Sustainable National Income: A Trend Analysis for the Netherlands for 1990-2000

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Contents

1. Introduction

It is well understood that national income is an inadequate indicator of social welfare. Depending on the perspective, national income is either incomplete, misleading, or both. Many attempts have been made to improve and/or supplement this central statistic of national accounts. One of these attempts, the correction of national income for environmental losses, has extensively been dealt with in Verbruggen (2000), Verbruggen *et al.* (2001), Gerlagh *et al.* (2002), and Hofkes *et al.* (2002). The methodology used in these studies resulted in a so-called Sustainable National Income (SNI), *i.e.* a national income that takes the environment as a welfare generating economic good into account, according to the methodology strongly advocated by Hueting (*e.g.* Hueting, 1992 and 1995).

In operationalising the Hueting methodology, an empirical and integrated environment-economy model has been used. The use of such a model inevitably asks for the formulation of a number of choices and additional assumptions to make the model run and come up with credible results. It is clear that these choices and additional assumptions can be questioned, even though they are extensively examined in the above-mentioned studies. One way of dealing with the sensitivity of the results is to look at the development of SNI over time rather than considering the level of SNI in one isolated year. More in particular, it is useful to look at the underlying forces that drive the change of SNI over a period of two or more years.

In this study we analyse the trend in the development of SNI for the Netherlands in the period 1990–2000. We decompose economic development into four fundamental forces: changes in the overall economic scale, changes in the composition of economic production and consumption, changes in the use of technologies and changes in the availability of technologies. A similar approach can be found in Grossman and Krueger (1993) who apply a decomposition analysis to interpret the empirical evidence in their influential study of the potential effects of North American Free Trade Agreement (NAFTA) on the environment.

In Chapter 2, we give a brief history of the background of the model and of the starting point for the analysis of this report. For a comprehensive description of the model, its assumptions and calibration the reader is referred to Dellink *et al.* (2001), Gerlagh *et al.* (2001), Gerlagh *et al.* (2002), Verbruggen *et al.* (2001), and Hofkes *et al.* (2002). Chapter 3 presents a description of the decomposition analysis. In Chapter 4, we present the numerical results. Finally, Chapter 5 concludes.

2. Model

2.1 Short description of the model

Applied General Equilibrium Model

In order to be able to calculate a sustainable national income (SNI) indicator, an applied general equilibrium (AGE) model for the Dutch economy has been constructed. The model has 27 sectors, and is extended to account for 9 environmental themes. The SNI-AGE model identifies domestically produced goods by the sectors where these goods are produced. There are two primary production factors, labour and capital.[1] The model distinguishes three consumers: the private households, the government, and the Rest of the World (ROW). In addition to these producers and consumers, there are several auxiliary agents that are necessary to shape specific features of the model. In order to capture non-unitary income elasticities in the model, the consumption of the private households is split into a ‘subsistence’ and a ‘luxury’ part. There is an ‘investor’ who demands investment goods necessary for economic growth, and a ‘capital sector’ which produces the composite capital good. Trade is modelled using the Armington specification for imports and a Constant Elasticity of Transformation (CET) production structure for sectors producing for both the domestic and the world market.[2] Besides the model elements mentioned above, common to many other AGE models, the model distinguishes 9 environmental themes: enhanced greenhouse effect, depletion of the ozone layer, acidification, eutrophication, smog formation (tropospheric ozone), dispersion of fine particles to air, dispersion of toxic substances to water, dehydration, and soil contamination. To each of the environmental themes, aggregated emission units are associated. For example, to the enhanced greenhouse effect, greenhouse gas emissions are associated, which are expressed in CO_2 equivalents (see also Appendix II).

An overview of the relationships in the model is presented in Figure 2.1 In the figure, black arrows represent commodity flows that are balanced by inverse income flows; grey arrows represent pure income transfers that are not balanced by commodity flows.

Environment

Next to the production factors labour and capital, the model distinguishes emission units as production factors as well. The reason for treating emission units as production factors is that a reduction of emission units will imply a reduction of output, when the inputs of labour and capital are maintained. Emission units can thus be seen as a valuable input to production. The figure shows the market for emission units, supplied by the government

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[1] In fact, capital is produced. The model accounts for maintenance costs and net investments.

[2] The CET production function is used for production processes with multiple output goods. In analogy to the CES production function, it is assumed that the relative change in output for the various output goods is proportional to the relative change in prices. For example, if there are two goods and their initial output levels are the same, then if the price of the first good increases by 1%, the relative output level of the first good will increase with σ%, where σ is the elasticity of transformation parameter.

in an amount that is consistent with the sustainability standards. Hence, the revenues from the sale of emission units enter the government budget. In addition to the common sectors recognized in the Dutch economy, there is an 'auxiliary' abatement producer that produces abatement goods, which can substitute for emissions as input of production. This substitution is represented by the abatement cost curves for the environmental themes. The abatement sector is not presented separately in the figure.

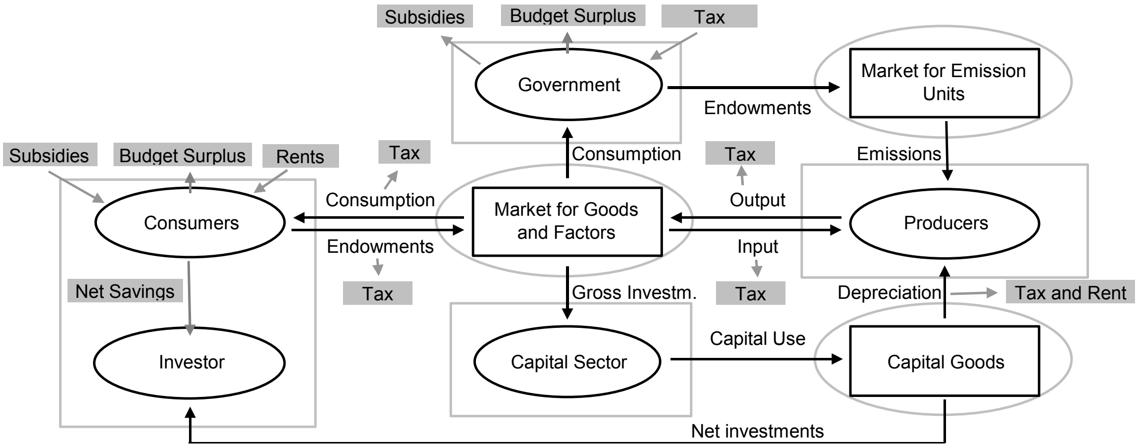

Figure 2.1 Overview of SNI-AGE model.

Government

The government levies taxes on consumption (VAT), the supply of endowments (labour income tax), and capital use (profit income tax). These public revenues balance, together with revenues from the sale of emission units, the public expenditures that consist of public consumption and lump sum subsidies for social security. Consumers spend their income from the sale of endowments and lump sum subsidies on consumption and net savings. Net savings are transferred to the 'investor', who spends it on the consumption of capital goods (thus: net savings equal net investments).

Balancing Budgets

Production technologies are assumed to have constant returns to scale, which implies that profits, apart from a rate of return on capital, are zero, and hence, that the value of inputs is equal to the value of outputs. In Figure 2.1, this is visualized by placing a grey box around the agents, over which the net income and expenditure flows sum to zero. The same applies to clearing markets, where (the value of) total supply matches total demand. A grey ellipse visualizes this.

By a careful examination of the income flows in Figure 2.1, we find that the budgets close, except for the budget balances of the private and public consumers. This is due to the omission of international trade from the figure. For the domestic economy as an entity, the budget surplus is equal to the surplus on the trade balance, represented through the well-known identity Y = C+I+(X–M), where Y–C–I is the income surplus of the consumers compared to the expenditures on consumption and investments, and (X–M) is the surplus of export compared to the imports. Of course, in case of a budget deficit the opposite holds.

Methodological Assumptions

Given the AGE model, calculation of the sustainable income follows the same procedure as a classic policy analysis, *i.e.,* in which one studies the consequences of a policy that strictly observes environmental sustainability standards. It is then necessary to make assumptions as to the time scale (e.g. static versus dynamic modelling), transition costs, labour market, international trade, emission reduction measures, 'double counting', private consumption and government budgets. In Appendix I, we briefly explicate the choices made. We have to be aware that results may significantly depend on the actual assumptions. It is thus not possible to consider the result as the unique SNI; preferably, we speak of an SNI calculation.

Regarding assumptions with respect to international trade, we calculate two variants. The specific assumptions made in these two variants are explicated below.

To calculate an SNI for a particular country, assumptions have to be made with respect to policies in the rest of the world. This is especially relevant for a small and open economy such as the Netherlands, as a unilateral sustainability policy could cause a major international reallocation of relatively environment-intensive production activities. We assume that similar sustainability standards are applied all over the world, taking due account of local differences in environmental conditions. However, it is not feasible to estimate the resulting costs and changes in relative prices in other countries. Instead, we have to make some simplifying assumptions, and in the results presented in this report, we present two variants.

The first variant abstracts from changes in prices on the world market. That is, we let prices change in the Netherlands, while relative prices on the world market remain unchanged. This variant can be interpreted as a situation in which the Netherlands explores a stringent sustainability policy, while other countries maintain their reference policy. Alternatively, this variant can also be interpreted as a situation in which there is a global sustainability policy, but in which there are no specific sectors – worldwide – that suffer more from an international sustainability policy compared to other sectors. Thus, whereas our calculations identify specific Dutch sectors for which prices increase when we have to meet a sustainability target, for other countries, it need not be the same sectors for which prices increase. On a worldwide level, sectoral changes might average out, and world market prices do not need to change. As relative prices in the Netherlands change, it becomes feasible for the Netherlands to partly reach its sustainability standards by importing relatively environment-intensive products, whose cost of production increase relatively much in the Netherlands, and by exporting less environment-intensive products, whose cost of production will relatively decrease in the Netherlands.

The second variant assumes price changes on the world market proportional to price changes in the Netherlands. This variant assumes that next to the Netherlands, the rest of the world explores a similar sustainability policy, and in addition, for other countries, sectoral changes are similar as in the Netherlands. This variant implies a more stringent restructuring of the Dutch economy, as shifting environmental problems abroad is no longer possible.

In the same international context, we have to specify an assumption concerning the trade balance. In the AGE model, the standard macro-economic balance equations apply, so that the sum of the public and private savings surpluses (or deficits) equals the trade balance deficit (or surplus). The savings surplus is assumed to constitute a constant share of national income. This, in turn, determines the trade balance through adjusting the exchange rate.

2.2 Calibration

The model is calibrated for 1990, 1995 and 2000 using historical data for the Netherlands for these years, provided by Statistics Netherlands (2004). The main data source is the NAMEA accounting system (Keuning, 1993), which captures both the economic and environmental accounts.[3] It should be noted that due to recent changes in the classification and definitions of activities in the System of National Accounts as well as in the registration of emissions in the Netherlands Emission Registration system (see De Boer, 2002), the economic and environmental data for 1990 as used in the present report differ from those used in Verbruggen (2000) (see also Appendix II).

Net National Income (NNI) at (current) market prices amounts to 213 billion euros in 1990, 268 billion euros in 1995 and grows to 340 billion euros in 2000 as shown in Table 2.1. As the Consumer Price Index (CPI) has risen by 24.4% over the period, real income has grown by 28.2% between 1990 and 2000, or 2.5% annually.

Table 2.1 NNI and economic growth in period 1990–2000.

Year	NNI in billion euros (current prices)	NNI in billion euros (1990 prices)	CPI 1990
1990	213.0	213.0	100
1995	268.4	235.4	114.0
2000	340.4	273.1	124.4

To get a feeling for what the economy looks like, we present the condensed Social Accounting Matrices (SAMs) in Table 2.2 and Table 2.3. The row entries represent goods, the column entries represent agents; a positive table entry denotes supply while a negative table entry denotes demand. Market equilibrium requires that supply matches demand. Consequently, rows sum to zero. For all sectors, the value of output equals the value of intermediate deliveries plus the value of production factors employed. Thus, the first five columns also sum to zero. The other column sums represent the trade surplus, X–M (note that a negative value means that exports exceed imports as a negative entry denotes demand for a good), net investments, I, consumption, C, and income from endowments, Y. The latter columns sum to zero according to the standard equation Y=C+I+X–M. To give an example, the value of goods produced by the agricultural sectors, both in 1990 and 1995, amounts to 17 billion euros, and 18 billion euros in 2000 (current prices). In 2000, more than half thereof, 11.2 billion euros, accounts for the value of intermediate deliveries by other sectors. The remaining 7.2 million euros is value added.

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[3] Due to differences in definitions and classifications, the levels of emissions in the NAMEA accounting system differ slightly from the levels of emissions in the Emission Registration database, see also Appendix II.2.

Table 2.2 Reference Social Accounting Matrix 1990 (billion Euros, current prices).

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	17	–13	–1	–0		–2		–2		0
Industries	–5	117	–30	–41	–0	6		–47		0
Services	–2	–33	175	–11	–0	–6		–123		0
Capital	–2	–8	–16	56			–29			0
Abatement	–0	–0	–0		0			–0		0
Labour	–1	–32	–74		–0				108	–0
Profits	–6	–22	–41						69	0
Taxes	–0	–8	–14	–5				–10	37	0
Sum	0	0	0	0	–0	–2	–29	–181	213	0

Table 2.3 Reference Social Accounting Matrix 1995 (billion Euros, current prices).

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	17	–11	–1	–0		–4		–2		–0
Industries	–5	134	–38	–44	–0	–4		–44		0
Services	–2	–40	227	–13	–0	–6		–166		0
Capital	–2	–10	–21	63			–30			
Abatement	–0	–0	–0		0			–0		0
Labour	–2	–36	–93		–0				131	0
Profits	–6	–25	–52						82	–0
Taxes	–0	–12	–23	–6				–14	55	0
Sum	0	0	0	–0	0	–13	–30	–225	268	0

Table 2.4 Reference Social Accounting Matrix 2000 (billion Euros, current prices).

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	18	–10	–1	–0		–4		–2		–0
Industries	–5	170	–52	–60	–0	1		–54		0
Services	–3	–57	313	–23	–0	–11		–220		0
Capital	–3	–18	–40	91			–30			
Abatement	–0	–0	–0		0			–0		0
Labour	–2	–42	–123		–0				166	0
Profits	–5	–27	–59						91	–0
Taxes	–0	–17	–38	–8				–20	83	0
Sum	0	0	0	–0	0	–14	–30	–295	340	0

The share of the agricultural sector in value added decreases from about 4 per cent of NNI in 1990 (8 billion euros divided by 213 billion euros) to about 3 per cent of NNI in 1995 (8 billion euros divided by 268 billion euros) to 2% in 2000. The share of industries in value added decreases from about 29% in 1990 to 25% in 2000, while the services share in value added increases from about 61% in 1990 to approximately 65% in 2000. In the period 1990–2000, gross investments amount to 56, 63 and 91 billion euros respectively, about half of which is for maintenance; net investments amount to 29, 30 and 30 billion euros respectively. Capital goods are mainly produced by industry. About half of total income (after taxes) is attributed to labour, capital returns account for 30 per cent, and taxes (excluding income taxes), account for the remaining 20 per cent of income.

As mentioned above, the AGE model includes 9 environmental themes: enhanced greenhouse effect, depletion of the ozone layer, acidification, eutrophication, smog formation (tropospheric ozone), dispersion of fine particles to air, dispersion of toxic substances to water, dehydration, and soil contamination. Table 2.6 on page 9 presents the development of the nine environmental themes over the period 1990–2000. Except for the enhanced greenhouse effect, dehydration, and soil contamination, the environmental themes show a clear downward trend.

Some trends

Because enhanced greenhouse gases remain at the same level and it is the binding theme in the SNI calculations for 1990 and 1995, we discuss the developments in greenhouse gas emissions for six economic sectors between the periods 1990–1995 and 1995–2000. We have picked these economic sectors, because these sectors are either large in terms of value added, or emission intensive with respect to greenhouse gases.

The sector ‘commercial services’ (A) is the largest sector in VA terms and has low emission intensity. Despite the low emission intensity of this sector, the ‘commercial services’ sector contributes to higher GHG emission levels due to its high growth rates in the 1990s, see Table 2.5. The sector ‘oil refineries’ (B) is a relative polluting sector. Between 1990 and 1995, this sector grew sharply, but its value added shrunk in the second time interval 1995–2000.

Table 2.5 Changes in contribution (in absolute terms) to GHG emissions (billion kg CO_2 eq) of six economic sectors in the period 1990–2000.

		Changes in contribution to GHG emissions		
		1990–1995	1995–2000	1990–2000
Commercial services	A	0.37	0.68	1.05
Oil refineries	B	4.01	4.63	8.63
Energy supply	C	1.11	1.61	2.72
Agricultural sector	D	–3.42	–5.23	–8.65
Non-commercial services sector	E	–2.90	1.00	–1.90
Chemical industry	F	0.91	–4.44	–3.54
Total of six sectors		0.08	–1.75	–1.69
Total of Dutch economy		–7.6	1.4	–6.2

Table 2.5 shows that ‘oil refineries’ contribute considerably to the increase of GHG emissions over the whole period. The ‘energy supply’ sector (C) has the highest emission intensity of all sectors, and it continues to grow at a high rate in the period 1995–2000. This sector contributes to the increase of GHG emissions by 2.7 billion kg CO_2 eq. The agricultural sector (D) has a high and increasing emission intensity, but the value added in this sector shrinks during both periods. From a greenhouse gas emission perspective, this shift away from agriculture contributes to a more sustainable composition of the economy. The non-commercial services sector (E) is one of the largest sectors. It has low emission intensity, and an accelerating growth, both contributing to a ‘greener’ composition of the economy over the period 1990–2000. Finally, the chemical industry (F) is relatively emission intensive. Although its share in total VA increased in the first half of the 1990s, its share in VA has decreased in the second half of the 1990s. Overall, the GHG emissions of the chemical industry declined between 1990 and 2000.

