amount that is supported by the environmental assets in this region in a sustainable way. This sustainability rule is highly restrictive for those areas endowed with limited environmental resources. Following this reasoning, each individual country should strive at ecological autarky and trade is considered as unsustainable by definition. This view is to some extent supported by Gale (2000) who points at two conflicting mechanisms related to specialisation which may lead to environmental overexploitation. According to the Ricardian theory of comparative advantages, international trade leads to product specialisation. This tendency is by definition harmful to ecosystems when it is assumed that their exploitation is only sustainable at a certain level of diversification. An opposite view, as for example reflected by Van Veen-Groot & Nijkamp (1999), points at the efficient use of natural resources enforced by international trade, obviously under the condition of proper natural resource pricing. International trade may bring about unfavourable environmental effects when the degree of internalisation of environmental problems differs between countries.

Regarding the direction of specialisation, so-called 'de-industrialisation' or the transformation towards a services (or knowledge) based economy has been considered a strategy to increase simultaneously social (employment) and environmental performance. It is unclear to what extent this transformation will genuinely result in dematerialization. Sustainability on a worldwide scale is not improved when the specialisation in services by some countries implies an increasing reliance on foreign product supply with relatively high environmental requirements. When environmentally unfriendly products are from one period to another no longer domestically produced but imported instead, direct accounting will indicate this substitution as an improvement in the environmental performance of the domestic economy. For the environment, this substitution may not be optimal, since pollution is principally 'exported' and not necessarily diminished.

In conclusion, the analysis of indirect environmental requirements is very relevant in appraising the overall environmental performance of countries and the evaluation of responsibility issues. Specifically for open economies, the environmental impacts connected to imported goods and services cannot be ignored. For these countries, direct accounting methods are insufficient to reveal environmental dependencies on the sector and international level.

This chapter discusses how environmental accounting can be used to analyse these indirect requirements on the macroeconomic level and discusses methods to calculate the displacement of environmental requirements via international trade. The next section contains a methodological overview of indicators that have been designed to measure the indirect requirements of a national economy. Section 7.3 discusses a number of simplifications to restrict the infinite data demands of such analyses. Subsequently, an empirical example presented in section 7.4 illustrates how the 'environmental balance of trade' of the Netherlands with several of its trade partnering countries can be decomposed according to differences in trade volume and product composition. This chapter winds up with conclusions and a number of recommendations regarding future work.

7.2 *Indicators with a focus on indirect requirements*

Several indicators have been developed with the purpose of showing the environmental burdens connected to trade flows. This section addresses some of the basic principles of estimating the trade related displacement of environmental requirements from one country to another. This section also continues the discussion on indicator additivity raised in chapter 3.

7.2.1 *Indicator scope*

When it is assumed that trade related transfers of environmental requirements follow the direction of product transfers, information on product flows within economic systems is essential in analysing environmental burden displacements. As shown in chapter 6, product flows designate the thermodynamic linkage between natural resource inputs and residual outputs.

7.1a One-way allocation of indirect environmental requirements

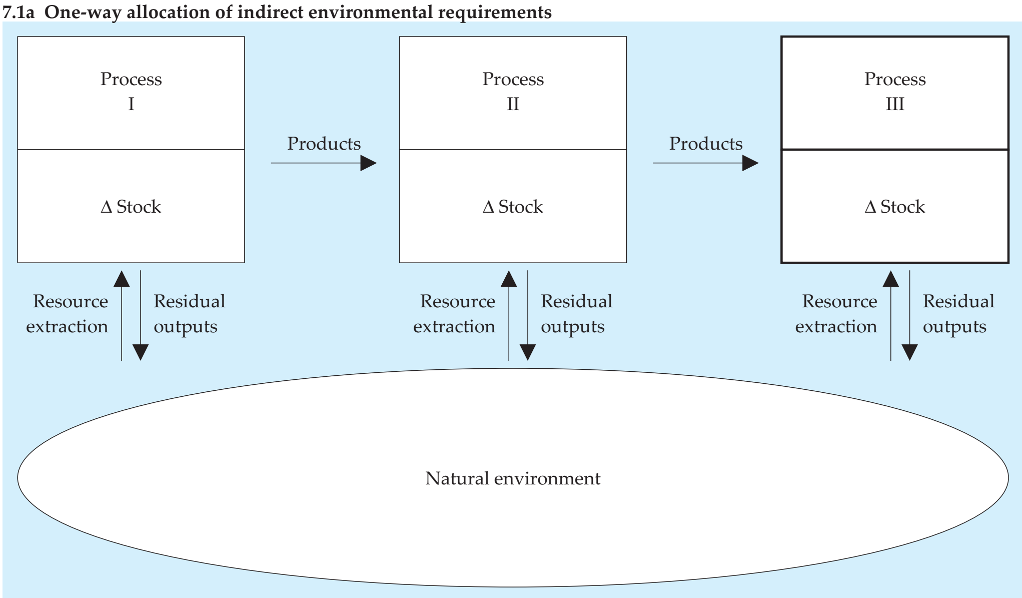
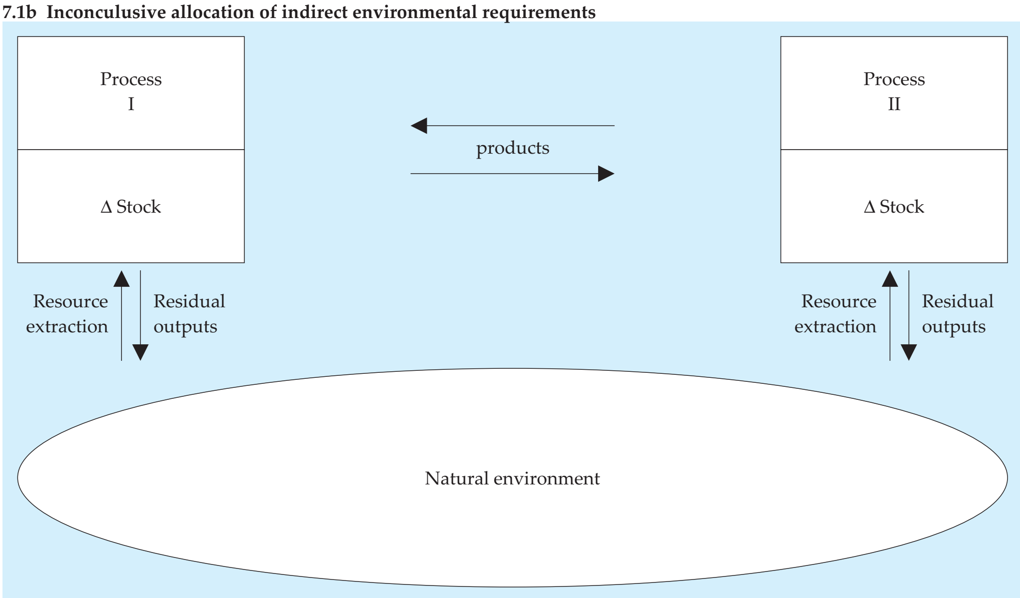


Figure 7.1a sketches a very simple product chain. Process (II) delivers a final product to a consumption process indicated by process (III). Process (I) delivers the raw or supplementary materials required in process (II). The product flows indicate the direction in which natural resource inputs or residual outputs in each stage of the entire product chain are allocated to the final user. In figure 7.1a this allocation is rather straightforward. Without changes in stocks, the direct and indirect environmental requirements of process (III), *i.e.* consumption, equals to the process wise summation of either all resource inputs or residual outputs. Although consumers are obviously not the extractors or emitters of all resource inputs and residual outputs in an economy, all environmental requirements in the total product chain are ultimately attributable to consumption.

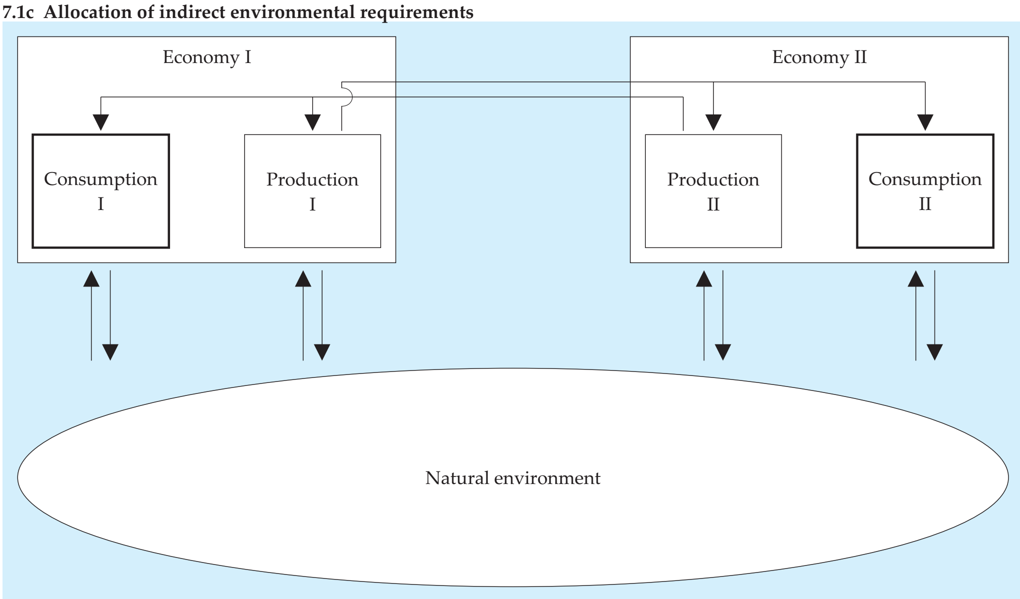
A systematic allocation of environmental requirements becomes increasingly complicated when product flows between processes are directed in both ways. This situation is illustrated in figure 7.1b. As shown in figure 3.5 of chapter 3, this scheme could for example represent the trade flows between two countries. Without any understanding about the final destination of product flows, a final allocation of the environmental requirements displaced by trade flows is simply impossible and, as discussed in chapter 3, may lead to indicator inconsistency.

An important question in relation to consistent indicator construction is how all environmental requirements are consistently allocated to the processes (I) and (II), taking consistently into consideration the environmental requirements attributed to their mutual product exchanges. The answer can be derived from the former example: the requirements have to be imputed to the final users in an economy. This is illustrated in figure 7.1c. Each production process ultimately aims at satisfying

7.1b Inconculusive allocation of indirect environmental requirements



7.1c Allocation of indirect environmental requirements



human needs by contributing to the provision of consumer goods. As such, all environmental requirements eventually contribute to the satisfaction of consumer needs and are ultimately attributable to final consumption.

The definition of flows presented in the figures 7.1a – 7.1c needs some further clarification. It must be noted that, from a material flow accounting perspective, in many cases consumption will not be the end stage of material flows. For example, consumer waste may partly be recycled or transferred to waste treatment facilities. It is therefore important to distinct product flows from residual flows. While consumers may not be the final waste emitters, they still can be considered the ultimate beneficiaries of production. Due to a clear distinction between product and residual flows, the NAMEA provides a consistent framework for allocating all environmental requirements to final consumption. This allocation also takes into consideration the positive (emissions to air) and negative (waste absorption) environmental requirements of waste treatment activities in the economy.

The Direct Material Input indicator of Adriaanse *et al.* (1997) omits a consumption perspective, which leads to its inconsistency. The Eurostat handbook (2001b) on economy wide material flow accounting introduces a total material consumption indicator that does not carry this inconsistency. The Ecological Footprint indicator developed by Wackernagel & Rees (1996) is also based on a consumption perspective. This indicator is calculated as the total sum of all land needed to generate a specific consumption package. This consumption may refer to individuals, communities, countries or even the whole world and is subdivided by different consumption categories, with each its own specific land requirement. As already discussed in chapter 3, the Ecological Footprint does not comprise a straightforward reallocation of land requirements from production to consumption as visualised by figure 7.1c. Instead, the indicator reflects, or should reflect, the minimum amount of space that is considered being required to sustain a predefined consumption pattern.

The NAMEA helps to designate two kinds of environmental interdependencies with the rest of the world. Firstly, the intersection of the rest of the world account with the environmental accounts records the cross-boundary transfers of environmental burdens. As shown in table 3.1, these transfers exist of two components: cross-boundary economic activities and the transfer of pollution via environmental media. Table 5.2 shows two kinds of indicators that are directly derived from the substance flow accounts of the NAMEA: the 'net emission by residents' (*I*) and the 'net accumulation on national territory' (*II*). The gaps between both indicators illustrate the significance of cross-boundary pollution in the Netherlands and show that the state of the domestic environment is only partly determined by domestic economic activity.

The second type of interdependency with the rest of the world concerns the displacement of environmental impacts through international trade. The so-called 'environmental balance of trade' (indicator III in table 7.1) determines for a specific pollution type or any other environmental requirement the balance of pollution attributed to exports minus pollution attributed to imports. The environmental balance of trade brings about a shift in focus from the producer oriented direct recording of environmental requirements (I) to the indirect recording or imputed

Table 7.1
Extending the emission aggregates to emissions attributed to consumption, the Netherlands, 1997

	NO_x	SO_2	NH_3	P	N	Acid-eq.	Nutrient-eq.
	1	2	3	4	5	*f(1–3)*	*f(4–5)*
	mln kg					*acid-eq.*	*mln kg N-eq.*
Emissions attributed to import (–)	313	134	115	53	610	179	1 144
Emissions attributed to export	521	239	181	73	854	295	1 585
(III) The environmental balance of trade	**207**	**105**	**65**	**20**	**244**	**117**	**441**
(I) Net emissions by residents	**701**	**236**	**188**	**78**	**917**	**338**	**1 701**
(IV) Environmental consumption = (I)– (III) = ($v^h + v^c$)	**494**	**131**	**122**	**59**	**673**	**221**	**1 260**
Direct emissions from households (v^h)	109	2	7	9	115	29	205
Attributed emissions (v^c)	385	129	115	50	558	193	1 055

1) $0.022 \times NO_X + 0.031 \times SO_2 + 0.059 \times NH_3$.
2) $10 \times P + N$.

Source: Statistics Netherlands (2000) and additional calculations.

environmental requirements to final commodity uses. The latter is labelled in table 7.1 as 'environmental consumption' (IV).
Table 5.2 shows that all intra-household activities such as own account transportation and house heating are part of the direct recording of environmental requirements. These direct emissions from households, *i.e.* v^h, are subsequently included in the 'environmental consumption' indicator. Further, this indicator resembles all acid and nutrient pollution from foreign and domestic production processes that was needed in the provision of domestic consumption in the Netherlands. [1)] The significant amount of pollution displaced by import and export reveals the open structure of the Dutch economy. These results underline the necessity to take into consideration import and export flows when analysing the total environmental requirements of domestic consumption.
As already mentioned, the indicators presented in table 5.2 (I and II) principally result from direct statistical observation. The third and fourth indicator presented in table 7.1 result from imputing pollution to product flows. The imputation of emissions, or any other environmental requirement, to domestic consumption can only be obtained from reallocating the environmental requirements of industries to their outputs and subsequently to the final users of these outputs. The next sections show how this imputation is accomplished by way of input-output analysis.
Others have introduced indicators quite similar to the 'environmental consumption' and 'the environmental balance of trade' indicators presented here. Trade related indicators are for example presented by Wyckoff & Roop (1994) who estimate for a range of countries the embodiment of carbon in imports of manufactured products Antweiler (1996) constructs 'pollution terms of trade' ratios measuring the amount of attributed pollution per money unit of export relative to that of import. Muradian *et al.* (2001) introduce a similar kind of indicator expressing the 'balance of embodied emissions in trade'.
In addition to the Ecological Footprint indicator of Wackernagel & Rees (1996), other consumption related indicators are for example developed by Konijn *et al*. (1997) measuring metal intensities of final products with the help of a hybrid input-output system. Tiwari (2000) calculate for India the energy intensities of final products at the industry level. A methodological discussion of attributing energy requirements to final products with the help of input-output models is also provided by Millar & Blair (1985, chapter 6). As mentioned, the Eurostat (2001b) methodological guide on economy-wide material flow accounting introduces a 'material consumption indicator' measuring the total material use associated with domestic product consumption, including import and excluding export related flows. Nijdam & Wilting (2003) recently calculated for the Netherlands a range of consumption based pressure indices for various environmental requirements. Based on a household budget survey, they compiled these indicators also for a range of consumption purposes such as living, clothing and leisure.
The primary aim of this chapter is to show how these trade and consumption related indicators fit into a national accounts based framework. The following section

discusses several conceptual features of the indicators (III) and (IV) presented in table 7.1.

7.3 *Attribution methods*

7.3.1 *The hypothetical two country case*

Figure 7.1c shows that a consistent allocation of indirect environmental requirements addresses the final users or the consumers in both countries. This section illustrates the estimation of such a reallocation of environmental requirements in a hypothetical two country case: the domestic economy and the rest of the world. This is done with the help of an input-output model. Similar to figure 7.1c, both countries depend via trade on each other's outputs. Suppose for simplicity reasons and for the time being that the total emission of a particular type of pollution in these two countries, denoted by the variables and , only results from production activities and that this pollution can be determined as a function of the total output of these production activities, denoted by vectors $\mathbf{x_1}$ and $\mathbf{x_2}$.

$$\begin{pmatrix} v_1^x \\ v_2^x \end{pmatrix} = \begin{pmatrix} \mathbf{e'}_1 & \mathbf{0} \\ \mathbf{0} & \mathbf{e'}_2 \end{pmatrix} \begin{pmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{pmatrix} \qquad (7.1)$$

The vectors $\mathbf{e_1}$ and $\mathbf{e_2}$ containing the emission coefficients are determined by

$$\mathbf{e}_1 = \hat{\mathbf{x}}_1^{-1}\mathbf{v}_1^x \quad \text{and} \quad \mathbf{e}_2 = \hat{\mathbf{x}}_2^{-1}\mathbf{v}_2^x$$

where $\hat{\mathbf{x}}_1^{-1}$ and $\hat{\mathbf{x}}_2^{-1}$ denote the inverse diagonal matrices of output vectors $\mathbf{x_1}$ and $\mathbf{x_2}$. Element $v_{l,j}^x$ of $\mathbf{v}_1^x$ corresponds to the total amount of pollution by production activity (*j*) in country (1) while element $e_{l,j}$ of $\mathbf{e_1}$ represents the emission coefficient or the pollution intensity, *i.e.* amount of pollution emitted per money unit of output of production activity (*j*).

