Sustainable National Income: A Trend Analysis for the Netherlands for 1990 - 1995

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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) and Gerlagh *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 so 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 in time rather than considering the level of SNI of 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 for the period 1990 - 1995. 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 (1991) who apply a decomposition analysis to interpret the empirical evidence in their influential study of the potential effects of NAFTA on the environment.

In Section 2, we give a brief history of the background of the model and of the starting point for the analysis of this paper. 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) and Verbruggen *et al.* (2001). Section 3 presents a description of the decomposition analysis. In Section 4, we present the numerical results. Finally, Section 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 fabricates 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.

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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.

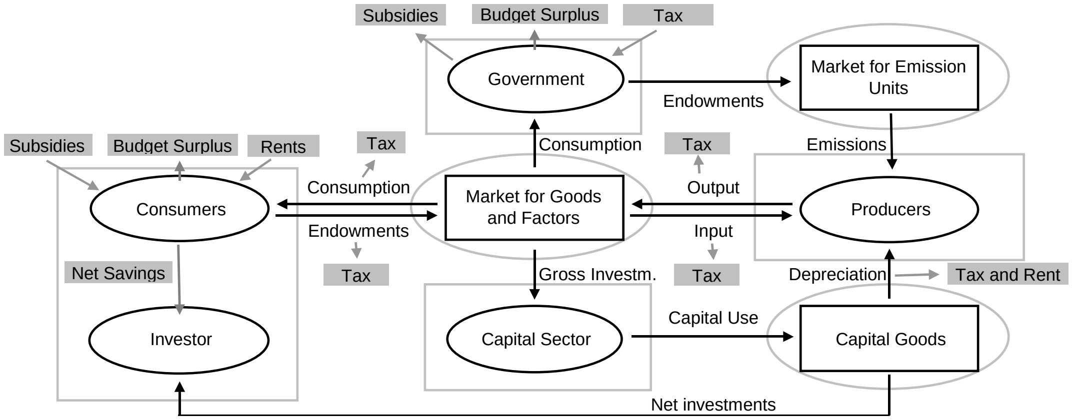

Figure 2.1 Overview of SNI-AGE model.

Demand and Supply

Demand and supply meet on the markets for goods and factors. The private consumers supply endowments (labour) that are used as inputs by the producers. The producers supply output of produced goods, which balances consumption by the private and public consumer and inputs for gross investments. Part of these investments reflects the depreciation of the capital stock, the remaining part, net investments, is used to sustain economic growth in the next period. The figure also shows the market for emission units, supplied by the government in an amount that is consistent with the sustainability standards. Hence, the revenues from the sale of emission units enter the government budget.

Government

The government levies taxes on consumption (VAT), the supply of endowments (labor 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 a 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 a 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. 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 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 and 1995 using historical data for the Netherlands for these years, provided by Statistics Netherlands (2000). The main data source is the

NAMEA accounting system (Keuning 1993), which captures both the economic and environmental accounts. 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).

To get a feeling for what the economy looks like, we present the condensed Social Accounting Matrices (SAMs) for these years in Table 2.1 and Table 2.2. 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. More then half thereof, 9.5 billion euros, accounts for the value of intermediate deliveries by other sectors. The remaining 7.5 million euros is value added.

Net National Income (NNI) at (current) market prices amounts to 213 billion Euros in 1990, growing to 268 billion Euros in 1995. As the Consumer Price Index has risen by 14% over the period, income has grown by 10.4% between 1990 and 1995, or 2.0% annually. The share of the agricultural sector decreases between 1990 and 1995 from about 4 per cent of NNI (8 billion euros divided by 213 billion euros) to about 3 per cent of NNI (8 billion euros divided by 268 billion euros). The share of industries in value added decreases from about 29 per cent to about 27 per cent, while the services share in value added increases form about 61 to 63 per cent. Gross investments amount to 56 and 63 billion Euros respectively, about half of which is for maintenance; net investments amount to 29 and 30 billion Euros respectively. Capital goods are mainly produced by industry. Both in 1990 and 1995, 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.

Table 2.1 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
Labor	-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 2.2 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
Labor	-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

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. For all these themes, data have been collected on actual emission/pollution levels[3] 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 1995 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 2.3 presents 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

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[3] 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.

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 1995.

From the table we can learn that the required reductions considerably decrease for most themes between 1990 and 1995. However, it is still the case that only part of the required reductions can be realized through technical measures. The remainder of the reduction has to be realized through a restructuring of the economy. Greenhouse gases are a case in point. Only about 90 bln kg of the emission reduction required can be realized through technical measures. Furthermore, it is to be noted that the actual emissions (base) of greenhouse gases decrease between 1990 and 1995. This effect is mainly due to the decreasing contribution of CFCs and halons (from 16.8 CO_2 equivalents in 1990 to 1.3 CO_2 equivalents in 1995). CO_2 emissions on the other hand increase from 183.0 CO_2 equivalents in 1990 to 194.5 CO_2 equivalents in 1995 (see also Table II.5 for the equivalences between the different substances).

Table 2.3 Base emissions and sustainability standards for the environmental themes in 1990 and 1995.

Environmental Theme	Units	Base	Sustainability Standard	Required Reduction (%)	
1990:					
Greenhouse effect	Billion kg. CO_2 equivalents	254.5	53.3	201.2	(79.1%)
Ozone layer depletion	Million kg. CFC11 equivalents	10.4	0.6	9.8	(94.2%)
Acidification	Billion acid equivalents	40.1	10.0	30.1	(75.1%)
Eutrophication	Million P-equivalents	188.9	128.0	60.9	(32.3%)
Smog formation	Million kilograms	527.1	240.0	287.1	(54.5%)
Fine particles	Million kilograms	78.6	20.0	58.6	(74.6%)
Dispersion to water	Billion AETP-equivalents	196.8	73.5	123.3	(62.7%)
Dehydration	Percentage affected area	100.0	0	100.0	(100.0%)
Soil contamination	Thousands contaminated sites	600.0	0	600.0	(100.0%)
1995:					
Greenhouse effect	Billion kg. CO_2 equivalents	246.9	53.3	193.6	(78.4%)
Ozone layer depletion	Million kg. CFC11 equivalents	0.3	0.6	0.0	(0.0%)
Acidification	Billion acid equivalents	34.0	10.0	24.0	(70.6%)
Eutrophication	Million P-equivalents	173.9	128.0	45.9	(26.4%)
Smog formation	Million kilograms	385.5	240.0	145.5	(37.7%)
Fine particles	Million kilograms	59.2	20.0	39.2	(66.2%)
Dispersion to water	Billion AETP-equivalents	99.6	73.5	26.1	(26.2%)
Dehydration	Percentage affected area	100.0	0	100.0	(100.0%)
Soil contamination	Thousands contaminated sites	598.5	0	598.5	(100.0%)

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

3. Decomposition Analysis

3.1 Methodology

As already mentioned in Section 2, the approach we use to correct National Income for environmental losses is meant to be a purely static one. 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.[4]

In the present analysis we are interested in the development of SNI between 1990 and 1995. For both years, we have calculated a SNI indicator, denoted by SNI1990 and SNI1995, 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 used technologies, 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 (1991) 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, since the sustainability standards do not change between 1990 and 1995, a decomposition of 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. The scheme of our decomposition analysis is presented in Figure 3.1.

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[4] 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.