Abatement technologies and sustainability standards

For all nine environmental themes, data have been collected on actual emission/pollution levels[4] and on the costs of available technical measures to prevent the environmental problems from occurring or to restore the environmental quality. These data are described in abatement cost curves. For information about the construction of the abatement cost curves, the reader is referred to Appendix II, which deals with methodological issues; data used and changes between 1990 and 2000 in more detail.

From a modelling perspective, the inclusion of abatement measures within an AGE model is the major extension of our analysis compared to the literature. Recall that emission units are treated as production factors, similar to labour and capital, since an enforced reduction of emissions decreases output.

Table 2.6 presents the emission levels per year and the sustainability standards for the various environmental themes. The sustainability standards are exogenous to the model calculations. There is some debate about whether the sustainability standards can be objectively assessed. In this study we take the sustainability standards as assessed by Hueting and de Boer. These standards are described extensively in Verbruggen (2000). Furthermore, it should be noted that the sustainability standards used in the calculations do not change between 1990 and 2000.

Table 2.6 Base emissions and sustainability standards for the environmental themes in the period 1990–2000.

Environmental theme	Units	Sustainability standard	Emission levels 1990	1995	2000
Greenhouse effect	Billion kg. CO_2 equivalents	53.3	254.5	246.9	248.3
Ozone layer depletion	Million kg. CFC11 equivalents	0.6	10.4	0.3	0.1
Acidification	Billion acid equivalents	10.0	40.1	34.0	31.3
Eutrophication	Million P-equivalents	128.0	188.9	173.9	137.5
Smog formation	Million kilograms	240.0	527.1	385.5	280.3
Fine particles	Million kilograms	20.0	78.6	59.2	53.2
Dispersion to water	Billion AETP-equivalents	73.5	196.8	99.6	88.3
Dehydration	Percentage affected area	0	100.0	100.0	100.0
Soil contamination	Thousands contaminated sites	0	600.0	598.5	590.0

From Table 2.6 we can learn that except for greenhouse gases the required reductions considerably decrease for most themes in the period 1990 and 2000. For the theme 'depletion of the ozone layer', actual emissions in 1995 are already at a sustainable level. The sharp fall in emissions is caused by the strict ban on sales of ozone emitting appliances[5]. For smog formation and dispersion of fine particles to air, the emission reduction potential of technical measures in 2000 suffice to meet the sustainability standards. However, for the other themes, it is still the case that only part of the required reductions

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[4] We use the terms emissions and pollution interchangeably to indicate the annual burden on the environment, even though we realize this terminology is not entirely correct.

[5] As mentioned in Verbruggen (2000), for technical modelling reasons, ozone emissions are measured as ozone use rather than actual emissions.

can be realized through technical measures as shown in Table II.7 in Appendix II.6. The remainder of the reduction has to be realized through a restructuring of the economy.

Along the period 1990–2000, greenhouse gases (GHG) are the most costly environmental theme in terms of the costs that need to be made to reach the sustainability standards. We notice that the emissions of greenhouse gases decrease between 1990 and 2000, although there has been a minor increase between 1995 and 2000. This effect is mainly due to the decreasing contribution of CFCs and halons (from 17.1 CO_2 equivalents in 1990 to 0.5 CO_2 equivalents in 2000). Pure CO_2 emissions increased from 183.0 billion kg CO_2 in 1990 to 205.3 billion kg CO_2 in 2000 (see also Table II.5 for the equivalences between the different substances). Of substantial importance to the sustainable income level is the known potential for GHG emissions reduction through technical measures, which has increased substantially over the period 1990–2000, due to additional and more credible information on the reduction potentials of renewable energy resources for 2000 (see Menkveld, 2002). For 1995, there were no good estimates on reduction potentials and costs for renewable energy sources. The GHG emission reduction potential through the implementation of technical measures amounted about 87.1 billion kg CO_2 equivalents in 1990. In 2000, 113.4 billion kg of the required GHG emission reduction can be realized through technical measures (see Table II.7).

3. Decomposition Analysis: methodology

As already mentioned in Chapter 2, the approach we use to correct National Income for environmental losses is static in nature. This does, however, not exclude the option of calculating SNI for a number of years and analyse the development of SNI over the years. Moreover, since the sensitivity of the calculated SNI level with respect to various assumptions will be approximately the same for various years, analysing changes in SNI over time, instead of considering the level of SNI for one isolated year, enables us to reduce the sensitivity of our results.[6]

In the present analysis we are interested in the development of SNI between 1990 and 2000. For the years 1990, 1995 and 2000, we have calculated an SNI indicator, denoted by SNI1990, SNI1995 and SNI2000, respectively. In order to be able to interpret the development of SNI over the years we apply a decomposition analysis. We distinguish four underlying forces of economic development: overall economic growth, changes in the composition of the economy, changes in technologies used for production, and changes in available but unused technologies. These first three forces are commonly referred to as the scale effect, the composition effect and the technique effect. A similar approach can be found in Grossman and Krueger (1993) who apply such a decomposition analysis to interpret the empirical evidence in their influential study of the potential effects of NAFTA on the environment.

In contrast to Grossman and Krueger's study, in this study, changes in actual emissions are not the focus of our analysis. Instead, we study changes in the SNI indicator. The difference in focus has two implications. First, it requires that we add to our decomposition analysis changes to abatement technologies that are available (and essential) for reaching a sustainable economy, but that are not used in the actual situation. We label these technologies 'available abatement technologies'. Changes in the SNI indicator that are due to changes in the available abatement technologies are labelled the abatement effect. Second, we do not use the decomposition to interpret changes in emissions, but changes in the sustainable income level. Recall that the sustainability standards do not change between 1990 and 2000, consequently a decomposition of emission trends in the sustainable economy makes no sense. Instead, we use a parallel approach, comparing changes in the actual economy with associated changes in the sustainable economy that defines the SNI indicator. The scheme of our decomposition analysis is presented in Figure 3.1.

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[6] The following illustration may be helpful. Consider a speed indicator that measures the speed of a vehicle with an uncertainty range of about 5 km/h. The range of uncertainty decreases if we use the speedometer to measure the increase in velocity. Assume that the velocity increases from, say 90±5 km/h to 100±5 km/h, according to the speedometer. Actually, velocity might have increased from 85 km/h to 95 km/h, or from 95 km/h to 105 km/h. In both cases, the speedometer correctly measures an increase of 10 km/h. The velocity might also have increased from 85 km/h to 96 km/h, but it is improbable that velocity has increased from 85 km/h to 105 km/h, or has been constant at 95 km/h. The uncertainty has thus apparently decreased.

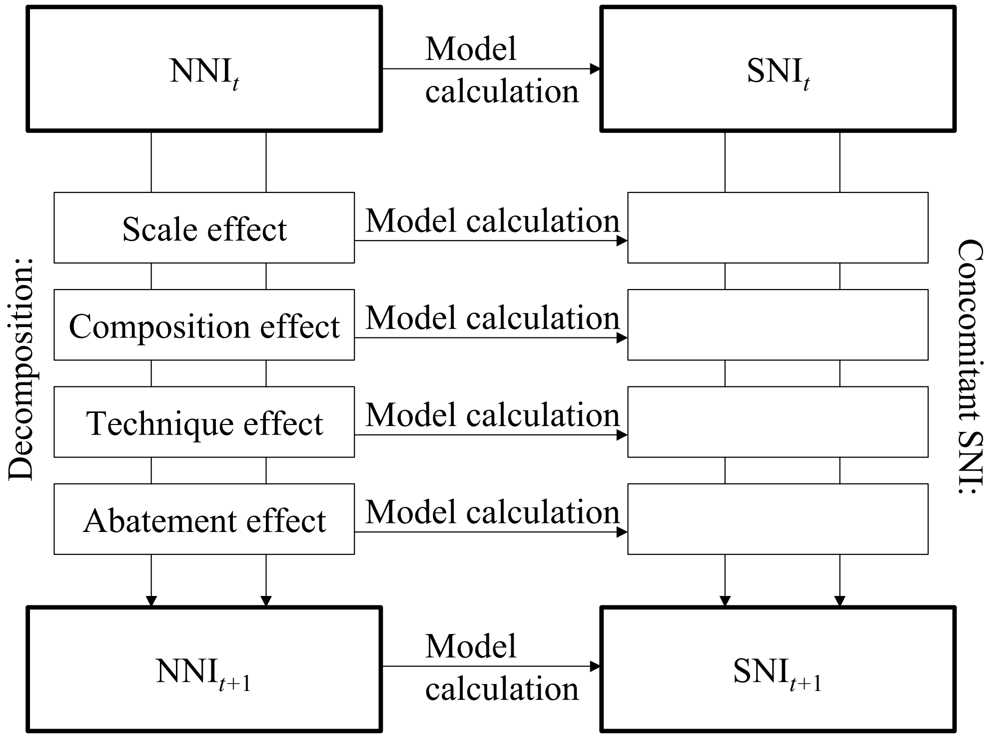

Figure 3.1 Decomposition scheme in the period t to t+1 for t=1990 and 1995.

Going from left to right in the figure represents the (standard) calculation of an SNI. Going from top to down represents the trend analysis, moving from *t* to *t*+1. Starting from the reference economy in period *t*, an SNI is calculated by imposing the sustainability standards, which results, through the model calculations, in a (hypothesized) sustainable economy that satisfies the sustainability standards. This procedure is applied for two periods, 1990–1995 and 1995–2000. The trend analysis for *t* to *t*+1 consists of a decomposition of the changes in the reference economy, i.e. we move from BaU at time *t* (upper left) to BaU at time *t*+1 (lower left). For each step of the decomposition, we calculate the associated sustainable income levels, i.e. for each step we move in the figure from left to right, applying the standard calculation of an SNI. This results in a concomitant SNI for each step of the decomposition procedure. The resulting breakdown of SNI (from upper right to lower right) is interpreted as a decomposition of the change in SNI between *t* and *t*+1.

4. Numerical Results: A trend analysis for 1990–2000

4.1 Calculation of SNI 1990–2000

Figure 4.1 presents an overall picture of income and sustainable income for the two SNI variants for the Netherlands in the period 1990–2000. The social accounting matrices, underlying the table, are given in Appendix IV. It should be reminded that variant 1 abstracts from changes in prices on the world market. As relative prices in the Netherlands change, it becomes feasible for the Netherlands to partly reach its sustainability standards by importing relatively environment-intensive products, whose cost of production relatively increase in the Netherlands, and by exporting less environment-intensive products, whose cost of production will relatively decrease in the Netherlands. Variant 2 assumes price changes on the world market proportional to price changes in the Netherlands. This variant implies a more stringent restructuring of the Dutch economy, as shifting environmental problems abroad is no longer possible.

It appears that the extent to which SNI drops is quite significantly determined by the specification of international trade. Table 4.1 presents the numbers underlying the graph, and it shows that in 2000, SNI variant 1 (with constant relative world market prices) is 25% below net national income, while SNI variant 2 (with world market prices changing proportionally to domestic prices) is 48% below net national income.

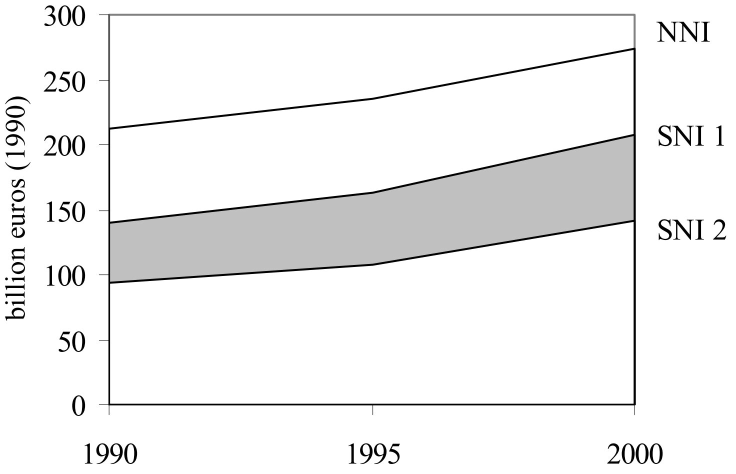

Figure 4.1 Trend in NNI, SNI variant 1 (SNI 1) and SNI variant 2 (SNI 2), 1990–2000.

Figure 4.1 is presented such that variant 1 (SNI1) stands for an upper bound of sustainable income, and variant 2 (SNI2) stands for a lower bound. So, the shaded area depicts a measure of uncertainty in sustainable income. We notice that for each separate year, the uncertainty in the SNI indicator, that is the distance between the level of SNI1 and SNI2 is about half the level of SNI2 (the lower limit), which reflects a considerable bandwidth or uncertainty for the SNI indicator of 50% of the minimum value. From Table 4.1, we see that the uncertainty decreases substantially when we study the development in the SNI over the periods, as mentioned in Chapter 3. While NNI has increased by 60.1 million euros (28.2%) between 1990 and 2000, sustainable national income has increased by 64.8 billion euros (46.4%) in variant 1 and by 46.8 billion euros (49.7%) in variant 2, respectively. In absolute terms, the increase in SNI is between 46.8 and 64.8 billion euros, a bandwidth of only 18 billion euros. In relative terms, the SNI has grown by an amount between 46.4% and 49.7%. The bandwidth has substantially decreased. From a different perspective, we could say that the growth rate of sustainable national income exceeds the growth rate of net national income, in both periods for both variants, and thus we may conclude that this finding is robust. Sustainable national income has improved relatively compared to net national income.

Table 4.1 Absolute value of NNI, SNI and SNI2, growth, and the relative gap between both SNI variants and NNI, 1990–2000.

	1990	1995	2000
Absolute values			
NNI	213.0	235.4	273.1
SNI 1	139.8	163.8	204.6
SNI 2	94.2	107.2	141.0
Absolute growth			
NNI		22.4	37.7
SNI 1		24.0	40.8
SNI 2		13.0	33.8
Relative growth			
NNI		11%	16%
SNI 1		17%	25%
SNI 2		14%	32%
Absolute gap			
SNI 1	73.2	71.6	68.5
SNI 2	118.8	128.2	132.1
Relative gap			
SNI 1	34%	30%	25%
SNI 2	56%	54%	48%

The gap between SNI and NNI measures the dependence of the economy on that part of natural resource use that exceeds the sustainable exploitation level (c.f. Gerlagh *et al.*, 2002). Both variants show a relatively improving SNI during the period 1990–2000 in the sense that the relative gap between SNI and NNI declines substantially. In particular, SNI variant 1 ranges from 34% below NNI in 1990 via 30% in 1995 to 25% in 2000. SNI variant 2 is 56% below NNI in 1990, 54% in 1995 and 48% in 2000. For both variants, we thus observe the trend that SNI moves relatively closer to the actual NNI. In other words, the relative decrease in national income necessary to obtain a sustainable economy decreases slightly between 1990 and 2000. Independent of the variants, the Dutch economy tends to decrease its over-dependence on natural resource exploitation, when considering the relative gap. We should be somewhat careful with this interpretation of decreasing dependence, however, as at the same time, the absolute gap between NNI and SNI variant 1 declines from 73 billion euros to 68 billion euros, while the absolute gap between NNI and SNI variant 2 increases from 119 billion euros to 132 billion euros.

Abatement cost curves for SNI

The SNI-AGE model considers a trade off between abatement costs and emissions reductions through economic activities. The SNI calculations indicate to what extent the total output of economic activity has been reduced and to what extent abatement techniques have been implemented. We distinguish abatable and unabatable emissions. Abatable emissions are defined as the total amount of emissions which can be reduced due to the implementation of abatement technologies. The total amount of emissions that cannot be reduced through technical measures is referred to as unabatable emissions. Unabatable emissions can only be reduced by a decrease of economic activities (NNI), or by restructuring of the economy towards emission-extensive sectors.

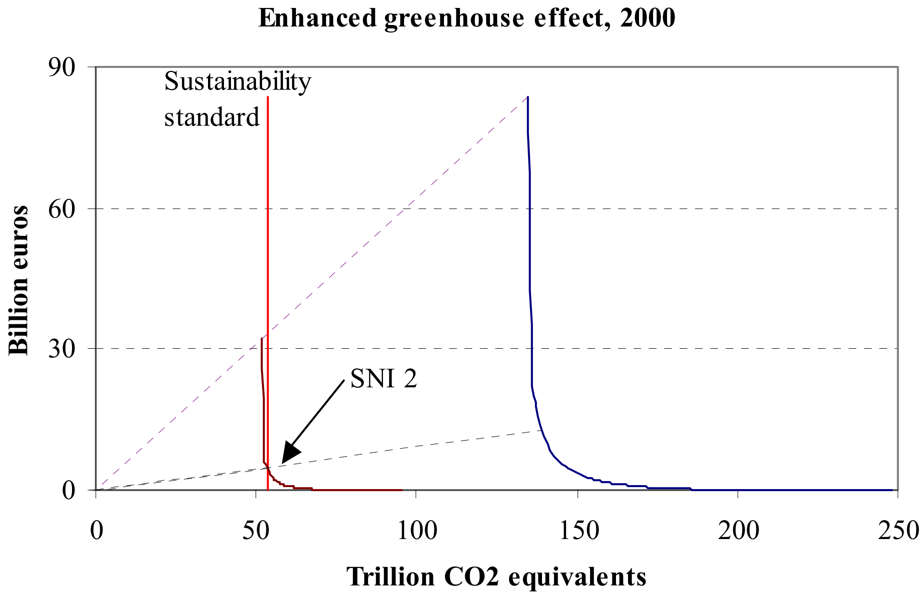

Figure 4.2 The initial abatement cost curve for GHG emissions in 2000 and the abatement cost curve for SNI variant 2 (SNI 2) in 2000.