With the help of a Leontief inverse, pollution in both countries can be determined as a function of final demand in both countries, denoted by the vectors $\mathbf{y_1}$ and $\mathbf{y_2}$. Suppose that matrices $\mathbf{A_1}$ and $\mathbf{A_2}$ represent the technical coefficients with respect to domestic production in both countries while matrices $\mathbf{M_1}$ and $\mathbf{M_2}$ represent the technical coefficients with respect to import, *i.e.*:

$$\mathbf{A}_1 = \mathbf{D}_1^x \hat{\mathbf{x}}_1^{-1} \text{ and } \mathbf{A}_2 = \mathbf{D}_2^x \hat{\mathbf{x}}_2^{-1}$$

where matrices $\mathbf{D}_1^x$ and $\mathbf{D}_2^x$ represent the domestically produced intermediate deliveries in both countries;

$$\mathbf{M}_1 = \mathbf{D}_1^m \hat{\mathbf{x}}_1^{-1} \text{ and } \mathbf{M}_2 = \mathbf{D}_2^m \hat{\mathbf{x}}_2^{-1}$$

where matrices $\mathbf{D}_1^m$ and $\mathbf{D}_2^m$ represent the imported intermediate deliveries in both countries;
Then the pollution model for the two countries can be formulated as follows.

$$\mathbf{x}_1 = \mathbf{A}_1\mathbf{x}_1 + \mathbf{M}_2\mathbf{x}_2 + \mathbf{y}_1$$

$$\mathbf{x}_2 = \mathbf{A}_2\mathbf{x}_2 + \mathbf{M}_1\mathbf{x}_1 + \mathbf{y}_2$$

Both equations can be jointly presented as follows.

$$\begin{pmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{pmatrix} = \begin{pmatrix} \mathbf{A}_1 & \mathbf{M}_2 \\ \mathbf{M}_1 & \mathbf{A}_2 \end{pmatrix} \begin{pmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{pmatrix} + \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \end{pmatrix} \tag{7.2}$$

From equation (7.2) the Leontief inverse can be derived in a similar way as the derivation of the Leontief inverse of a regular one-country open Leontief model. Substitution of equation (7.1) into (7.2) then leads to the following two-country pollution model.

$$\begin{pmatrix} v_1^x \\ v_2^x \end{pmatrix} = \begin{pmatrix} \mathbf{e'}_1 & \mathbf{0} \\ \mathbf{0} & \mathbf{e'}_2 \end{pmatrix} \begin{pmatrix} \mathbf{I} - \mathbf{A}_1 & -\mathbf{M}_2 \\ -\mathbf{M}_1 & \mathbf{I} - \mathbf{A}_2 \end{pmatrix}^{-1} \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \end{pmatrix}$$

or

$$\begin{pmatrix} v_1^x \\ v_2^x \end{pmatrix} = \begin{pmatrix} \mathbf{e'}_1 & \mathbf{0} \\ \mathbf{0} & \mathbf{e'}_2 \end{pmatrix} \begin{pmatrix} \mathbf{L}_{11} & \mathbf{L}_{12} \\ \mathbf{L}_{21} & \mathbf{L}_{22} \end{pmatrix} \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \end{pmatrix} \tag{7.3}$$

This model determines the pollution levels in both countries as a function of the final demands in both countries. Pollution in country (1) is jointly determined by the final demands in both countries. Similarly, pollution in country (2) is jointly determined by the final demands in both countries. The partitioning of the Leontief-inverse as shown in the second part of equation (7.3) is determined as follows.

$$\mathbf{L}_{11} = \left(\mathbf{I} - (\mathbf{I} - \mathbf{A}_1)^{-1}\mathbf{M}_2(\mathbf{I} - \mathbf{A}_2)^{-1}\mathbf{M}_1\right)^{-1}(\mathbf{I} - \mathbf{A}_1)^{-1}$$

$$\mathbf{L}_{12} = \left(\mathbf{I} - (\mathbf{I} - \mathbf{A}_1)^{-1}\mathbf{M}_2(\mathbf{I} - \mathbf{A}_2)^{-1}\mathbf{M}_1\right)^{-1}(\mathbf{I} - \mathbf{A}_1)^{-1}\mathbf{M}_2(\mathbf{I} - \mathbf{A}_2)^{-1}$$

$$\mathbf{L}_{21} = \left(\mathbf{I} - (\mathbf{I} - \mathbf{A}_2)^{-1}\mathbf{M}_1(\mathbf{I} - \mathbf{A}_1)^{-1}\mathbf{M}_2\right)^{-1}(\mathbf{I} - \mathbf{A}_2)^{-1}\mathbf{M}_1(\mathbf{I} - \mathbf{A}_1)^{-1}$$

$$\mathbf{L}_{22} = \left(\mathbf{I} - (\mathbf{I} - \mathbf{A}_2)^{-1}\mathbf{M}_1(\mathbf{I} - \mathbf{A}_1)^{-1}\mathbf{M}_2\right)^{-1}(\mathbf{I} - \mathbf{A}_2)^{-1}$$

where

$\mathbf{L}_{11}$ contains the technical coefficient multipliers representing the output requirements of country (1) with respect to one unit of final demand in country (1);

$\mathbf{L}_{12}$ contains the technical coefficient multipliers representing the output requirements of country (1) with respect to one unit of final demand in country (2);
$\mathbf{L}_{21}$ contains the technical coefficient multipliers representing the output requirements of country (2) with respect to one unit of final demand in country (1);
$\mathbf{L}_{22}$ contains the technical coefficient multipliers representing the output requirements of country (2) with respect to one unit of final demand in country (2).

The variables v_1^x and v_2^x in equations (7.1) and (7.3) represent the direct emissions from production in each two countries. Equations (7.4a) and (7.4b) show that the final demand vectors in both countries, *i.e.* $\mathbf{y_1}$ and $\mathbf{y_2}$, equal the sum of domestic final uses, represented by vector **d**, and foreign final uses or export, represented by vector **f**.

$$\mathbf{y}_1 = \mathbf{d}_1 + \mathbf{f}_1 \qquad (7.4a)$$

and

$$\mathbf{y}_2 = \mathbf{d}_2 + \mathbf{f}_2 \qquad (7.4b)$$

So $\mathbf{f_1}$ represents that part of final output $\mathbf{y_1}$ exported to country (2) and vector $\mathbf{f_2}$ represents the final output of country (2) exported to country (1). Subsequently, total final consumption in both countries (including net capital formation and inventory changes), represented by the vectors $\mathbf{c_1}$ and $\mathbf{c_2}$, equals:

$$\mathbf{c}_1 = \mathbf{d}_1 + \mathbf{f}_2 \qquad (7.5a)$$

and

$$\mathbf{c}_2 = \mathbf{d}_2 + \mathbf{f}_1 \qquad (7.5b)$$

Subsequently, pollution attributed to consumption in both countries, *i.e.* $\mathbf{c_1}$ and $\mathbf{c_2}$, is determined with the help of equations (7.6a) and (7.6b). The aggregates v_1^c and v_2^c in these equations correspond to the attributed part of the 'environmental consumption' indicators of both countries. The environmental consumption indicator (IV) in table 7.1 includes in addition the direct emissions of households (v^h).

$$v_1^c = (\mathbf{e}_1'\mathbf{L}_{11} + \mathbf{e}_2'\mathbf{L}_{21})\,\mathbf{d}_1 + (\mathbf{e}_1'\mathbf{L}_{12} + \mathbf{e}_2'\mathbf{L}_{22})\,\mathbf{f}_2 \qquad (7.6a)$$

$$v_2^c = (\mathbf{e}_1'\mathbf{L}_{12} + \mathbf{e}_2'\mathbf{L}_{22})\,\mathbf{d}_2 + (\mathbf{e}_1'\mathbf{L}_{11} + \mathbf{e}_2'\mathbf{L}_{21})\,\mathbf{f}_1 \qquad (7.6b)$$

Trade flows between countries (1) and (2) contain intermediate and final products. Vector $\mathbf{s_1}$ denotes the export of country (1). In our two country model, export of country (1) equals by definition the import of country (2). The latter is indicated by vector $\mathbf{t_2}$. Vectors $\mathbf{s_2}$ and $\mathbf{t_1}$ are defined accordingly.

$$\mathbf{s}_1 = \mathbf{t}_2 = \mathbf{M}_2\mathbf{x}_2 + \mathbf{f}_1 \tag{7.7a}$$

$$\mathbf{s}_2 = \mathbf{t}_1 = \mathbf{M}_1\mathbf{x}_1 + \mathbf{f}_2 \tag{7.7b}$$

Finally, the environmental balance of trade of country (1), *i.e.* indicator (III) in table 7.1, can be determined as the difference between direct output of pollution in the domestic economy and pollution attributed to final consumption, or, as the difference between pollution attributed to export minus pollution attributed to import.

$$v_1^x - v_1^c = v_1^s - v_1^t \tag{7.8}$$

$$v_1^s = \mathbf{e}_1{'}\mathbf{L}_{12}\mathbf{y}_2 + (\mathbf{e}_1{'}\mathbf{L}_{11} + \mathbf{e}_2{'}\mathbf{L}_{21})\mathbf{f}_1 \tag{7.9a}$$

$$v_1^t = \mathbf{e}_2{'}\mathbf{L}_{21}\mathbf{y}_1 + (\mathbf{e}_2{'}\mathbf{L}_{22} + \mathbf{e}_1{'}\mathbf{L}_{12})\mathbf{f}_2 \tag{7.9b}$$

When looking at equation (7.9a), the term $\mathbf{e_1{'}L_{12}y_2}$ expresses the pollution attributed to country (1)'s export of intermediate requirements to country (2) while the term $\mathbf{(e_1{'}L_{11}+e_2{'}L_{21})f_1}$ expresses all pollution attributed to country (1)'s export of final products. As such, equations (7.9a) and (7.9b) express the total amount of pollution attributed to export (or import). Since pollution attributed to the export (or import)

Table 7.2
Origin and destination of carbon dioxide (CO_2) pollution attributed to product flows in the Netherlands, 1997

	Gross recording		Net recording	
	billion kg			
Origin				
Domestic production	(v^x)	163	(v^x)	163
Import	(v^t)	125	(v^t- v^{ts})	66
Total, origin		288		229
Destination				
Domestic use	(v^c)	133	(v^c)	133
Export	(v^s)	156	(v^{xs})	97
From domestic production	(v^{xs})	97		
From import	(v^{ts})	59		
Total, destination		288		229

of final products contains pollution fractions originating from both countries, certain pollution fractions are transferred twice. To be precise, both equations (7.9a) and (7.9b) include fractions $\mathbf{e_1'L_{12}f_2}$ and $\mathbf{e_2'L_{21}f_1}$, *i.e.* pollution attributed to the foreign intermediate requirements of final product exports. In fact, the partitioned Leontief matrix presented in equation (7.3) shows that, at different stages in a production process, attributed pollution to intermediate products may be transferred several times between both countries. These loop effects are a general feature of input-output models. The multiple displacement of pollution underlines that the environmental balance of trade indicator is a more meaningful indicator compared to a separate attribution of environmental requirements to either import or export. The environmental balance of trade indicator balances-out these multiple pollution reallocations. Also, these loop effects do not disturb the environmental consumption indicator. From equations (7.6a) and (7.6b) it becomes clear that the model consistently allocates all generated pollution to the final demand in both countries.

Table 7.2 shows that one may decide to follow a gross or net recording in the attribution of pollution to import and export. The net recording excludes pollution originating from the production of foreign intermediate requirements of final product exports, *i.e.* the fractions $\mathbf{e_1'L_{12}f_2}$ and $\mathbf{e_2'L_{21}f_1}$ in the equations (7.9a) and (7.9b), indicated by variable v^{ts} in table 7.2. Variable v^{xs} denotes pollution attributed to export originating from domestic production. In the Netherlands in 1997, the gross-net difference in the recording of import and export, *i.e.* v^{ts}, corresponds to 59 billion kilogram of carbon dioxide emissions.

Finally, it must be noted that the attributed part of the environmental consumption indicators *i.c.* v^c, presented in the tables 7.1 and 7.2 for various pollutants, represents the pollution attributed to all domestic final demand categories, that is, consumption of households, consumption of government and *net* fixed capital formation (as well as net inventory changes). Pollution attributed to replacement investments are in the input-output calculations, presented here, reallocated according to the use of capital at the industry level. As such, replacement investments serve as a proxy for the pollution attributable to the use of capital, *i.e.* capital services. In other words, capital services are represented as an additional industry in the input-output model.

7.3.2 *Short cut solutions*

The world does not exist of only two countries. Clearly, the data requirements of a full-fledged model taking into consideration the specific environmental characteristics of bilateral trade relations of several countries expands the data needs of the model progressively. Usually, only the product composition of trade flows is known on a bilateral level but not necessarily the industry branch of destination. In other words, information is not necessarily available to allocate the import from a foreign country to the individual intermediate or final users in the domestic economy. Therefore, simplifications are often required to construct indicators such as the environmental balance of trade or environmental consumption.

In an input-output analysis of water pollution, De Boer & Karres (1977) evaluate a number of short-cut solutions. The most crucial assumption they make is that the domestic production system is representative for the manufacturing of its imports. In this way, the attribution of pollution to consumption can be carried out with the help of data on the domestic economy (including its import) only. De Boer & Karres arrive at the following approximation to estimate the attributed environmental requirements of domestic final consumption, *i.e.* v^c, in country (1).

$$v_1^c \approx \mathbf{e}_1'\left((\mathbf{I}-\mathbf{A}_1-\mathbf{M}_1)^{-1}\mathbf{M}_1+\mathbf{I}\right)(\mathbf{I}-\mathbf{A}_1)^{-1}(\mathbf{d}_1+\mathbf{f}_2)$$

$$= \mathbf{e}_1'(\mathbf{I}-\mathbf{A}_1-\mathbf{M}_1)^{-1}\left(\mathbf{M}_1(\mathbf{I}-\mathbf{A}_1)^{-1}+(\mathbf{I}-\mathbf{A}_1-\mathbf{M}_1)(\mathbf{I}-\mathbf{A}_1)^{-1}\right)(\mathbf{d}_1+\mathbf{f}_2)$$

$$= \mathbf{e}_1'(\mathbf{I}-\mathbf{A}_1-\mathbf{M}_1)^{-1}(\mathbf{M}_1+\mathbf{I}-\mathbf{A}_1-\mathbf{M}_1)(\mathbf{I}-\mathbf{A}_1)^{-1}(\mathbf{d}_1+\mathbf{f}_2)$$

$$= \mathbf{e}_1'(\mathbf{I}-\mathbf{A}_1-\mathbf{M}_1)^{-1}(\mathbf{d}_1+\mathbf{f}_2) \qquad (7.10)^{2)}$$

Obviously, this approximation reduces the data demands substantially. On the other hand, its simplifying assumptions have to be evaluated to determine to what extent this model may lead to oversimplification and incorrect results. Comparing this model with the attributed element of the environmental consumption indicator estimation in the 'two country case', as defined by equations (7.6a) and (7.6b), results to the following three simplifying assumptions.

a) $\mathbf{M}_2 \approx \mathbf{0}$

Firstly, it is assumed that the intermediate requirements exported to the rest of the world, *i.e.* country (2), are insignificant compared to the (rest of the) world economy output. This will result in technical coefficients from import ($\mathbf{M_2}$) close to zero and subsequently in insignificant feedback effects. Generally, this assumption is admissible when analysing relatively small economies. However, this assumption may prove invalid when analysing trade relationships on a bilateral level. An aggregated representation of the rest of the world conceals the bilateral dependencies between countries or multilateral dependencies in certain economic regions.

b) $\mathbf{A}_2 \approx \mathbf{A}_1 + \mathbf{M}_1$

c) $\mathbf{e}_2 \approx \mathbf{e}_1$

Subsequently, it is assumed that foreign production technologies (b) and pollution intensities (c) are similar to the domestic production structure. This implies that the amount of pollution accumulated to one money unit of imported commodity (*j*) equals the amount of pollution accumulated to one money unit of domestic production of commodity (*j*). This assumption has shown to be in some cases reprehensible with respect to differences in the pollution profiles between countries (*cf.* De Haan, 1999). For example, differences in the energy supply sectors between countries will result in diverging air emission profiles. Some countries rely predominantly on nuclear or hydropower while others depend mostly on fossil energy. Even among the latter group of countries, emission patterns may differ due to differences in the fuel mix (coal, oil and gas) and corresponding emission coefficients. Further, these assumptions are problematic for imported products that omit a domestically produced counterpart, *i.e.* element $x_{1,j}$ of $\mathbf{x_1} = 0$ while the corresponding element $t_{1,j}$ of $\mathbf{t_1} \neq 0$. In practice this problem may be solved by identifying in the model a domestic production activity that is most closely related to the manufacturing of the non-competitive imported product. However, for relatively small, open and highly specialised economies like the Netherlands this can be problematic.

In conclusion, while these two simplifying assumptions may lead to distortions in outcomes, the De Boer & Karres model severely reduces data demands and is therefore applied to compile provisional estimates of the Dutch environmental balance of trade with 18 other countries as presented in the next section. The environmental balance of trade indicators presented in this chapter are used to detect the influence of differences in trade volumes and product composition on a bilateral level. Differences in pollution intensities are being ignored for the time being. The final section in this chapter contains a number of recommendations regarding possibilities and limitations of further improvements.

7.4 *Estimating the environmental balance of trade*

This section contains a more detailed presentation, as compared to table 7.1, of the 'environmental balance to trade' indicator by taking into consideration differences in bilateral trade relationships of various countries with the Netherlands. Before showing the results, the data used in this analysis are briefly discussed first. In addition, this section shows how these bilateral environmental balances of trade can be decomposed into a 'trade balance' and 'trade composition' component. The trade balance component nets out the trade volume differences between import and export. The trade composition component nets out attributed pollution differences between import and export due to differences in product composition.

7.4.1 *Data issues*

The input-output table used in the analysis comprises an annually compiled (104×104) industry-by-industry table in basic prices for the Netherlands in 1997. The following adjustments have been made. Firstly, trade and transport margins and capital services are recorded as additional industries. As a result, final demand only contains *net* fixed capital formation, thus excluding replacement capital formation. The environmental requirements of trade margins and capital services are subsequently cumulated to other final demand. In addition, financial intermediation services indirectly measured are allocated to their expected users and this equally reduces final demand.

The input-output table is augmented with an import matrix with equal dimensions. This matrix includes all intermediate and final consumption from import. In this table, imports of goods and services are reallocated to their main domestic producers. Several additional calculations, and sometimes additional assumptions, were needed to allocate also the non-competitive imports to industries such as various agricultural and mining products but also business and household travel expenses.

The import and export commodity data are classified according to country of origin/destination and to product group and are made consistent with national accounts totals. Additional estimates for services are based on information from the balance of payments statistics. Subsequently, the import and export data according to product group have been translated from a product classification to an industry classification in consistence with the input-output table. Regarding the import matrix, only the row sums of this matrix, and not each individual element, are subdivided by country of origin. Re-exports have been excluded from imports and exports. Import figures are denominated in c.i.f. prices and this may somewhat overestimate the amount of pollution attributed to imports.

The annually published environmental accounts in the Netherlands contain 36 individual industries (*cf.* table 5.3a). These accounts have been further subdivided into the 104 industries represented in the input-output table. More detailed information is particularly added for agriculture, horticulture and husbandry and a number of chemical industries.

7.4.2 The applied model

For each country the balance of trade with the Netherlands is calculated as follows. It must be noted that in the subsequent analysis subscript (*i*) does no longer refer to the import or export of country (*i*) but reversibly to the country of origin, in case of import, or country of destination, in case of export. Suppose $\mathbf{t_i}$ denotes the vector of outputs, classified by industry, imported from country (*i*) and $\mathbf{s_i}$ denotes the vector of industry outputs exported to country (*i*). Then the bilateral environmental balance of trade with country (*i*), *i.e.* v_i^{s-t}, is determined as the environmental requirements attributed to export v_i^s minus the corresponding environmental requirements attributed to import v_i^t.

$$v_i^{(s-t)} = v_i^s - v_i^t = \mathbf{l^{*\prime}(s_i - t_i)} \qquad (7.11)$$

where

$$\mathbf{l^{*\prime} = e^{\prime}(I - A - M)^{-1}}$$

In this equation vector **e** equals the domestic emission coefficients with respect to a certain type of pollution or any other environmental requirement and the Leontief inverse includes the technical coefficients with respect to import and domestic (Dutch) production. Variables without subscript refer by definition to the domestic economy.