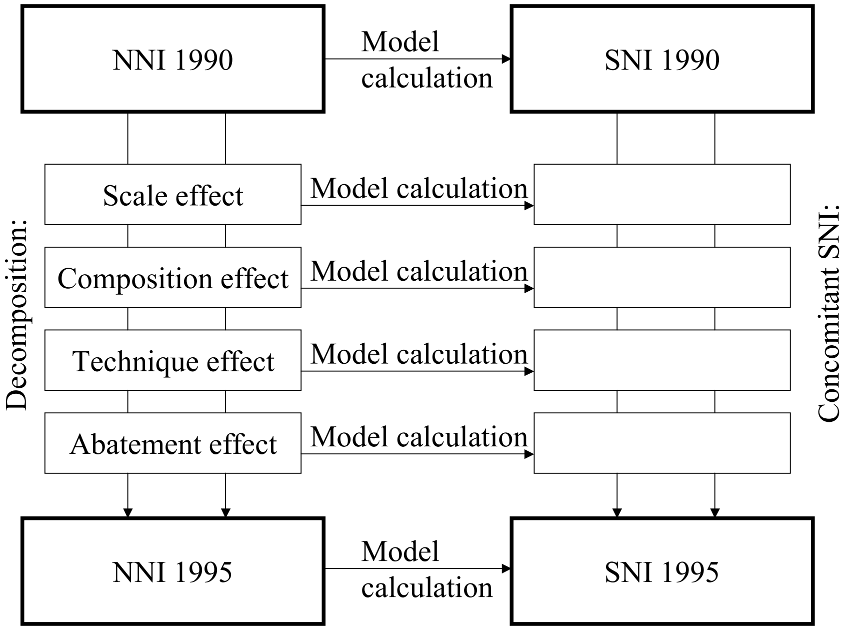

Figure 3.1 Decomposition scheme.

Going from left to right in the figure represents the (standard) calculation of a SNI. Going from top to down represents the trend analysis, moving from 1990 to 1995. Starting from the reference economy in 1990, a 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 separate years, 1990 and 1995. The trend analysis for 1990 - 1995 consists of a decomposition of the changes in the reference economy, i.e. we move from BaU 1990 (upper left) to BaU 1995 (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 a 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 1990 and 1995.

4. Numerical Results: A trend analysis for 1990–1995

4.1 Calculation of a SNI for 1990 and 1995

Table 4.1 presents the macro-economic results of the two SNI variants for 1990 and 1995. The social accounting matrixes, underlying the table, are given in Appendix III. 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 increase relatively much 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.

Table 4.1 shows how NNI can be divided up in three different ways. First, national income is partitioned by income source: labour, capital, income from taxes, and income from the sale of emission permits. This break up corresponds to the various rows in the lower half of the SAM. Second, national income is partitioned along the different sectors contributing to the value added. This break up corresponds to the various columns at the left half of the SAM. The row entry ‘other’ in Table 4.1 corresponds to the capital and abatement sector, and to taxes and emission permits paid for directly by consumers. Third, national income is partitioned into different expenditure categories: private and public consumption, net investments, and the trade balance. This break up corresponds to the various columns in the right half of the social accounting matrix (SAM). The first two divisions of SNI have to be corrected for double counting, which describes that part of value added that the government spends on the reduction of dehydration and soil clean up.

It appears that the extent to which SNI drops is quite significantly determined by the specification of international trade. SNI variant 1 (with constant relative world market prices) ranges from 34% below national income in the base situation in 1990 to 30% below national income in the base situation in 1995. SNI variant 2 (with world market prices changing proportionally to domestic prices) ranges from -56% in 1990 to –54% in 1995.

At this point it should be noted that, at least for variant 1, the results reported in this study differ from those reported in Verbruggen (2000). For variant 2 the calculated SNI is the same as reported in Verbruggen (2000). For variant 1, however, SNI improves as compared to Verbruggen (2000), which implies a much larger difference between the two variants in the present study. This difference is mainly due to the different trade elasticities used (see also Appendix II.3). As the two variants now correctly represent two more or less extreme assumptions with respect to international trade (possibility to shift part of the environmental problems to abroad by import and export substitution, versus no possibilities for import or export substitution), the results for the two variants in the present study can be interpreted as constituting an interval within which an SNI will probably fall. We will come back to this interpretation of the two variants at the end of Section 4.

Table 4.1 Macro economic results for SNI 1990 and 1995 (billion Euros, 1990 prices).

Variant 1	NNI1990	SNI1990		NNI1995	SNI1995	
National Income	**213.0**	**139.8**	**(-34%)**	**235.4**	**163.8**	**(-30%)**
Labour	107.6	55.2	(-49%)	115.3	72.6	(-37%)
Capital	68.9	34.3	(-50%)	72.0	38.9	(-46%)
Income from Taxes	36.5	6.2	(-83%)	48.2	0.0	(-100%)
Emission permits	0.0	54.5		0.0	63.3	
Double counting	0.0	-10.4		0.0	-11.0	
National Income	**213.0**	**139.8**	**(-34%)**	**235.4**	**163.8**	**(-30%)**
Agricultural Production	7.6	3.5	(-54%)	6.4	2.7	(-58%)
Industrial Production	61.8	47.1	(-24%)	64.2	54.6	(-15%)
Services Production	128.9	79.3	(-38%)	147.1	96.6	(-34%)
Other VA	14.8	20.3	(37%)	17.7	20.9	(18%)
Double counting	0.0	-10.4		0.0	-11.0	
National Income	**213.0**	**139.8**	**(-34%)**	**235.4**	**163.8**	**(-30%)**
Private households consumption	124.6	96.2	(-23%)	153.2	118.8	(-22%)
Government consumption	56.8	27.4	(-52%)	44.5	22.7	(-49%)
Net investments	29.2	14.5	(-50%)	26.1	14.1	(-46%)
Trade Balance	2.3	1.6	(-33%)	11.6	8.3	(-29%)
Exports	*102.9*	*70.9*	*(-31%)*	*112.2*	*88.8*	*(-21%)*
Imports	*-100.5*	*-69.3*	*(-31%)*	*-100.7*	*-80.5*	*(-20%)*
Variant 2	NNI1990	SNI1990		NNI1995	SNI1995	
National Income	**213.0**	**94.2**	**(-56%)**	**235.4**	**107.2**	**(-54%)**
Labour	107.6	11.7	(-89%)	115.3	13.8	(-88%)
Capital	68.9	15.1	(-78%)	72.0	16.1	(-78%)
Income from Taxes	36.5	0.0	(-100%)	48.2	0.0	(-100%)
Emission permits	0.0	78.1		0.0	88.9	
Double counting	0.0	-10.7		0.0	-11.6	
National Income	**213.0**	**94.2**	**(-56%)**	**235.4**	**107.2**	**(-54%)**
Agricultural Production	7.6	16.0	(111%)	6.4	15.6	(145%)
Industrial Production	61.8	46.7	(-24%)	64.2	52.7	(-18%)
Services Production	128.9	27.2	(-79%)	147.1	32.8	(-78%)
Other VA	14.8	14.9	(1%)	17.7	17.7	(-0%)
Double counting	0.0	-10.7		0.0	-11.6	
National Income	**213.0**	**94.2**	**(-56%)**	**235.4**	**107.2**	**(-54%)**
Private households consumption	124.6	72.3	(-42%)	153.2	84.7	(-45%)
Government consumption	56.8	14.4	(-75%)	44.5	11.1	(-75%)
Net investments	29.2	6.4	(-78%)	26.1	5.8	(-78%)
Trade Balance	2.3	1.1	(-53%)	11.6	5.6	(-51%)
Exports	*102.9*	*25.6*	*(-75%)*	*112.2*	*51.1*	*(-54%)*
Imports	*-100.5*	*-24.5*	*(-76%)*	*-100.7*	*-45.5*	*(-55%)*

Note: The 1995 values are corrected for inflation between 1990 and 1995 of 14%.

A common finding for both variants and both years is that the sustainable economy shows drastic compositional changes. This is particularly due to the imputed prices for emission permits. The consumption of private households decreases substantially in both variants in both years, indicating that the sustainability policy not only affects the composition of the economy, but also the overall level of activity. The drop in private consumption is however smaller than the drop in national income, as the private households have some possibility to redirect their expenditures to less environment-intensive products. The decrease in government consumption is larger than for the private households, even though the assumption is made that the relative decrease in the size of the government is equal to the relative decrease in the consumption of private households. The larger decrease for the government is caused by the changes in relative prices, which affect the government (with its large demand share of services) differently from the private households.

It appears that under both variants SNI slightly improves from 1990 to 1995. In other words the decrease in national income necessary to obtain a sustainable economy decreases slightly between 1990 and 1995. To give a interpretation of the trend in the development of SNI between 1990 and 1995 we apply in section 4.2 the decomposition analysis as described in Section 3.