Figure 4.2 presents the abatement cost curve of the enhanced greenhouse effect for the benchmark economic situation in 2000, and in the case of SNI variant 2 in 2000. Comparing SNI variant 2 with the benchmark NNI situation, we find that due to the decrease in total output and the shift in economic activity towards sectors that are less dependent on greenhouse gas emissions, the level of GHGs that would be emitted without additional technical measures has decreased by 62%, from 248 to 94 billion kg CO_2 equivalents (also presented in the third entry column of Table 4.2). Technical measures are required to reduce a further 41 billion kg to reach the sustainability standard of 53 billion kg. The SNI-AGE model assumes that the potential reduction levels and associated abatement costs of environmental themes change proportionally with changes in economic activity.[7] The technical measures that were available for 113 billion kg CO_2 equivalents now can only reduce 43 billion kg (38% of 113). Figure 4.2 illustrates the proportional rescaling of the original abatement cost curve for the climate theme in 2000

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[7] Note that this proportional change occurs at the level of economic sectors.

towards the origin. In the figure, the sustainable level of GHG emissions in SNI variant 2 in 2000 is the intersection of the sustainability standard for the climate theme and the re-scaled abatement cost curve. Almost all technical measures, 41.5 out of 43 billion kg, that is 97% of the reduction potential of emissions through abatement techniques (last column of Table 4.2), has to be applied to reach the sustainability target. The abatement costs amount 3.9 billion euros (1990 prices; last column of Table 4.3).

In addition to Figure 4.2, Table 4.2 presents results on the abatement cost curves of the environmental themes for the SNI calculations in the period 1990–2000. We recall that emission reductions can be achieved by reducing emission intensive economic activities or by implementing abatement technologies. The first three columns present the reduction in emission due to a reduction of economic activity and restructuring between sectors. The second set of three columns present the share of available abatement technologies that have been applied to reach the sustainability standards. From Table 4.2 we can see that for SNI 1 in 2000, for example, the emission of greenhouse gases declined by 62.2% due to a reduction of economic activity. A further 94.5% of all available abatement technologies for the climate theme have been implemented to achieve the sustainability level. In the case of empty cells, there is no need to implement technical measures, because the sustainability standards have already been met due to the decrease in the volume of the economy.

Table 4.2 Reduction of emissions through changed activities and implementation of abatement technologies under SNI variant 1 and 2, 1990–2000.

	Emission reduction through activity reduction			Share of available abatement technologies used to meet sustainability standards		
	1990	1995	2000	1990	1995	2000
SNI 1						
Greenhouse effect	66.6%	65.4%	62.2%	89.9%	89.7%	94.5%
Ozone layer depletion	63.7%			87.4%		
Acidification	72.0%	73.5%	71.0%	17.7%		
Eutrophication	81.1%	82.2%	75.8%			
Smog formation	44.0%	40.0%	37.6%	53.9%		
Fine particles	62.5%	63.0%	54.9%	58.9%	26.1%	25.2%
Dispersion to water	63.3%	53.7%	49.5%			
SNI 2						
Greenhouse effect	66.3%	65.1%	61.5%	91.3%	91.0%	96.5%
Ozone layer depletion	73.0%			81.6%		
Acidification	67.2%	67.7%	64.8%	38.1%	21.5%	28.6%
Eutrophication	68.4%	69.2%	65.1%			
Smog formation	64.9%	62.9%	58.7%			
Fine particles	67.9%	67.6%	62.9%	37.8%		
Dispersion to water	69.4%	69.4%	66.2%			

Note: Table II.8 in Appendix II.7 presents the levels of abatable and unabatable emissions for NNI, SNI1 and SNI2 in the period 1990–2000.

In addition to the share of abatement technologies used for each environmental theme, Table 4.3 shows the associated abatement costs. The enhanced greenhouse effect is the restricting theme in all three years for both SNI variants. This is also reflected by the substantial abatement costs for this environmental theme, see Table 4.3. For both variants, the abatement costs of the enhanced greenhouse effect are steadily increasing, while the level of abatement costs in variant 2 are substantially higher than in variant 1. The abatement costs for the other environmental themes except dehydration and soil contamination are low.

Table 4.3 Abatement costs in billion euros (1990 price level), 1990–2000.

	Initial abatement costs			Abatement costs for SNI 1			Abatement costs for SNI 2		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
Greenhouse effect	0.00	0.00	0.00	1.39	1.76	2.07	2.16	2.72	3.85
Ozone layer depletion	0.04	0.00	0.00	0.02			0.01		
Acidification	0.03	0.07	0.07	0.01	0.01	0.00	0.04	0.04	0.07
Eutrophication	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smog formation	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Fine particles	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Dispersion to water	0.35	0.35	0.09	0.07	0.01	0.01	0.05	0.01	0.01

To give an interpretation of the trend in the development of SNI between 1990 and 2000 we apply in Section 4.2 the decomposition analysis as described in Chapter 3. For the results of the decomposition analysis over the period 1995–2000, we refer to Hofkes *et al.* (2002). Below, we discuss the decomposition in 1995–2000 separately, and we compare the decomposition analysis for both periods.

4.2 A trend decomposition for 1990-2000

In order to be able to better interpret the trend in the development of SNI we decompose the change in the SNI indicator into four effects according to the methodology presented in Chapter 3. First, the scale effect measures the increase in income due to increases in labour and capital productivity, without paying attention to changing (relative) preferences. An increase in the productivity of production factors also increases the income levels that can be maintained under sustainability standards. In a sustainable economy, however, natural resources are valued as essential production factors as well. Second, the change in the composition of the economy can be a powerful element for decreasing actual emissions (composition effect). Particularly, if the economy shifts towards less emission intensive industries, SNI can grow. Third, a decrease in the emission intensity of production processes is the most direct way of decreasing actual emissions (technique effect). Subsequently, efforts of reaching sustainability standards become easier, so that SNI indicators gain from decreasing emission intensities. Finally, SNI indicators can gain from the availability of technical measures to reduce emissions that are left unused in the benchmark NNI allocation, but that are applied in the SNI calculations (abatement effect).

Table 4.4 presents the results of the decomposition analysis for NNI, SNI1, SNI2 and GHG emissions. The columns with the SNI indicators in Table 4.4 describe the concomitant sustainable income levels for the two variants SNI1 and SNI2 on the right half of the flow diagram in Figure 3.1. For each stage, the tables also present the relative change, that is the change in income or emissions that is associated with that particular decomposition effect. Table 4.4 is divided into two panels. The top and bottom panel present the 1990–1995 and 1995–2000 decompositions respectively. Note that the results of the 1990–1995 decomposition are derived from Hofkes *et al.* (2002).

Table 4.4 shows that, whereas net national income has grown by 16.0% between 1995 and 2000, GHG emissions have increased by 0.6%, and sustainable national income has increased by 24.9% and 31.5%, for variant 1 and 2, respectively. We use the decomposition method to help us better understand the mechanisms at play, that explain the differences in relative growth levels. We elaborate upon the decomposition analysis stage by stage for each separate effect, as done by Hofkes *et al.* (2002). Throughout the decomposition analysis we consider all prices and values at the 1990 level. Table III.1 to Table III.4 in Appendix III shows the subsequent SAM matrices of the different stages in the NNI decomposition in the period 1995 and 2000.

Table 4.4 Decomposition of changes in NNI, SNI1 and SNI2 (billion Euros, 1990 prices), and GHG emissions (billion kg. CO_2 equivalents).

	NNI	(change)	SNI1	(change)	SNI2	(change)	GHG emissions	(change)
1990	213.0		139.8		94.2		254.5	
Scale effect	235.4	(+10.5%)	148.7	(+6.4%)	96.6	(+2.6%)	281.0	(+10.5%)
Composition effect	235.4		151.3	(+1.8%)	99.2	(+2.7%)	265.8	(–5.4%)
Technique effect	235.4		164.1	(+8.4%)	107.8	(+8.6%)	246.9	(–7.1%)
Abatement effect	235.4		163.8	(–0.1%)	107.2	(–0.3%)	246.9	
1995 (relative to 1990)	235.4	(+10.5%)	163.8	(+17.2%)	107.2	(+13.9%)	246.9	(–3.0%)
Scale effect	273.1	(+16.0%)	177.1	(+8.1%)	108.6	(+1.3%)	286.5	(+16.0%)
Composition effect	273.1		185.5	(+4.7%)	111.3	(+2.5%)	289.4	(+1.0%)
Technique effect	273.1		196.2	(+5.8%)	128.0	(+15.0%)	248.3	(–14.2%)
Abatement effect	273.1		204.6	(+4.3%)	141.0	(+10.2%)	248.3	
2000 (relative to 1995)	273.1	(+16.0%)	204.6	(+24.9%)	141.0	(+31.5%)	248.3	(+0.6%)
2000 (relative to 1990)	273.1	(+28.2%)	204.6	(+46.4%)	141.0	(+49.7%)	248.3	(–1.4%)

Scale effect

Based on the economic growth between time *t* and *t*+1, we scale the economy up at time *t* by the economic growth in the period, such that NNI reaches the same level as at time *t*+1. We maintain all other characteristics such as the sectoral composition of the economy, the emission intensities per sector and the abatement cost curves. So, emissions increase proportionally with the economy. For the resulting economy, we reiterate the procedure for calculating the two variants of the SNI indicator. We can interpret the scale effect in NNI as the increase in income due to improved labour and capital productivity. For the SNI indicators, the scale effect can be interpreted along the same lines as the increase in income due to improved labour and capital productivity, but since a sustainable economy takes into account emission units as a production factor, the SNI indicators will probably gain less from the increase in labour and capital productivity. Thus, the size of the scale effect is likely to be lower for the SNI than for the NNI measure.

In the period 1990–2000, NNI grew by 28.2%. Table 4.4 shows that over this period, both SNI variants increased due to the scale effect. The growth in SNI was smaller than in NNI, and the reason is that, when economic production, consumption, and emissions grow uniformly, it becomes increasingly difficult to meet the sustainable standards because of the increasing emissions, while the sustainability standards remain unchanged. In addition, the growth in SNI variant 2 was smaller than the growth in variant 1, as variant 2 is more stringent.

The scale effect of SNI shows a similar trend for both periods, as shown in Table 4.4. Between 1990 and 1995, NNI grew by 10.5%, while SNI variant 1 and 2 grew by 6.4% and 2.6% respectively. Whereas NNI grows by 16.0% between 1995 and 2000, the SNI level grows by 8.1% in variant 1. The scale effect leads to an increase of sustainable income in variant 2 by 1.3%. So, the SNI growth rates due to the scale effect in both periods are well below the economic growth. In addition, the SNI growth rate of variant 2 is well below the growth rate of variant 1.

Composition effect

The next step of the decomposition consists of the inclusion of the changes in the economic structure. Total value added remains unchanged, but the sectoral composition of value added changes. In addition, the total output per sector and the intermediate deliveries between economic sectors change with the decomposition as well. Thus, the economy in terms of total output[8] has the size and composition of time *t*+1, but the emission intensities of economic activities and the abatement technologies of time *t* are maintained. Note that we refer to the emission intensities of total output per sector rather than emission intensities per value added.

The first and second column of Table V.1 in Appendix V shows the sectoral changes in value added and output between 1995 and 2000. The total value added of the production sectors grows by 15.1%, while total output of these sectors increase by 26.2%. The total output has grown at a higher pace than value added, because there has been a sharp increase of intermediate deliveries between sectors. In particular, the use of services in the industrial production has grown sharply, which can be derived by comparing the SAM matrices of 1995 and 2000 in Table III.1 and Table III.4 respectively.

In the calculation of the composition effect for GHG emissions, the emission intensities of time *t* are still applied, while the economy has the structure of the economy of time *t*+1. The third column of Table V.1 in Appendix V shows the change in GHG emissions per sector between 1995 and the economy in 2000 given the emission intensity of output in 1995. While value added of the production sectors increase by 15.1%, total GHG emissions increase by 18.8% given the constant emission intensities per output. Thus the overall GHG emission intensity of output has decreased, because total output has grown at a higher pace than GHG emissions, see Table V.1 in Appendix V. This result indicates that the economy shifts towards more emission-extensive products, although the emissions per unit of value added slightly increased.

The composition effect of GHG emissions is ambiguous. Between 1990 and 1995, the GHG emissions decline by –5.4% due to compositional changes but in the period 1995 –

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[8] The size of an economy is usually measured in terms of value added rather than in terms of total output. Total output is the sum of value added and intermediate deliveries. While the economy in terms of value added grew with 16% in the period 1995–2000, the growth of total output in the same period was more than 25%.

2000, GHG emissions increase by 1.0%, from 286.5 to 289.4 billion kg CO_2 eq., because of compositional changes, see Table 4.4. As mentioned, this increase in GHG emissions is caused by a more than proportional increase of total output of production.

In the period 1990–1995, the change in composition of the economy lowered the emission intensity of value added, and consequently, lowered the burden of economic growth on sustainable income. The SNI variant 1 increased by 1.8% and SNI variant 2 increased by 2.7% (see Table 4.4). In contrast to the previous period, between 1995 and 2000, GHG emissions increase due to the composition effect, and we would expect an increase in the burden of economic growth on sustainable income, that is, a negative effect of composition on SNI. However, the sustainable income level increases due to the composition effect by 4.7% under variant 1, and by 2.5% under variant 2. The simultaneous increase of GHG emissions and the SNI indicators seems counterintuitive. However, the reason for this positive effect in GHG emissions is that the compositional change in the economy is accompanied by a large increase in the volume of output (value added plus intermediates) of economic production sectors. In particular, the volume of output of most economic sectors increased more than proportional with respect to economic growth in the period 1995–2000. In our SNI-AGE model, emissions are associated with the volume of output and not with value added. In terms of output, the economy does show a shift towards more emission-extensive sectors, because GHG emissions intensity of output declines, as can be derived from Table V.1. For this reason, the SNI indicators can increase despite a positive composition effect in GHG emissions. The above makes it clear that a divergence in development between value added and output makes it difficult to interpret the composition effect. Further analysis as well as possible adjustment of the way in which emissions are associated with output is considered as an important subject for future work.

Technique effect

In the third step of our decomposition analysis, we adjust the economic input-output data and the emissions data to account for the change, in every sector, in emission intensity per output or value added. The technique effect considerably contributes to the decrease of GHG emissions in the period 1990–2000. The emission intensities of most economic activities have been lowered, and as a result, the technique effect results in considerable increases in SNI, see Table 4.4. This trend is consistent for the period 1990–2000.

Similar to the compositional effect, the technique effect is not uniform over the various sectors. Some sectors show an increase, other sectors a decrease in emissions per value added.

Figure 4.3 shows the relative change in GHG emissions per VA per sector between 1995 and 2000. In the sector with the largest value added, the commercial services sector, the GHG emissions per value added decrease by 12%. The largest increase in emissions per value added (+50%) is found in the other mining and quarrying sector. This sector accounts for 6% of national income. The transport services sector shows the largest decrease in emissions per value added (–48%), and this sector accounts for 10% in total value added.

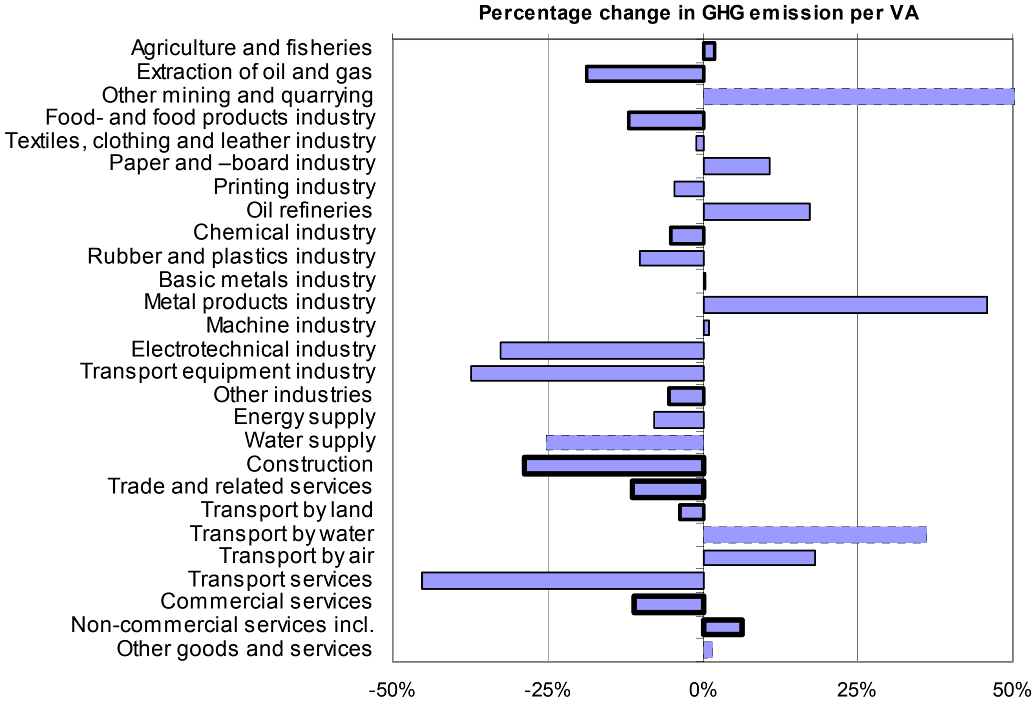

Figure 4.3 Percentual changes in GHG emissions per Value Added for all considered sectors, 1995–2000.

Note: In Figure 4.3, the thickness of the bar borders represent the value added of a sector. The thickest border represents sectors with a VA above average. The next thickest border represents a VA between half times average and average. The normal sized border represents a VA between one eighth and a half time average, while the dotted line represents a VA below one eighth of average VA.

Overall, between 1990 and 1995, the improved technologies lowered the GHG emission level by 7.1%. Consequently, in both variants SNI increased by approximately 8.5% due to the technique effect. In the period 1995–2000, the average emission intensity has decreased by 14.2%. In the period 1995–2000, the technique effect largely compensates the scale effect and the composition effect, so that the GHG emission level of 2000 ends up just above the level of 1995. Due to the large technique effect in GHG emissions in the period 1995–2000, Table 4.4 shows that SNI variant 1 increases by 5.8%, while under variant 2, SNI increases by 15.0%. Since emissions on the margin require a more than proportional abatement effort for an equal reduction, the decrease in emissions due to the technique effect will lead to a more than proportional gain in sustainable income levels. Indeed, except for SNI variant 1 between 1995 and 2000, the relative increase of the technique effect is larger than the decrease of the GHG emissions. From Table 4.4 we can conclude that the technique effect is the most important effect from which both SNI variants have gained in the period 1990–2000.