The results are presented in the tables 7.3a – 7.3d. The first column in these tables presents for each country of destination (*i*) the amount of pollution attributed to export v_i^s. The second column contains for each country of origin the amount of pollution attributed to import (v_i^t). Subsequently, the bilateral environmental balances of trade, *i.e.* $v_i^s - v_i^t$, are presented in the third column. Here, it must be acknowledged that only a gross recording of pollution attributed import and export is applicable to the compilation of environmental trade balances on the bilateral level.

With the help of a *cross section* structural decomposition analysis, these balances of trade are decomposed according to two separate effects: a product composition (*pc*) and a trade balance effect (*tb*). [3] The basic principles of structural decomposition analysis are further discussed in chapter 8. The composition effect quantifies that part of the environmental balance of trade resulting from differences in product composition between import and export. The balance of trade effect separates that part of the environmental balance of trade entirely attributed to volume differences between export and import. Both components are derived as follows.

Firstly, the bilateral trade balance in money terms is determined by summing up all elements of $\mathbf{s_i}$ and $\mathbf{t_i}$ respectively:

$s_i^{tb} = \mathbf{i's_i}$ and $t_i^{tb} = \mathbf{i't_i}$ and the bilateral trade balance in money terms equals $s_i^{tb} - t_i^{tb}$.

Differences in import-export composition are detected by vectors representing the industry shares in import and export:

$$\mathbf{s_i^{pc}} = \frac{1}{s_i^{tb}}\mathbf{s_i} \text{ and } \mathbf{t_i^{pc}} = \frac{1}{t_i^{tb}}\mathbf{t_i}$$

where the sum of industry shares in both vectors is equal to one, *i.e.*

$$\sum_j s_{i,j}^{pc} = \sum_j t_{i,j}^{pc} = 1 .$$

A cross section structural decomposition analysis can be conducted by formulating the two possible 'full' regular decomposition forms. [4] These are presented by equations (7.12a) and (7.12b).

$$v_i^{(s-t)} = \mathbf{l^{*}{}'}(\mathbf{s_i^{pc}} s_i^{tb} - \mathbf{t_i^{pc}} t_i^{tb})$$

$$= \mathbf{l}^{*}{}'(\mathbf{s}_{\mathbf{i}}^{\mathbf{pc}} s_i^{tb} - \mathbf{t}_{\mathbf{i}}^{\mathbf{pc}} s_i^{tb} + \mathbf{t}_{\mathbf{i}}^{\mathbf{pc}} s_i^{tb} - \mathbf{t}_{\mathbf{i}}^{\mathbf{pc}} t_i^{tb})$$

$$= \mathbf{l}^{*}{}'\left([\mathbf{s}_{\mathbf{i}} - \mathbf{t}_{\mathbf{i}}]^{\mathbf{pc}} s_i^{tb} + \mathbf{t}_{\mathbf{i}}^{\mathbf{pc}} [s_i - t_i]^{tb}\right) \quad (7.12a)$$

or

$$= \mathbf{l}^{*}{}'(\mathbf{s}_{\mathbf{i}}^{\mathbf{pc}} s_i^{tb} - \mathbf{s}_{\mathbf{i}}^{\mathbf{pc}} t_i^{tb} + \mathbf{s}_{\mathbf{i}}^{\mathbf{pc}} t_i^{tb} - \mathbf{t}_{\mathbf{i}}^{\mathbf{pc}} t_i^{tb})$$

$$= \mathbf{l}^{*}{}'\left([\mathbf{s}_{\mathbf{i}} - \mathbf{t}_{\mathbf{i}}]^{\mathbf{pc}} t_i^{tb} + \mathbf{s}_{\mathbf{i}}^{\mathbf{pc}} [s_i - t_i]^{tb}\right) \quad (7.12b)$$

where

$\mathbf{s}_{\mathbf{i}}^{\mathbf{pc}} - \mathbf{t}_{\mathbf{i}}^{\mathbf{pc}} = [\mathbf{s}_{\mathbf{i}} - \mathbf{t}_{\mathbf{i}}]^{\mathbf{pc}}$ and $s_i^{tb} - t_i^{tb} = [s_i - t_i]^{tb}$

In equations (7.12a) and (7.12b) the product composition component, *i.e.* $[\mathbf{s}_{\mathbf{i}}-\mathbf{t}_{\mathbf{i}}]^{\mathbf{pc}}$, and the balance of trade component, *i.e.* $[s_i-t_i]^{tb}$, are presented between rectangular brackets. Both components are multiplied by a weight and the two possible full decomposition forms result into two different sets of weights attached to $[\mathbf{s}_{\mathbf{i}}-\mathbf{t}_{\mathbf{i}}]^{\mathbf{pc}}$ and $[s_i-t_i]^{tb}$ respectively. Equations (7.13a) and (7.13b) present both components separately by using the average of these two decomposition forms.
The production composition effect is determined by equation (7.13a).

$$v_i^{(s-t)^{pc}} = \mathbf{l}^{*}{}'[\mathbf{s}_{\mathbf{i}} - \mathbf{t}_{\mathbf{i}}]^{\mathbf{pc}} \frac{s_i^{tb} + t_i^{tb}}{2} \quad (7.13a)$$

The trade balance component is determined by equation (7.13b).

$$v_i^{(s-t)^{tb}} = \mathbf{l}^{*}{}'(\mathbf{s}_{\mathbf{i}}^{\mathbf{pc}} + \mathbf{t}_{\mathbf{i}}^{\mathbf{pc}}) \frac{[s_i - t_i]^{tb}}{2} \quad (7.13b)$$

Both effects sum up to the total environmental balance of trade.

$$v_i^{(s-t)} = v_i^{(s-t)^{pc}} + v_i^{(s-t)^{tb}} \quad (7.14)$$

7.4.3 *Results*

Tables 7.3a – 7.3d present the balances of trade for four different pollution types: carbon dioxide (CO_2), which is by far the most important greenhouse gas polluter, the theme indicators for acid pollution, nutrient pollution and (net) solid waste. The latter indicator is straightforwardly measured in million kilograms and excludes recycled and incinerated waste.
Tables 7.3a – 7.3d show environmental trade surpluses for all four pollution categories. In other words, for all four pollution categories, the Dutch production system is more environmentally intensive than domestic consumption. The specialisation of the Dutch economy seems to have been directed to relatively

Table 7.3a
The environmental balance of trade of the Netherlands, carbon dioxide (CO_2) pollution, 1997

	Export [1]	Import [1]	Environmental balance of trade	Composition effect	Trade balance effect
	1.	2.	3. = 1.– 2. = 3a. + 3b.	3a.	3b.
	mln kg				
Belgium and Luxembourg	20 520	14 820	5 710	–1 410	7 120
Denmark	2 480	1 620	860	50	810
Germany	40 850	26 530	14 320	–1 190	15 510
Finland	1 470	1 840	–360	–410	40
France	13 460	9 170	4 290	1 250	3 040
Greece	1 230	320	910	140	770
Ireland	1 220	1 180	40	380	–340
Italy	7 960	4 740	3 220	200	3 020
Japan	2 430	2 780	–360	680	–1 040
Norway	1 320	1 910	–590	1 170	–1 770
Austria	2 100	1 150	960	–50	1 000
Portugal	1 060	740	310	130	190
Spain	4 480	3 460	1 020	–180	1 200
Czech Republic	440	290	150	–30	180
United Kingdom	16 840	13 430	3 410	2 210	1 200
United States of America	7 810	10 380	–2 580	460	–3 040
Sweden	3 210	3 920	–710	–110	–600
Switzerland	3 070	1 800	1 270	220	1 050
Other countries	23 900	25 340	–1 440	5 050	–6 500
Total	155 850	125 420	30 430	8 560	21 840

[1] All import-export data exclude re-exports. The environmental requirements attributed to imports and exports follow a gross recording method (cf. table 7.2).

polluting industries. The relatively largest surplus is found for acidification (table 7.3b) where pollution attributed to total export is 65% higher than pollution attributed to import. The relatively smallest surplus shows up for solid waste (table 7.3d) for which export exceeds import by only 13%.

Balance of trade deficits only occur at the individual country level. Also, bilateral environmental balances of trade may change sign when comparing different environmental themes. For example, the Netherlands has a trade surplus with Denmark for carbon dioxide emissions (table 7.3a) but has a deficit with respect to acid pollution (7.3b).

In the last two columns, the environmental balance of trade is decomposed into the product composition and trade balance effect. Since the Dutch economy has a substantial trade surplus, the overall trade balance effect is positive for all four pollution categories. Also, for all pollution categories, the trade balance effects show rather similar distribution patterns over countries. Apparently, direct pollution shares at the industry level only marginally influence the trade balance component

Table 7.3b
The environmental balance of trade of the Netherlands, acid pollution , 1997

	Export [1]	Import [1]	Environmental balance of trade	Composition effect	Trade balance effect
	1	2	3. = 1.– 2. = 3a. + 3b.	3a.	3b.
	acid–eq. [2]				
Belgium and Luxembourg	36.7	24.9	11.8	–0.6	12.3
Denmark	4.1	4.7	–0.6	–2.4	1.8
Germany	80.9	38.8	42.1	15.5	26.6
Finland	2.5	1.7	0.9	0.8	0.1
France	24.5	13.6	10.9	5.8	5.0
Greece	4.4	0.5	3.9	1.9	2.0
Ireland	2.2	2.7	–0.5	0.2	–0.7
Italy	19.3	5.7	13.6	8.0	5.5
Japan	5.3	2.3	3.0	4.7	–1.7
Norway	2.6	2.3	0.3	3.3	–3.0
Austria	3.0	1.3	1.8	0.5	1.3
Portugal	2.1	1.0	1.1	0.8	0.3
Spain	8.1	3.7	4.4	2.7	1.7
Czech Republic	0.5	0.3	0.2	0.0	0.2
United Kingdom	31.3	17.6	13.7	11.8	1.9
United States of America	12.3	12.8	–0.5	3.8	–4.3
Sweden	4.6	3.9	0.7	1.4	–0.7
Switzerland	5.9	1.9	4.0	2.4	1.6
Other countries	45.0	38.9	6.1	17.3	–11.2
Total	295.3	178.6	116.7	77.8	38.9

[1] All import-export data exclude re-exports. The environmental requirements attributed to imports and exports follow a gross recording method (*cf.* table 7.2).
[2] = $0.22 \times NO_X + 0.31 \times SO_2 + 0.59 \times NH_3$.

of the four environmental themes taken into consideration. Differences between these four themes are dominated by trade composition effects.

The total composition effect is negative in the case of solid waste but positive for all other pollution types. Of all four pollution categories, acidification has the highest contribution of the composition effect in the total environmental balance trade which equals 67%. The corresponding shares of carbon dioxide and nutrient pollution are 28% and 43% respectively. Dutch exports are dominated by relatively environmental intensive products such as agricultural products, basic chemicals and transport services. Agricultural products embody a substantial amount of acid (especially ammonia NH_3) and nutrient pollution while the chemical and transport services industries have relatively high (fossil) energy demands. Therefore, a substantial amount of carbon dioxide and acid (specifically nitrogen oxides NO_X) emissions are attributed to these goods and services. To some extent, the commodity composition of Dutch exports is explained by two important environmental endowments of the Dutch economy: a beneficial geographical location for all kinds of distribution activities and the availability of substantial natural gas deposits.

Table 7.3c
The environmental balance of trade of the Netherlands, nutrient pollution, 1997

	Export [1]	Import [1]	Environmental balance of trade	Composition effect	Trade balance effect
	1	2	3. = 1.– 2. = 3a. + 3b.	3a.	3b.
	nutrient–eq. [2]				
Belgium and Luxembourg	183.5	164.9	18.6	–53.2	71.8
Denmark	24.2	16.4	7.8	–0.2	8.0
Germany	470.5	255.6	214.9	51.1	163.7
Finland	8.9	7.3	1.6	1.4	0.2
France	152.4	113.9	38.5	2.5	36.0
Greece	32.8	2.5	30.3	16.4	13.9
Ireland	10.8	19.1	–8.3	–4.2	–4.1
Italy	116.1	32.5	83.6	51.1	32.6
Japan	19.5	7.9	11.6	17.5	–6.0
Norway	7.0	6.6	0.3	8.6	–8.2
Austria	19.2	7.5	11.7	3.8	7.9
Portugal	10.4	9.1	1.2	–0.8	2.1
Spain	42.0	25.5	16.5	6.4	10.1
Czech Republic	3.9	1.6	2.2	0.9	1.3
United Kingdom	163.9	76.9	87.0	77.5	9.5
United States of America	37.9	97.6	–59.7	–38.2	–21.5
Sweden	22.9	19.8	3.1	6.8	–3.6
Switzerland	18.2	7.4	10.8	5.5	5.3
Other countries	241.1	271.9	–30.8	36.7	–67.4
Total	1 585.2	1 144.2	441.0	189.5	251.5

[1] All import-export data exclude re-exports. The environmental requirements attributed to imports and exports follow a gross recording method (*cf.* table 7.2).
[2] $= 10 \times P + N$.

Divergences in composition effects exist when looking at individual countries. For example, imports from Germany, the most important trade partner of the Netherlands, are more carbon dioxide and waste intensive than the Dutch exports to this country. The carbon dioxide intensity of German import surpasses export since energy intensive products such as cars, machinery and other metal products dominate the former. As already mentioned, differences in the energy supply sector between countries are currently not reflected in the results (specifically the carbon dioxide figures in table 7.3a). The positive composition effects found with the other two pollution categories, acidification and eutrophication, reflect the substantial share in agricultural and processed food products exported to Germany.
Finally, for all four pollution types, a pollution share attributed to export of approximately 15 % has not yet been addressed to specific countries. For import this share varies from 20% to 24%. With the exception of acidification, the Netherlands appears to have on average an environmental trade deficit with these remaining unidentified countries. The composition effects are for all pollutant types positive

Table 7.3d
The environmental balance of trade of the Netherlands, (net) solid waste, 1997

	Export [1]	Import [1]	Environmental balance of trade	Composition effect	Trade balance effect
	1	2	3. = 1.– 2. = 3a. + 3b.	3a.	3b.
	mln kg				
Belgium and Luxembourg	568	479	89	–126	214
Denmark	76	51	25	–	25
Germany	1 198	872	326	–157	483
Finland	45	68	–23	–25	1
France	391	285	106	15	91
Greece	50	12	38	8	30
Ireland	39	37	1	12	–11
Italy	230	144	87	–3	90
Japan	68	82	–14	16	–30
Norway	47	63	–16	45	–61
Austria	58	42	16	–16	32
Portugal	33	26	7	1	6
Spain	115	102	12	–21	33
Czech Republic	13	9	4	–2	6
United Kingdom	518	361	157	122	35
United States of America	216	296	–80	6	–85
Sweden	92	144	–52	–33	–20
Switzerland	93	48	45	15	30
Other countries	682	887	–205	–	–204
Total	4 530	4 009	521	–143	665

[1] All import-export data exclude re-exports. The environmental requirements attributed to imports and exports follow a gross recording method (*cf.* table 7.2).

and quite substantial for CO_2, acid and nutrient pollution. This further confirms that the competitiveness of the Netherlands on international markets is related to relatively pollution intensive products.

7.5 *Conclusions and recommendations*

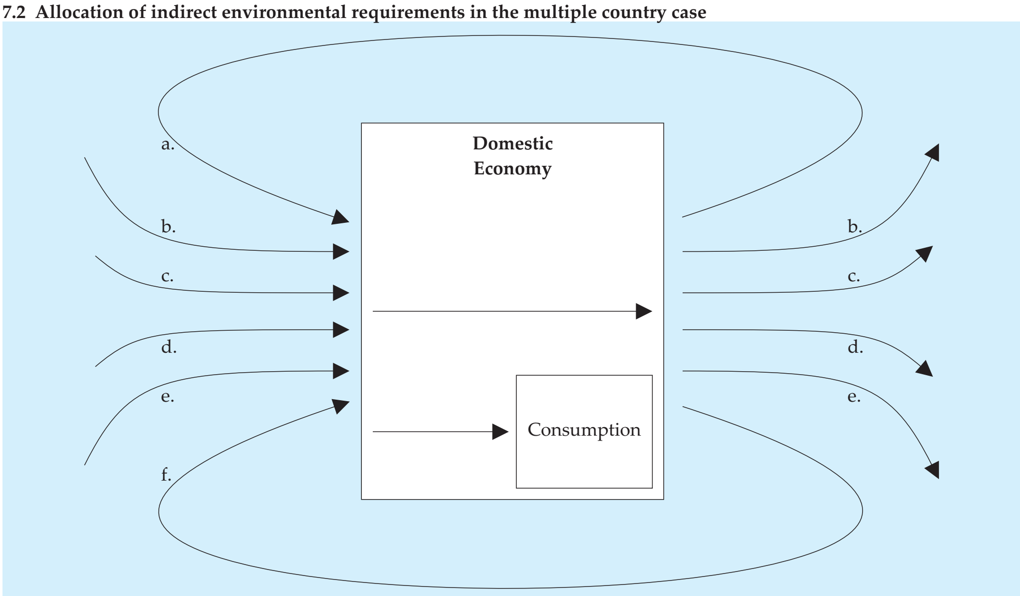
The direct recording of environmental requirements is a crucial accounting principle which assures the representation of factual events in environmental accounting. However, the environmental indicators based on direct recording provide only a partial picture of the environmental performance of an economy. In this chapter, it is suggested to extend the scope of environmental accounting with two interconnected environmental performance indicators on the macro level: the ‘environmental balance of trade’ and ‘environmental consumption’. Both indicators establish a shift in focus from a production oriented perspective towards a consumption perspective.

These additional indicators are specifically needed to detect the environmental consequences of ongoing trade liberalisation and the opening of domestic markets. When countries are forced to specialise according to their comparative advantages, the product composition of domestic output will increasingly differ from the product composition of domestic consumption. This will subsequently lead to a growing discrepancy of the direct environmental requirements of an economy and its total sum of environmental requirements attributed to domestic consumption. These indicators will also be helpful in showing to what extent a shift to a knowledge based services economy will genuinely lead to dematerialization or instead to transferring polluting industries to lesser developed countries. On more detailed levels, environmental consumption indicators are for example helpful in showing the influence of changing household life style patterns on the economy wide environmental performance, *cf*. Slob *et al*. (1996) and Nijdam & Wilting (2003).

It must be acknowledged that implementing the ‘environmental balance of trade’ and ‘environmental consumption’ indicators depends on model wise imputations that usually depend on short cut assumptions. Therefore these indicators must be considered of a somewhat different nature compared to those NAMEA indicators mainly resulting from statistical observation. Uncertainties in these indicators are not necessarily conceptually related but more to their practical implementation.