4.2 A trend decomposition for 1990 - 1995

In this section, we decompose the calculated changes in the SNI presented in the previous section into a scale effect, a composition effect, an technique effect, and an abatement effect, according to the methodology presented in Section 3.1. A summary of the decomposition is presented in Table 4.2 and Table 4.3. The first table presents the classic decomposition approach; it describes changes in national income, related to the four decomposition effects, and the changes in GHG emissions. That is, it describes income and emissions in the left half of the flow diagram in Figure 3.1. The second table describes changes in sustainable income associated therewith. That is, it describes the concomitant sustainable income levels for the two variants SNI1 and SNI2, 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 4.2 Decomposition of changes in NNI (billion Euros, 1990 prices), and GHG emissions (billion kg. CO_2 equivalents).

	NNI	(% change)	GHG emissions	(% change)
1990	213.0		254.5	
Scale effect	235.4	(+10.4%)	281.0	(+10.4%)
Composition effect	235.4		265.8	(-5.4%)
Technique effect	235.4		246.9	(-7.1%)
Abatement effect	235.4		246.9	
1995 (relative to 1990)	235.4	(+10.4%)	246.9	(-3.0%)

Table 4.3 Decomposition of changes in SNI1 and SNI2 (billion Euros, 1990 prices).

	SNI1	(%change)	SNI2	(%change)
1990	139.8		94.2	
Scale effect	148.7	(+6.4%)	96.6	(+2.6%)
Composition effect	151.3	(+1.8%)	99.2	(+2.7%)
Technique effect	164.1	(+8.4%)	107.8	(+8.6%)
Abatement effect	163.9	(–0.1%)	107.4	(–0.3%)
1995 (relative to 1990)	163.8	(+17.2%)	107.2	(+13.9%)

The tables show that, whereas net national income has grown by 10.4%, in a five years period, GHG emissions have decreased by 3.0%, and sustainable national income has increased by 17.2% and 13.9%, 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. First, we convert the reference SAM for 1990 (as discussed in Section 2) to 1995 prices and subsequently we extend this SAM to include the levels of emissions associated to each theme. Table 4.4 presents the resulting SAM for 1990.

Table 4.4 Reference Social Accounting Matrix extended with levels of emissions (billion Euros, 1990 prices), 1990.

	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
Labor	-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
Greenhouse effect	50.9	126.3	39.2					38.1		254.5
Ozone layer depletion	0.1	7.4	2.8					0.2		10.4
Acidification	16.9	10.1	9.2					4.1		40.2
Eutrophication	131.3	30.9	9.3					20.8		192.3
Smog formation	9.9	216.7	96.1					204.3		527.1
Fine particles	7.7	37.4	20.4					13.1		78.6
Dispersion to water	0.9	137.3	9.3					49.2		196.8

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.

As the first step of the trend analysis, we calculate the second row of Table 4.2 and blow up the economy by 10.4%, such that net national income, which amounted to 213 billion Euros in 1990 (in 1990 prices), reaches the same level as in 1995, that is, 235.4 billion Euros, at 1990 prices. The resulting SAM is presented in Table 4.5. We maintain all characteristics such as the sectoral composition of the economy. So, emissions are increased proportionally.

Table 4.5 Reference Social Accounting Matrix extended with levels of emissions and scale effect (billion Euros, 1990 prices), 1990.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	19	-14	-1	-0		-2		-2		0
Industries	-6	129	-33	-45	-0	6		-51		0
Services	-2	-37	194	-12	-0	-7		-136		0
Capital	-3	-9	-18	62			-32			0
Abatement	-0	-0	-0		1			-0		0
Labor	-2	-36	-82		-0				119	0
Profits	-6	-24	-46						76	-0
Taxes	-0	-9	-15	-5				-11	40	-0
Sum	0	0	0	0	0	-3	-32	-200	235	0
Greenhouse effect	56.2	139.4	43.3					42.0		281.0
Ozone layer depletion	0.1	8.1	3.1					0.2		11.5
Acidification	18.7	11.1	10.1					4.5		44.4
Eutrophication	144.9	34.1	10.3					22.9		212.3
Smog formation	11.0	239.3	106.1					225.5		581.9
Fine particles	8.5	41.3	22.5					14.5		86.8
Dispersion to water	1.0	151.6	10.3					54.4		217.3

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.

For the resulting economy, we reiterate the procedure for calculating the two variants of the SNI indicator. The results are presented in the second row of Table 4.3. Table 4.3. shows that, whereas NNI grows by 10.4% from 213 billion Euros to 235.4 billion Euros, the SNI level only grows by 6.4%, from 139.8 billion Euros to 148.7 billion Euros, in variant 1. 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. The sustainability standard does not change as the economy grows, and thus, the amount of required emission reductions increases from 201.2 billion kg CO_2 equivalents (254.5 minus 53.3) to 227.7 billion kg CO_2 equivalents (281 minus 53.3). The abatement of the additional 26.5 billion kg requires a more than proportional effort. As a result, the relative increase in the calculated SNI indicator, after the scale effect, is well below the relative increase in net national income. The same argument applies to variant 2, even more strongly since in this variant, it is more difficult to meet the sustainability standards. Thus, the scale effect leads to an increase of sustainable income in variant 2 by only 2.6%, from 94.2 billion Euros to 96.6 billion Euros.

The next step of the decomposition consists of the inclusion of the changes in the economic structure. In this step, we consider an economy that has the same size and composition as the 1995 economy, but for which production technologies are based on the 1990 data, insofar emission are concerned. More precisely, all sectors are assumed to have the same emission intensity, and the same abatement technologies available as in 1990.

Dependent on whether the economy specialises in relatively more environment intensive sectors or in relatively less environment intensive sectors, emissions will increase or decrease, respectively, due to the composition effect. Figure 4.1 gives a picture of the combined scale and composition effect. It portrays the relation between the intensity of GHG emissions per value added and the relative change in value added, per sector, from 1990 to 1995. The size of a circle represents the value added of the corresponding sector in 1990. For example, circle A represents the sector 'commercial services', which has a very low emission intensity of only 0.08 kgC per euro value added, compared to an average of 1.1 kgC/euro. This sector is among the largest sectors of the economy (a large circle in the figure), and its growth rate was among the highest. In absolute terms, this sector contributes most to income growth over the period 1990-1995. The increase in the share of services is a major explanation of the delinking of growth and GHG emissions. Circle B represents the 'oil refineries'. This sector is relative polluting, 3.5 kgC/euro, and grows at a rate of 34.3%, contributing to an increased emission intensity. Circle C represents the 'energy supply' sector. This sector has the highest emission intensity of all sectors, 13.9 kgC/euro, and it grows at the rate of 9.4%, almost matching the average of 10.2%. Circle D represents the agricultural sector. It has a high emission intensity of 6.7 kgC/euro, and its value added decreases by 15.8%, thereby contributing to a more sustainable composition of the economy.

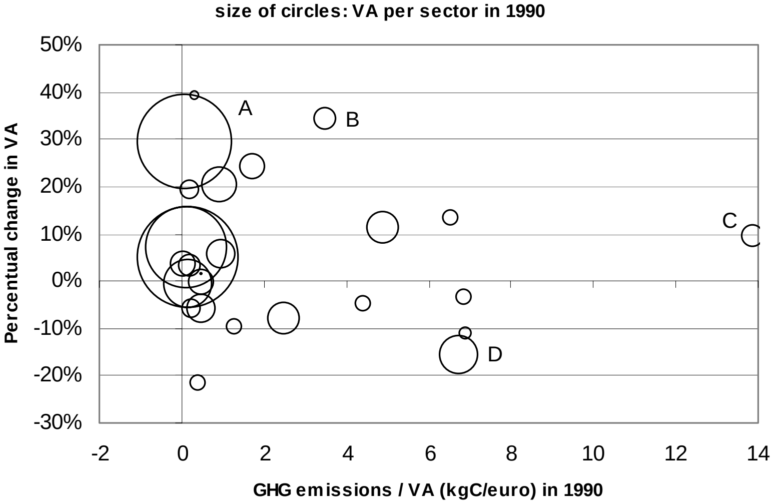

Figure 4.1 Change in Value Added (VA) per GHG emission intensity between 1990 and 1995.