Abatement effect

Finally, we calculate the abatement effect, which concerns the potential of emission reduction of unused but available abatement technologies. The available abatement technologies are essential for reaching a sustainable income level, and they will affect the right part of Figure 3.1. NNI (in the left part of Figure 3.1) remains unaffected by these changes.

Next to the potential of emission reduction, the implementation of abatement technologies depends on the level of associated abatement costs. The abatement effect reflects the change of the set of unused but available abatement technologies. Dependent on how the set of abatement technologies changes in a period, the abatement effect can be positive or negative. If the abatement effect is positive, higher levels of SNI can be achieved.

To illustrate the mechanism at play, we discuss a number of possible changes in the set of abatement technologies between two periods and the consequences for the abatement effect. Firstly, we consider an example of changing abatement costs and similar reduction potentials of emissions. Suppose that we consider a similar set of abatement technologies for two years. If the potential of emission reduction remains unchanged while the associated costs are reduced, the abatement effect is likely to be positive. Oppositely, if the abatement costs would increase for delivering the same reduction, the abatement effect would have been negative. Secondly, we consider an example of changing potentials of emission reduction and constant total abatement costs. In this case, higher potentials of emission reductions will result in positive abatement effects, while lower potentials of emission reductions will result in negative abatement effects.

In general, if the set of abatement technology changes, its potential of emission reduction and the associated abatement costs change simultaneously. A positive abatement effect can result from an increase in potentials of emission reduction, a decline in the abatement costs, or a combination of both. If the potential of emission reduction decrease and the abatement costs increase, the abatement effect will be negative. In the case of a combination of increasing potentials of emission reduction and increasing abatement costs, or the combination of declining potentials of emission reduction and decreasing abatement costs, the abatement effect is ambiguous.

During the period 1990–2000, GHG emissions were the binding theme. Table 4.4 shows a clear change in trends in the abatement effect during the period 1990–2000. In the first half of the 1990s, the abatement effect was negligible, but in the second half of the 1990s, the abatement effect was substantial, see Table 4.4. Apparently, the set of abatement technologies for the reduction of GHG emission in 1995, in comparison with 1990, was not extended with many new low-cost abatement technologies. In the period 1995–2000, however, the abatement cost curve shifts. New low-cost abatement technologies have become available. As a result, the abatement effect is positive for both SNI variants, 4.3% and 10.2% for variant 1 and 2 respectively. Yet, we have to make a qualification to this result. Part of this abatement effect in the period 1995–2000 is due to the availability, in 2000, of more credible information (specifically on renewable energy sources) rather than to new available technical measures. Still, the calculations suggest opportunities for a delinking of economic growth and environmental pressure.

5. Conclusions

The SNI trend analysis and its decomposition provide us with information on underlying forces that determine the shifts in the (over-)dependence on natural resources of our economy. In this study we have analysed the development of SNI for the Netherlands over the period 1990–2000. It appears that SNI improves substantially from 1990 to 2000. SNI variant 1 increases from 139.8 billion euros in 1990 to 204.6 billion euros in 2000, while SNI variant 2 increases from 94.2 to 141.0 billion euros over the period 1990–2000. Growth rates in sustainable income levels exceed growth rates in national income for the whole period as well as for the sub-periods 1990–1995 and 1995–2000. Over the period 1990–2000, the absolute gap between NNI and SNI declined for SNI variant 1, while the absolute gap between NNI and SNI variant 2 increased. Over the whole period 1990–2000, the enhanced greenhouse effect appears to be the binding environmental constraint that determined most of the developments for the SNI. As measured by the gap between NNI and SNI, the Dutch economy can become less dependent on activities linked to greenhouse gas emissions. Over the period 1990–1995 an *absolute* delinking of economic growth and environmental pressure (i.e. GHG emissions) has taken place, while there was relative delinking in the period 1995–2000. Despite the optimistic results on the upward trends in SNI, the gap between NNI and SNI remains considerable. The key question is of course whether the trend will be sustained in the future.

In order to be able to better interpret the trend in the development of SNI we have decomposed the change in the SNI indicator into four effects. First, in a way of speaking, the scale effect measures the increase in income due to increases in labour and capital productivity, without paying attention to changing (relative) preferences. An increase in the productivity of production factors also increases the income levels that can be maintained under sustainability standards. Yet, in a sustainable economy, the natural resources are valued as essential production factors as well, and the income gain from labour and capital productivity for the sustainable income level falls short of the gains for the standard net national income measure.

Second, the change in the composition of the economy is a powerful element for decreasing actual emissions. Yet, there are limitations to a further change in composition towards emission extensive sectors, and thus, it deprives the economy of part of its opportunities for meeting the sustainability standards in the concomitant sustainable economy. That is, the increase in actual emissions has to be strictly lower than the increase in total economic output. So, the economic restructuring can contribute to an increase in actual emissions, but if this increase is lower than the increase of total output, it leaves more room for opportunities to meet the sustainability standards in the concomitant sustainable economy. Then, the composition effect can be even positive despite the fact that the composition effect on actual emissions is positive as well.

Third, a decrease in the emission intensity of production processes is the most direct way of decreasing actual emissions. Furthermore, since emissions on the margin require a more than proportional abatement effort for reaching a sustainable economy, the decrease in emissions also leads to a more than proportional gain in sustainable income levels. This explains that the magnitude of the increase in the sustainable income levels tends to be higher than the magnitude of the decrease in emission intensity. The exception is SNI variant 1 in the period 1995–2000. In this case the scale effect and composition effect have probably absorbed part of the potential increase in SNI variant 1. Based on the decomposition analysis of the trends in NNI and both SNI variants, we conclude that the fall in actual emission intensities as reflected in the technique effect is the most important effect that has contributed to the increasing SNI throughout the period 1990–2000.

Fourth, development of new cheap abatement options that are not used in the actual situation lead to an increase in the SNI indicator labelled the abatement effect. The abatement effect is partly complementary to the technique effect, since the implementation of emission reduction measures can partly exhaust the set of measures available for further reductions, so that the abatement effect can be (small but) negative. This is the case in the period 1990–1995. In the period 1995–2000, however, the set of emission reduction measures has been enlarged.

The absolute level of SNI for an isolated year is still surrounded by a large range of uncertainty. However, by looking at the trend in development of SNI, the uncertainty seems to be reduced. We note that an extensive sensitivity analysis of the trend results with regards to possible model improvements and/or extensions would be valuable, but would require more research.

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Appendix I. Methodological assumptions

Correcting national income for environmental losses is meant to be a strictly static approach. The SNI calculations are not burdened with other costs than environment-related loss of functions. To arrive at a sustainable economy in the real world, a drastic restructuring and reallocation of economic activities has to take place. This inevitably involves a premature write-off of capital goods (transition or adaptation costs). However, these non-environment-related costs do not enter the SNI. In a way of speaking, it is assumed that the change to a sustainable economy is foreseen in advance, long enough that economic agents are able to integrate this transition in the planning of their investment decisions. By this way of reasoning, it is implicitly assumed that the early announcement enhances the substitution possibilities in the economy. This, in turn, should be expressed by applying medium to long-term substitution elasticities in the model calculations, instead of short-term elasticities, which are common in static modelling. However, long-term substitution elasticities are not readily available for the Dutch economy. As it presently stands, elasticities of a rather short to medium-term nature are applied.

The already mentioned premise that in the calculation of an SNI only environmental losses are considered as relevant corrections also means that influences from the labour market on the SNI, be it positive or negative, should be neglected. According to Hueting, a sustainable economy will certainly not worsen the employment situation. We assume employment neutrality, through an exogenously given, inelastic, labour supply, and clearing markets through an adjusting wage rate.

In addition to correcting national income for the cost of technical and volume measures to meet the sustainability standards, national income should also be corrected for so-called double counting. Double counting refers to the expenditures on compensatory, restoratory and preventive measures to re-establish or maintain environmental functions, sometimes denoted as defensive measures. According to Hueting and many others, these expenditures wrongly enter national income as value added: the earlier loss of environmental functions was not written off, whereas restoration is written up. This line of reasoning can indeed be maintained in case defensive measures are taken in the sphere of consumption, not entering a production process as intermediate input. In our SNI calculations, the cost to reduce dehydration and the clean up of contaminated soils are double counting cases.

For cleaning up soils that are contaminated in the past, it seems fair to adjust past income for the costs, and not to adjust current income. It is not obvious which procedure to follow, and we decided to use an ad-hoc solution. It is assumed that the total cost of soil clean up is borne by the government. This can in all fairness not be charged to one particular year. Therefore, it is assumed that the soil clean-up activities are spread over a 20-years period. Each year, 5% of the total cost for soil clean up is contracted out and entered in the SNI calculations as a yearly deduction of government income. The total clean-up costs are estimated to amount to 185 billion euros in 1990. Due to the fact that new contaminated soils may be discovered in a five-year period, we assume that the total clean up costs (in real terms) remain valid in 1995 and 2000. The reduction cost of dehydration are also assumed to be financed out of, and likewise deducted from, the government budget and amount to 250 million euros (1990 price level) on a yearly basis in the period 1990–2000.

Since sustainable income will be substantially below current income, and prices will substantially change, assumptions have to be made about the economic behaviour of consumers. In the model, the effects of lower overall income levels are approached by the use of different income elasticities for different consumer goods. Demand for agricultural products decreases less than proportional, demand for services decreases more than proportional, and the demand elasticity for manufactured products depends on the stage of income. In this way, consumption is thought of as consisting of necessary goods for subsistence and luxury goods. If income falls, the consumption of necessary goods will remain relatively stable, which is compensated by a more than proportional decrease in the consumption of luxury goods. For each consumption good in the model, an income elasticity is specified.

Moreover, relative price changes will affect consumption patterns, which will become more sustainable. In addition to income substitution effects, the model includes price elasticities. In general, the consumption of environment-intensive goods will decrease, whereas less environment-intensive goods and services will show an increase in relative consumption levels. It is assumed that private consumers have more substitution possibilities than the public consumer (the government), whose demand is determined by public services that have to be supplied.

In line with the neglect of transition costs and employment neutrality, the government is supposed to obey budget neutrality. It is assumed that the government is the owner of the environmental functions, constraining their use to a sustainable level. The use of these functions should be paid for. Emissions to the environment are thus considered as public endowments, and as these emissions are constrained by sustainability standards, the value that is imputed in the context of the modelling exercise entirely accrues to the government. Put differently, the government sells emission permits of which the price is endogenously determined in the model. To guarantee budget neutrality, the revenues from the sale of emission permits are recycled by a linearly homogeneous reduction of taxes. In case revenues from emission permits exceed the government budget, the surplus will be redistributed to private households through a lump sum subsidy.

Finally, we have to explicate the use of prices for income measurement. This is not so much a modelling assumption, as well a matter of presentation. In a statistical calculation of sustainable income, the correction of national income is expressed in market or shadow prices. If, however, SNI calculations are made with the help of an AGE model, relative prices change, i.e. prices of environment-intensive products increase compared to other products. In all figures and tables below, we use the Paasche price indexing. Values are calculated by using prices of the new equilibrium, and prices are scaled such that the value of consumption in the reference case measured in new prices equals the value of consumption at old prices.

Appendix II. Calibration

II.1 Introduction

This section describes how the Sustainable National Income – Applied General Equilibrium (SNI-AGE) model is calibrated. The calibration process consists of two steps. In Section II.2, we first construct a data matrix with economic input output data and emissions data; this data matrix describes the actual situation. Second, we make an inventory of technical measures that are available for the reduction of emissions associated with various environmental themes. These data provide information, which is required for modelling the transformation from the actual economy, where income is measured by the Net National Income (NNI) indicator, to the sustainable economy, where income is measured by the Sustainable National Income (SNI) indicator. Section II.3 deals with the values of the elasticities used in the model. The elasticities represent the reactions of the agents in the model. Section II.4 discusses the methodology underlying the construction of a list of independent technical measures. Section II.5 gives, for each environmental theme, a qualitative overview of the technical measures that have been collected from databases, studies and expert judgments. Finally, all independent technical measures are summarised in the so-called abatement cost curves for 1995 and 2000 presented in Section II.6.

II.2 Constructing the input for the SNI-AGE model

We recall from Verbruggen (2000) that the SNI-AGE model distinguishes 27 different economic sectors. The model specifies 1 agricultural sector, 18 industrial sectors and 8 services sectors. The input data of the SNI-AGE model on the current state of the economy are obtained by aggregating the input-output table and the competitive import table consisting of 105 economic sectors in 1995 and 92 economic sectors in 1990, as provided by Statistics Netherlands (2000).

The input-output table is partly based on the supply table (supplier, product) and the use table (product, user). The supply table describes for each product, which quantities of the product are supplied by different producers to the market, with imports mentioned separately per producer. The use table describes for each product, which quantities of the product are bought on the market by different users, i.e. producers, consumers and export. Multiplying the supply table with the use table would render an input-output table based on the assumption that every user of a product has obtained a quantity of the product composed of quantities supplied by different suppliers in the same proportions. The actual input-output table is based on additional information on actual deliveries from supplying to using sectors. Part of this information, however, is based on ad-hoc assumptions. Therefore, the input-output table offers more information than the supply table and the use table together, while part of this additional information is not as reliable as the supply and use tables.

While very detailed sectoral information is available for calculating the gross national income, the information for calculating a net national income is more limited. Sectoral information about consumption of fixed capital (depreciation) is only available for 15 sectors from the National Accounts (Statistics Netherlands, 1999, page 33). The values for the 27 sectors of the SNI-AGE model are calculated, using the sectoral outputs as the relevant weights.

The sectoral emissions of all considered substances are based on the central database of the Emission Registration (ER) as described by CCDM (2000) and the National Accounting Matrix including Environmental Accounts (NAMEA) from Statistics Netherlands. The emissions part of the NAMEA is largely based on the ER. NAMEA contains 37 sectors, which are aggregated into the 27 sectors of the SNI-AGE model. The ER and NAMEA provide sufficient information for calculating the emissions to air and to water for each substance and each economic sector. Emissions to soil are not fully recorded in the ER and NAMEA and have to be supplemented with data from Statistics Netherlands and some of the data had to be estimated at an ad hoc basis. This is especially the case for the environmental theme eutrophication, for which theme, besides the well-documented agricultural sector, additional information needs to be collected about the waste sector. For more details the reader is referred to De Boer (2002).

Recently, there has been a major revision of the Emission Registration system in the Netherlands (see, for instance, De Boer, 2002). This revision consisted of a new sectoral classification of the Dutch economy according to the standard firm classification of 1993 (SBI1993) and adjustments due to the retrospectively introduced System of National Accounts of 1993 (SNA1993). The resulting time series of emissions at the sectoral level had to be made consistent, which also led to adjustments in the estimated total amount of emissions.[9]

Central to the calculation of a sustainable national income are the sustainability standards that need to be satisfied. These sustainability standards are exogenous to the model calculations done in this study. The standards are described extensively in Verbruggen (2000). Table 2.6 shows for the various environmental themes the initial emissions (base), the sustainability standard and the required reduction for the period 1990–2000.

II.3 Values of elasticities

The reactions of the agents are given by the elasticities in the model. For the households, the elasticities comprise substitution elasticities to identify the rate at which different consumption goods are interchangeable in the satisfaction of needs, the income elasticities to identify the change of the consumption pattern when income decreases, and the trade elasticities to identify the change in trade patterns when domestic prices change. The values for the elasticities, which are based on the *TaxInc* model (Keller 1980, Statistics Netherlands, 1990), are given in Table II.1 to Table II.3. The values of elasticities are similar to the ones used by Hofkes *et al*. (2002).[10]

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[9] As a result the levels of emissions in 1990 as used in the present report differ from those used in Verbruggen (2000). These changes had the largest impact on eutrophication.

[10] We use the same values for the trade elasticities (Armington import and export elasticities) as in Hofkes *et al*. (2002). These values differ from those used in Verbruggen (2000). In Verbruggen (2000), erroneously, the values 4 and 0 were used in variant 1 for the Armington export and import elasticities, respectively.

Table II.1 Consumer income elasticities.

Sector	Name	Consumer income elasticities
Y1	Agriculture and fisheries	0.48
Y2	Extraction of oil and gas	0.38
Y3	Other mining and quarrying	0.38
Y4	Food- and food products industry	0.44
Y5	Textiles, clothing and leather industry	0.88
Y6	Paper and –board industry	0.38
Y7	Printing industry	0.70
Y8	Oil refineries	1.33
Y9	Chemical industry	0.88
Y10	Rubber and plastics industry	1.00
Y11	Basic metals industry	0.59
Y12	Metal products industry	1.10
Y13	Machine industry	1.01
Y14	Electrotechnical industry	1.01
Y15	Transport equipment industry	1.41
Y16	Other industries	1.11
Y17	Energy supply	0.27
Y18	Water supply	0.20
Y19	Construction	1.25
Y20	Trade and related services	1.40
Y21	Transport by land	0.39
Y22	Transport by water	0.39
Y23	Transport by air	0.39
Y24	Transport services	0.39
Y25	Commercial services	0.79
Y26	Non-commercial services	0.76
Y27	Other goods and services	0.00

Table II.2 Consumer substitution elasticities.

	Demand (σ_h^{top})	Food (σ_h^{food})	Transport (σ_h^{trans})	Services (σ_h^{serv})	Other (σ_h^{other})
Private households	0.5	0.8	0.5	0.9	0.5
Government consumer	0	0	0	0	0

Table II.3 Trade elasticities.