The required simplifications can be made at various stages in the analysis. For the European Community, the harmonisation of NAMEAs for air emissions seems clearly a good starting point for further extending these calculations, by for example

7.2 Allocation of indirect environmental requirements in the multiple country case



taking into consideration differences in production and pollution structures among EU countries. Another option could be the construction of a regionalised EU wide NAMEA system, in which case the required short cuts could be expanded at Europe's borders.

Ongoing trade liberalisation and the opening of domestic markets will inevitably result in increasing trade related transfers of environmental requirements between countries. A Europe-wide accounting framework will show that many countries re-export the environmental requirements they received via imports. This is visualised in figure 7.2. As explained earlier, portions of indirect pollution received from country (*i*) will subsequently be passed on via export to country (*j*). On the bilateral level, there is no reason to assume that the intermediate requirements exported to specific countries will be insignificant and therefore feedback effects, as shown for the countries (*a*) and (*f*) may be emerge. Since a bilateral environmental balance of trade indicator cannot be compiled on the basis of a net recording method as illustrated in table 7.2, this may somewhat complicate its interpretation. A gross recording implies that pollution attributed to export may include pollution portions originating from foreign countries. In this way, the pollution intensities of import and export both reflect to some extent the environmental performance of foreign economies.

In the empirical analysis presented in this paper, short cuts were made at a rather early stage. There are two simplifications regarding the treatment of non-competitive imports where this simple model can be expected to be quite deficient. The main producer of non-competitive imported commodities cannot really be identified in a domestic input-output table and any attempt to do so is somewhat arbitrary. However, at least in the Netherlands, a substantial part of imports exist of non-competitive commodities and ignoring these imports totally results in a partial representation of the environmental requirements attributed to imports and therefore an overestimation of the environmental balance of trade.

Secondly, the production of non-competitive imports such as for example tropical products *e.g.* wood, crops, minerals will often coincide with environmental impacts that are not present in the domestic economy. For example, these environmental requirements may concern the overexploitation of crucial natural resources such as water, soil or wood. In this case, a possible attribution of these environmental requirements to final users inevitably depends on the existence of environmental statistics or accounts in these countries.

In other words, there are two clear directions in which the 'environmental balance of trade' and 'environmental consumption' indicators can be improved. Comparable and interlinked systems of environmental-economic accounts may help to postpone the stage at which simplifying assumptions must be made. Further, environmental accounting should not be restricted to those environmental concerns appearing within the borders of a country. Due to the existence of trade dependencies, it may be important to stretch out the inclusion of environmental concerns towards those typical to foreign countries or regions.

Notes

[1] To be precise, besides consumption this total also includes all other domestic final commodity uses such as *net* capital formation and inventory changes. The results in table 7.1 are based on the simplifying assumption that the domestic production technology and emission coefficients are representative for imported commodities. Its exact estimation is explained in more detail in the subsequent section. The attributed element of the environmental consumption indicator (IV), v^c, is estimated with the help of equation (7.10) while the environmental balance of trade indicator (III) is estimated with the help of equation (7.11).

[2] To be precise, De Boer & Karres estimate the total pollution attributed to imported and domestically produced final demand, *i.e.* $\mathbf{y_1} + \mathbf{f_2}$. This minor change is made to directly compare this model with the environmental indicators discussed here.

[3] In contrast to the *time-series* structural decomposition analyses presented in chapter 8.

[4] In contrast to structural decomposition forms with a residual term, *cf*. chapter 8.

Chapter 8. A dynamic analysis of NAMEA indicators [1)]

8.1 Introduction

The NAMEA answers to the need to review the environmental consequence of economic development and provides a statistical framework for analysing historic trends but also for future oriented scenario evaluation. As such, the NAMEA indicators are helpful in illustrating for example the extent to which environmental performance improvements may compensate for economic growth effects. The accounts may also be helpful in indicating how far structural economic changes and the transition towards services-based economies provide genuine opportunities to improve environmental performance. Structural change refers in this context to shifts in industry composition and consumption patterns.

This chapter discusses the use of structural decomposition analysis as way to disentangle historic trends in NAMEA indicators. Structural decomposition analysis is introduced as a tool to describe how different kinds of changes in the economy influence the environmental requirements of an economy.

Decomposition analysis has been applied in various forms to show on the national and industry branch level the importance of technical and structural changes in for example the ex post inter-temporal developments in employment (*cf*. Skolka, 1989 and Forssell, 1990), energy consumption (*cf*. Lin & Polenske, 1995), material consumption (*cf*. Hoekstra, 2003) and pollution (and solid waste) (*cf*. Wier, 1998, Mukhopadhyay & Chakraborty, 1999, Jacobsen, 2000 and De Haan, 2001). Structural decomposition analysis usually refers to those decomposition methods that are carried out with the help of supply-use or input-ouput systems. A detailed overview of the literature on structural decomposition analysis is provided by Rose & Casler (1996).

This chapter reviews the results of a structural decomposition analysis in which the annual changes in a number of air pollutants and solid waste are decomposed according to their causes. Decomposition analyses reveal the underlying economic driving forces which together sum up the changes in resource inputs and residual outputs of a national economy from one year to another. The analyses presented in this chapter are applied with the help of NAMEA's for the Netherlands, covering annual data for the period 1987–1998.

An important precondition for a meaningful time series analysis is that volume changes in the monetary accounts can be determined whereby the influence of price changes is eliminated. This and other data issues are discussed in section 8.2. Section 8.3 elaborates on the methodological backgrounds of structural decomposition analysis. This section includes a sensitivity analysis in order to investigate the problem of non-uniqueness. Decomposition analysis usually generates a multitude of decomposition forms and each form may provide to some extent diverging results.

Section 8.4 discusses the results. Firstly, the macroeconomic developments over time are presented for carbon dioxide (CO_2), acid pollution and solid waste. Secondly, this section presents for carbon dioxide a further breakdown by branches of industry. Besides production, the environmental characteristics of households and international trade are included in a systematic representation of the origin and destination of pollution as introduced in chapter 7. This chapter winds up with a number of conclusions and recommendations.

8.2 *Data issues*

Obviously, a meaningful comparison of environmental and economic data over time is only possible without the influence of price changes. Therefore, in this analysis economic changes are captured in terms of volume changes. In the Dutch national accounts, the annually compiled supply-use and input-output tables are for each year (*t*) provided in current (*t*) as well as in constant prices (*t*-1). The volume change in one variable between two subsequent years can be derived by 'chaining' one year in current prices to a subsequent year in prices of the previous year. The national accounts revision according to the European system ESA-1995 has caused a gap in the national accounts data so that data before 1995 are not directly comparable to more recent data. Fortunately, the method of chaining does not necessarily disturb the decomposition analysis since 1995 is included in the former series in constant prices as well as in the latter series in current prices. Nevertheless, disturbances can occur when the indirect pollution effects attributed to imports are included in the analysis as described in the former chapter.

It must be acknowledged that the input-output and import matrices used in the structural decomposition analysis presented in table 8.3 of this chapter differs from those applied in the analysis presented in chapter 7. The most important differences are the following. Firstly, the import matrices applied in this chapter exclude non-competitive imports. Secondly, the intermediate requirements in the input-output tables used in this chapter omit entries for capital services. Thirdly, the input-output analyses presented in chapter 7 are carried out on a much more detailed level, 104 instead of 34 production activities.

8.3 *Conceptual issues*

The NAMEA time series help to track down different causes of annual changes in environmental requirements. In this respect, input-output analysis provides a systematic approach. In a simple input-output model, the annual change in pollution (Δv) can be described as a linear additive function of economic growth in terms of 'eco-efficiency' gains or losses, measured by the changes in eco-intensities or the total pollution per money unit of output *(*Δe), changes in the economic production structure *(*Δl*)*, changes in the composition of final demand expenditures (Δy_s) and finally the volume increase in final demand *(*Δy_v),:

$$\Delta v = a\Delta e + b\Delta l + c\Delta y_s + d\Delta y_v$$

Decomposing changes in emissions between the years (0) and (1) in a Leontief input-output model results in four different expressions, corresponding to each of these four causes. Various structural decomposition analyses have been devoted to environmental issues, often focussing on energy consumption or energy related pollution *e.g.* Wier (1998), Mukhopadhyay & Chakraborty (1999) and Jacobsen (2000). As shown by Wier (1998), in the analysis of fossil fuel combustion related air pollution, change in pollution per money unit of output (Δe) can be further decomposed into changes in energy efficiency, fuel mix and emission coefficients per unit of energy input. The analysis in this chapter contains pollution categories not necessarily restricted to fuel combustion. Therefore, changes in eco-intensity, *i.e.* Δe, are not further decomposed here.
The structural decomposition analysis can be derived as follows. Suppose that the element v^x_{ij} of $\mathbf{V^x}$ represents pollutant type *i* (in kilograms) generated by production activity *j*. Then total pollution generated by all production activities can be determined as a function of total outputs:

$$\mathbf{v^x} = \mathbf{Ex}$$

Element v^x_i of vector $\mathbf{v^x}$ indicates pollution type *i* generated in total by all production activities: $\mathbf{v^x}=\mathbf{V^x i}$. Vector **i** denotes the summation vector consisting of ones, vector **x** corresponds to the total output vector. The matrix containing the pollution coefficients is determined as follows:

$$\mathbf{E} = \mathbf{V^x}\hat{\mathbf{x}}^{-1}$$

Element e_{ij} of **E** indicates the pollution intensity or coefficient, *i.e.* the total amount of pollutant *i* generated by one money unit of output from activity *j*. The diagonal matrix of vector **x** is indicated by $\hat{\mathbf{x}}$**.**
The standard Leontief equation in which total output is determined as a function of final demand, *i.e.* vector **y**, equals:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{y}$$

Matrix **A** represents the technical coefficients and matrix denotes the Leontief inverse. Subsequently, pollution generated by all production activities can be determined as:

$$\mathbf{v^x = Ex = EL\left[y / (i' y)\right](i' y)} \tag{8.1}$$

In this expression, vector $\mathbf{y}$ is divided by its total sum to arrive at a vector $\mathbf{y_s = y / (i'y)}$ containing the industry shares in final demand.

The sum of these industry (j) shares is equal to one:

$$\sum_j y_{sj} = 1, j = \{l...n\}$$

The total final demand level is subsequently indicated by scalar $y_v = \mathbf{i'y}$. With the help of vector $\mathbf{y_s}$ and scalar y_v, changes in the composition of $\mathbf{y}$ are separated from volume changes in $\mathbf{y}$.
Equation (8.1) can be summarised as follows:

$$\mathbf{v^x = E\ L\ y_s} y_v \tag{8.2}$$

Equation (8.2) can be used to decompose changes in pollution between two periods (0) and (1):

$$\mathbf{\Delta v^x = v^x(1) - v^x(0) = E(1)L(1)y_L(1)}y_v(1) \mathbf{- E(0)L(0)y_L(0)}y_v(0) =$$

$$\mathbf{(\Delta E)L(1)y_L(1)}\ y_v(1) \mathbf{+ E(0)L(1)y_L(1)}\ y_v(1) \mathbf{- E(0)L(0)y_L(0)}y_v(0) =$$

$$\mathbf{(\Delta E)L(1)y_L(1)}y_v(1) \mathbf{+ E(0)(\Delta L)y_L(1)}y_v(1) \mathbf{+ E(0)L(0)y_L(1)}y_v(1) \mathbf{- E(0)L(0)y_L(0)}y_v(0) =$$

$$\mathbf{(\Delta E)L(1)y_L(1)}y_v(1) \mathbf{+ E(0)(\Delta L)y_L(1)}y_v(1) \mathbf{+ E(0)L(0)(\Delta y_L)}y_v(1) \mathbf{+ E(0)L(0)y_L(0)}y_v(1) -$$

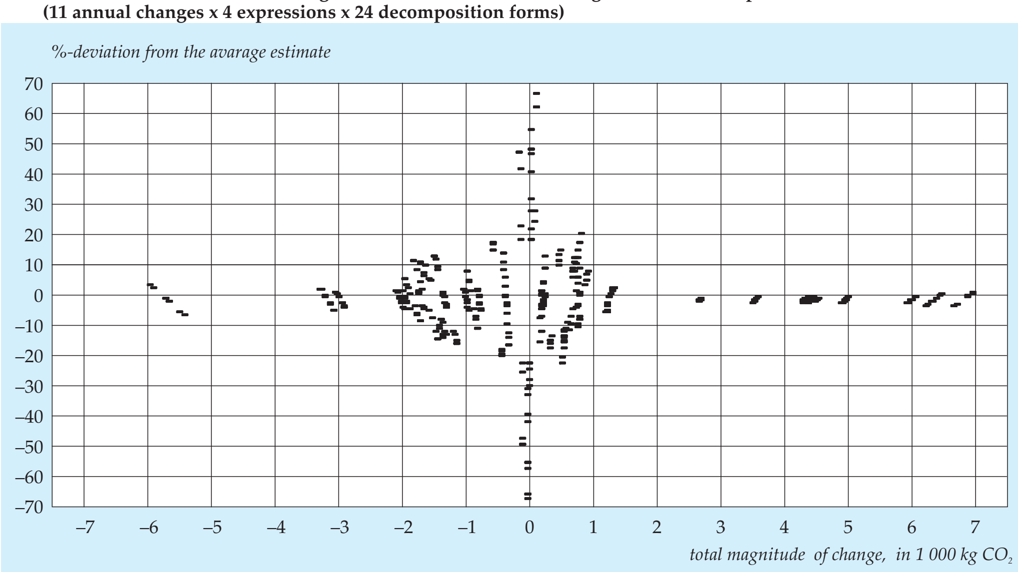
$$\mathbf{E(0)L(0)y_L(0)}y_v(0) =$$

$$\mathbf{(\Delta E)L(1)y_L(1)}y_v(1) \mathbf{+ E(0)(\Delta L)y_L(1)}y_v(1) \mathbf{+ E(0)L(0)(\Delta y_L)}y_v(1) +$$

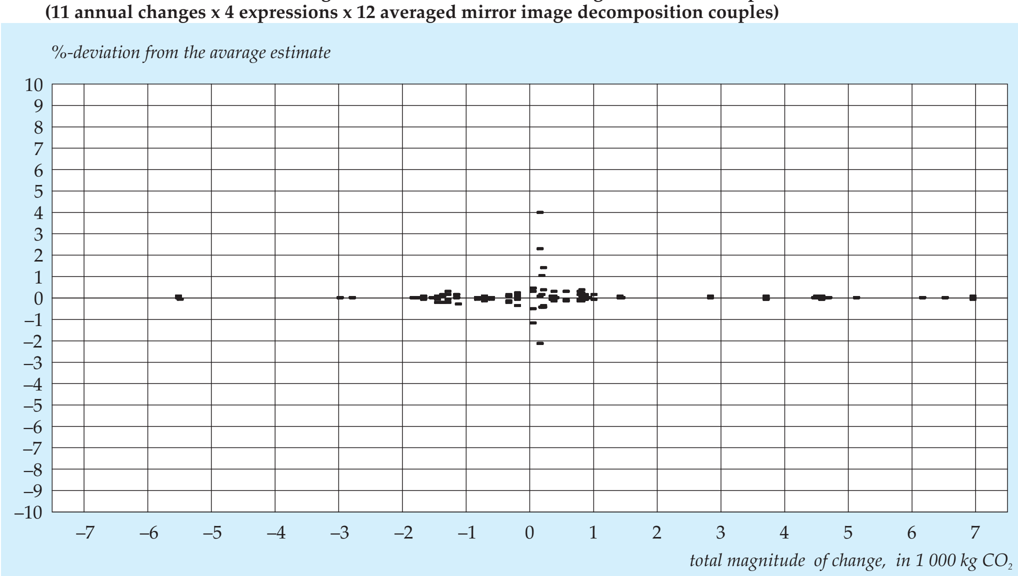
$$\mathbf{E(0)L(0)y_L(0)}(\Delta y_v) \tag{8.3}$$

As shown by Dietzenbacher & Los (1998), this solution is not unique. In case of n variables, there exist $n!$ decomposition forms. These follow a similar structure as presented in equation (8.3), each including four separate terms with only one single change factor, *i.e.* the Δ term, in each of them. Van der Kruk (1999) shows that the number of decomposition forms far exceeds $n!$ when also those forms are taken into consideration that include multiple change factors, *i.e.* interaction terms such as $\mathbf{(\Delta E)(\Delta L)y_s(1)}y_v(1)$ and $\mathbf{(\Delta E)(\Delta L)(\Delta y_s)}y_v(1)$, for example. However the economic interpretation of multiple change factors is not straightforward and therefore they are not taken into consideration here.
So in our case we have 24 different equations which lead to different results and these are caused by the different weights attributed to the four separate change factors in each equation. Figures 8.1a and 8.1b show the results of two sensitivity

8.1a Percent deviation from the average estimate in relation to the magnitude of each expression (11 annual changes x 4 expressions x 24 decomposition forms)



8.1b Percent deviation from the average estimate in relation to the magnitude of each expression (11 annual changes x 4 expressions x 12 averaged mirror image decomposition couples)



analyses which both refer to annual changes in carbon dioxide pollution over the period 1987–1998. The vertical axis in figure 8.1a represents for each of the 'change terms' (= weight × change factor) in the decomposition equation, the percent deviation from its average of the 24 possible decomposition forms. The horizontal axis represents the total magnitude of each individual term expressed in 1 000 kg carbon dioxide. The percent deviation varies from approximately –60% up to almost +70%. However, figure 8.1a shows that these extreme deviations only occur in change terms of relatively small magnitude, *i.e.* far less then ± one thousand kilogram of carbon dioxide. In comparison to the total carbon dioxide pollution of 200 billion kilogram that was generated by the Dutch economy in 1997, the order of magnitude of these changes is indeed very small. For larger changes the percent deviations are smaller but can still be substantial (±20%) for changes ranging from –2 000 up to approximately +1 500 kilogram. Outside this range, the percent deviations are very small.

One of the options considered by Dietzenbacher & Los (1998) to overcome the 'non-uniqueness problem' is to use the average of the two so-called polar decomposition forms. As illustrated by equation (8.3), the first polar form is derived by starting the decomposition with the first variable in (8.2), followed by the second, third and finally the fourth variable. The second polar is derived exactly the other way around, *i.e.* going from the fourth variable systematically back to the first variable. Next to the polar form in (8.3), the second polar form is given by:

$$\Delta \mathbf{v}^{\mathbf{x}} = (\Delta \mathbf{E})\mathbf{S(0)}\mathbf{y_s(0)}y_v(0) + \mathbf{E(1)}(\Delta \mathbf{S})\mathbf{y_s(0)}y_v(0) + \mathbf{E(1)S(1)}(\Delta \mathbf{y_s})y_v(0) + \mathbf{E(1)S(1)y_s(1)}(\Delta y_v) \quad (8.4)$$

The two polar forms have opposite weights with respect to time, *i.e.* base year (0) versus end year (1) variables, attached to each of the corresponding change factors. In other words, each term in one polar has its 'mirror image' represented in the other. In this respect the two polar forms are not unique. On the contrary, *each* decomposition form has its mirror image. So, in our case of 4 variables, the 24 different decomposition forms appear to exist of 12 pairs of mirror images.