Note: Sector "other goods and services" (29 kgC/euro, 233% growth) has been excluded from this graph to facilitate the presentation. This sector is very small as it contributes 0.02% to total value added.

Though the figure does not present a very strong relationship, a relationship between the intensity of GHG emissions per value added and the relative change in value added is, nonetheless, present. The sectors that grow most have a low emission intensity (the circles at the left-upper corner), whereas emission intensive sectors grow less then the average of 10.4%.

Whereas Figure 4.1 may be considered not conclusive for providing evidence for a shift to less emission intensive sectors, the data presented in Table 4.2 and Table 4.6 are. Due to changes in the composition of the economy, GHG emissions decrease by 5.4%, from 281 to 265.8 billion kg CO_2 eq., relative to a uniform blow up of the economy. Stated in other words, thanks to the change in composition, the economic growth of 10.4% is accompanied by a moderate increase in GHG emissions of 4.4% from 254.5 to 265.8 billion kg.

Table 4.6 Reference Social Accounting Matrix extended with levels of emissions, scale effect and composition effect (billion Euros, 1990 prices), 1990.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	15	-9	-1	-0		-3		-1		0
Industries	-5	117	-33	-38	-0	-3		-38		0
Services	-2	-35	199	-12	-0	-5		-145		
Capital	-2	-9	-18	55			-26			-0
Abatement	-0	-0	-0		0			-0		0
Labor	-1	-32	-82		-0				115	0
Profits	-5	-22	-45						72	-0
Taxes	-0	-10	-20	-5				-12	48	
Sum	-0	0	0	-0	-0	-12	-26	-197	235	0
Greenhouse effect	43.9	130.5	44.2					47.2		265.8
Ozone layer depletion	0.1	7.2	3.1					0.2		10.7
Acidification	14.6	10.3	9.9					5.0		39.8
Eutrophication	113.2	31.4	10.2					25.7		180.7
Smog formation	8.6	212.4	109.2					253.4		583.5
Fine particles	6.6	36.6	22.2					16.3		81.8
Dispersion to water	0.8	137.6	9.5					61.1		209.0

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 4.3 shows that, indeed, the change in composition of the economy lowers the burden of economic growth on sustainable income. The sustainable income level increases due to the composition effect by 1.8% under variant 1, from 148.7 to 151.3 billion Euros, and by 2.7% under variant 2, from 96.6 to 99.2 billion Euros.

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 emission intensity per value added. That is, in this step all data, except for available abatement technologies (that are not used in the actual situation), coincide with the 1995 data. Figure 4.2 shows the relative change in GHG emissions per VA per sector. It can be seen from this figure that for most sectors the GHG emission intensity decreases between 1990 and 1995. The two largest sectors, commercial and non-commercial services, show a decrease in emissions per value added. The largest increase in emissions per value added is found in the printing sector, but this sector accounts for less then 2% of national income.

Agric
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Other m
Food- and foo
Textiles, clothing a
Paper a

Rubber a
Ba
Meta

Table 4.7 Reference Social Accounting Matrix extended with levels of emissions, scale effect, composition effect and emission effect (billion Euros, 1990 prices), 1990.

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	15	-9	-1	-0		-3		-1		-0
Industries	-5	117	-33	-38	-0	-3		-38		0
Services	-2	-35	199	-12	-0	-5		-145		-0
Capital	-2	-9	-18	55			-26			0
Abatement	-0	-0	-0		1			-0		0
Labor	-1	-32	-82		-0				115	0
Profits	-5	-22	-45						72	
Taxes	-0	-10	-20	-5				-12	48	0
Sum	-0	0	0	-0	-0	-12	-26	-197	235	0
Greenhouse effect	47.5	120.0	40.1					39.4		246.9
Ozone layer depletion	0.0	0.1	0.2					0.0		0.3
Acidification	14.6	7.4	8.9					3.2		34.1
Eutrophication	123.9	22.3	8.1					19.7		173.9
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 ten rows of the table are expressed in billion Euros, while the sectoral levels of emissions are expressed in physical units.

Finally, we come to the fourth step of the decomposition, which we labelled the abatement effect. This effect concerns available abatement technologies that are not used in the actual situation. Thus, the reference scenario (in the left part of Figure 3.1) remains unaffected by these changes. The available abatement technologies are essential for reaching a sustainable income level, and they will affect the right part of Figure 3.1. If new abatement technologies have been developed, the sustainable income will rise, *i.e.* a positive technology effect. On the other hand, if abatement technologies available in 1990 are actually implemented in 1995, then they cannot be used for a second time, that is, the set of abatement technologies that is available for further emission reduction is partly exhausted, and the abatement effect will be negative. This seems to be the case in the period 1990-1995, as Table 4.3 shows that the abatement effect is negative for both SNI1 and SNI2, –0.1% and –0.3%, respectively. In Appendix II, the abatement cost curves are shown for both 1990 and 1995 (Figure II.4 and Figure II.5). For most of the environmental themes, changes are so small that they are almost invisible. In Table II.6, we see that for all but one of the themes, the amount of abatable emissions has decreased over time.

We can now summarise our trend analysis. Economic growth has accounted for an income growth of 22.4 billion euros (1990 prices), that is, 10.4% over the period 1990-1995, or 2.0% annually. Over the same period, GHG emissions have decreased by 3.0%. There has been an absolute delinking of economic growth and GHG emissions. A reduction in emission intensities of most production processes explains more than half of the relative decrease in emissions; a change in the composition of the economy explains the remainder. This decomposition is presented in Table 4.2.

Sustainable national income has increased by 24 billion euros (17.2%) in variant 1 and by 13 billion euros (13.9%) in variant 2, respectively. Figure 4.3 presents the overall picture of income and sustainable income. The figure is presented such that variant 1 stands for an upper bound of sustainable income, and variant 2 stands for a lower bound. So the shaded area depicts a measure of uncertainty in sustainable income. The growth rate of sustainable national income exceeds the growth rate of net national income, in both variants, and thus, this finding is robust. Sustainable national income has improved relative to net national income. At the same time, the gap between the variants increased.

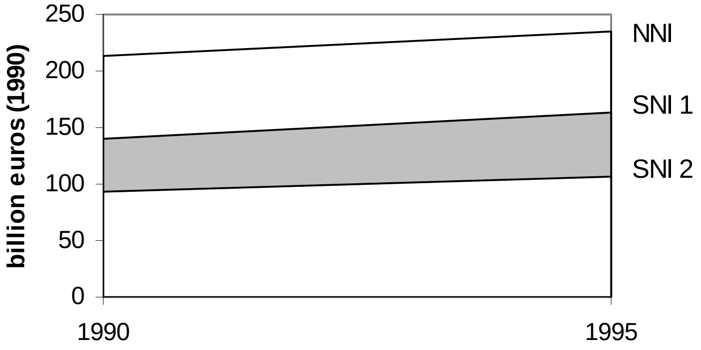

Figure 4.3 Trend in NNI, SNI1 and SNI2.

5. Conclusions

In this study we have analysed the trend in the development of SNI for the Netherlands for the period 1990 – 1995. It appears that SNI improves substantially from 1990 to 1995. Growth rates in sustainable income levels exceed growth rates in national income. Both in 1990 and 1995 the enhanced greenhouse effect appears to be the binding environmental constraint. Over the period 1990-1995 an absolute delinking of economic growth and environmental pressure has taken place. The key question is of course whether this trend has been sustained over the period 1995-2001 and 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 size of the composition effect on sustainable income is well below the size of the composition effect on actual emissions. 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 sustainable income levels increase by about 8.5%, more than the decrease in emissions of 7.5% attributed to the emission intensity effect. Yet, the implementation of emission reduction measures partly exhausts the set of measures available for further reductions, and thus, the technique effect is (small but) negative.