Imports & domestic production (σ_{imp}^{Arm})	3
Exports & domestic demand (σ_{exp}^{Arm})	3

For the producers, the elasticities comprise substitution elasticities that govern the possibilities to change the production processes by using less of one input and more of another input. A typical production structure employed in the model is presented in Figure II.1. Capital and labour are combined in a capital-labour composite good, with substitution elasticity σ_2. The values for the elasticities, which are based on the Dutch *TaxInc* model (Keller, 1980; Statistics Netherlands, 1990) and are sector specific, are given in Table II.4. The values for σ_2 range from 0 to 0.9. Intermediates are combined into one composite intermediate good, with substitution elasticity σ_3, the value of which is typically in the same range as σ_2. The capital-labour composite and composite intermediate good are combined to produce the sector specific output good, with elasticity of substitution σ_1, the value of which lies in the range between 0 and 2. Some fraction of sectoral emissions cannot be reduced through technical measures. These unabatable emissions are proportional to output, and enter the nested CES structure at the highest level, at which there are no substitution possibilities. The remaining part of emissions is 'abatable', that is, they decrease if the input of abatement goods is increased. In modelling terms, abatement measures are a substitute for the abatable emissions; the substitution elasticity is denoted by σ_4.

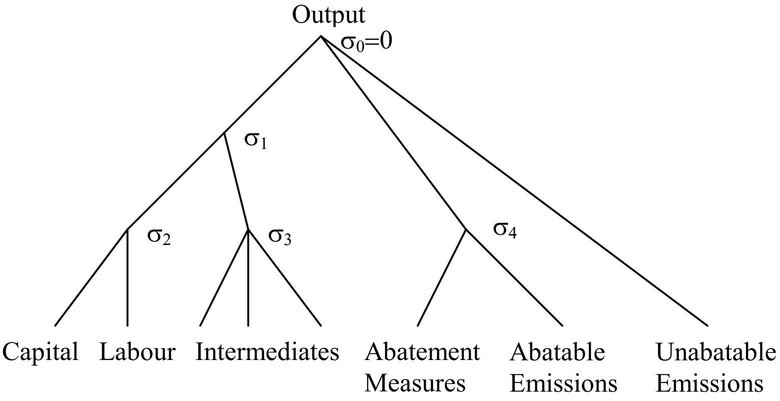

Figure II.1 Nested CES production structure with abatable and non-abatable emissions.[11]

Viewed from another perspective, we can draw the so-called iso-output curve that portrays the trade off between abatement measures and abatable emissions, given a fixed output level (Figure II.2). By definition, the mirror image of the iso-output curve is the abatement cost curve. Abatement costs increase if the emission level has to decrease. The slope of the curve represents the marginal costs of technical options that are open to the agents for reducing their emission levels.

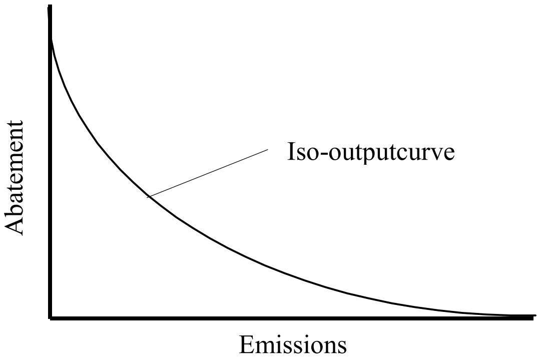

Figure II.2 Iso-output curve: the trade off between abatement and emissions.

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[11] For convenience, in the CES structure, we have not drawn the multiple lines associated with the environmental themes separately. For each environmental theme, a distinction is made between abatable and unabatable emissions, and abatement measures are treated as a substitute for abatable emissions.

The calibration of the substitution elasticity between pollution and abatement is based on the abatement cost curves for the various environmental themes. The abatement cost curves are discussed below.

Table II.4 Producer substitution elasticities.

	Sector Name	Top level (σ_j)	Intermediates (σ_j^{intm})	Value added (σ_j^{prim})
Y1	Agriculture and fisheries	0.4	0.1	0.3
Y2	Extraction of oil and gas	0.9	0.5	0.5
Y3	Other mining and quarrying	2	1.3	0.8
Y4	Food- and food products industry	0.4	0.2	0.2
Y5	Textiles, clothing and leather industry	0.4	0.2	0.2
Y6	Paper and –board industry	0.5	0.2	0.3
Y7	Printing industry	1.4	0.6	0.9
Y8	Oil refineries	0.9	0.5	0.5
Y9	Chemical industry	0.3	0.2	0.1
Y10	Rubber and plastics industry	0.3	0.2	0.1
Y11	Basic metals industry	0	0	0
Y12	Metal products industry	0.7	0.2	0.4
Y13	Machine industry	0.7	0.2	0.4
Y14	Electrotechnical industry	0.6	0.6	0
Y15	Transport equipment industry	0.3	0	0.3
Y16	Other industries	1.2	0.6	0.6
Y17	Energy supply	0.1	0.1	0
Y18	Water supply	0.1	0.1	0
Y19	Construction	1	0.3	0.7
Y20	Trade and related services	1.8	0.7	1.1
Y21	Transport by land	0.7	0.3	0.4
Y22	Transport by water	0.7	0.3	0.4
Y23	Transport by air	0.7	0.3	0.4
Y24	Transport services	0.7	0.3	0.4
Y25	Commercial services	1.5	0.7	0.9
Y26	Non-commercial services	0	0	0
Y27	Other goods and services	0	0	0

II.4 Setting up a list of independent technical measures

Before we describe the technical measures available in 1990, 1995 and 2000, we will discuss the methodology behind the abatement cost curves. In order to construct abatement cost curves, we need to extract a list of independent technical measures from the list of all available technical measures. For this purpose, we need to eliminate interactions between technical measures. Four types of interactions can be found among the measures, namely, mutual exclusiveness of measures, compulsory sequentiality of measures, interaction between environmental themes and substances, and interaction between measures.

First of all, introduction of one measure may make certain other measures inapplicable (mutual exclusiveness). For instance, a fuel switch from coal to gas excludes the measure of coal gasification. As in Hofkes *et al.* (2002), we use a methodology that allows the measure with the lowest cost efficiency to be exploited, if necessary.[12] Consider the case where we have two exclusive measures (M1 and M2), with costs c1 and c2 and effects e1 and e2 respectively. Let e2>e1 and c1/e1<c2/e2, which means that measure 1 is more cost efficient than measure 2, while measure 2 can reduce more than measure 1 (see Figure II.3).

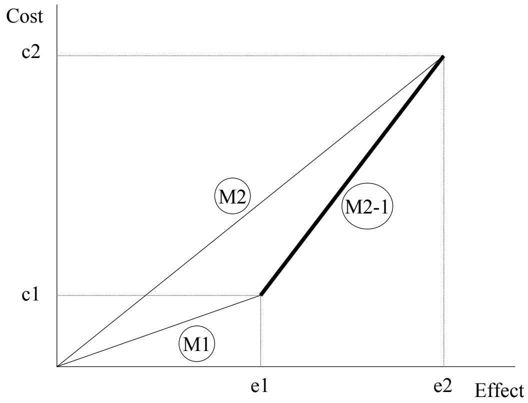

Figure II.3 Construction of a residual measure from two exclusive measures.

Then an alternative measure 'M2-1' (sequential after M1) can be calculated with costs c2–c1 and effects e2–e1. Measure M2-1 cannot be taken before M1 is taken, as the efficiency of M2-1 is, by construction, lower than the efficiency of M2, which is, by assumption, lower than M1's efficiency. In this way we exploit both the cheapest options by including M1 and the maximum attainable emission reduction potential by including M2-1. Note that taking both M1 and M2-1 is equivalent to taking M2.

Sometimes, a measure cannot be taken before another one is introduced (compulsory sequence). For instance, a third stage waste water treatment cannot be realised before a second stage treatment. This does not turn out to be a problem in our set of measures, as it is always the case that when, say, measure 1 should be taken before measure 2, then measure 2 has a lower cost efficiency than measure 1. Hence, we do not need to perform a correction with respect to sequentiality of measures.

It is possible that measures exist which reduce emissions in more than one environmental theme, i.e. interaction between environmental themes occurs. These measures are included in each relevant abatement cost curve in order to maximise the reduction potential per environmental theme. Hence, a single measure can appear in various abatement cost curves when the measure has an impact on multiple environmental themes. This overestimates the total abatement cost. However, in the current set up of the SNI-AGE model it

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[12] For mutual exclusive measures our methodology differs from the methodology in the report by Verbruggen (2000). He suggests that in the case where two measures cannot be taken together, the technical measure with the highest cost efficiency should be included and the other one should be removed from the analysis, irrespective of the reduction potential. This implies that it is possible to underestimate the total reduction potential within an environmental theme.

is not clear how to eliminate this double counting of costs between the abatement cost curves. For the time being we take this for granted.

From calculations with the SNI-AGE model for 1990, 1995 and 2000, it becomes clear that the sustainability standards for the enhanced greenhouse effect and acidification are the most stringent ones. The structure of a sustainable economy is characterised by reductions in the volume of output in such a way that it is no longer necessary to exploit the full technical reduction potential for other environmental themes, for which the sustainability standards are comparatively less stringent. With this knowledge in mind, it is possible to make an ad-hoc decision on which measure to choose when two (or more) measures are mutual exclusive and have interactions between environmental themes. Such a decision has been made in the case of four mutual exclusive technical options on the introduction of reformed petrol into road traffic, which has a joint effect on acidification and dispersion of fine particles to air. Some of these options reduce smog formation, while it leads to an increase of acidification. In this case, we have selected the option, which leads to the highest reduction of acidification.

There are also measures, which can reduce various substances within one environmental theme. This is not a problem, as the environmental themes are constructed in such a way that the amount of reduction can be expressed in the same units for each substance.

For some technical measures the sum of the reduction capacities differs from the reduction capacity when these measures are taken together. This is known as interaction between measures. Introducing a third, mutual exclusive, solves this problem. This mutual exclusive measure consists of the combined reduction potential. Such a combined measure is also known as a measure package.

II.5 Technical measures for 1995 and 2000

This section describes the list of measures for the environmental themes in 1995 and 2000. For a description of the list of measures in the period 1990–1995 we refer to Hofkes *et al.* (2002).

The inventory of measures for 2000 consists of three lists of potential technical measures. First, experts of RIVM have updated the existing list of technical measures for the environmental themes acidification, eutrophication, smog formation and dispersion of fine particles to air. Second, we consulted RIVM experts on the existing list of GHG emissions. They confirm that the 1995 list reported by De Boer (2000a,b) remains valid for 2000, although they argue that the 1995 list misses some GHG emission reduction options related to renewable energy (such as solar energy, wind power etc.). Menkveld (2002) provides estimates of GHG emission reduction and costs for these renewable energy options. Third, the list of technical measures for the environmental theme dispersion of toxic substances to water is still valid for 2000. The information on this theme is derived from recent studies (Van der Woerd *et al.* (2000), Alsema and Nieuwlaar (2001) and Vringer and Hanemaaijer (2000)), but unfortunately, there is no additional information available. For the calculation of the SNI 2000, we update the abatement cost levels with the correction for inflation.

Each technical measure consists of an emission reduction potential and the yearly costs, using a flat interest rate of 5%. The first two lists of technical measures consist only of those technical measures that were already known in 2000 or were available in demo version in 2000. Futuristic measures, which only exist on design tables, are not considered. This definition is broader than the usual definition at the National Institute of Public Health and the Environment (RIVM) where only those measures are considered which are likely to be taken in the near future. The various types of interactions among technical measures are also given in these three lists.

For the purpose of calculating an SNI, we only need to know the technical potential, while it is not necessary to consider the expected market penetration of technical measures. The focus on technical potential is justified as the transition from a NNI to an SNI would involve rigorous changes in the economy, where besides technical measures also volume measures need to be taken in order to satisfy stringent environmental standards (see also Table 2.6).

Below we describe per environmental theme the available technical measures for 1995 and how the list of technical measures are updated for 2000. Basically three different effects play a role. The first effect is that a measure that was available in 1995 has been taken by 2000. In this case the measure is no longer available in 2000 and it can be removed from the list. The second possibility is that a measure that was available in 1995 is still available in 2000. In this case the measure is retained for 2000, but the costs of this measure are increased with the increase in the consumer price index between 1995 and 2000, which amounts to 9.2% (http://statline.cbs.nl). The third effect is that new measures have become available in 2000. In the latter case the new measures are added to the list. Finally, it is noted that, where possible, we refer to existing databases and related literature.

II.5.1 The enhanced greenhouse effect

The enhanced greenhouse effect is caused primarily by the greenhouse gases carbon dioxide (CO_2), methane (CH_4), di-nitrogen oxide (N_2O), freons (chlorofluorocarbons (CFCs), unsaturated[13] chlorofluorocarbons (HCFCs), unsaturated fluorocarbons (HFCs)) and halons. These substances are aggregated using the long-term Global Warming Potentials of the substances as shown in Table II.5. The Global Warming Potentials of HCFCs and HFCs are negligible and they are not mentioned in the table.

Technical measures and costs to reduce CO_2 emissions were taken largely from the ICARUS 4 database which is an extended versions of ICARUS2 (Blok, 1991; Blok *et al.*, 1991), where 1990 is the base year and 2015 the view year. This database consists of about 300 measures ranging from more efficient energy use and co-generation to local solar power systems. Furthermore, the list of technical measures and costs to reduce CO_2 emissions is extended by information from ECN's MARKAL model (Okken, 1991; Okken *et al.*, 1992).

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[13] "Unsaturated" means that *not* all hydrogen (H) atoms in the hydrocarbon are replaced by chloride (C) or fluoride (F).

Table II.5 Equivalences among substances within environmental themes.

Enhanced greenhouse effect	Depletion of the ozone layer		Acidification	Eutrophication		Dispersion of toxic substances to water	
1000 kg CO_2 =	1 kg CFC 11 =		1 acid equivalent =	1 phosphor equivalent =		1 million kg 1,4-dichlorobezene equivalent =	
27.25 kg		CH_4	46 kg	32.8 kg	NO_2	3.6 kg	mercury
7.04 kg		N_2O	32 kg		SO_2	3.4 kg	cadmium
0.68 kg	1.00 kg	CFC 11	17 kg	12.2 kg	NH_3	666.7 kg	lead
0.23 kg	1.22 kg	CFC 12		1.0 kg	P	55.6 kg	zinc
0.48 kg	1.11 kg	CFC 113		10.0 kg	N	3.2 kg	copper
0.17 kg	1.18 kg	CFC 114				0.3 kg	nickel
0.10 kg	2.50 kg	CFC 115				217.4 kg	chromium
1.54 kg	0.20 kg	halon 1211				6.3 kg	arsenic
0.35 kg	0.08 kg	halon 1301				13.0 kg	PAHs

Measures to reduce CH_4 emissions were collected from various sources (see De Boer, 2000a) and comprise changes in the composition of animal fodder; more efficient use of manure; measures in the production and distribution of natural gas; and measures at waste dumps. The measures on changing animal fodder and more efficient management of manure are also effective for reducing N_2O. The measures to reduce CFCs and halons consist largely of replacing them by HCFCs and HFCs (with much lower warming potential) or by other substances.

For 2000, we retain the measures for reducing greenhouse gas emissions from 1995, since there is no additional information. The 1995 list of measures was taken from the prepared ICARUS4 database (Alsema and Nieuwlaar, 2001). This database has not been updated recently. According to the expects of RIVM, the abatement cost curve in 2000 is likely to e similar to the curve in 1995. So, all measures are retained, while the costs are increased by 9.2%; representing the increase in the consumer price index between 1995 and 2000. The measures from ECN's MARKAL model have been removed from the list, because we have explicitly added four renewable energy options to the list (Menkveld, 2002).

II.5.2 Depletion of the ozone layer

The depletion of the ozone layer is primarily caused by emissions of CFCs and halons. These substances are aggregated into the long-term Ozone Depletion Potentials of the substances as shown in Table II.5. Like the enhanced greenhouse effect, this is a climate problem. De Boer (2000b) discusses the inventory of the reduction measures for this environmental theme. All 15 measures entail the replacement of the polluting gas with other substances. Note that in many cases the replacement gases are HCFCs or HFCs. As these gases did not pose an environmental problem in 1990, they are not included in the analysis. However, in reality these replacement gases have non-negligible global warming potentials and small ozone depletion potentials.

As in 1995, the actual emissions in 2000 for the depletion of the ozone layer are already within the sustainability standard. This is caused by the strict ban on sales of ozone emitting appliances. As mentioned in Verbruggen (2000), for technical modelling reasons, ozone emissions are measured as ozone use rather than the actual emissions. For example, the sales of ozone appliances are used to estimate the emissions of ozone. The reason for this is that it is very difficult to obtain data of actual ozone emissions after use, while the data on ozone use are relatively easy to obtain and are more reliable (see also De Boer, 2000b).

II.5.3 Acidification

The substances that cause acidification are nitrous dioxide (NO_2), sulphur dioxide (SO_2) and ammonia (NH_3). The first two are mainly related to the combustion of fossil fuels, the last one mainly to manure application in agriculture. Emissions of the three substances can be aggregated into acid equivalents, using the molecular weights of each substance, as shown in Table II.5. For 1990 the measures to reduce acidification were taken from RIVM's RIM^+ database[14], while for 1995, the availability of measures for abating acidification has been derived from changed Vringer and Hanemaaijer (2000). For 2000 the 1995 list of technical measures to reduce acidification has been updated. For 1995, the list consists of 127 measures, of which 18 remain on the list for 2000. These measures aim at reducing nitrous dioxide (NO_2) in various economic activities ranging from implementing more efficient central heating systems in houses to more energy-efficient energy production. The potentials op emission reduction and the costs of these 18 measures have been revised. The costs are in current prices. In addition, RIVM experts have added 10 new measures to reduce acidification. In particular, the measures aim at reducing nitrous dioxide (NO_2) and sulphur dioxide (SO_2) in transportation and industry, and atand ammonia (NH_3) in agriculture. It should be noted that the new measures are more or less the aggregation of individual measures in different economic sectors.

II.5.4 Eutrophication

The substances that cause eutrophication are phosphorus (P) and nitrogen (N). These mainly stem from agricultural use of fertiliser and manure, but emissions of NH_3 and NO_2 from the environmental theme acidification contribute as well. The substances can be aggregated into phosphor equivalents, where 1 kg phosphorus leads to 10 times more eutrophication than 1 kg nitrogen. The weights of NH_3 and NO_2 are calculated using the molecular weights. Table II.5 shows the resulting weights for each substance. In 1995, the measures to reduce eutrophication, as well as their costs, are taken from RIM^+, and amount to a number of 129 options, of which 115 are also present in the abatement cost curve for acidification.