Figure 8.1b shows the results of a sensitivity analysis representing the averages of each of these 12 pairs of mirror images. The vertical axis shows for all four change terms represented in these 12 averages the percent deviation from the full average of all 24 decomposition forms. The horizontal axis shows again the total magnitude of change. Figure 8.1b indicates that the average of any pair of mirror image decomposition forms substantially diminishes the percent deviation from the average estimate. For the more substantial change terms, the deviations are approximately zero. Only for very small change terms, the percent deviations range now from –2.1% to +3.9%, which is still a remarkable decrease in comparison to the individual estimates represented in figure 8.1a. Both figures indicate that change terms with the highest absolute deviation are also those of the smallest magnitude. In this respect, the scattering of dots in the Figures 8.1a and 8.1b shows rather similar patterns. One major exception is of course the horizontal compression of the scatters in figure 8.1b in comparison to figure 8.1a. The comparison of both figures almost allows for a visual identification of most of the mirror images. In our case one may conclude that the average of any pair of mirror image decomposition forms will

sufficiently reduce the variance in decomposition results which is unlikely to be of a much higher order than the variance in the basic data.
One may argue that in the single 'full' decomposition forms presented in figure 8.1a weights are chosen somewhat arbitrarily to ensure a full decomposition without a residual. Indeed, in all the 24 full decomposition forms, each weight attached to the four change factors exist of different combinations of base/end year variables. Wier (1998) applies an alternative method in which for all change factors the average is taken of two calculations, using either base or end year weights for all variables represented in the weights. In this way, the similar weight structure attached to each change factor foresees in the mutual comparability between the different change terms. However, their method carries the disadvantage of a residual term in the decomposition equation. The sensitivity analysis in figure 8.1b shows that this arbitrariness does not affect the results very much when the average of any mirror image couple is used in the decomposition analysis. Each mirror image couple substantially reduces the influence of weight differences. Only for the smallest change terms, minor percent deviations can be observed between the four mirror image couples.
Although in our case this may perhaps be of minor importance, the total average of all possible decomposition forms overcomes any further arbitrariness in the weight composition. In the total average, each weight attached to the four different change factors has exactly the same structure. As an illustration, table 8.1 presents the composition of the complete weight attached to Δy_v in the total average of 24 decomposition forms. The weight consists of eight combinations of so-called 'weight strings' and 'weight values'. The number of weight strings reflects all possible permutations of base/end year variables represented in the weight. The weight values result from the number of appearances of the corresponding weight strings in the 24 decomposition forms.
Table 8.1 shows that the total weight exists of four couples of 'mirror image weight strings'. Each member of one couple is represented by an equal weight value. In the

Table 8.1
The composition of the weight attached to Δy_v in the average of all 24 decomposition forms

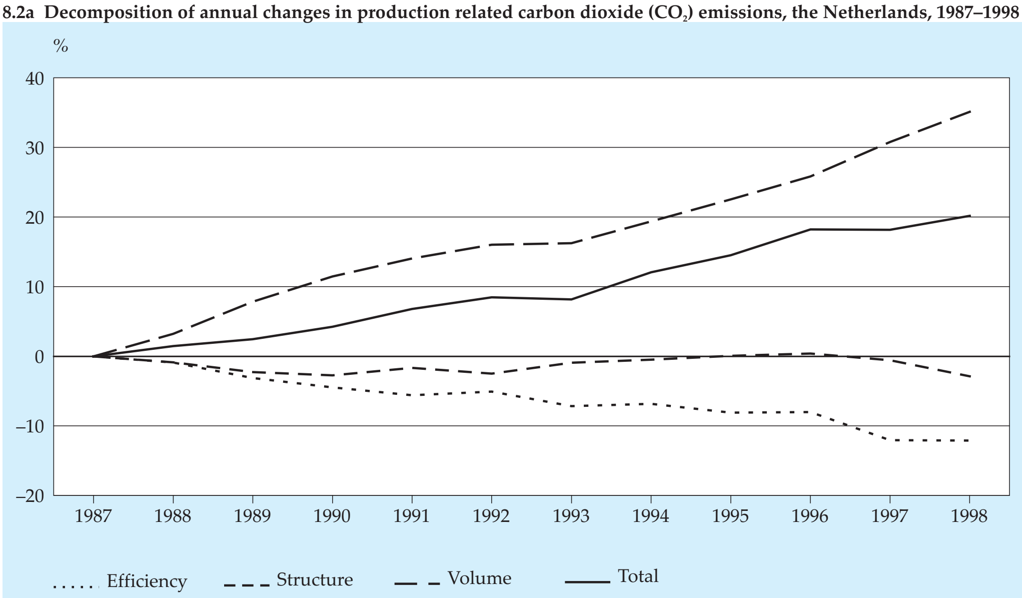
Weight values		Weight strings			
		E	**L**	**y_s**	
1/4	×	(1	1	1)	+
1/4	×	(0	0	0)	+
1/12	×	(1	0	0)	+
1/12	×	(0	1	1)	+
1/12	×	(1	1	0)	+
1/12	×	(0	0	1)	+
1/12	×	(1	0	1)	+
1/12	×	(0	1	0)	

full average this symmetric representation of weight strings is found in all four change terms. More generally, this symmetry in weight values is equally present in decomposition forms containing any number other than four variables. In our case, the average of all 24 decomposition forms could be regarded as a special case of 'mirror image weighting' embracing all four couples of mirror image weight strings. In conclusion, the advantage of calculating the average of two mirror images is obviously its simplicity since only two out of 24 decomposition forms have to be taken into consideration. However, the total average of all possible decomposition forms overcomes any further arbitrariness in the weight composition and is therefore used in all the empirical analyses presented in the next section. One could imagine that a single pair of mirror images is used in cases where the number of variables in the decomposition equation is much higher.

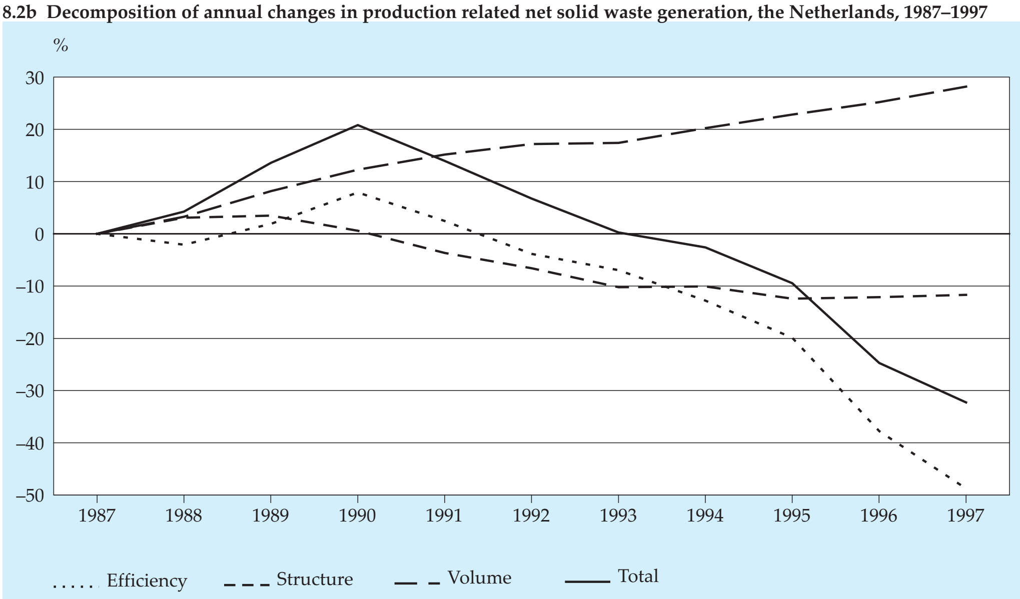
8.4 Results

Figures 8.2a – 8.2c give a first impression of the results. For the period 1987–1998, the bold lines indicate the total annual percent change in pollution from domestic production. The remaining three lines show how these annual changes are broken down according to the structural decomposition analysis presented in section 8.3:
- eco efficiency ($\Delta\mathbf{E}$);
- structure of production ($\Delta\mathbf{L}$);
- structure of demand ($\Delta\mathbf{y_s}$);
- volume, demand (Δy_v).

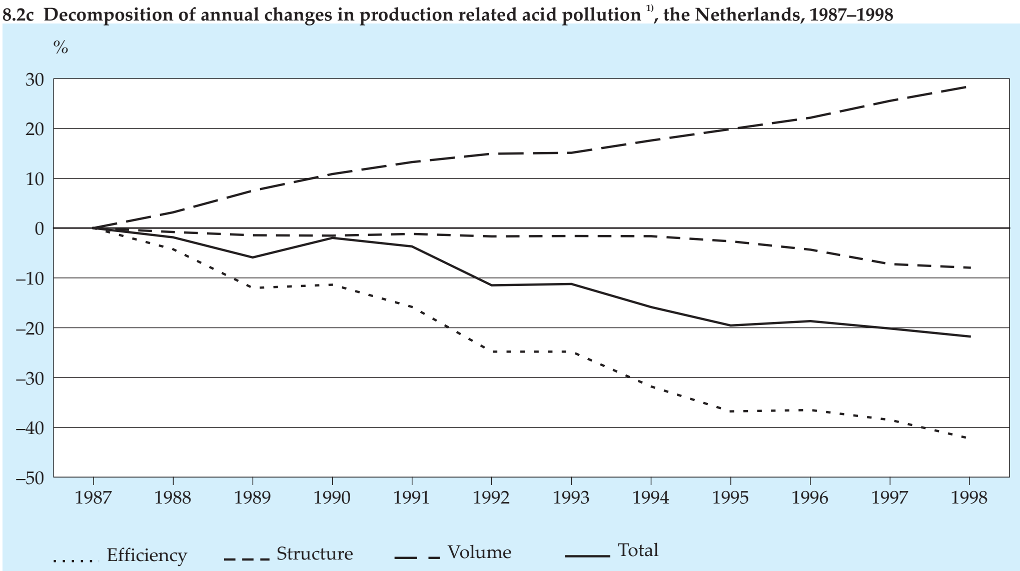
8.2a Decomposition of annual changes in production related carbon dioxide (CO_2) emissions, the Netherlands, 1987–1998



8.2b Decomposition of annual changes in production related net solid waste generation, the Netherlands, 1987–1997



8.2c Decomposition of annual changes in production related acid pollution [1], the Netherlands, 1987–1998



[1] = 0.22 x NO_X + 0.31 x SO_2 + 0.59 x NH_3

Since the structure effects derived from the decomposition analyses are generally rather small, structure effects related to production ($\Delta\mathbf{L}$) and demand ($\Delta\mathbf{y}_s$) are taken together in the figures 8.2a – 8.2c. The bold line represents the total net sum of these three separate effects. Figure 8.2a refers to the emission of carbon dioxide (CO_2), figure 8.2b to solid waste and figure 8.2c to the weighted aggregation of the acid precursors. Since carbon dioxide makes up more than 80% of the overall greenhouse indicator, the transparency of the analysis is better served by the single representation of carbon dioxide in figure 8.2a. For solid waste no data were yet available for 1998 at the time the analysis was carried out.

The decomposition analyses presented in these figures reveal the dynamics in the NAMEA data that are not directly discovered in a regular comparison of economic and environmental indicators. In all three examples, basically two major forces have determined the development of pollution over time. On the one hand, expenditure growth strongly triggered the growth in pollution. On the other hand, efficiency improvements led to a downward movement of pollution. The structure effects were less strong and had in most cases a negative impact on emissions. Structure effects were most significant on the demand side.

A shift of final consumption from product groups with relatively high pollution requirements to products with lesser ones, resulted in all cases to a decline in production related pollution over the whole period. Changes in the production structure were less significant and their contribution to pollution varied from positive to negative. In general, the structure related changes may have been somewhat underestimated due to the fairly condensed input-output tables that were used in the analysis.

The cases of acidification and solid waste show that efficiency gains and structural changes (–) outweighed the volume increases (+) so that on balance total production related pollution significantly decreased between 1987 and 1997/1998. For carbon dioxide the opposite development is shown. In spite of substantial efficiency gains of more than 12%, production related carbon dioxide emission increased between 1987 and 1998 with 20%. Without efficiency gains and structure changes, pollution growth would have reached 35%.

Table 8.2 provides a further breakdown of the decomposition results by branches of industry for carbon dioxide only. The decomposition analysis refers to changes between 1987 and 1998. As explained in the former section, changes in monetary variables refer to changes in volumes and the decomposition results are equally determined by chaining one year to another. The estimates by industry are derived by the following reformulation of equation (8.2)

$$\mathbf{v}^{\mathbf{x}} = \hat{\mathbf{e}}_{\mathbf{i}}\,\mathbf{L}\mathbf{y}_{\mathbf{s}}\,y_v \qquad (8.5)$$

where:

$i = CO_2$;

$\mathbf{v}^{\mathbf{x}}$ represents the vector with emissions of CO_2 by industries;

$\hat{\mathbf{e}}_{\mathbf{i}}$ denotes the diagonal matrix of vector $\mathbf{e}_{\mathbf{i}}$, containing the CO_2 emission coefficients by industries.

Table 8.2
Decomposition of changes in carbon dioxide (CO_2) emissions by industries in the Netherlands, 1987–1998 (as % of the total amount of 138.6 billion kg CO_2 emitted by all industries in 1987)

	Efficiency change	Structure change, production	Structure change, demand	Volume change, demand	Total change (=row sums)
	%				
Agriculture and forestry	0.0	–1.3	–0.2	2.2	0.8
Fishing	–0.2	–0.7	0.3	0.8	0.2
Crude petroleum and natural gas production	0.6	–0.1	–0.1	0.4	0.8
Other mining and quarrying	0.1	0.0	0.0	0.1	0.1
Manufacture of food products,	–0.4	–0.1	–0.1	1.1	0.4
Manufacture of textile and leather products	–0.1	0.0	–0.1	0.1	–0.1
Manufacture of paper and paper products	0.0	–0.1	0.0	0.4	0.3
Publishing and printing	0.1	0.0	0.0	0.1	0.1
Manufacture of petroleum products	–0.5	0.1	–1.1	2.5	1.0
Manufacture of chemical products	–5.1	0.4	–0.1	5.0	0.2
Manufacture of rubber and plastic products	0.1	0.0	0.0	0.0	0.1
Manufacture of basic metals	–0.5	–0.4	0.2	1.7	0.9
Manufacture of fabricated metal products	0.0	0.0	0.0	0.1	0.1
Manufacture of machinery n.e.c.	0.0	0.0	0.0	0.1	0.1
Manufacture of electrical equipment	–0.5	–0.1	0.0	0.2	–0.3
Manufacture of transport equipment	–0.1	0.0	0.0	0.1	–0.1
Manufacture of construction materials	–0.3	–0.1	–0.2	0.7	0.2
Other manufacturing	0.0	0.1	0.0	0.1	0.2
Electricity, gas and water supply	1.2	0.7	–5.1	9.7	6.5
Construction	–0.4	0.1	–0.1	0.5	–0.1
Trade and repair of motor vehicles	–0.2	0.0	0.0	0.2	0.1
Wholesale trade	–0.5	0.1	0.1	0.4	0.1
Retail trade, repair (excl. motor vehicles)	–0.4	–0.1	0.1	0.5	0.2
Land transport	–0.8	0.1	0.4	1.7	1.4
Water transport	–0.2	–0.1	0.4	1.4	1.5
Air transport	–3.1	0.3	3.0	2.0	2.2
Supporting transport activities	–0.1	0.0	0.0	0.1	0.0
Financial, business services and communication	–0.5	0.3	0.2	0.7	0.7
Public administration and social security	0.0	–0.1	–0.2	0.6	0.2
Health and social work activities	–0.8	0.0	–0.2	0.5	–0.5
Sewage and refuse disposal services	0.7	0.7	0.2	0.8	2.4
Other services	0.2	0.0	–0.2	0.4	0.4
Total change (=column sums)	–12.1	–0.2	–2.6	35.1	20.2

Substitution of vector $\mathbf{e}_i'$ by its diagonal matrix $\hat{\mathbf{e}}_i$ leads to a decomposition of emissions at the individual industry branch level.
The classification in table 8.2 broadly indicates the level of detail provided by the Dutch NAMEA. All percent changes in the table refer to the total amount of carbon dioxide of 138.6 billion kg emitted by all industries in 1987. In this way, all percentages in the table add up row and column wise and are therefore comparable between the different change factors and industry branches. So, for example production structure changes, which are presented in the second column of table 8.2, have decreased the emission of carbon dioxide in agriculture and forestry by

1.3% points (which equals –1.8 billion kg) and the total increase in all industries was 20.2% (27.9 billion kg).
In most industries, reductions in carbon dioxide pollution due to efficiency gains were combined with increases related to volume changes of final demand. The structure changes with respect to production remained rather inconclusive while the structure changes on the demand side indicated in general at a substitution of relatively highly polluting products by more environmentally friendly ones. Substantial efficiency gains in both the manufacturing of chemical products and air transport services were totally phased out by increases in carbon dioxide pollution caused by demand side changes. These two industries contributed together 8% points to the economy wide accomplished efficiency improvements of 12% points. Air transport substantially increased its share in final demand and finally contributed on balance 2% points to the total increase in carbon dioxide pollution of 20.2%.
The 2.4% points net contribution by the sewage and refuse disposal services needs some further explanation. This rise in carbon dioxide emissions has been caused by a substantial increase in waste that has been incinerated instead of being dumped. The negative efficiency improvement may have resulted from increasing temperatures at which waste has been incinerated in later years in order to avoid the emissions of highly toxic air pollutants such as dioxins. These results show that the treatment of one waste flow may have negative consequences for others.
The volume component in the structural decomposition analysis shows how pollution would have evolved when following economic growth rates. Therefore, the influence of eco-productivity changes, as defined in chapter 5, on pollution developments are quantified by the difference between the volume component change and the actual pollution change, or alternatively, by the negative sum of efficiency changes and structure (production + demand) changes. For carbon dioxide emissions, eco-productivity gains had an lowering effect on production related pollution of 14,9% over the period 1987–1998 (*cf*. table 8.2). As a result of differences in the composition of economic growth volume indexes the eco-productivity measures resulting from the decomposition analyses presented here may slightly differ from those presented in table 5.4 of chapter 5.
The above presented results are restricted to the analysis of pollution generated by domestic production activities. From the perspective of a national economy, this means that at least two important aspects have not yet been taken into consideration. Firstly, besides industries, the NAMEA provides information on the direct emission of pollutants by households. Households equally contribute to a substantial amount of pollution such as waste (water) generation and air emissions related to household activities such as heating, cooking and private transport. Secondly, as discussed in the former chapter, the environmental aspects of international trade should not be neglected in a consumer oriented analysis of environmental performance.