The results sustain our expectation that by looking at the trend in development of SNI rather than considering the absolute level of SNI for an isolated year reduces the sensitivity of the results. The formal proof of this proposition of reduced sensitivity would require an extensive sensitivity analysis on the trend results. The same holds with respect to the question of desirable and attainable model improvements and/or extensions. New insights to this question 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 a 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, labor 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 (estimated to amount to 408 billion guilders) 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 reduction cost of dehydration are also assumed to be financed out of, and likewise deducted from, the government budget and amount to 550 million guilders on a yearly basis.

Since sustainable income will be substantially below current income, and prices will substantially change, assumptions have to be made about the economic behavior 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 1990 and 1995 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

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Table II.1 Cons

Sector	Name
Y1	Agriculture
Y2	Extraction c
Y3	Other minin
Y4	Food- and f
Y5	Textiles, clo
Y6	Paper and –
Y7	Printing ind
Y8	Oil refinerie
Y9	Chemical in
Y10	Rubber and

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.

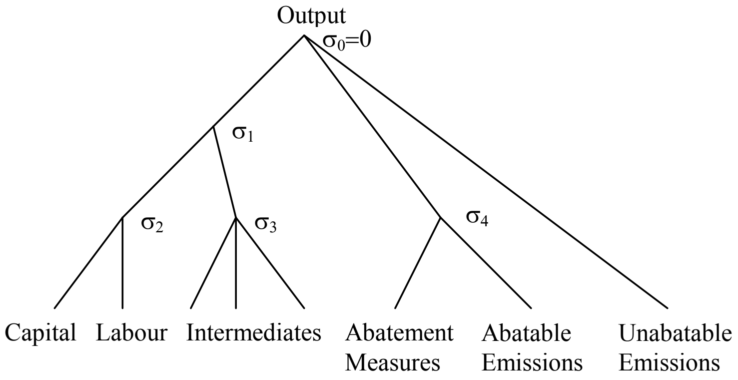

Figure II.1 Nested CES production structure with abatable and non-abatable emissions.[5]

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.

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.

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[5] 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.

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

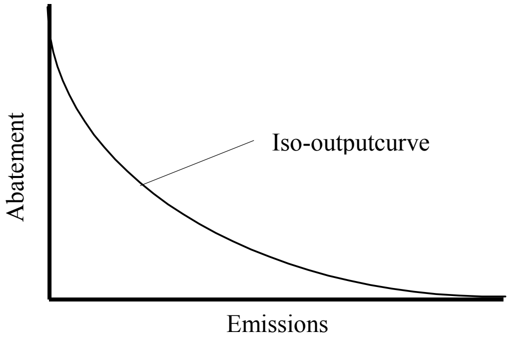

Figure II.2 Iso-output curve: the trade off between abatement and emissions.

II.4 Setting up a list of independent technical measures

Before we describe the technical measures available in 1990 and 1995, 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. We follow the same methodology as in Verbruggen (2000) as far as possible.

Introduction of one measure may make certain other measures inapplicable. For instance, a fuel switch from coal to gas excludes the measure of coal gasification. The methodology, which has been applied for calculating the current version of the abatement cost curves for 1990 and 1995, differs for mutual exclusive measures from the methodology in the report by Verbruggen (2000). Verbruggen (2000) 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.

In this report we use a methodology that allows the measure with the lowest cost efficiency to be exploited, if necessary. 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).

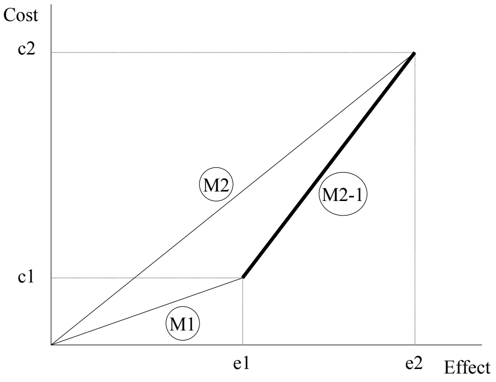

Figure II.3 Construction of a residual measure from two exclusive measures.

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. 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 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 and 1995, 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 1990 and 1995

The inventory of measures for 1990 consists of three lists of potential technical measures. First, Dellink and Van der Woerd (1997) provide a list of technical measures for the environmental themes acidification, eutrophication, smog formation and dispersion of fine particles to air. Second, De Boer (2000a,b) reports on the enhanced greenhouse effect and the depletion of the ozone layer. Third, Van der Woerd et al (2000) provides a list of technical measures for the environmental theme dispersion of toxic substances to water, which is valid for 1995.

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 1990 or were available in demo

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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 CO2 =	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

Technical measures and costs to reduce CO_2 emissions were taken largely from 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).

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 1995, the majority of the measures for reducing greenhouse gas emissions is taken from the recently prepared ICARUS4 database (Alsema and Nieuwlaar, 2001). In the 4th version of the ICARUS database it is possible to take 1995 as the base year and 2020 as the view year. The output of ICARUS4 has been made consistent with other abatement cost curves by using an interest rate of 5%. This leads to 471 measures for reducing CO_2 emissions, after removing dependencies among measures (see Section II.4). The measures to reduce CFCs are removed from the list, as practically all these measures have been taken by the year 1995. The measures from ECN's MARKAL model have been retained. Furthermore, the measures for adjusting fodder are removed, as they have been taken as well. The measure amount of land filling with waste has been used for 25% between 1990 and 1995 and the cost and effects of these measures have been adjusted accordingly. So, in 1995 75% oft his measure is still available. All other measures are retained, while the costs are increased by 14%; representing the increase in the consumer price index between 1990 and 1995.

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.

The actual emissions in 1995 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. The measures to reduce acidification were taken from RIVM's RIM^+ database[7] and comprise about 170 options in 1990.

The availability of measures for abating acidification has changed rigorously between 1990 and 1995 (see also Lise, 2000). This is mainly revealed by a recent study at RIVM (Vringer and Hanemaaijer, 2000), which makes an inventory of measures for abating acidification. This database is known as the "CEF-sheets". The measures in the CEF-sheets do not correspond with measures in RIM^+, due to a totally different set up. As a result all measures in the energy and industrial sector in 1990 have been replaced by new measures from the CEF-sheets in 1995. The measures from the CEF-sheets are adopted in such a way that these measures are implemented beyond the policy agenda. This means that the degree of implementation of these measures is put to 100%. Experts from RIVM have estimated the degree of implementation of the measures for the traffic and transportation sector between 1990 and 1995. Some SO_2 reducing measures at oil refineries from the RIM^+ database are retained for 1995. These measures are implemented for 20% between 1990 and 1995 and the costs and effects in 1995 are adjusted accordingly, by reducing the costs by 20% (and then increase them again with the consumer price index) and by reducing the impacts by 20%. Finally, RIVM experts have suggested adding one aggregate measure to the list of technical measures to account for possibly missing

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[7] 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.

measures. This measure package constitutes about 5% (0.76 million acid equivalents) of the total reduction potential of acidification.

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 1990, the measures to reduce eutrophication, as well as their costs, are taken from RIM$^+$, and amount to a number of 145 options, of which 125 are also present in the abatement cost curve for acidification.

It appeared to be necessary to make an adjustment to the environmental theme eutrophication. Due to a recently introduced new definition of emissions contributing to eutrophication (see Section II.2), the registered amount of P emissions decreased considerably, namely by 40% between the old and the new data for 1990. In 1990, an aggregated measure was available to clear the excess amount of manure. This measure, which is the only one that can substantially reduce P emissions, could reduce more than initial P emissions under the new registration definition. As this is impossible, the P emission reduction potential of this measure has been decreased by 40 % (i.e. proportionally to the new registered amount of P emissions) for the new abatement cost curve in 1990. This adjustment was not required for the abatement cost curve in 1995, as a RIVM expert provided three alternative measures.

Consultation with a RIZA expert showed that all technical measures in the list of 1990 with a potential of reducing phosphorus to 75% should not appear in the list of 1995, as the target of 75% phosphorus reduction was already achieved in 1995. This RIZA expert also suggested to reduce the possibility to extract nitrogen from waste water by 25% between 1990 and 1995, due to a reduction in nitrogen emissions. These suggestions have been followed and are applied to the list of technical measures for 1995.