RIVM experts reviewed the list of measures used for 1995. They argue that 31 measures of the 129 in 1995 are still not implemented. The reduction potentials and the costs of these measures have been adjusted according to the view of the RIVM experts. In addition, 9 new measures are added to the list, including the reduction of NO_x emissions in agriculture and transportation, and measures to reduce P and N emissions in agriculture. Note that 26 of the 40 measures also appear in the abatement cost curve for acidification.

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[14] RIM^+ is the improved version of RIM, a Dutch acronym for Computation and Information system for the Environment. This model contains emission coefficients and emission factors for various economic sectors, as well as technical measures with their costs and their effects on emissions.

II.5.5 Smog (tropospheric ozone) formation

For the abatement cost curve of smog formation (VOC: Volatile Organic Components, in particular hydrocarbons), 19 measures were identified in 2000, while there were and 37 measures in 1995. The experts of RIVM concluded that 36 measures identified in 1995 have been implemented in 2000. In addition, they add 18 new measures to the list for 2000. Most measures apply to the manufacturing sectors or to the transportation sectors.

II.5.6 Dispersion of fine particles to air

Another important source for local air pollution are the emissions of fine particles (PM10) to air. Dellink and Van der Woerd (1997) constructed an abatement cost curve for dispersion of fine particles to air. The curve contains 36 measures, starting with 3 measures that are relatively cheap and are specifically aimed at reducing PM10 emissions. Furthermore, the curve also contains measures that primarily aim at reducing NO_2, but also reduce dispersion of fine particles to air, as a secondary effect.

In 2000, there are 18 measures that can reduce dispersion of fine particles to air; the number of measures in 2000 is half the number of measures in 1995. Four measures of the list in 1995 are still not implemented. There are 10 new options to reduce PM10 in industrial sectors, one option specifically for consumers, and four options for transportation. All other measures are secondary effects of measures for reducing acidification.

II.5.7 Dispersion of toxic substances to water

The environmental theme ‘dispersion of toxic substance to water’ consists of 8 heavy metals and 9 Polycyclic Aromatic Hydrocarbons (PAHs). The substances can be aggregated to “(aquatic eco)toxicity equivalents” using the Aquatic Eco-Toxicity Potentials (AETPs) as shown in Table II.5. Van der Woerd *et al.* (2000) provide 127 independent options to reduce dispersion of toxic substances to water for 1995. According to the RIVM experts, there is no additional or updated information on measures, so the list is maintained for 2000 with two adjustments. Firstly, the total reduction capacity is scaled analogue to the rescaling in 1995, and secondly, the abatement costs are adjusted for inflation.

The total reduction capacity of the list of 127 options to abate dispersion of toxic substances to water expressed in AETP equivalents is higher than the initial emissions in 2000 (as was the case in 1995). This is infeasible, as it can never be the case that more than the total initial emissions are abatable through technical measures. This observation holds for the total sum, but also for each substance. This inconsistency is caused by the fact that the study by Van der Woerd *et al* (2000), considers substantially higher initial emissions than the ones, which we obtained from the ER. To solve this inconsistency, we rescale the reduction effects of all 127 options by a fixed factor.

This factor is the maximum of the reduction-current emission ratio per substance. After comparing the initial emissions with the reduction capacity of each substance, it turns out that in 2000 mercury can be reduced by the highest ratio, namely 9.50. Hence, the reduction capacity of all abatement options has to be reduced by at least this factor, so we set the factor to 9.6. Due to this high factor, 35% of the emission level in 2000 can be reduced by technical measures. In 1995, chromium had the largest ratio, and the factor was set to 4.5. Under this assumption, 65% of the initial emissions can be reduced in 1995.

II.5.8 Dehydration and soil contamination

For dehydration and soil contamination, we have to rely on the cost estimates for 1990, because there is no additional cost effectiveness information available 2000. The cost estimates are surrounded with a substantial amount of uncertainty. For 2000, we correct the 1990 costs estimates for inflation (CPI for 2000 it is 124.4 with 1990 as base year). Table II.6 shows volumes and annual costs (in the current price level) for dehydration and soil contamination in the period 1990–2000. According to the experts of Statistic Netherlands, the number of soil-contaminated sites has decreased slightly, although they argue that this number is highly uncertain. Therefore, we make an estimate of the cleaning up costs of the soil contamination theme. The costs are similar to the costs in 1995 and these costs are increased with price inflation between 1995 and 2000.

Table II.6 Volume and annual costs of dehydration and soil contamination, 1990–2000.

	Phyical volume		Annual cost (in million euros)	
	Dehydration	Soil contamination	Dehydration	Soil contamination
Year				
1990	100%	600.000	250	9.257
1995	100%	598.500	285	10.553
2000	100%	590.000	311	11.524

II.6 Abatement cost curves

For all 9 environmental themes except ozone layer, we have a list of technical measures and for all measures we known the potential of emission reduction and the abatement costs according to the methodology as described in Section II.4. The list of measures is then ordered by the cost-effectiveness, i.e. the ratio of emission reduction over abatement costs. Then for each measure, we determine the cumulative reductions of emissions and the cumulative costs. Based on these two series, we estimate the abatement cost curves of environmental themes for 2000.

Figure II.4 and Figure II.5 present the abatement cost curves for 1995 and 2000 graphically (in current prices). They are based on the collected technical environmental measures as discussed in Section II.5. There are considerable alterations in the abatement cost curves for acidification, eutrophication, smog formation and dispersion of fine particles to air, while the alterations for the enhanced greenhouse effect and dispersion of toxic substances to water are small. In the case of acidification, eutrophication, and smog formation, the abatable emissions through technical measures diminished as well as the associated abatement costs. For enhanced greenhouse effects and dispersion of fine particals to air, the abatable emissions and the abatement costs increased between 1995 and 2000. The abatable emissions of the theme ‘disersion of toxic substances to water’ decreased while the abatement costs increased. Since our focus in this section is on the period 1995–2000, we do not present an abatement cost curve for the depletion of the ozone layer, because the sustainability standard is met for this theme in 1995 and in 2000.

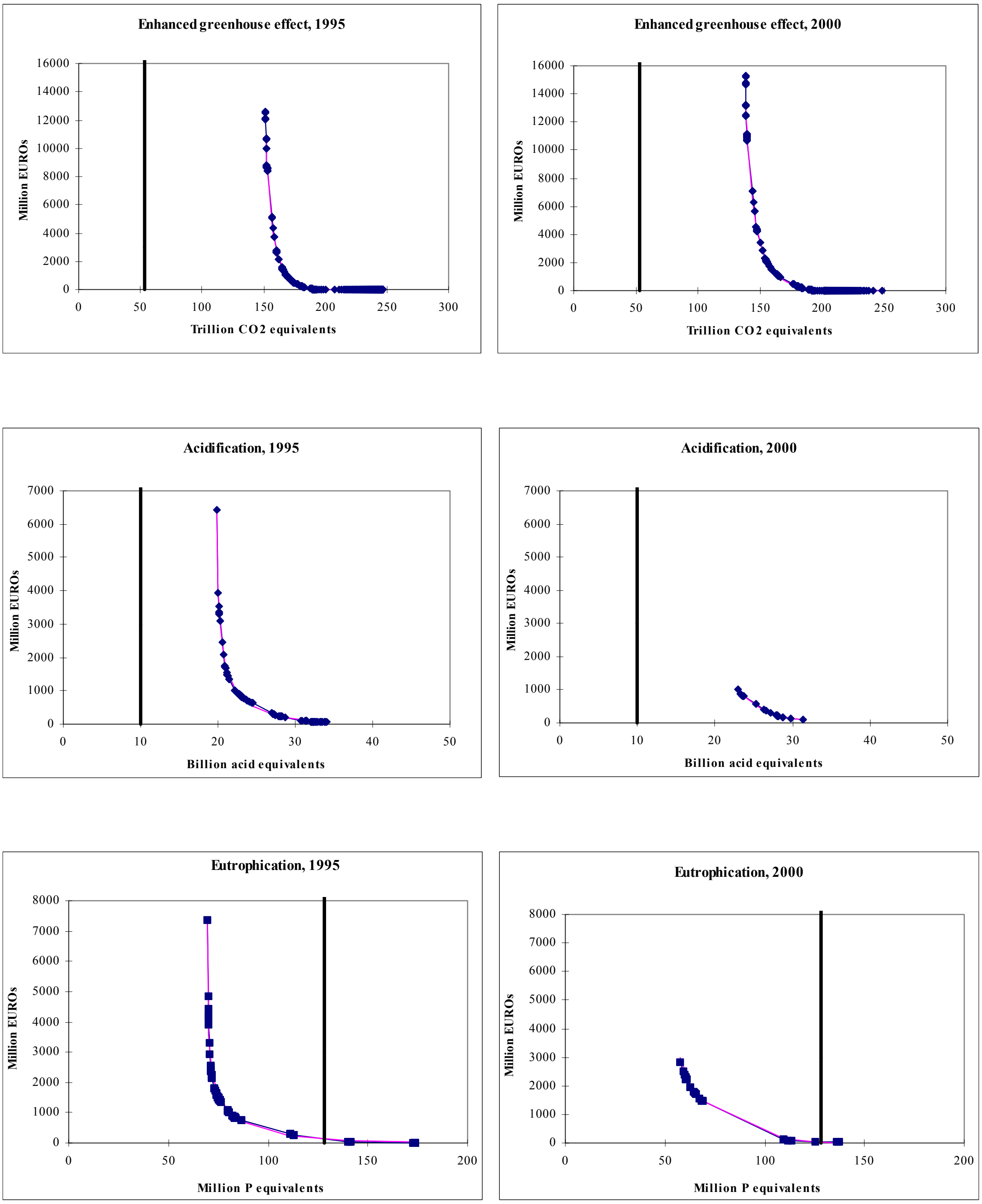

Figure II.4 The annual cumulative abatement cost curves for the enhanced greenhouse effect, acidification and eutrophication in 1995 and 2000 (current prices).

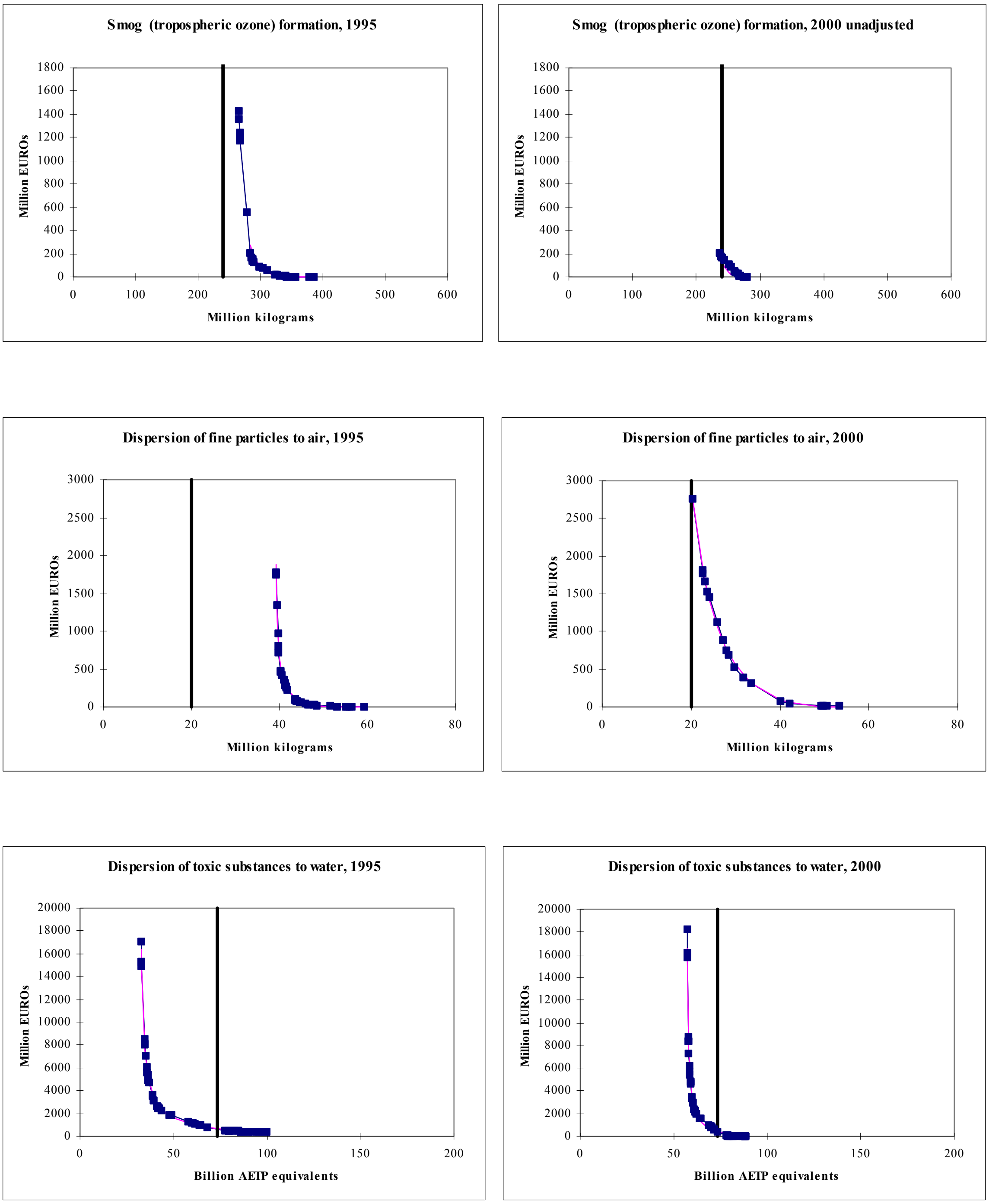

Figure II.5 The annual cumulative abatement cost curves for smog formation, dispersion of fine particles to air and dispersion of toxic substances to water in 1995 and 2000 (current prices).

Table II.7 provides some additional information to Figure II.4 and Figure II.5 in tabular form. It shows per environmental theme the required emission reduction, the abatable emissions through technical measures, the 'remaining emissions' which cannot be abated through technical abatement measures (difference between required emission reduction and technically abatable emissions), and the 'remaining emissions' in percentages from the required reduction. In 2000, the abatable emissions through technical measures do not suffice to achieve the sustainability standards for the themes Enhanced greenhouse effect and Acidification. In the case of Enhanced greenhouse effect the 'remaining emissions' declined from 98.4 units in 1995 to 81.7 in 2000, while for Acidification the 'remaining emissions' increased from 9.8 to 11.2 billion acid equivalents. In 2000, the abatable emissions for Smog formation (52.5 million kilograms) and Fine particals (35.3 million kilograms) exceeded the level of required reduction (40.3 million kg for smog formation and 33.2 million kg for Fine particals), while this was not the case in 1995.

Table II.7 Required reduction and abatable emissions in 1990, 1995 and 2000.

Environmental Theme	Required reduction	Abatable through technical measures	'Remaining emissions' (%)	
1990:				
Greenhouse effect	201.2	87.1	114.1	(56.7%)
Ozone layer depletion	9.8	10.0	–0.2	
Acidification	30.1	25.4	4.8	(15.9%)
Eutrophication	60.9	120.0	–59.1	
Smog formation	287.1	174.8	112.3	(39.1%)
Fine particles	58.6	42.8	15.8	(27.0%)
Dispersion to water	123.3	131.7	–8.4	
Dehydration	100%	100%	0.0	
Soil contamination	600.0	600.0	0.0	
1995:				
Greenhouse effect	193.6	95.2	98.4	(50.8%)
Ozone layer depletion	0.0	-	-	
Acidification	24.0	14.2	9.8	(40.8%)
Eutrophication	45.9	104.3	–58.4	
Smog formation	145.5	119.9	25.5	(17.5%)
Fine particles	39.2	20.0	19.2	(49.0%)
Dispersion to water	26.1	66.6	–40.5	
Dehydration	100%	100%	0.0	
Soil contamination	598.5	598.5	0.0	
2000:				
Greenhouse effect	195.0	113.4	81.7	(41.9%)
Ozone layer depletion	0.0	-	-	
Acidification	21.3	10.2	11.2	(52.3%)
Eutrophication	9.5	81.1	–71.6	
Smog formation	40.3	52.5	–12.1	
Fine particles	33.2	35.3	–2.1	
Dispersion to water	14.8	31.8	–16.9	
Dehydration	90%	90%	0.0	
Soil contamination	590.0	590.0	0.0	

Note: See Table 2.6 for the units of the environmental themes. The units for dehydration and soil contamination are omitted; these problems need to be solved for 100%. The 'remaining emissions' are calculated by subtracting column 3 from column 2.

II.7 Emissions resulting from SNI calculations

Table II.8 Unabatable and abatable emissions for NNI and SNI variant 1 and 2, and the share of abatement technologies applied, 1990–2000.