Table 8.3 [2)]
Origin and destination of carbon dioxide (CO_2) pollution

	1990	1990 + demand effects 1990–1997	1997	Demand effect	Production effect	Total
	1	2	3	4 =(2–1)/1	5 =(3–2)/1	6 =(3–1)/1
Origin	*billion kg*			*%-change*		
Domestic						
Production = v^x (direct)	145	171	163	18	–5	13
Consumption = v^h (direct)	33	41	37	24	–12	12
Rest of the World						
Import = v^t (attributed)	89	116	109	30	–8	23
Total, origin	266	328	309	23	–7	16
Destination						
Domestic						
Consumption = v^h (direct) + v^{c-z} (attributed)	115	139	132	20	–6	14
Gross Capital formation = v^z (attributed)	26	27	27	3	–	2
Rest of the World						
Export = v^s (attributed)	125	162	150	30	–10	21
Total, destination	266	328	309	23	–7	16
Environmental balance of trade ($v^s - v^t$)	36	47	42	29	–14	16

Table 8.3 provides a complete macro-economic overview of the origin and destination of carbon dioxide pollution. This overview includes the domestic pollution generated by production *and* consumption activities and shows subsequently the amount of pollution attributed to import and export. Table 8.3 firstly indicates the pollution source and secondly for what kind of purpose or user this pollution has been generated. In this set-up, the table follows the 'supply = demand' identity introduced in the former chapter. Consequently, the sum of carbon dioxide pollution classified by sources equal by definition the total sum of destinations. At the same time a comparison is made between the years 1990 and 1997. The estimates for 1990 are presented in the first column while the corresponding figures for 1997 are presented in the third column. The second column represents again the results of a decomposition analysis.

When looking at the origin of carbon dioxide emissions, total domestic pollution includes emissions by households (v^h) as well as the sum of emissions by industries, *i.e.*

$v^x = \mathbf{v^{x}}'\mathbf{i}$,

where vector $\mathbf{v^x}$ contains the carbon dioxide emissions by industries as in equation (8.5). Both v^x and v^h are shown in the first two rows of table 8.3 and result directly from the NAMEA emission accounts of 1990 and 1997 (*cf*. table 5.3a). The third row represents carbon dioxide pollution attributed to imports (v^t). As explained in the former chapter, this pollution is supposed to have been emitted in those countries from which these imports originate. Ideally, these import related carbon dioxide emissions would be estimated with the help the NAMEAs of countries exporting to the Netherlands. However, a first approximation presented here is again based on the assumption that the domestic production technology is representative for the environmental effects of imported products.

The allocation of this total carbon dioxide pollution ($v^x + v^c + v^t$) to the different final demand categories consumption, gross capital formation and exports, is determined as follows.

Firstly, carbon dioxide pollution from domestic (v^x) and foreign producers (v^t) attributed to the various final demand categories is denoted by vector $\mathbf{v^a}$. This attributed pollution is determined by an input-output model quite similar to that applied in the analyses presented in chapter 7.

$$\mathbf{v^a}' = \mathbf{e_i}'(\mathbf{I} - \mathbf{A} - \mathbf{M}^*)^{-1}(\mathbf{Y} + \mathbf{F_t}) \qquad (8.6)$$

$$\mathbf{v^a}'\mathbf{i} = v^x + v^t \qquad (8.7)$$

$$\mathbf{Y}{+}\mathbf{F_t} = \left[\mathbf{y}^{c-z^*} + \mathbf{f}_t^{c-z^*} \middle| \mathbf{y}^{z^*} + \mathbf{f}_t^{z^*} \middle| \mathbf{s}\right] \qquad (8.8)$$

The vector with carbon dioxide pollution coefficients, $\mathbf{e_i}$, and the technical coefficients related to domestic production, matrix **A**, and import, matrix **M***, are defined in a similar way as in chapter 7. The asterisk indicates that matrix **M*** applied in equation (8.6) omits the non-competitive imports.

Matrices **Y** and $\mathbf{F_t}$ are a matrix expansion of the vectors **y** and $\mathbf{f_t}$, by adding column wise entries for the different final demand categories: final consumption (*c-z**), *gross* capital formation (*z**) and export denoted by vector **s**.[3)] The column wise subdivision in the right hand side of equation (8.8) indicates a threefold partitioning of vector $\mathbf{y{+}f_t}$ leading to matrix $\mathbf{Y}{+}\mathbf{F_t}$ with the dimensions: industry × final demand category.

Final demand originating from import, *i.e.* vector $\mathbf{f_t}$, corresponds to the vector $\mathbf{f_2}$ in the two country case model introduced in chapter 7. Subscript (*t*) is used in equation (8.6) to indicate that import of final products, as presented here, may originate from several countries. As in chapter 7, re-exports are totally excluded from the analysis.

The three entries of vector $\mathbf{v^a}$ represent the carbon dioxide pollution attributed to the three final demand categories represented in equation (8.8), originating from domestic as well as from foreign production.

Secondly, carbon dioxide pollution directly emitted by households (v^h) is obviously related to household activities and therefore equally allocated to (household) consumption as its destination. The total destination of carbon dioxide pollution, denoted by vector $\mathbf{v^y}$ and classified according to the three final demand categories presented in equation (8.8), is finally determined by adding to vector $\mathbf{v^a}$, the direct emissions by households represented by scalar v^h.

$$\mathbf{v^y} = \begin{bmatrix} v^h \\ 0 \\ 0 \end{bmatrix} + \mathbf{v^a} \tag{8.9}$$

Pollution generated by government activities is in the NAMEA fully described in relation to government production (and not consumption) and as such included in v^x. With the help of equation (8.6), this carbon dioxide pollution is systematically attributed to government consumption.

Consequently, equations (8.6) and (8.9) together allocate emissions to final demand and the corresponding estimates for the years 1990 and 1997 are presented in the first and third column of table 8.3. As already mentioned the second column in this table is the result of a decomposition analysis and shows the increase in carbon dioxide emissions resulting from the growth and the compositional changes in final demand between 1990 and 1997. The results are determined as follows.

In the NAMEA, households are described as the 'producers' of their own pollution that is directly linked to household expenditure. Similarly to the emission coefficients of manufacturing industries, the direct carbon dioxide pollution from households can be determined as a function of total household consumption

$$v^h = e^h \times c^h \tag{8.10}$$

where scalar c^h denotes household consumption and e^h equals the average amount of carbon dioxide emitted by households per money unit of household consumption expenditure, *i.e.* the total average direct carbon dioxide pollution intensity of households:

$$e^h = \frac{v^h}{c^h}$$

With the help of this direct pollution intensity, the decomposition of changes in household pollution Δv_c can be derived as follows.

$$\Delta v^h = e^h(1)c^h(1) - e^h(0)\, c^h(0) \tag{8.11}$$

Subsequently, CO_2 pollution attributed to final demand ($\mathbf{v^a}$) can be decomposed on the basis of equation (8.6).

If $\mathbf{I_i^*}' = \mathbf{e_i}'(\mathbf{I} - \mathbf{A} - \mathbf{M})^{-1}$

then

$$\Delta \mathbf{v^a}' = \mathbf{I_i^*}'(\mathbf{1})(\mathbf{Y} + \mathbf{F_t})(\mathbf{1}) - \mathbf{I_i^*}'(\mathbf{0})(\mathbf{Y} + \mathbf{F_t})(\mathbf{0}) \tag{8.12}$$

Both Δv^h and $\Delta \mathbf{v^a}$ are decomposed according to two determining change factors, making their results mutually comparable:
Intensity (Δe_i) and production structure effects ($\Delta \mathbf{S}^*$) in equation (8.12) are grouped together as *'production effects'*. Production effects also include changes in CO_2 pollution resulting from Δe^h as presented in equation (8.11).
Structure effects on the demand side (Δy_s) and the volume effects (Δy_v) are together labelled as *'demand effects'*. Similarly, demand effects also include changes in household carbon dioxide pollution resulting from Δc^h.
In this context, households are being represented as the own account producers of household services such as heating, cooking and transport services and subsequently the carbon dioxide pollution that directly results from these activities.
Demand effects are calculated by the taking the average of the two possible decomposition forms which, in case of Δv^h and $\Delta \mathbf{v^a}$, yields:

$$\Delta v^h_{demand} = ½\,[e^h(0) + e^h(1)](\Delta c^h) \tag{8.13}$$

$$\Delta \mathbf{v^a_{demand}} = ½\,\left[\mathbf{I_i^*}'(\mathbf{0}) + \mathbf{I_i^*}'(\mathbf{1})\right]\Delta(\mathbf{Y}+\mathbf{F_t}) \tag{8.14}$$

Demand effects for Δv^x and Δv^m are derived accordingly. The second column in table 8.3 is derived by adding to the 1990 figures the corresponding 1990–1997 changes resulting from the demand effects. In this way, the second column in the table indicates the changes in pollution between 1990 and 1997 in case production effects would not have occurred.
Volume changes in the monetary variables presented in equations (8.13) and (8.14) are captured by chaining. Since the latest national account revision in the Netherlands lead to adjustments in import data, the calculations presented in table 8.3 are entirely based on national accounts data before the revision, containing preliminary estimates for 1996 and 1997 (*cf*. Statistics Netherlands, 1998). The revision is less disturbing in the previously presented structural decomposition analyses restricted to domestic production related pollution only.
The substantial amount of pollution attributed to imports and exports, as shown in table 8.3, reveals the very open structure of the Dutch economy and this has already been discussed in chapter 7. A comparison between the first and third column shows the changes between 1990 and 1997. In this period, the total growth in carbon dioxide emissions connected to import, domestic production and consumption equalled 16%. The columns representing the percent changes show the increase in carbon dioxide emissions resulting from growth and shifts in final demand and

indicate that without efficiency improvements or changes in the production structure, the corresponding carbon dioxide increase would have reached 23%.
The relatively high demand effected changes for both imports and exports (+30%) show that the importance of international trade in the Dutch economy further increased in this period. Obviously, the demand effect on the carbon dioxide balance of trade was of a similar order (29%). However, the production effects were much higher for export than for import, leading despite substantial demand effects, to a somewhat modest overall increase of the environmental balance of trade (+16%). This shows that efficiency improvements were relatively higher in the exporting industries than in the importing industries.
The substantial growth in the direct carbon dioxide emissions by households that was triggered by the demand effect (24%) was to a large extent neutralised by the corresponding production effect (–14%). This indicates that household consumption growth has been dominated by consumer items other than fossil fuel consumption. When looking at the total direct and attributed emissions connected to total consumption expenditures, the production effects were much smaller (6%).

8.5 *Conclusions and recommendations*

NAMEA time series appear to be a powerful tool in analysing pollution changes over time. Structural decomposition analysis provides a systematic and flexible technique to disentangle changes in pollution according to different causes such as economic growth, changes in the economic structure, eco-efficiency changes at the level of producers and consumers.
There are various techniques available to carry out a structural decomposition analysis. The method used here builds on the so-called 'full' decomposition form without a residual term. One problem that has to be solved is the non-uniqueness of these kind of decomposition forms. The *n* variables in a decomposition equation lead to *n!* decomposition forms containing one single change factor. In our case, the non-uniqueness problem can be solved pragmatically by either using the average of one mirror image couple or by using the full average of all 24 decomposition forms. Mirror image couples are approximately just as reliable as the full average of all decomposition forms.
One disadvantage of decomposition models when detecting trends in eco-productivity is that, due to index differences, results may not be entirely comparable to the straightforwardly compiled eco-productivity figures as presented in table 5.4. On the other hand, decomposition models provide a consistent overall picture of how efficiency improvements and structure changes influence developments in eco-productivity over time.
The decomposition analyses presented in this chapter refer to annual macro-economic developments covering the period 1987–1998, results on the industry level and a comprehensive overview of the origin and destination of pollution attributed to

product flows through the Dutch economy. The latter estimates include the environmental consequences of consumption and international trade. Results presented so far show limited changes in pollution due to structural changes at the production as well as the consumption level. In other words, shifts towards a services based economy have not substantially contributed to pollution reductions between 1987 and 1998 in the Dutch economy. Yet, longer time series of full-fledged import matrices are helpful in analysing possible shifts over time of relatively polluting inputs from domestic to foreign production. The import matrices used in the time series analysis presented in this chapter are partial by neglecting non-competitive imports. Also, the import matrices before 1995 where, at the time these analyses were carried out, not (yet) compiled according to the latest national accounts revision.

Notes

1) This chapter is derived from De Haan (2001).

2) The total amount of carbon dioxide (CO_2) pollution attributed to imports and exports are substantially lower compared to the results presented in chapter 7 (*cf*. Table 7.2). This has the following reasons. Firstly, the import matrices applied in the time-series analysis presented in this chapter do not include non-competitive imports. Secondly, the intermediate requirements in the input-output tables used in this chapter omit entries for capital services. Thirdly, the input-output analyses presented in chapter 7 are carried out on a much more detailed level, 104 instead of 36 production activities. As a consequence, pollution attributed to import and export are understated while emissions attributed to final product use including gross instead of net capital accumulation is overstated. Other differences are due to the 1995 national accounts revision.

3) An asterisk is added to z^* to indicate that final demand here includes *gross* fixed capital formation instead of *net* capital formation.

Chapter 9. Summary, conclusions and future work

9.1 Summary

The System of National Accounts (SNA-1993, Commission of the European Communities *et al.*, 1993) contributes to internationally harmonised statistics on the economic functioning of countries. Well known indicators derived from this system are economic growth (*i.e.* the volume increase of gross domestic product), per capital national income and the government deficit (or debt). An important feature of the national accounts is that these and other indicators are embedded in one single accounting framework. This enhances the analytical power of economic indicators, for example by facilitating their coherent representation in macro-economic models and productivity studies.

This thesis discusses extensions and modifications of the SNA with the purpose of improving the representation of environmental-economic relationships in the system. As a consequence of the SNA's main focus on market transactions, the non-priced use of the environment in production and consumption processes remains largely uncovered. However, due to the increased competition between environmental functions, the environment has become part of daily economic decision making. This explains the need to incorporate environment concerns into economic accounting which is the main goal of environmental accounting.

The need of strengthening the representation of environmental-economic interactions in the national accounts can be argued in at least two ways. Firstly, there is a need of comparability. A sound comparison of economic and environmental information is crucial in the monitoring of environmental performance. For example, such a comparison may help to address the natural resource inputs or pollution outputs that coincide with the income, employment or consumption level of an economy. Reversibly, it is important to know the amounts of value added, employment and product consumption that may be at stake in the preservation of certain environmental functions. A priori, the SNA-1993 has several beneficial characteristics that may contribute to the construction of such an environmental pressure oriented monitoring system at the meso level (*i.e.* industry branches and household activities) and macro level. This thesis explores directions in which the national accounts may be extended to arrive at such an environmental accounting system.

Secondly, environmental accounts have also been recommended as a way to arrive at improved total measures of welfare. In this context it must be acknowledged that national accounts indicators such as gross domestic product and net national income differ in many ways from a generally acknowledged conception of welfare.

For example, in addition to environmental amenities, national income as defined in the SNA, does not keep record of leisure, the non-market production of household services, the welfare effects of income inequality and many other positive and negative externalities of production and consumption activities. To some extent, the SNA-1993 is deliberately refrained from welfare measurement. Its main focus on market transactions excludes automatically any of the non-priced determinants of welfare.

Accounting concepts are often established on practical grounds. This becomes particularly apparent in the discussion on defensive consumption expenditures. Depending on certain assumptions, on welfare-theoretic grounds defensive expenditures could be considered as not genuinely welfare enhancing since they are supposed to compensate the negative externalities of production and consumption activities. Defensive expenditure may relate to environmental externalities but also to other undesirable side effects, *e.g.* traffic accidents, health effects related to work or living conditions. It has been argued that expenditures on these compensating measures should not add to gross domestic product but instead should be accounted for as the costs of production.

In the SNA-1993 the borderline between intermediate consumption and final consumption is drawn on pragmatic grounds. Products, not used as the intermediate deliveries in production processes, are simply defined as being consumed (apart from gross fixed capital formation and export). A welfare-oriented demarcation of consumption will inevitably give rise to extensive moral debates about the positive or negative welfare contributions of many consumption expenditure categories, *e.g.* environmental protection expenditure, healthcare, defence, alcohol, tobacco, just to name a few. The system's transparency, internal coherence and international comparability are served by straightforwardly applicable accounting guidelines. This moves the system away from welfare measurement, especially when these welfare effects are not well observed via the market system and subsequently not easily accounted for in terms of exchange values. One may conclude that, generally, assessing the social welfare related benefits and demerits of these various consumer items cannot be side-stepped from political judgements.

This does certainly not imply that the national accounts require no modifications in the context of environmental accounting. An alternative view on the functioning of economic systems may give rise to changing accounting concepts. For example, in this thesis it is argued that the rather passive representation of households as final consumers in the national accounts needs modification in order to keep record of their direct environmental interactions. Households not only consume but also produce polluting services on own account.

Chapter 2 starts with an introduction of three basic national accounting concepts: exchange values, the production boundary and the asset boundary. These three concepts play a fundamental role in any attempt to represent in monetary terms the welfare effects of environmental deterioration in the national accounting system. The main conclusion drawn from this discussion is that limitations of these concepts only to some degree concern their representation in the SNA-1993. More generally, these limitations much more relate to the scope of economic accounting as a descriptive statistical tool. Environmental losses are only to a limited extent assessable in monetary terms, especially when values at stake are socially or morally motivated or when the nature of environmental functions are complex and the uncertainties about their deterioration, and the subsequent repercussions, are high.

Chapter 2 summarises the main features of two environmental accounting propositions: cause-oriented versus effect-oriented accounting methods. Both accounting perspectives are complementary in scope. Without any notion of environmental damages and how these occur, cause-oriented accounting is principally meaningless. Equally, without identifying the driving forces of environmental damages, effect-oriented accounting is rather footloose in terms of environmental policy. However, due to several reasons mentioned in chapter 2, it is often infeasible to fully integrate both accounting approaches in the SNA sense. The causes and effects of environmental deterioration are in many cases less easily captured by a system of current accounts and balance sheets as facilitated by the SNA-1993.

Effect-oriented accounting approaches are most likely adopted in countries that economically depend on the exploitation of natural resources such as mineral deposits, forests, fish stocks or nature parks generating tourism related income flows. For these countries, it is particularly important to monitor how changes in environmental assets coincide with other parts of the county's asset portfolio, *e.g.* human capital, infrastructure and other produced capital. Cause-oriented accounting is especially relevant in cases where there is a policy need to lower environmental pressure. This need does not necessarily relate the domestic depletion or degradation of environmental assets but may also refer to foreign natural resource dependencies or the preservation of environmental functions on a continental or global scale. Since environmental policy in the Netherlands has been putting a lot of emphasis on the targeting of various environmental pressures, cause-oriented accounting has dominated the development of environmental accounts at Statistics Netherlands.

In *chapter 3*, it is acknowledged that physical flow accounting is a fundamental step in identifying the interrelationships between the natural environment and the economic system. This chapter illustrates that various frameworks are available to structure physical flow accounts at the meso and macro level. Generally, these frameworks are complementary in scope. Controversies particularly arise together with indicators that are being defined in various accounting approaches. These controversies may refer to less meaningful weighting methods that are sometimes being used to arrive at aggregated environmental pressure indicators. Also, the principle of indicator additivity is sometimes being violated which makes it impossible to aggregate these indicators over regions or countries or to compare these indicators with the regular national accounts indicators such as gross domestic product. One important conclusion drawn from this discussion is that physical flow accounting should address as much as possible the variety of environmental concerns that are connected to different physical flow categories. Mass based aggregates, as for example defined in the total material flow accounts, do not very well address the wide range of environmental concerns that are at stake.