II.5.5 Smog (tropospheric ozone) formation

For the abatement cost curve of smog formation (VOC: Volatile Organic Components, in particular hydrocarbons), 27 measures were identified in 1990 and 37 measures in 1995. In 1990, the measures with the highest cost-efficiency are mainly identified in VROM’s KWS2000 programme and relate to households, the construction sectors, industry, services and the energy sector. The relatively more expensive measures are mainly within the target group of traffic and transportation, and are mostly not primarily aimed at VOC reduction. They include emission standards for river crafts, locomotives and LPG vans and measures to prevent fuel evaporation.

In 1995, the CEF-sheets provide a number a measures to reduce VOC (Volatile Organic Components) emissions in the industrial sector. In addition, measures in the traffic and transportation sector also reduce VOC emissions to a considerable extent, as a secondary effect. Finally, the national agreement for the reduction of hydrocarbons (KWS2000) is being implemented as agreed upon. This means that 55% of the measures have been taken between 1990 and 1995. This is not true for households, where the emissions increased between 1990 and 1995. It is assumed here that it is still technically possible to achieve the KWS2000 standard for households.

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 1995, there exist only a few measures that can reduce dispersion of fine particles to air. These measures are provided by the CEF-sheets. There are four options to reduce PM10 by industries and one option for consumers. Except for one measure on "switching from coal to gas at power plants", all emission reduction possibilities for the energy sector have been taken before 1995. All other measures are secondary effects of measures in the traffic and transportation sector 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.

The total reduction capacity of the list of 127 options to abate dispersion of toxic substances to water expressed in AETP equivalents is 3 times the initial emissions in 1995. This is impossible, 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 suggest to divide the effects of all 127 options by a fixed factor, which is calculated as follows. After comparing the initial emissions with the reduction capacity of each substance, it turns out that chromium can be reduced by the highest factor, namely 4.34. Hence, the reduction capacity of all abatement options has to be reduced by at least this factor. Then we assumed that the reduction capacity in 1995 should be divided by factor 4.5 (which is slightly higher than chromium's 4.34). Under this assumption, 65% of the initial emissions can be reduced in 1995.

In order to construct an abatement cost curve for 1990, we need to make a number of additional assumptions, as we do not have any additional information about 1990. There are a number of ways to extend the abatement cost curve from 1995 to 1990. Here, we use the 127 options of 1995 for base year 1990 and we keep the reduction potential of 1995 (65%) *constant* for 1990. This is equal to dividing the reduction capacity of 1995

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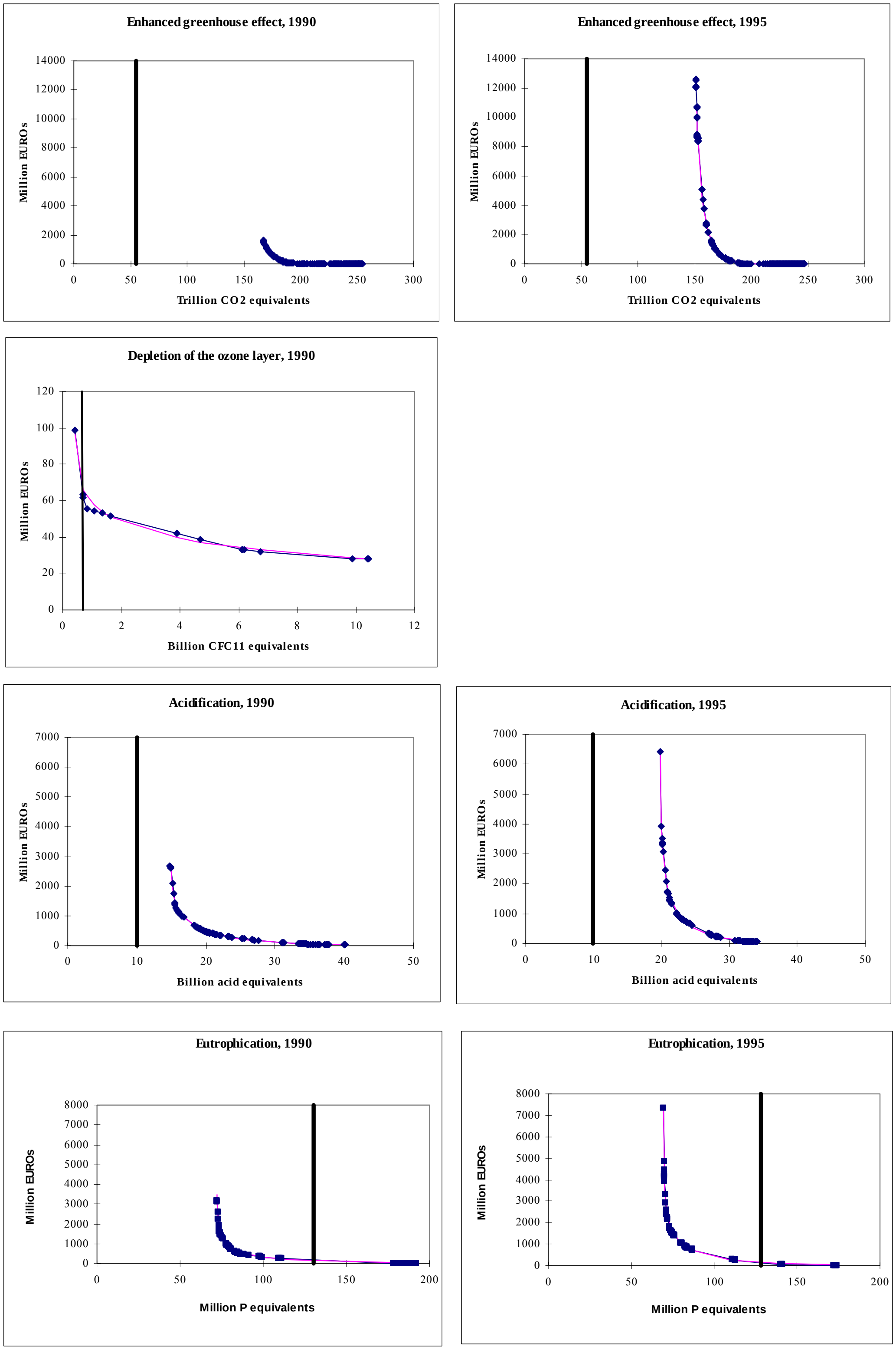
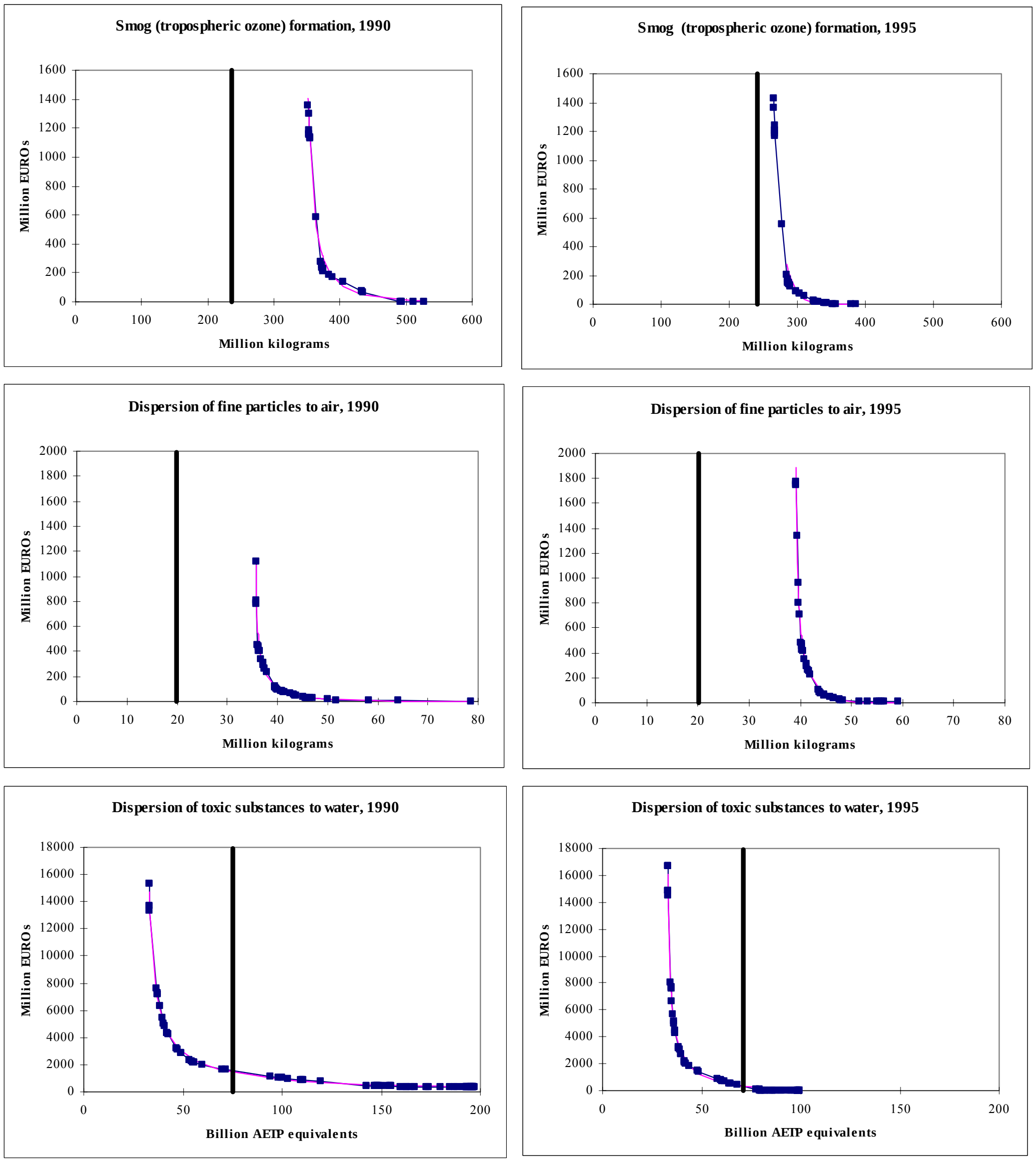