	Unabatable emissions			Abatable emissions			Share of abatement technologies applied		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
NNI									
Greenhouse effect	167.4	151.7	134.9	87.1	95.2	113.4			
Ozone layer depletion	0.4	–	–	10.0	–	–			
Acidification	14.7	19.8	21.1	25.4	14.2	10.2			
Eutrophication	68.9	69.6	56.4	120.0	104.3	81.1			
Smog formation	352.3	265.6	227.8	174.8	119.9	52.5			
Fine particles	35.8	39.2	17.9	42.8	20.0	35.3			
Dispersion to water	65.1	33.0	56.5	131.7	66.6	31.8			
SNI 1									
Greenhouse effect	49.7	49.7	51.0	3.6	3.7	2.4	89.9%	89.7%	94.5%
Ozone layer depletion	0.2	–	–	0.5	–	–	87.4%		
Acidification	4.1	5.2	6.1	5.9	4.8	3.9	17.7%		
Eutrophication	13.6	12.3	13.6	114.4	22.7	19.0			
Smog formation	193.0	151.6	142.2	47.0	54.4	26.4	53.9%		
Fine particles	13.4	14.5	8.1	6.6	5.5	11.9	58.9%	26.1%	25.2%
Dispersion to water	23.2	15.1	28.5	50.3	48.6	30.6			
SNI 2									
Greenhouse effect	50.2	50.1	51.8	3.1	3.2	1.5	91.3%	91.0%	96.5%
Ozone layer depletion	0.1	–	–	0.5	–	–	81.6%		
Acidification	4.8	6.3	7.4	5.2	3.7	2.6	38.1%	21.5%	28.6%
Eutrophication	22.7	21.3	19.6	105.3	37.2	27.3			
Smog formation	121.2	93.6	94.1	118.8	32.7	17.2			
Fine particles	11.4	12.7	6.6	8.6	7.1	11.7	37.8%		
Dispersion to water	19.3	10.0	19.1	54.2	30.4	19.5			

Note: See Table 2.6 for the units of the environmental themes. The units for dehydration and soil contamination are omitted; these problems need to be solved for 100%.

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Appendix III. SAM of the decomposition of NNI between 1995 and 2000

Table III.1 Social Accounting Matrix for NNI 1995 (billion Euros, 1990 prices).

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	15	–9	–1	–0		–3		–1		0
Industries	–5	118	–33	–38	–0	–3		–38		0
Services	–2	–35	199	–12	–0	–5		–146		0
Capital	–2	–9	–18	55			–26			0
Abatement	–0	–0	–0		0			0		0
Labour	–1	–32	–82		0				115	–0
Profits	–5	–22	–45						72	0
Taxes	–0	–10	–20	–5				–12	48	0
Sum	0	0	0	–0	–0	–12	–26	–198	235	0
Greenhouse effect	47.5	120.0	40.1					39.4		246.9
Ozone layer depletion	0.0	0.1	0.2					0.2		0.3
Acidification	14.6	7.4	8.9					3.2		34.0
Eutrophication	123.9	22.3	8.2					19.7		174.0
Smog formation	8.8	154.1	64.3					158.3		385.5
Fine particles	7.9	22.2	18.2					10.9		59.2
Dispersion to water	0.9	65.1	8.2					25.4		99.6

Note: The first nine rows of the table are expressed in billion Euros, while the sectoral levels of emissions (latter seven rows) are expressed in physical units.

Table III.2 Social Accounting Matrix for NNI 1995 with scale effect (billion Euros, 1990 prices).

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	17	–11	–1	–0		–4		–2		0
Industries	–5	137	–38	–44	0	–4		–44		0
Services	–2	–10	231	–13	–0	–6		–169		0
Capital	–2	–10	–21	64			–30			0
Abatement	–0	–0	–0		0			–0		0
Labour	–2	–37	–95		–0				134	0
Profits	–6	–25	–53						84	–0
Taxes	–0	–12	–23	–6				–14	56	–0
Sum	0	0	0	0	0	–13	–30	–229	273	0
Greenhouse effect	55.1	139.2	46.5					45.7		286.5
Ozone layer depletion	0.0	0.1	0.2					0.0		0.3
Acidification	17.0	8.5	10.3					3.7		39.54
Eutrophication	143.7	25.9	9.5					22.8		201.9
Smog formation	10.2	178.7	74.6					183.7		447.2
Fine particles	10.2	25.7	21.1					12.6		68.7
Dispersion to water	1.0	75.5	9.5					29.4		115.5

Note: The first nine rows of the table are expressed in billion Euros, while the sectoral levels of emissions (latter seven rows) are expressed in physical units.

Table III.3 Social Accounting Matrix for NNI 1995 with scale and composition effect (billion Euros, 1990 prices), 1995.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	15	–8	–1	–0		–4		–2		0
Industries	–4	137	–42	–48	–0	1		–43		0
Services	–2	–46	252	–19	–0	–9		–176		
Capital	–2	–14	–32	73			–24			–0
Abatement	–0	–0	–0		0			–0		0
Labour	–2	–33	–98		–0				133	0
Profits	–4	–21	–48						73	–0
Taxes	–0	–14	–30	–7				–16	67	
Sum	–0	0	0	–0	–0	–12	–24	–237	273	0
Greenhouse effect	46.9	148.0	51.8					42.6		289.4
Ozone layer depletion	0.0	0.1	0.2							0.3
Acidification	14.5	9.8	11.0					3.4		38.7
Eutrophication	122.3	26.0	9.7					21.7		179.7
Smog formation	8.8	192.3	80.5					171.6		453.2
Fine particles	7.8	28.2	22.4					11.8		70.2
Dispersion to water	0.9	78.1	10.0					27.6		116.5

Note: The first nine rows of the table are expressed in billion Euros, while the sectoral levels of emissions (latter seven rows) are expressed in physical units.

Table III.4 Social Accounting Matrix for NNI 2000 (billion Euros, 1990 prices).

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	15	–8	–1	–0		–4		–2		–0
Industries	–4	137	–42	–48	–0	1		–43		0
Services	–2	–46	252	–19	–0	–9		–176		–0
Capital	–2	–14	–32	73			–24			0
Abatement	–0	–0	–0		0			–0		0
Labour	–2	–33	–98		–0				133	0
Profits	–4	–21	–48						73	
Taxes	–0	–14	–30	–7				–16	67	0
Sum	–0	0	0	–0	–0	–12	–24	–237	273	0
Greenhouse effect	47.8	120.7	40.3					39.6		248.3
Ozone layer depletion	0.0	0.0	0.1					0.0		0.1
Acidification	13.5	6.8	8.2					2.9		31.3
Eutrophication	97.9	17.6	6.5					15.5		137.5
Smog formation	6.4	112.0	46.8					115.1		280.3
Fine particles	7.1	20.0	16.4					9.8		53.2
Dispersion to water	0.8	57.8	7.3					22.5		88.3

Note: The first nine rows of the table are expressed in billion Euros, while the sectoral levels of emissions (latter seven rows) are expressed in physical units.

Appendix IV. SAM of SNI variant 1 and 2 for 1990, 1995 and 2000

Table IV.5 Social Accounting Matrix for SNI variant 1 (billion Euros, 1990 prices), 1990.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	5	–9	–0	–0		7		–2		0
Industries	–1	74	–21	–22	–8	22		–43		0
Services	–0	–13	111	–5	–3	–31		–59		0
Capital	–0	–3	–10	28			–15			0
Abatement	–0	–1	–0		13			–11		0
Labour	–0	–14	–39		–1				55	0
Profits	–1	–8	–26						34	–0
Taxes	–0	–1	–2	–1				–2	6	
Greenhouse effect	–2.9	–23.1	–12.1					–15.7	53.8	0
Ozone layer depletion									0.0	0
Acidification	–0.0	–0.0	–0.0					–0.0	0.1	0
Eutrophication	–0.0								0.0	0
Smog formation		–0.1	–0.1					–0.2	0.3	0
Fine particles								–0.0	0.0	0
Dispersion to water		–0.1						–0.1	0.2	
Sum	0	0	0	–0	0	–2	–15	–134	150	1

Table IV.6 Social Accounting Matrix for SNI variant 2 (billion Euros, 1990 prices), 1990.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	21	–17	–0	–1		–0		–3		–0
Industries	–4	73	–10	–10	–11	1		–39		0
Services	–0	–6	41	–2	–2	–2		–29		0
Capital	–1	–2	–3	12			–6			0
Abatement	–1	–1	–0		14			–11		0
Labour	–0	–3	–8		–0				12	
Profits	–2	–6	–8						15	–0
Taxes										
Greenhouse effect	–14.2	–37.4	–11.6					–14.6	77.7	0
Ozone layer depletion										
Acidification	–0.1	–0.0	–0.0					–0.0	0.2	0
Eutrophication	–0.0								0.0	0
Smog formation								–0.0	0.0	0
Fine particles									0.0	0
Dispersion to water		–0.1						–0.1	0.1	0
Sum	0	0	0		–0	–1	–6	–97	105	0

Table IV.7 Social Accounting Matrix for SNI variant 1 (billion Euros, 1990 prices), 1995.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	4	–6	–1	–1		6		–2		0
Industries	–0	83	–25	–23	–9	16		–41		0
Services	–0	–17	135	–6	–3	–31		–78		0
Capital	–0	–4	–12	30			–14			0
Abatement	–0	–1	–1		14			–12		0
Labour	–0	–19	–52		–1				73	–0
Profits	–0	–9	–30						39	
Taxes										
Greenhouse effect	–2.3	–26.6	–14.8					–19.3	63.0	–0.0
Ozone layer depletion		–0.0	–0.0						0.0	0.0
Acidification	–0.0	–0.0	–0.0					–0.0	0.1	0.0
Eutrophication	–0.0							–0.0	0.0	
Smog formation								–0.0	0.0	0.0
Fine particles								–0.0	0.0	0.0
Dispersion to water		–0.0						–0.0	0.1	0.0
Sum	–0	0	0	–0		–8	–14	–152	175	0

Table IV.8 Social Accounting Matrix for SNI variant 2 (billion Euros, 1990 prices), 1995.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	20	–14	–1	–1		–1		–3		0
Industries	–3	77	–12	–10	–13	–2		–37		0
Services	–0	–7	50	–2	–2	–2		–37		0
Capital	–1	–2	–4	12			–6			
Abatement	–1	–2	–1		15			–12		
Labour	–0	–4	–10		–0				14	
Profits	–1	–6	–9						16	–0
Taxes										
Greenhouse effect	–14.0	–42.8	–14.3					–17.3	88.5	0.0
Ozone layer depletion		–0.0	–0.0						0.0	0.0
Acidification	–0.1	–0.0	–0.1					–0.0	0.3	0.0
Eutrophication	–0.0								0.0	0.0
Smog formation								–0.0	0.0	0.0
Fine particles								–0.0	0.0	0.0
Dispersion to water		–0.0						–0.0	0.0	0.0
Sum	0	0	0	0	0	–6	–6	–107	119	0

Table IV.9 Social Accounting Matrix for SNI variant 1 (billion Euros, 1990 prices), 2000.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	4	–6	–1	–1		6		–3		0
Industries	–1	97	–33	–31	–8	21		–45		0
Services	–0	–25	183	–11	–4	–35		–108		0
Capital	–0	–7	–23	45			–15			0
Abatement	–0	–1	–1		13			–11		0
Labour	–0	–20	–66		–2				89	0
Profits	–0	–10	–34						44	–0
Taxes	–0	–5	–12	–2				–7	26	
Greenhouse effect	–2.5	–22.0	–14.0					–17.1	55.6	0
Ozone layer depletion									0.0	0
Acidification	–0.0	–0.0	–0.0					–0.0	0.1	0
Eutrophication	–0.0								0.0	0
Smog formation		–0.1						–0.0	0.0	0
Fine particles	–0.0	–0.0	–0.1					–0.0	0.2	0
Dispersion to water		–0.0						–0.0	0.1	
Sum	0	0	0	–0	0	–9	–15	–192	215	0

Table IV.10 Social Accounting Matrix for SNI variant 2 (billion Euros, 1990 prices), 2000.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	22	–14	–1	–1		–2		–5		–0
Industries	–3	95	–17	–14	–14	–1		–47		0
Services	–0	–10	74	–3	–2	–4		–54		0
Capital	–1	–4	–7	18			–6			0
Abatement	–1	–2	–1		17			–13		0
Labour	–0	–5	–16		–0				22	
Profits	–1	–6	–10						18	–0
Taxes										
Greenhouse effect	–15.9	–52.8	–21.0					–22.5	112.2	0
Ozone layer depletion										
Acidification	–0.2	–0.1	–0.2					–0.1	0.6	0
Eutrophication	–0.0								0.0	0
Smog formation			–0.0					–0.0	0.0	0
Fine particles	–0.0		–0.0						0.0	0
Dispersion to water		–0.0						–0.0	0.0	0
Sum	0	0	0		–0	–6	–6	–141	153	0

Appendix V. Sectoral changes, 1995–2000

Table V.1 Sectoral changes in VA, total output of production, GHG emissions and GHG emission intensity of VA in the period 1995–2000.

	% change in				
	VA	Total output	GHG emission old intensities	GHG emission intensity of output	GHG emission
Primary sector					
Agriculture and fisheries	–12.6%	–1.0%	–1.0%	–10.1%	–11.0%
Secondary sector					
Extraction of oil and gas	–0.3%	17.1%	17.1%	–30.7%	–18.9%
Other mining and quarrying	41.5%	57.8%	57.8%	34.8%	112.7%
Food- and food products industry	2.6%	3.6%	3.6%	–12.8%	–9.6%
Textiles, clothing and leather industry	–5.3%	1.0%	1.0%	–7.3%	–6.3%
Paper and –board industry	–3.0%	10.1%	10.1%	–2.5%	7.4%
Printing industry	8.0%	15.3%	15.3%	–10.7%	3.0%
Oil refineries	–2.2%	68.0%	68.0%	–31.6%	14.8%
Chemical industry	–11.7%	22.5%	22.5%	–31.6%	–16.2%
Rubber and plastics industry	5.1%	15.7%	15.7%	–18.3%	–5.5%
Basic metals industry	–6.8%	10.4%	10.4%	–15.1%	–6.3%
Metal products industry	5.5%	19.5%	19.5%	29.0%	54.1%
Machine industry	14.4%	35.2%	35.2%	–14.5%	15.6%
Electrotechnical industry	0.4%	25.2%	25.2%	–45.9%	–32.2%
Transport equipment industry	18.2%	30.0%	30.0%	–43.1%	–26.0%
Other industries	8.2%	22.2%	22.2%	–16.3%	2.3%
Energy supply	19.6%	19.8%	19.8%	–8.0%	10.2%
Water supply	12.3%	18.0%	18.0%	–29.0%	–16.2%
Construction	20.9%	30.0%	30.0%	–33.9%	–14.0%
Tertiary sector					
Trade and related services	14.5%	25.0%	25.0%	–18.9%	1.4%
Transport by land	13.8%	21.2%	21.2%	–9.6%	9.5%
Transport by water	2.6%	19.4%	19.4%	17.1%	39.9%
Transport by air	16.4%	47.4%	47.4%	–6.8%	37.3%
Transport services	11.4%	26.2%	26.2%	–51.8%	–39.2%
Commercial services	32.4%	46.2%	46.2%	–19.4%	17.8%
Non-commercial services	11.5%	17.1%	17.1%	1.5%	18.8%
Other goods and services	–8.4%	1.3%	1.3%	–8.2%	–7.0%
Primary sector	–12.6%	–1.0%	–0.8%	–10.1%	–11.0%
Secondary sector	6.7%	22.8%	23.3%	–19.1%	–1.2%
Tertiary sector	20.0%	31.1%	28.8%	–8.4%	20.1%
Production sectors (emitting)	15.1%	26.2%	18.8%	–20.2%	0.7%

Note: Changes in VA and total output are corrected for price changes due to inflation. The Column ‘Changes in GHG emissions with old intensities’ measures the change of GHG emissions in the economy of 2000 given the emission intensities of output for 1995 with respect to the initial level of GHG emissions in 1995. Due to different emission intensities of sectors, the total change if the secondary sector, tertiary sector and all productions sectors do not correspond to the change in output.

Appendix VI. Sensitivity Analysis SNI 2000

VI.1 Introduction

In Chapter 4, we presented the results for the Sustainable National Income (SNI) for the Netherlands for 1990 and 1995, for variants 1 and 2, which are different with respect to assumptions on international trade. Though variant 2 seems to come closest to Hueting's intentions, the two variants stand for our hesitation to pinpoint one set of assumptions as the unambiguous choice that represents Hueting's methodology. The two variants are not meant to be exhaustive. There are many other assumptions in the model for which there are reasonable alternatives. We carried out the same sensitivity analysis for the calculations of 2000, similar to the sensitivity analysis for 1990 (c.f Verbruggen, 2000) as well as 1995 (see Hofkes *et al*., 2002). That is, we made two exercises that give an impression of the possible changes in the calculated SNI if we follow different assumptions. The first exercise, presented in Section VI.2, shows the numerical changes in the SNI for 1995 when emissions would be linked to the inputs of intermediates and the specific consumption patterns, instead of being linked to the output of a sector and the aggregate consumption level.

The second exercise, presented in Section VI.3, sketches the changes in the SNI in 2000 that may come about when different sustainability standards are used. For some environmental themes such as the enhanced greenhouse effect, it is still uncertain, from a natural scientist's point of view, which current level of emissions can be considered sustainable. Since the SNI is (by definition) dependent on the sustainability standards, it is thought to be crucial for the user of the SNI figures to have a basic understanding of the sensitivity of results vis-à-vis uncertainties in the sustainability standards.

In Section VI.4, we turn to a more general examination of our model. In general, applied general equilibrium (AGE) models are used to calculate economy-wide consequences of specific environmental policies, for example energy taxes or carbon emission taxes. In this report, we apply our AGE model for a different purpose, namely for calculating an SNI, which does not reflect an environmental policy, as it is a green national income measure. Nonetheless, the model has a general structure comparable with other AGE models and should be capable of calculating the costs of specific environmental policies. Thereupon, we examined the model's behaviour when using it for that purpose, and we compare our results with results in the literature. We choose to calculate the costs, measured in loss of income, of a greenhouse gas emission tax that aims at reducing greenhouse gas emissions by 50%.

Finally, Section VI.5 provides conclusion about the outcome of the sensitivity analysis on basic assumptions in the SNI model.

VI.2 Reallocating emissions: numerical results

Emissions can be linked to the inputs of intermediates and the specific consumption patterns, instead of being linked to the output of a sector and the aggregate consumption level, with the help of an econometric approximation as described in Verbruggen (2000).

Table VI.1 shows for four environmental themes the resulting reallocation of emissions. This table shows, for instance, that greenhouse gas emissions attributed to Oil refineries increases most, and that emissions that first were attributed to the Chemical industry are decreased, since they can be attributed to the intermediate deliveries from the Oil refineries.

Table VI.1 Absolute changes in the sectoral allocation of emissions when emissions are attributed to intermediate deliveries and consumption patterns, 2000.