Chapter 3 further illustrates the benefits of national accounts guidelines in the set up of physical flow accounts. National accounts conventions may contribute to a sound attribution of pollution to individual activities and subsequently individual economies. They are particularly useful in addressing the environmental impacts of international operating economic activities such as international transportation. Secondly, a uniform application of national accounting guidelines may contribute to a consistent comparability of national accounts indicators and environmental pressure indicators. The representation of physical flow accounts in a national accounts framework helps to illustrate the economic significance of physical environmental-economic interactions. The NAMEA (National Accounting Matrix including Environmental Accounts) presented in the subsequent chapters systematically records the origin or destination of physical flows in connection to economic transactions as presented in the national accounts. Such a coherent linkage of monetary and physical data guarantees a consistent comparison of environmental burdens to economic benefits, or environmental benefits to economic costs.

Chapter 4 introduces the National Accounting Matrix (NAM). The NAM incorporates the supply-use tables and institutional sector accounts into one national accounting framework. Chapter 4 reviews several properties of the NAM. A matrix accounting format is particularly useful for satellite accounts with a need to represent the entire circular flow of income in an economy. This is for example the case for satellite accounts that may serve as the underlying data frameworks in (environmentally extended) macroeconomic models.

Chapter 4 continues with discussing the conceptual design of the NAMEA by De Boo *et al*. (1991). Their work preceded the implementation of the NAMEA in the Netherlands and other countries. However, their original design was much more ambiguous. De Boo *et al*. added to the NAM simultaneously an 'agents account' (*i.e.* for the recording of environmental requirements) and a 'changes in ecosystem account'. As discussed in chapter 2, such an integrated representation of agents on the one hand and changes in ecosystems on the other is in many cases problematic. The account for changes in ecosystems as introduced by De Boo *et al.* is multidimensional in scope by the combined recording of accumulation of agents, the resulting changes in ecosystem assets and subsequently the repercussions. Obviously, this complicates the actual implementation of such a changes in ecosystem account.

The NAMEA presented in *chapter 5* approximately corresponds to the NAMEA as annually compiled and published by Statistics Netherlands (2000). This NAMEA contains accounts for five categories of environmental pressures: greenhouse effect, ozone layer depletion, acidification, eutrophication (*i.e.* nutrient overburden) and solid waste. These environmental themes have been targeted in various National

Environmental Policy Plans in the Netherlands. Instead of attributing agents to changes in environmental assets, this NAMEA alternatively allocate agents to the environmental themes. The environmental theme indicators establish a linkage between agents and the environmental problems to which they are expected to contribute. As such, the environmental themes provide a transparent presentation of a restricted set of aggregated environmental pressure indicators, which help to evaluate the environmental performance of an economy.

Chapter 6 reviews the strengths and weakness of the NAMEA with respect to its application to a wider range of environmental requirements, *e.g.* water, land use and the dispersion of toxic pollutants. One important common characteristic of all pressure indicators in the NAMEA is their completeness in terms of coverage. In this way, the NAMEA system is able to deliver indicators showing how environmental requirements are related to different types of economic driving forces (*cf*. chapter 8).

Chapter 6 illustrates that a national economy perspective fits adequately well with those environmental requirements that contribute to environmental concerns on a global or a continental scale. However, a *national* accounting perspective easily ignores local conditions that partly determine the environmental impacts on regional scales. Regarding the coverage of different types of environmental requirements, the environmental theme approach is pragmatic. The theme approach becomes particularly relevant when it is able to address specific environmental policies and concomitant targets. Although the representation of environmental requirements in the NAMEA is not necessarily restricted to physical flows, so far, the NAMEA has most widely been applied to pollution and waste.

The environmental themes, as represented in the NAMEA, are deliberately untied from a total material balance set-up. A range of different units are used in the substance flow accounts of the NAMEA to indicate the various categories of environmental pressures of production and consumption. Yet, most individual substances accounted for in the NAMEA are established on the basis material balance identities. These identities safeguard a consistent representation of flow origins and destinations.

In *chapter 7*, it is suggested to extend the scope of cause-oriented environmental accounting by way of two interconnected environmental performance indicators on the macro level: the ‘environmental balance of trade’ and ‘environmental consumption’. Both indicators establish a shift in focus from the ‘direct recording’ of environmental requirements at the process level to a product use, or consumption, perspective. The environmental consumption indicator determines the total sum of environmental requirements attributable to the total final consumption in an economy. The environmental balance of trade determines the difference between the environmental requirements attributed to export and to import. Both indicators are particularly useful in detecting the environmental consequences of ongoing trade liberalisation and the opening of domestic markets.

The definition and construction of both indicators are based on input-output models. Provisional calculations for the Netherlands indicate that the Netherlands has an environmental trade surplus for all pollution categories analysed, *i.e.* carbon dioxide, acid pollution, nutrients and solid waste. In addition, the results show that Dutch exports are dominated by relatively environmental intensive products such as agricultural products, basic chemicals and transport services. With the exception of solid waste, differences in product composition between import and export additionally contribute to the positive environmental balances of trade for the other three pollution categories.

In *chapter 8*, it is illustrated how NAMEA time series may contribute to analysing changes in the environmental requirements of the economy over time. In combination with structural decomposition analysis, the NAMEA provides a helpful system to disentangle changes in pollution according to several economic driving forces, *e.g.* economic growth, changes in the production structure, shifting consumer behaviour and eco-efficiency changes at the level of producers and consumers.

The decomposition analyses presented in chapter 8 are based on so-called 'closed' decomposition forms without a residual term. These closed decomposition forms are not unique. From an equation with *n* variables, *n!* different decomposition forms can be derived with different weights attached to the various change factors in the decomposition equation. The variables in these weights refer to either the beginning or end of the analysed period of time. Each of the *n!* decomposition forms has a 'mirror image' with opposite weights denominated in time. A sensitivity analyses shown in chapter 8 indicates that any couple of mirror image decomposition forms reduces substantially the deviation in outcomes. This implies that any mirror image couple leads to sufficiently reliable estimates.

The results contain the macro-economic developments, results on the industry level and a comprehensive overview of the origin and destination of pollution attributed to product flows. The results show rather limited changes in pollution due to structural changes of the economy, *i.e.* shifts in the industry composition of the economy. Also changes in consumer behaviour only moderately contribute to pollution changes. In other words, shifts towards a services-based economy have not (yet) resulted in substantial pollution reductions between 1987 and 1998 in the Dutch economy. With the exception of carbon dioxide pollution, pollution reductions resulting from efficiency improvements outweighed economic growth effects, leading on balance to declining industry related pollution patterns over time.

9.2 *Conclusions*

This section sums up the main findings of this thesis with the help of the five research questions raised in the chapter 1.

The main goals of environmental accounting are in chapter 2 categorised by identifying two main accounting approaches: cause-oriented accounting versus effect-oriented accounting. The main features of both approaches are summarised in table 2.2. Cause-oriented accounting focuses on the systematic representation of the environmental requirements of production and consumption activities. In this capacity cause-oriented accounting specifically anticipates to the first national accounts shortcoming raised in chapter 1: the SNA-1993 does not provide guidelines for the compilation of accounts that quantify the environmental dimension of economic behaviour. Effect-oriented accounting deals with measuring changes in the environmental state. A national accounts balance sheet, or asset stock account, is one tool to measure these changes. A balance sheet is particularly useful in mapping changes in wealth of rent generating environmental assets and this wealth is subsequently made comparable to that of other, produced or financial, assets. The use of balance sheets in monitoring sustainability according to the so-called Hartwick non-declining wealth rule, depends on several conditions. For example, a balance sheet should incorporate all relevant categories of capital and appropriate prices must be found for each of these capital categories. Accounting limitations, as discussed in chapter 2, will restrict the incorporation in balance sheets of those environmental assets with uncertain functions and values. With respect to the second SNA-1993 shortcoming addressed in chapter 1, the incompleteness of the national accounts from a welfare perspective is less related to SNA-1993 accounting conventions but much more to what generally can be accomplished in a descriptive system of economic accounts.

The second, third and fourth research questions raised in chapter 1 specifically refer to cause-oriented accounting. The second question about the type of indicators that should be used to measure environmental-economic dependencies is extensively dealt with in chapter 3. The following two conclusions that can be drawn from this discussion. Firstly, physical flow accounts and related indicators should as much as possible address the relevance of different physical flows from an environmental impact perspective. This principle seems trivial but is not always present in physical flow accounting practice. Secondly, the indicators defined in the accounts should preferably target the material interactions between the environment and the economy, *i.e.* national resource inputs or (net) residual outputs. Indicators measuring material throughputs carry the same deficiency as indicators pinpointed at intermediate product consumption: they inevitably suffer from double counting.

Regarding the third research question on cause-oriented accounting structures, the various types of accounting structures presented in chapter 3 are complementary in scope and their use depend on the type of analysis pursued. The NAMEA framework, presented in the subsequent chapters 4 and 5, illustrates the advantage of a national accounts orientation. Firstly, national accounts definitions are helpful in a sound delineation of the environmental requirements of an economy, taking consistently into consideration internationally operating activities such as transport and tourism. The IPCC regulations for monitoring greenhouse pollutants are undoubtedly less difficult to implement. However, these regulations do not address the responsibility of pollution from international transportation to individual economies. National accounts conventions and statistics are helpful in doing so.

Secondly, the NAMEA contributes to a consistent comparison of the monetary and the physical dimension of economic performance. This allows for the compilation of so-called environmental-economic profiles and related environmental productivity or intensity indicators at the industry/household and macro level. Some of the analytical uses of this accounting approach are illustrated in chapters 7 and 8 of this thesis.

The feasibility of recording the environmental requirements of economic activities in a national accounts framework, *i.e.* research question four, is particularly addressed in chapter 6. A national economy perspective fits adequately well with those environmental requirements occurring on a global or a continental scale. However, accounting at a national level may ignore some of the local conditions of environmental impacts occurring on a regional scale. Regarding the coverage of various types of environmental requirements, the environmental theme approach is pragmatic and should preferably address as much as possibly the environmental targets in national and international environmental policies.

Finally, chapter 2 discusses the fifth research question raised in chapter 1 about the possible distortions in the SNA-1993 from an environmental perspective. The issue of defensive expenditure has already been referred to in the former section of this chapter. Another deficiency raised by various authors is the recording of depletion of rent generating natural resources in the income generation account. Such a recording coincides well in a general desire to identify the value of services provided by all sorts of capital in the income generation account. This is at present subject to discussion in the Canberra II Group on capital measurement. Yet, chapter 2 raises a number unsolved issues in the depletion debate that may obfuscate a consensus in due course.

9.3 *Future work*

In the Gothenburg summit held in 2001, the European Council not only added an environmental dimension to the Lisbon Strategy but also adopted a European Strategy for Sustainable Development. Key areas identified in the latter policy strategy include climate change, sustainable transport, biodiversity, health and the environment, natural resource use and waste management. Also, the international dimension of sustainable development has been raised, also in connection to the foreign environmental repercussions of international trade. These policy areas largely coincide with those identified in the most recent Environmental Policy Plan of the Netherlands (VROM, 2002). The latter puts Dutch environmental policy in a global sustainability perspective by emphasising the intergenerational and global consequences of economic and social development over the next thirty years. Both policies acknowledge the importance of international strategies with respect to many environmental concerns, *e.g.* climate change, biodiversity, resource depletion.

Reliable and comparable statistics play a crucial role in these strategies. The Johannesburg Declaration signed at the World Summit and Sustainable Development, held in 2002, recommends the further development of indicators for sustainable development. The increasing international orientation of environmental policy obviously puts much emphasis on the international comparability of statistics and indicators. In Europe, the development of an indicator monitoring system is presently part of the EU Sustainable Development Strategy. The Structural Indicators introduced for measuring progress made regarding the Lisbon objectives also include several environmental indicators.

EU member states and the Statistical Office of the European Community, Eurostat, have been putting a lot of effort in the development of environmental accounts, which are now regularly published in several member states, often in conjunction with national accounts data. In the course of a Eurostat working program, environmental accounts that have been developed over the past seven years are NAMEA tables for air emissions and energy, water accounts, economy-wide material flow accounts, environmental protection expenditure and taxes accounts and natural resources accounts.

There are several reasons why environmental indicator sets, as for example developed in the context of the Lisbon objectives and the EU sustainability strategy, should be embedded in integrated accounting systems. Sustainability focuses by definition on long term problems requiring regular observations over time and in connection to structural economic changes. Shifting trade relationships and economic structure changes have been identified in environmental policies as key drivers of environmental change. Especially in the context of cause-oriented accounting, consistent policy design can only be based on integrated environmental and economic data. The demand for integrated assessments is growing as a result of a growing desire to appraise the costs and benefits of environmental policy. Therefore, it would be very unfortunate if the European system of sustainable development indicators would be constructed totally independent from the environmental accounting frameworks recently developed in Europe.

Yet, there is also an obstacle. Integration of environmental statistics on the basis of the national accounts implies that definitions must be modified in order to achieve consistency with the monetary national accounts data. As a consequence, depending on the definitions used, different figures may exist for one phenomenon and this subsequently may lead to policy confusion. In the Netherlands, this problem has become particularly apparent in the context of greenhouse gas pollution monitoring. The Kyoto targets are monitored on the basis of the IPPC guidelines on greenhouse gas inventories. Yet, these guidelines are inconsistent in relation to environmental performance monitoring. For example, consistent comparisons of greenhouse gas pollution developments with economic growth can only be made on the basis of a NAMEA type of framework. This also holds for the construction of environmental productivity measures and the concomitant decomposition analyses presented in this thesis. The multiple existence of greenhouse gas pollution indicators, showing sometimes different trends over time, implies that additional information must be provided about what exactly is being measured. The bridge table presented in this thesis (*cf*. table 3.2) is one way to explain these differences in definitions. However, there is also an obligation of all institutes involved in the measurement of greenhouse gas emissions to acknowledge and to communicate these differences thoroughly to the users of these statistics.

Short term development areas identified by Eurostat (2003) are waste accounts, land use and land cover accounts, water quality accounts and related accounts for water emissions and use of raw materials accounts for selected materials. In addition to these development areas, priority is also being given to the harmonised EU-wide reporting of the above-mentioned accounting areas that have been developed over the last seven years. This consolidation of accounting work is very important and may substantially contribute to their policy relevance. A frequent EU-wide reporting of environmental accounts will undoubtedly contribute to further harmonisation, international comparisons and benchmarking. These comparisons may also contain standardised sets of related input-output calculations as for example presented in this thesis. Like analysing the determinants of labour productivity growth in the so-called 'new' economy, an internationally harmonised system of NAMEAs supports research in the main driving forces behind the environmental productivity gains that are considered being required to arrive at a sustainable economy.

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Nederlandstalige samenvatting

Het universele systeem van nationale rekeningen, zoals beschreven in het System of National Accounts (Commission of the European Communities *et al*., 1993), draagt bij tot internationaal geharmoniseerde statistieken over het economisch functioneren van landen. Welbekende indicatoren die aan het stelsel van nationale rekeningen worden ontleend zijn bijvoorbeeld de economische groei (de volumegroei van het bruto binnenlands product), het besteedbaar inkomen per hoofd van de bevolking en het overheidstekort (als percentage van het bruto binnenlands product). Een belangrijke eigenschap van de nationale rekeningen is dat al deze macro-economische indicatoren zijn verankerd in één samenhangend informatiesysteem. Dit verhoogt de analytische kracht van deze indicatoren, bijvoorbeeld via modelstudies of productiviteitsmetingen.

Het systeem van nationale rekeningen richt zich in belangrijke mate op de registratie van markttransacties. Hierdoor blijft in dit systeem het gebruik van het milieu grotendeels onderbelicht omdat voor het dagelijkse gebruik ervan lang niet altijd hoeft te worden betaald. Dit geldt bijvoorbeeld ook voor productieve activiteiten die worden verricht door huishoudens, zoals het bereiden van maaltijden of het eigen vervoer van personen of goederen. Door het ontbreken van waarneembare transacties wordt de waarde van deze productie, en die van de hierbij ingezette arbeid, niet geregistreerd in de nationale rekeningen.

Milieuschaarste is het gevolg van concurrerende gebruiksrichtingen: het lozen van afvalstoffen maakt een rivier minder geschikt als bron voor drinkwater. Milieugebruik kan leiden tot maatschappelijke kosten die niet noodzakelijkerwijs zichtbaar worden gemaakt in de economische boekhouding van landen. Toch kan het van belang zijn de milieurelaties in het economische verkeer te kwantificeren, zeker wanneer overheidsingrijpen wenselijk wordt geacht om de sociale kosten van milieuverliezen terug te dringen.

Het beschrijven van milieurelaties in het systeem van nationale rekeningen is het centrale thema van dit proefschrift. In de afgelopen tien tot twintig jaar is op velerlei wijzen getracht binnen het stelsel van nationale rekeningen een samenhangend beeld te schetsen van de wijze waarop milieuvoorraden en milieufuncties worden aangetast door productie en consumptie. Een methodologisch overzicht is te vinden in een recentelijk verschenen internationaal handboek over geïntegreerde milieurekeningen (Commission of the European Communities *et al*., 2003).