Figure II.4 The annual cumulative abatement cost curves for the enhanced greenhouse effect, depletion of the ozone layer, acidification and eutrophication in 1990 and 1995 (current prices).


Smog (tropospheric ozone) formation, 1990

Smog (tropospheric ozone) formation, 1995

Dispersion of fine particles to air, 1990

Dispersion of fine particles to air, 1995

Dispersion of toxic substances to water, 1990

Dispersion of toxic substances to water, 1995

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 1990 and 1995 (current prices).

The situation in 1995 gives a different picture. First of all, there is no abatement cost curve for depletion of the ozone layer (see Section II.5.2), as the emission standard has already been achieved in the initial situation. Again the gap is relatively the greatest for the enhanced greenhouse effect (see Table II.6). On the other hand, as Table II.6 shows, it has become somewhat easier to technically reduce the enhanced greenhouse effect in 1995, as the 'remaining emissions' decreased from 114 to 98 million tonnes CO_2 equivalents. So, there is a relatively small technological improvement between 1990 and 1995 in the technical ability to reduce the enhanced greenhouse effect, though the costs have increased substantially, as can be see in Figure II.4.

Table II.6 Require

Environmental Theme
1990:
Greenhouse effect
Ozone layer depletion
Acidification
Eutrophication
Smog formation

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Appendix III. Social Accounting Matrices, SNI variant 1 and 2, 1990 and 1995

Table III.1 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
Labor	-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 III.2 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
Labor	-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 III.3 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
Labor	-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 III.4 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		
Labor	-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

Appendix IV. Sensitivity Analysis SNI 1995

IV.1 Introduction

In Section 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 1995, as we have carried out in the first report for 1990 (Verbruggen 2000). That is, we made two exercises, that give an impression of the possible changes in the calculated SNI if alternative assumptions are made. The first exercise, presented in Section IV.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 IV.3, sketches the changes in the SNI in 1995 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 IV.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 a 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 behavior 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 IV.5 provides conclusion about the outcome of the sensitivity analysis on basic assumptions in the SNI model.

IV.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 IV.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 IV.1 Absolute changes in the sectoral allocation of emissions when emissions are attributed to intermediate deliveries and consumption patterns.

	Greenhouse effect	Acidification	Smog Formation	Fine particles
Units	MtC equivalents	10E9 acid equivalents	kt	kt
Agriculture	-3.9	0.0	-3.3	0.0
Oil and gas extraction	15.7	0.0	0.0	-0.1
Other mining	0.7	0.0	0.0	0.0
Food-related industry	9.4	0.0	21.5	0.0
Textile- and leather industry	1.5	0.0	-0.1	0.0
Paper and –board industry	-0.3	0.0	-0.1	0.0
Printing industry	-0.2	0.0	0.0	0.0
Oil refineries	23.9	0.0	0.0	0.0
Chemical industry	-8.7	0.0	-0.4	0.0
Rubber and plastics industry	-0.2	0.0	0.0	0.0
Basic metals industry	-0.5	0.0	0.0	0.0
Metal products industry	-0.3	0.0	0.0	0.0
Machine industry	-0.2	0.0	-0.4	0.0
Electrotechnical industry	-0.3	0.0	0.0	0.0
Transport equipment industry	-0.2	0.0	12.6	0.0
Other industries	-1.2	0.0	-0.1	0.0
Energy supply	9.3	0.0	0.0	0.0
Water supply	-0.1	0.0	0.0	0.0
Construction	-1.4	0.0	-0.1	-0.1
Trade and related	-4.8	0.0	-5.1	-0.1
Transport by land	-4.1	0.0	-0.5	0.0
Transport by water	0.8	1.0	-0.1	1.8
Transport by air	-1.5	0.0	-0.8	0.0
Transport services	1.1	-0.1	-0.1	-0.3
Commercial services	-3.7	0.0	-0.2	0.0
Non-commercial services	6.8	0.0	-1.7	0.0
Other goods and services	-0.2	0.0	-0.4	0.0
Subsistence consumer	-17.0	-0.5	-9.6	-0.9
Private consumer	-20.2	-0.2	-11.2	-0.4
Ratio of reallocated emissions (R_e)	0.45	0.11	0.13	0.11

Note: There are no significant changes in emissions for depletion of the ozone layer, 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 Section 3. Table IV.2 shows the results.

Table IV.2 Changes in SNI in 1995 due to reallocation of emissions.

	Income (billions Euros/year)		Income, per cent decrease relative to BAU	
	variant 1	variant2	variant 1	variant 2
BAU	268.4		0.0%	
Results of Section 3	186.7	122.2	30.4%	54.5%
Results after reallocating emissions	207.7	128.1	22.6%	52.3%

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 Section 4, we have already seen that under variant 2, there are fewer opportunities for the economic 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. Since the impact of the emission reallocation is the highest for variant 1, we focus on the sectoral changes within this variant. Figure IV.1 shows the changes in sectoral output levels that are caused by the reallocation of emissions.

We can see from Figure IV.1 that the reallocation of emissions leads to a decrease in output in five sectors, namely Agriculture and fisheries (sector 1): 3 per cent point, Extraction of oil and gas (sector 2): 19 per cent point, Other mining and quarrying (sector 3): 2 per cent point, Oil refineries (sector 8): 7 per cent point, and Other goods and services (sector 27): 22 per cent point. Here, 'per cent points' are expressed as percentages of the BAU output level. There is a substantial decrease in output for Extraction of oil and gas, which corresponds with the 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 IV.1). However, most sectoral output levels increase. Notably, four sectors increase their total income by more than 60 per cent point, namely Metal products industry (sector 12), Machine industry (sector 13), Electrotechnical industry (sector 14), and Transport equipment industry (sector 15). Relative to these sectors, the output of the Oil refineries decreases considerably.