	Greenhouse effect	Smog Formation
Units	MtC equivalents	kt
Agriculture	–2.4	–2.1
Oil and gas extraction	11.7	–0.4
Other mining	–0.1	–0.1
Food-related industry	10.6	16.3
Textile- and leather industry	2.9	–0.2
Paper and –board industry	–0.3	–0.2
Printing industry	–0.2	0.0
Oil refineries	29.8	0.1
Chemical industry	–9.6	–0.4
Rubber and plastics industry	–0.1	–0.1
Basic metals industry	–0.3	–0.1
Metal products industry	–0.3	–0.1
Machine industry	0.0	–0.3
Electrotechnical industry	–0.4	–0.3
Transport equipment industry	0.0	7.4
Other industries	–0.8	–0.3
Energy supply	–3.2	0.0
Water supply	0.1	–0.1
Construction	–1.0	–0.5
Trade and related	–4.6	–4.3
Transport by land	–4.0	5.8
Transport by water	2.5	0.2
Transport by air	–2.2	–0.6
Transport services	–0.4	–0.4
Commercial services	–3.7	–0.9
Non-commercial services	–2.2	–2.0
Other goods and services	–0.2	3.2
Subsistence consumer	–9.1	7.4
Private consumer	–13.0	–27.1
Ratio of reallocated emissions (R_e)	0.46	0.29

Note: There are no significant changes in emissions for depletion of the ozone layer, acidification, euthrophication and dispersion to water.

After having reallocated part of the emissions as described above, we are able to recalculate the SNI values for the two variants presented in Chapter 4. Table VI.2 shows the results.

Table VI.2 Changes in SNI in 1995 and 2000 (price level 1990) due to reallocation of emissions.

	NNI	SNI (billions Euros/year)		Income, per cent decrease relative to BAU	
		variant 1	variant2	variant 1	variant 2
1995:					
Results of Chapter 4	235.4	163.8	107.2	30.4%	54.5%
Results after reallocating emissions	235.4	182.3	112.4	22.6%	52.3%
2000:					
Results of Chapter 4	273.1	204.6	141.0	25.1%	48.4%
Results after reallocating emissions	273.1	220.1	150.4	19.4%	45.0%

The effects of the reallocation of emissions are substantial. Under variant 1, with constant relative prices on the world market, the reallocation of emissions increases income by 21 billion Euros. Compared to the reference 'business as usual', the decrease in income moves from a 30% decline to a 23% decline. Under variant 2, with constant shares of exports and imports, the effect is smaller. Now, reallocated emissions increases income by 6 billion Euros; compared to the reference 'business as usual', income moves from a 54% decline to a 52% decline.

There is no simple explanation for the increase in income that is reached by reallocating emissions. Our analysis points to an increased flexibility of the economy to cope with sustainability standards, as the main cause for the increase in sustainable income. An analysis of the distribution of emissions over the economy shows that the distribution becomes more skewed (uneven) after the reallocation of emissions. Emissions are reallocated towards the sectors that were already pollution intensive, and away from sectors that were already pollution extensive. As a result, the economy can be more discriminating in its choice of sectors that shrink when the economy has to meet the sustainability standards. This argument also explains why the increase in sustainable income is more pronounced under variant 1 then under variant 2. In Chapter 4, we have already seen that under variant 2, there are fewer opportunities for the economy to decrease economic activity in specific polluting sectors, and thus, a more skewed distribution of emissions has no big impact.

We also look at the sectoral effects in 2000. Since the impact of the emission reallocation is the highest for variant 1, we focus on the sectoral changes within this variant. Figure VI.1 shows the changes in sectoral output levels that are caused by the reallocation of emissions.

We can see from Figure VI.1 that the reallocation of emissions leads to a decrease in output in three sectors, namely Extraction of oil and gas (sector 2): 0.5 per cent point, Textiles, Clothing and Leather industry (sector 5): 5.8 per cent point, and Energy distribution (sector 17): 1.0 per cent point. Here, 'per cent points' are expressed as percentages of the BAU output level. The decrease in output for Extraction of oil and gas is rather small compared to increased allocation of greenhouse gases to this sector. Intuitively, we would expect a larger impact for the sector Oil refineries, which has the highest increase in greenhouse gas emissions after reallocating emissions (see Table VI.1). However, most sectoral output levels increase. Notably, three sectors increase their total income by more than 50 per cent point, namely Chemical industry (sector 9), Basic Metal industry (sector 11), and other goods and services (sector 27).

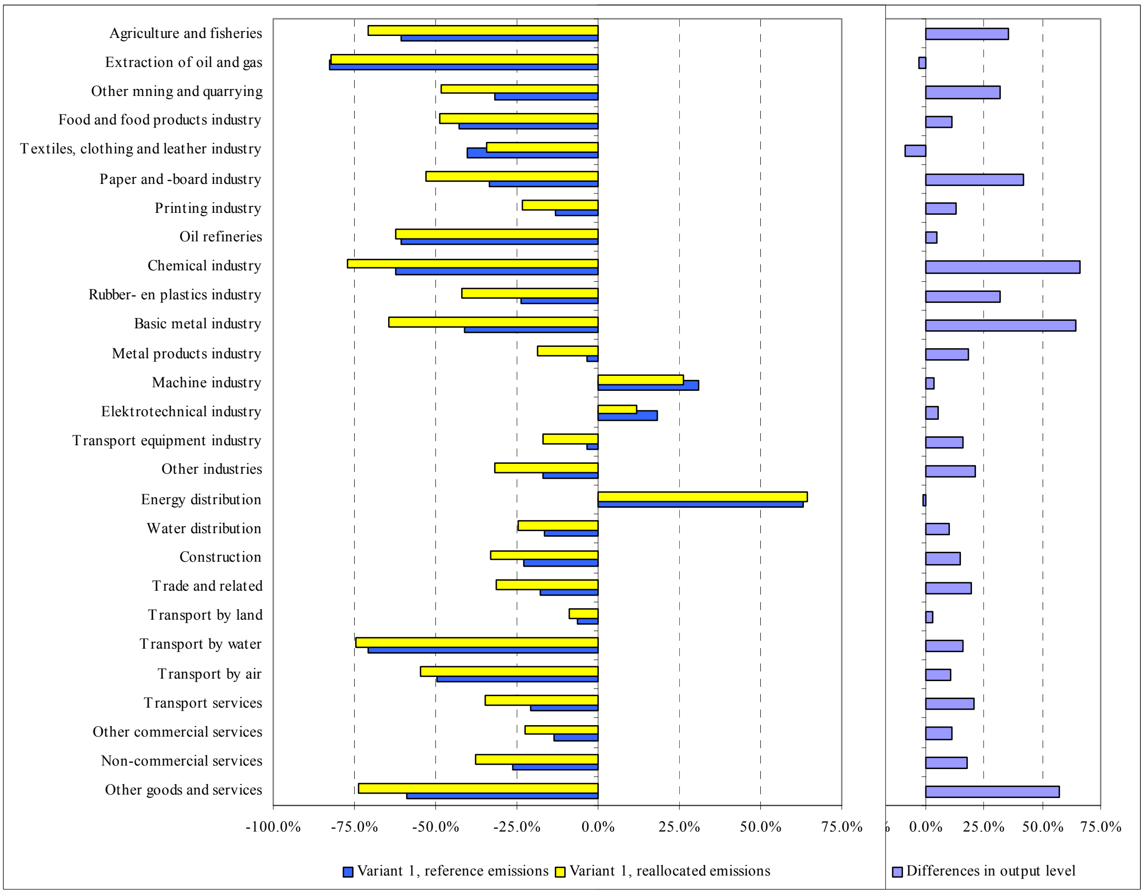

Figure VI.1 Sectoral output in variant 1 with reference emissions and with reallocated emissions, presented as per cent points (percentages of BAU levels) in 2000.

VI.3 Assessing the impacts of different sustainability standards

The second exercise is meant to give an impression of the dependence of the SNI on the sustainability standards. For some environmental themes such as the enhanced greenhouse effect, it is still uncertain, from a natural scientist's point of view, which current level of emissions can be considered sustainable. To have a basic understanding of the implications of this uncertainty, we have calculated the SNI levels for different sustainability standards that were weaker and stronger than the standards used in Chapter 4, respectively. Table VI.3 shows the results for variants 1 and 2.

From Table VI.3, we see that, under variant 2, the SNI in 2000 increases by 12.4 billion Euros, or 4.7 per cent points, if the quantity of allowed emission units is increased by 10%. Relative to its own level, the SNI increases by 8.8%. The SNI-level seems to be almost proportional to the level of emissions allowed under the sustainability standards. This almost linear relation also applies to the case where the environmental standard is decreased. The reason we think this proportionality holds for variant 2 is that, at the sustainable state, the economy has used most of its flexible options to achieve the required emission reductions. The only option left to reduce emissions even further is by applying a uniform reduction of all economic production activities.

Table VI.3 Changes in SNI (price level 1990) due to small changes in the sustainability standards.

	NNI	SNI (billions Euros/year)		Income, per cent decrease relative to NNI	
		variant 1	variant2	variant 1	variant 2
1995:					
Allowed emissions +10%	235.4	171.1	117.3	27.3%	50.2%
Results of Chapter 4	235.4	163.8	107.2	30.4%	54.5%
Allowed emissions –10%	235.4	155.6	96.8	33.9%	58.9%
2000:					
Allowed emissions +10%	273.1	211.4	153.4	22.6%	43.8%
Results of Chapter 4	273.1	204.6	141.0	25.0%	48.5%
Allowed emissions –10%	273.1	196.8	128.1	28.0%	53.1%

Variant 1, however, tells a different story. Table VI.3 shows for variant 1 that the SNI in 2000 increases by 6.8 billion Euros, or 2.4 per cent points, if the quantity of allowed emission units is increased by 10%. Relative to its own level, the SNI increases by 3.3%. The explanation is that, apparently, more substitution possibilities are still open and no uniform reduction of economic activities is required.

The results of this excercise for the SNI indicators in 2000 largely correspond to the findings for 1995 (Hofkes *et al*., 2002). The relationship between sustainbility standards and SNI is almost linear in particular for variant 2, and the relative changes in SNI variant 2 are substantially larger than for SNI variant 1.

VI.4 An additional exercise: reducing GHG emissions by 50%

This section is used for a more general examination of the SNI-AGE model. AGE models have often been used to calculate economy-wide consequences of specific environmental policies, for example energy taxes or carbon emission taxes. Here, we examine the behaviour of the model when using it for that purpose. Furthermore, we compare our results with typical results in the literature. We choose to calculate the costs, measured in loss of income, of a greenhouse gas emission tax that aims at reducing greenhouse gas emissions by 50%. Though this aim represents a rather stringent environmental policy, comparable calculations have been carried out in the literature, because of the understood urgency of the enhanced greenhouse effect.

Similar to the calculations for the SNI, we have two basic variants, one with constant relative prices on the world market, and the other world market prices change proportionally to domestic prices. Table VI.4 presents the results.

Table VI.4 Income effects of a 50% GHG emission reduction, under different assumptions.

	NNI	SNI (billions Euros/year) variant 1	variant2	Income decrease (%) variant 1	variant 2
1995:					
50% GHG emission reduction	235.4	226.1	220.9	4.1%	6.3%
Idem, reallocated emissions	235.4	226.1	222.2	4.1%	5.7%
2000:					
50% GHG emission reduction	273.1	251.0	245.9	8.2%	10.0%
Idem, reallocated emissions	273.1	251.6	247.0	8.0%	9.7%

In 2000, the calculated costs of a 50% GHG emission reduction do not differ too much between the various assumptions. Using the basic emission data, costs amount to 8.2% or 10.0%, dependent on whether world market prices remain unchanged, or change proportionally with prices in the domestic market, respectively. If emissions are reallocated as described in Table VI.1, the costs are slightly lower, and amount for 8.0% in variant 1 and 9.7% in variant 2. The range of costs in 2000 from 8 to 10% is substantially higher than the range of costs in 1995, as shown by Table VI.4. In addition, our range of costs for 2000 is higher than the range found in the literature. Boer *et al.* (1991a, 1991b) give an overview of AGE models that are used for this purpose, and find a decrease of income ranging from 1 to 4.5%. One explanation of finding a higher range of costs is the higher level of GHG emission in 2000 with respect to the level in 1995. Consequently, more measures are necessary to achieve the objective of halving GHG emissions.

We can also use this scenario exercise to study the sectoral effects of a greenhouse gas policy. Furthermore, we will also use the reallocated emission data of Table VI.1 so that the exercise will help us to get a basic feeling about the impact of the distribution of emissions over sectors. Figure VI.2 gives the sectoral effects, for variant 1, that is, when world market prices are unaffected. Sectoral changes are diverse. The Transport by water sector decreases by more 60%. For other sectors, a stringent GHG emission reduction policy even leads to growth in production, such as Metal product industry, Machine industry, Electrotechnical Industry and Energy distribution. Comparing the calculated effects based on the initial emission data and the reallocated emission data, the figure supports the credibility of the reallocation procedure. Without emission reallocation, the output of the Oil refineries sector decreases by less then 20%, while many other sectors show a much sharper decrease. Having emissions reallocated, the Oil refineries sector and the Extraction of Oil and gas sector are hit sharply, showing a decline when emissions are reallocated.

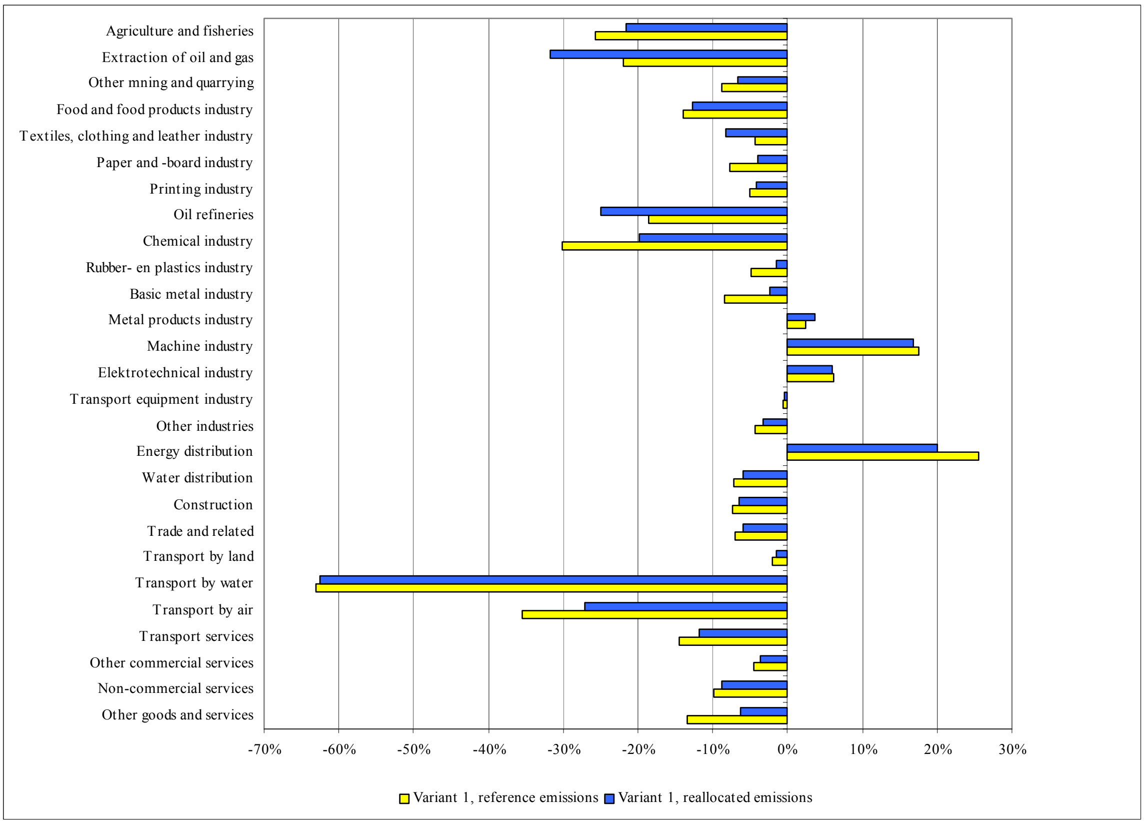

Figure VI.2 Sectoral effects on output under a 50% GHG emission reduction; comparison between reference emission data and reallocated emissions data.

VI.5 Conclusions

The main conclusion of this appendix is that the reallocation of emissions to intermediate deliveries may lead to a substantially higher sustainable national income level. We simulated the linking of emissions to inputs by reallocating emissions. Under variant 1, where world market prices are unaffected, the income reduction (as compared to the BAU allocation) changes from 25% to 20%. Under variant 2, where world market prices change proportionally to domestic prices, the income reduction changes from 48% to 45%. These findings correspond to the results for 1995 as presented in Hofkes *et al*. (2002). We have to be careful in interpreting the numerical results, though, for at least two reasons. First, the reallocation of emissions is based on an econometric approximation that does not explain the pollution flows. Second, in the results of the calculations of the SNI, the enhanced greenhouse effect is the critical theme. When another environmental theme would be critical, we could expect a different result, because for other themes we found a lower share of emissions that could be attributed to intermediate deliveries.

As for the relation between sustainability standards and the calculated SNI-level, we found an almost linear relation between allowed emissions and the SNI-level under variant 2. Under this variant, it seems that the major option left to further reduce emissions consists of a nearly uniform reduction of all economic production activities. The other way around, we can also say that any allowed increase of emissions will lead to an almost uniform increase in economic activities. Uncertainty regarding the sustainable level of emissions, based on the natural scientific analysis of the processes at play, thereby directly translate into an almost proportional uncertainty regarding the sustainable income level. For variant 1, the same conclusion holds though the sensitivity of sustainable income with respect to sustainability standards is less.

Finally, we have also used the model for a more standard policy analysis, as opposed to the SNI-calculations presented in Chapter 4. Though we have not gone into the details, we note that the results of this exercise are in line with the results found in the literature.

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