Het belang van milieurekeningen kan worden onderschreven vanuit twee invalshoeken. In de eerste plaats is er het belang van onderlinge vergelijking. Een consistente vergelijking van informatie over de economie en het milieu is van cruciaal belang bij het in kaart brengen van het 'milieugedrag' van economische actoren. Hierbij kan het bijvoorbeeld gaan om de totale hoeveelheid grond- stoffengebruik of vervuiling die behoort bij het genereren van een bepaald inkomensniveau, werk-

gelegenheidsniveau of de vervaardiging van bepaalde consumptiegoederen. Omgekeerd is het van belang inzicht te verwerven in welke inkomens, werkgelegenheid en consumptiegoederen er op het spel staan bij het behoud van bepaalde milieufuncties. Het systeem van nationale rekeningen heeft op voorhand een aantal sterke eigenschappen dat kan bijdragen aan het zichtbaar maken van bovengenoemde interacties. Een belangrijk deel van dit proefschrift beschrijft de karakteristieken van een dergelijke uitbreiding van het nationale rekeningenstelsel.
In de tweede plaats is het nuttig om de daadwerkelijke sociale kosten van milieuverliezen in kaart te brengen. Zoals al aangegeven is vanuit welvaartsoptiek de reikwijdte van nationale rekeningen automatisch beperkt doordat het systeem zich in hoofdzaak richt op de registratie van markttransacties. Deze beperking heeft niet alleen betrekking op milieu-aspecten maar bijvoorbeeld ook op het (dis)nut ontleend aan vrije tijd en op welvaartseffecten samenhangend met inkomens- ongelijkheid. Ook de beperkte productiegrens, waarbinnen veel productieve activiteiten van huishoudens niet worden meegeteld, is vanuit welvaartsoptiek een belangrijke beperking.
Nationale rekeningenconventies zijn niet altijd gebaseerd op welvaartstheoretische principes maar doorgaans praktisch van aard. Dit wordt geïllustreerd door de discussie over zogenaamde 'defensieve uitgaven'. Van defensieve uitgaven wordt soms verondersteld dat zij niet daadwerkelijk bijdragen aan de welvaart doordat ze dienen ter compensatie voor de negatieve externe effecten van productie en consumptie. Deze effecten kunnen betrekking hebben op milieuverliezen, verkeersongelukken, of aan werk gerelateerde gezondheidseffecten. Een van de mogelijkheden die is aangedragen om de welvaartsontwikkeling beter te volgen in het systeem van nationale rekeningen is om defensieve bestedingen altijd als intermediaire leveringen te registreren. Op deze wijze tellen zij niet mee in het bruto binnenlands product van landen en geeft de volumegroei van het bruto binnenlands product een beter beeld van de welvaartsontwikkeling.
Het onderscheid in de nationale rekeningen dat wordt gemaakt tussen intermediair verbruik en finale consumptie is pragmatisch van aard. Producten die niet fungeren als halffabrikaten of hulpgoederen in productie worden per definitie als finale consumptie geboekt en tellen zodoende mee in het bruto binnenlands product. Daarnaast wordt de welvaartsbijdragen van goederen en diensten lang niet altijd weerspiegeld door de marktprijzen of productiekosten waartegen zij worden geregistreerd. Dit geldt in het bijzonder voor goederen en diensten zoals alcohol, tabak, gezondheidszorg en defensie. Een meer welvaartsgerichte oriëntering van het systeem leidt onherroepelijk tot tal van morele afwegingen. De transparantie en internationale vergelijking van de nationale rekeningen zijn hierbij niet gebaad.
Hoofdstuk 2 begint met een discussie over het gebruik van drie elementaire concepten in het systeem van nationale rekeningen: waardering conform marktprijzen, de productiegrens en de afbakening van (niet-financiële) activa. Er zijn in de literatuur veel voorstellen gedaan om deze concepten in het systeem te wijzigen met als doel de welvaartseffecten samenhangend met milieuverliezen binnen het stelsel van

nationale rekeningen inzichtelijk maken. De belangrijkste conclusie die volgt uit deze discussie is dat beperkingen van het systeem van nationale rekeningen vooral worden bepaald door de reikwijdte van op beschrijvende statistiek gebaseerde rekeningenstelsels en veel minder door verstoorde of onjuiste conventies. Milieuverliezen zijn lang niet altijd uitdrukbaar in geld, zeker wanneer waardebepalingen volgen uit morele dan wel sociale overwegingen. Daarnaast is het niet altijd mogelijk om alle relevante milieuvoorraden eenduidig te definiëren en daarom te waarderen. Politieke besluitvorming speelt bij waardebepalingen en de afbakening van milieubezittingen zoals het bepalen van eigendomsrechten of bestemmingsplannen (natuurgebied versus recreatiegebied) een cruciale rol. Deze rol kan niet worden overgenomen door beschrijvende statistieken. Deze hebben hierbij juist een ondersteunende rol door te voorzien in relevante samenhangende informatie op basis waarvan deze waardebepalingen kunnen plaatsvinden.

In hoofdstuk 2 worden twee soorten milieurekeningen onderscheiden: oorzaakgerichte versus effectgerichte milieurekeningen. Oorzaakgerichte milieurekeningen beschrijven de wijze waarop productie- en consumptieactiviteiten invloed uitoefenen op het milieu. Aan deze milieurekeningen kunnen zogenaamde milieudrukindicatoren worden ontleend die aangeven op welke wijzen productie- en consumptieactiviteiten de kwaliteit van het milieu beïnvloeden. Effectgerichte milieurekeningen beschrijven de daadwerkelijke veranderingen in het milieu. Deze benadering is tot op heden vooral toegepast op het kwantificeren van milieuvoorraden met eenduidige gebruikfuncties zoals grond, minerale en biotische natuurlijke hulpbronnen. Over het algemeen zijn voor deze functies relevante marktprijzen beschikbaar waarmee overeenkomstige voorraden, en veranderingen hierin, kunnen worden gewaardeerd.

Hoofdstuk 2 vat de belangrijkste eigenschappen van beide typen milieurekeningen samen. Beide benaderingswijzen zijn complementair van aard. Zonder enige notie van milieuschaden en hoe deze tot stand komen, blijven oorzaakgerichte milieurekeningen zonder enige betekenis. Omgekeerd is het van belang bij het in kaart brengen van milieuvoorraden zichtbaar te maken welke invloed de mens hierop uitoefent. In hoofdstuk 2 wordt een aantal redenen aangedragen waarom een volledig geïntegreerde beschrijving van oorzaken en gevolgen niet altijd mogelijk is. De complexiteit van het eenduidig kwantificeren van bepaalde milieuvoorraden zoals ecosystemen is al eerder genoemd. Daarnaast zijn oorzaak-gevolg relaties veelal complex van aard en onderhevig aan grote discrepanties in locatie en tijd. Dit bemoeilijkt het leggen van eenduidige relaties in rekeningenstelsels tussen milieudruk enerzijds en milieueffecten anderzijds.

Hoofdstuk 3 geeft een beschrijving van rekeningenstelsels die worden gebruikt bij het in kaart brengen van de 'fysieke economie', dat wil zeggen, de stof- en energiestromen in het economische systeem. Stofstroomrekeningen en energie- rekeningen zijn een elementair onderdeel van de oorzaakgerichte milieu- rekeningen. Tegenstellingen hangen vooral samen met de indicatoren gepresenteerd in verschillende stelsels. Deze beogen doorgaans een samenvattend beeld te schetsen van de ontwikkelingen in milieudruk. Hierbij wordt soms gebruik gemaakt van minder betekenisvolle weegmethoden. Zo geven indicatoren ontleend aan een geaggregeerde, in kilogrammen uitgedrukte, representatie van de stofstroomhuishouding van een economie geen indicatie van de verscheidenheid aan stofstromen in het economische systeem en de hieraan gerelateerde milieueffecten. Daarnaast zijn afbakeningen van indicatoren soms inconsistent waardoor deze niet optelbaar zijn over landen of regio's en ook niet kunnen worden gerelateerd aan nationale rekeningenindicatoren zoals het bruto binnenlands product.

Hoofdstuk 3 illustreert vervolgens de voordelen van stofstroomrekeningen die zijn gebaseerd op nationale rekeningenconventies. In de eerste plaats leiden nationale rekeningen conventies tot een consistente beschrijving van de vervuiling van een economie. Hierbij wordt de vervuiling van internationaal opererende activiteiten, zoals luchtvaart en zeevaart, op een consistente wijze toegerekend aan afzonderlijke economieën. Deze relatief vervuilende activiteiten worden grotendeels genegeerd in de gangbare emissie-inventarisaties op basis waarvan internationale afspraken zijn gemaakt over de uitstoot van broeikasgassen. Ten tweede maakt het gemeenschappelijke gebruik van nationale rekeningen conventies een directe vergelijking mogelijk tussen de monetaire en de fysieke dimensie van het economische systeem. Deze vergelijking draagt bij tot een heldere afweging van economische baten en milieulasten, en omgekeerd, van milieubaten en economische kosten.

Hoofdstuk 4 begint met een introductie van de nationale rekeningenmatrix. Een matrixpresentatie van de nationale rekeningen heeft een aantal eigenschappen die nuttig zijn bij het opzetten van geïntegreerde rekeningen voor milieu en economie. De nationale rekeningenmatrix is in het bijzonder geschikt voor satellietrekeningen waarvoor het van belang is om een totaalbeeld te schetsen van het complete economisch systeem. Dit is bijvoorbeeld het geval wanneer satellietrekeningen dienen als datasysteem voor macro-economische modellen.

Vervolgens beschrijft hoofdstuk 4 de NAMEA (National Accounting Matrix including Environmental Accounts) zoals oorspronkelijk ontwikkeld door De Boo *et al*. (1991). Dit ontwerp heeft als voorbeeld gediend voor de NAMEA zoals deze regulier wordt samengesteld in Nederland en in andere landen. Echter, het originele ontwerp was veel ambitieuzer van opzet. Naast een stelsel van stofstroomrekeningen bevat dit ontwerp een rekening voor het kwantificeren van verandering in milieu-activa (ecosystemen). Deze rekening heeft tot doel een beschrijving te geven van de accumulatie van stoffen in het milieu, de hieruit volgende veranderingen in ecosystemen en vervolgens de hieruit volgende repercussies (*i.e.* welvaartseffecten). Naast problemen bij het beschrijven van oorzaak-gevolg relaties wordt de interpretatie van deze tweede rekening bemoeilijkt door het multidimensionale karakter ervan.

De presentatie van de NAMEA in hoofdstuk 5 komt nagenoeg overeen met de jaarlijkse publicatie van dit systeem door het Nederlandse Centraal Bureau voor de Statistiek. Deze NAMEA bevat een reeks van stofstroomrekeningen die worden samengevat in vijf milieudrukindicatoren: klimaatverandering, ozonlaagaantasting, verzuring, vermesting en afval. Deze indicatoren zijn ontleend aan milieuthema's zoals gepresenteerd in diverse nationale milieubeleidsplannen in Nederland. Deze milieuthema-indicatoren geven een beschrijving van de milieupresentaties van een economie, echter zonder hierbij de relatie met milieueffecten daadwerkelijk te kwantificeren. Wel geeft de NAMEA, indien relevant, een expliciete registratie van grensoverschrijdende vervuilingstromen. Hierdoor weerspiegelen de milieudrukindicatoren in de NAMEA enerzijds de milieudruk afkomstig van het binnenlandse productie-consumptiesysteem en anderzijds de milieudruk die wordt ondervonden op nationaal grondgebied.

Hoofdstuk 6 beoordeelt de toepasbaarheid van het NAMEA-systeem voor een bredere reeks van milieuthema's waaronder water- en landgebruik en de verspreiding van toxische stoffen. Een belangrijke randvoorwaarde voor het opnemen van een milieudrukindicator in de NAMEA is dat deze een uitputtende beschrijving dient te geven van de milieulast van actoren zoals afgebakend in het systeem van nationale rekeningen. Alleen dan zijn deze indicatoren geschikt voor analyses waarbij de volledige economie in ogenschouw wordt genomen.

Hoofdstuk 6 laat zien dat het perspectief van de nationale rekeningen prima aansluit op het beschrijven van grootschalige (mondiale) milieuproblemen. Echter, dit perspectief is minder eenduidig verenigbaar met het beschrijven van regionale of locale milieuproblemen. Vooral locale milieuproblemen laten zich minder eenvoudig vangen in milieudrukindicatoren op nationaal niveau. Dit probleem kan worden ondervangen via regionale onderverdelingen in het systeem. Dit is recentelijk toegepast in een NAMEA voor Nederland geënt op zoetwaterbeheer.

De thema-indicatoren in de NAMEA zijn pragmatisch van opzet en winnen aan relevantie wanneer deze aansluiten op doelstellingen zoals geformuleerd in milieubeleid. Zoals gezegd zijn de milieudrukindicatoren in de NAMEA nadrukkelijk niet gericht op de eendimensionale weerspiegeling van de totale fysieke huishouding van een economie gemeten in kilogrammen. De NAMEA legt de nadruk juist op stofstromen met een specifieke milieurelevantie. Via de milieuthema's worden stofstromen in verband gebracht met milieuproblemen waaraan zij zijn gerelateerd. Hierbij is het mogelijk dat specifieke stofstromen bijdragen aan meer dan één milieuthema. Zo worden stikstofoxiden in de NAMEA zowel in verband gebracht met het thema verzuring als met het thema vermesting.

In hoofdstuk 7 worden de NAMEA indicatoren uitgebreid met twee typen van onderling samenhangende macroindicatoren: de 'milieuhandelsbalans' en de 'milieuconsumptie'. Beide indicatoren verschuiven het perspectief van de oorzaakgerichte milieurekeningen naar de eindgebruikers van goederen en diensten: de consument. In eerste instantie registreert de NAMEA het grondstoffengebruik en de uitstoot van emissies op het niveau van processen zoals deze statistisch worden waargenomen. Deze registratiewijze wordt in dit proefschrift betiteld als de 'directe' registratie van grondstoffengebruik of emissies. Bij de consumptiegerichte registratie worden het directe grondstofgebruik en emissies toegerekend aan

goederenstromen en vervolgens aan de eindgebruikers van goederen en diensten in de economie.
Een bijkomstigheid van het consumptieperspectief is de noodzakelijke registratie van vervuiling samenhangend met invoer en uitvoer. Omdat de binnenlandse consumptie deels uit geïmporteerde goederen en diensten bestaat is de vervuiling die moet worden toegerekend aan de consumptie eveneens deels afkomstig uit het buitenland. Omgekeerd moet de binnenlandse vervuiling via uitvoer deels worden toegerekend aan buitenlandse consumenten. De milieuhandelsbalans kwantificeert het grondstoffenbeslag, dan wel vervuiling, toegerekend aan uitvoer minus invoer. Deze indicatoren worden gedefinieerd en bepaald via zogenaamde input-output modellen. In hoofdstuk 7 wordt aangegeven welke aannames doorgaans noodzakelijk zijn om indicatoren zoals de milieuhandelsbalans en de milieuconsumptie te berekenen.
De economische theorie stelt dat, door voortschrijdende vrijhandel en het opheffen van handelsbarrières, landen hun productie steeds verder zullen aanpassen aan hun comparatieve voordelen. Door toenemende specialisatie zal de milieulast behorende bij de productiesystemen van landen verder af gaan wijken van de milieulast toegerekend aan de binnenlandse consumptie. De in dit hoofdstuk gepresenteerde uitkomsten laten zien dat de Nederlandse milieuhandelsbalans een overschot heeft voor alle onderzochte milieudrukindicatoren: kooldioxide-emissies, verzurende emissies, vermestende emissies en afval. Dit overschot wordt slechts deels bepaald door het in geld gemeten surplus op de Nederlandse handelsbalans maar wordt mede tot stand gebracht door de specialisatie van de Nederlandse economie in relatief milieubelastende bedrijfstakken zoals landbouw, chemische industrie en transport. Hierdoor versterkt de productsamenstelling het positieve saldo van de Nederlandse milieuhandelsbalans gemeten bij alle, in de analyse gepresenteerde, milieudrukindicatoren met uitzondering van afval.
In hoofdstuk 8 wordt getoond hoe NAMEA tijdreeksen kunnen worden gebruikt bij het analyseren van de ontwikkeling van milieudrukindicatoren in tijd. Hierbij wordt gebruik gemaakt van de zogenaamde 'structurele decompositie analyse' waarmee de invloed van verschillende economische ontwikkelingen op de vervuiling kan worden gekwantificeerd. Voorbeelden van economische ontwikkelingen, waarvan de invloed op de milieudruk inzichtelijk kan worden gemaakt, zijn economische groei, structuurveranderingen, milieu-efficiencyveranderingen en verschuivingen in consumentengedrag.
Bij de decompositie-analyses, gepresenteerd in dit hoofdstuk, is steeds gekozen voor zogenaamde 'gesloten' decompositievergelijkingen zonder restterm. Hierbij treedt het probleem op van non-uniciteit. Uit een vergelijking met *n* variabelen kunnen *n!* gesloten decompositievormen worden afgeleid waarbij steeds wisselende gewichten worden toegekend aan de verschillende veranderingsfactoren in de decompositievergelijking. De variabelen in deze gewichten refereren aan het begin of aan het einde van de beschouwde periode. Nu heeft iedere decompositievorm een 'spiegelbeeldvorm' met precies tegenovergestelde gewichten uitgedrukt in tijd.

Uit een gevoeligheidsanalyse, gepresenteerd in hoofdstuk 8, blijkt dat het gemiddelde van twee willekeurige spiegelbeeldvormen de onderlinge variantie in uitkomsten substantieel reduceert. Dit betekent dat een willekeurig koppel van 'spiegelbeeldgemiddelden' leidt tot een acceptabele onderlinge vergelijking van afzonderlijke veranderingsfactoren in de decompositieanalyse.

De uitkomsten in hoofdstuk 8 hebben betrekking op kooldioxide-emissies, verzurende emissies en afval in Nederland gedurende de periode 1987–1998. De analyses beschrijven zowel de ontwikkelingen op macroniveau als op bedrijfstakkenniveau. Deze laten zien dat structuurveranderingen in de betreffende periode nauwelijks van invloed zijn geweest op de ontwikkeling in de onderzochte milieudrukindicatoren. Ook verschuivingen in consumentengedrag zijn beperkt van invloed geweest. De twee belangrijkste factoren die de ontwikkeling van de vervuiling in tijd hebben bepaald zijn enerzijds de economische groei en anderzijds milieu-efficiencywinsten. Met uitzondering van kooldioxide is het effect van deze laatste component per saldo steeds groter geweest dan de invloed van economische groei, hetgeen heeft geleid tot een dalende milieudruk in de beschouwde periode. Vervolgens is ook gekeken naar veranderingen in de milieuhandelsbalans voor kooldioxide in de periode 1990 en 1997. Bij zowel invoer als uitvoer waren volume-effecten substantieel en relatief even groot (30%). Echter milieu-efficiencywinsten waren relatief hoger bij uitvoer dan bij invoer waardoor de groei van de kooldioxide toegerekend aan uitvoer uiteindelijk lager was dan die van de invoer. Hierdoor bleef de groei van de kooldioxidehandelsbalans in deze periode beperkt tot 16%.

Tenslotte volgen in hoofdstuk 9 een overzicht van conclusies en een aantal aanbevelingen betrekking hebbend op mogelijke toekomstige ontwikkelingen op het terrein van milieurekeningen. Milieubeleid wordt steeds vaker in een internationaal perspectief geplaatst. Hiermee wordt onderschreven dat duurzaamheid niet alleen betrekking heeft op een rechtvaardige uitruil van bestaansmogelijkheden tussen huidige en toekomstige generaties maar ook tussen regio's. Dit betekent dat de internationale vergelijking van milieu-indicatoren aan belang zal winnen. Milieurekeningen kunnen hierbij een nuttige rol vervullen, bijvoorbeeld bij de standaardisatie van concepten, de onderlinge vergelijking van milieu-indicatoren evenals hun vergelijking met indicatoren betrekking hebbend op andere, economische en sociale, facetten van duurzaamheid.

Het is betreurenswaardig dat bij de recente ontwikkelingen van indicatoren in Europa nagenoeg geen aandacht uitgaat naar het gebruik van rekeningenstelsels. Dit geldt zowel voor indicatoren die zijn geïntroduceerd in het kader van de Lissabonstrategie en de Europese duurzaamheidstrategie. De veelzijdige ontwikkeling van milieurekeningen in recente jaren is veelbelovend. Illustratief in dit opzicht is het onlangs verschenen internationale handboek over geïntegreerde rekeningen voor milieu en economie (SEEA-2003). In Europa zijn de eerste stappen gezet naar het harmoniseren van milieurekeningen waaronder de NAMEAs voor luchtemissies. Een geharmoniseerde en reguliere publicatie van milieurekeningen draagt ongetwijfeld bij tot een toenemende beleidsrelevantie van deze statistieken op nationaal en internationaal niveau. Het verdient daarom aanbeveling om milieuindicatoren voor nationaal en internationale beleid zoveel mogelijk te ontlenen aan deze samenhangende rekeningenstelsels.