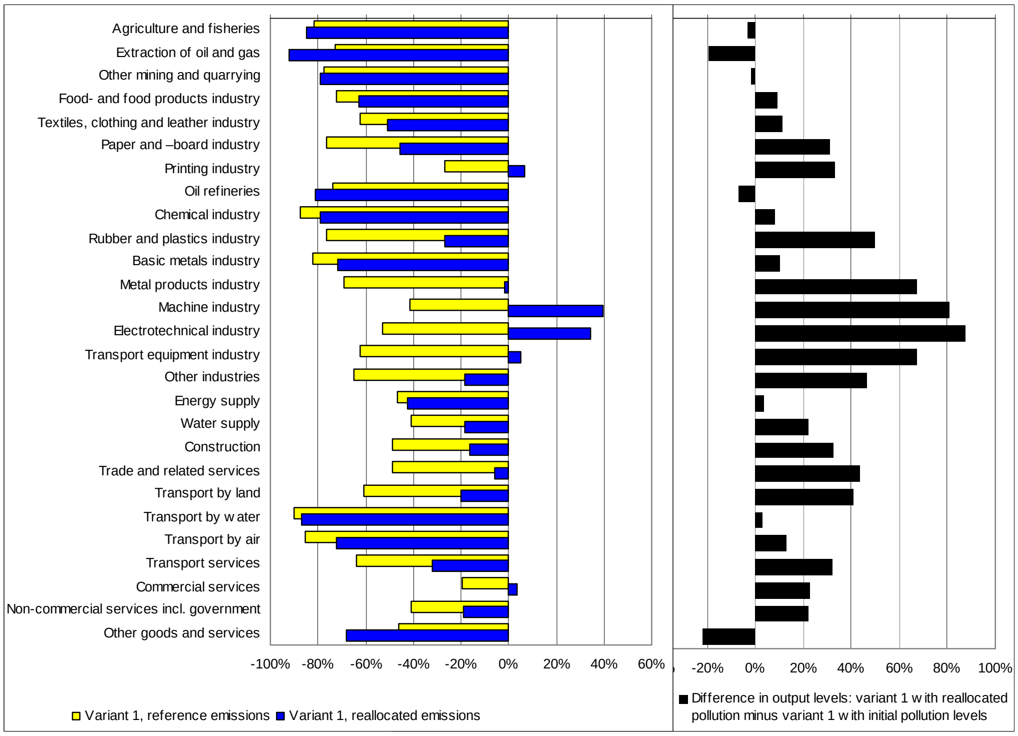

Figure IV.1 Sectoral output in variant 1 with reference emissions and with reallocated emissions, presented as per cent points (percentages of BAU levels).

IV.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 Section 3, respectively. Table IV.3 shows the results for variants 1 and 2.

Table IV.3 Changes in SNI due to small changes in the sustainability standards.

	Income (billions Euros/year)		Income, per cent decrease relative to BAU	
	variant 1	variant2	variant 1	variant 2
BAU	268.4		0.0%	
Allowed emissions +10%	195.1	133.7	27.3%	50.2%
Results of Section 3	186.7	122.2	30.4%	54.5%
Allowed emissions –10%	177.4	110.3	33.9%	58.9%

From Table IV.3, we see that, under variant 2, the SNI increases by 12 billion Euros, or 4 per cent points, if the quantity of allowed emission units is increased by 10%. Relative to its own level, the SNI increases by 9%. 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.

Variant 1, however, tells a different story. Table IV.3 shows for variant 1 that the SNI increases by 8 billion Euros, or 3 per cent points, if the quantity of allowed emission units is increased by 10%. Relative to its own level, the SNI increases by 4%. The explanation is that, apparently, more substitution possibilities are still open and no uniform reduction of economic activities is required.

IV.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 behavior 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 IV.4 presents the results.

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

	Income (billion Euros/year)		Income decrease (%)	
	variant 1	variant2	variant 1	variant 2
BAU	268.7		0.0%	
50% GHG emission reduction	257.8	251.8	4.1%	6.3%
Same as above, reallocated emissions	257.8	253.3	4.1%	5.7%

The calculated costs of a 50% GHG emission reduction does not differ substantially between the various assumptions. Using the basic emission data, costs amount to 4.1% or 6.3%, 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 IV.1, costs are constant for variant 1 and decrease to 5.7% for variant 2. Our range of costs, from 4.1% to 6.2% is close to the range found in the literature. Boero *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%.

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 IV.1 so that the exercise will help us to get a basic feeling about the impact of the distribution of emissions over sectors. Figure IV.2 gives the sectoral effects, for variant 1, that is, when world market prices are unaffected. Sectoral changes are diverse. Some sectors show a decrease of output of about 60%, notably Transport by water and air. For other sectors, a stringent GHG emission reduction policy even leads to growth in production. 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 10%, while many other sectors show a much sharper decrease. Having emissions reallocated, the Oil refineries sector is hit sharply, showing a cut in output by about 42%, while Extraction of oil and gas is hit by 44%.

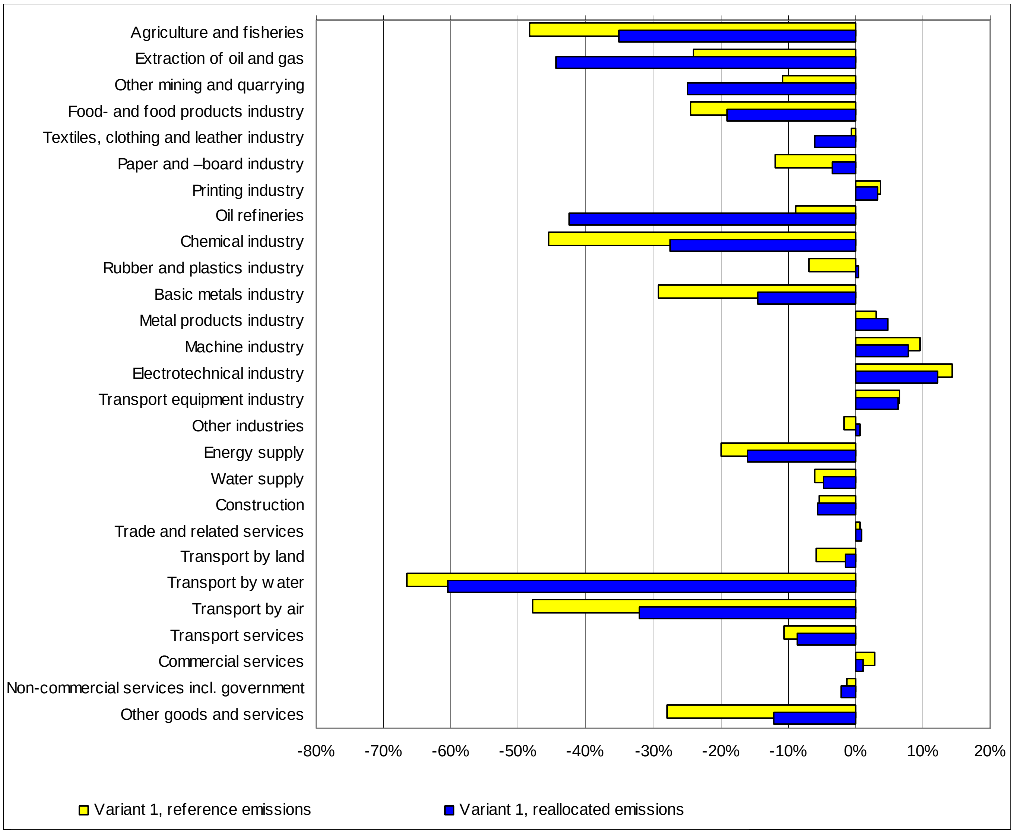

Figure IV.2 Sectoral effects on output under a 50% GHG emission reduction; comparison between reference emission data and reallocated emissions data.

IV.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 30% to 23%. Under variant 2, where world market prices change proportionally to domestic prices, the income reduction changes from 54% to 52%. 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 Section 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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