Trend analysis of sustainable national income for the Netherlands, 1990-2000

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Abstract

This paper presents a trend analysis of the Sustainable National Income (SNI) indicator for the Netherlands over the period 1990–2000. The SNI indicator, first proposed by Hueting, corrects net national income (NNI) for the costs to bring back environmental resource use to a 'sustainable' level. We use an applied general equilibrium (AGE) model specifying 27 production sectors given a set of pre-determined sustainability standards. The AGE model is extended with emissions and abatement cost curves, based on a large data set for nine environmental themes. The numerical results indicate that, over time, SNI moves closer to NNI. In addition, we apply a 4-factor decomposition analysis of the SNI trend to identify the underlying forces of economic development. Overall productivity growth led to an increase in NNI and a less than proportional increase in SNI (scale effect). Changes in composition of the economy had a small effect on SNI (composition effect). Emission intensities substantially decreased and led to lower emissions and an increased SNI (technique effect). Finally, during the sub-period 1995-2000, many new emission-poor technologies became available but were left unused, leaving actual emissions unchanged but increasing SNI (abatement effect).

Trend analysis of sustainable national income for the Netherlands, 1990-2000

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. Famous examples include Nordhaus and Tobin (1972) and Daly and Cobb (1989). One direction of the literature has focused on the correction of national income for environmental losses, leading to various measures of so-called green GDP (for applied studies, see Repetto *et al*. 1989, Castañeda 1991, Cruz and Repetto 1991, 1992, and more recently, Thampapillai and Uhlin 1997, Liu 1998, and Torras 1999). Within this concept, Hueting (1992, 1995) has described a measure labeled Sustainable National Income (SNI) that is based on the assumption of an absolute preference for conservation of the natural environment. Under this assumption, the practical calculation of the SNI indicator resembles the maintenance cost approach (UN 1993). This paper analyzes the development of this measure for the Netherlands over the period 1990-2000. The paper builds on earlier work described in Verbruggen (2000), Verbruggen *et al.* (2001), Gerlagh *et al.* (2002), and Hofkes *et al*. (2002).

In operationalising the Hueting methodology, an empirical and integrated environment-economy model has been used. The use of such a model goes with 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. Whereas, for each year, the calculated SNI indicator is sensitive to the assumptions, the development over time of the SNI indicator will be less dependent. It is thus useful to study the SNI dynamic, and particularly, 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 1990–2000. We decompose economic development into four fundamental forces: changes in the overall economic scale, changes in the composition of economic production and consumption, changes in the use of technologies and changes in the availability of technologies. A similar approach can be found in Grossman and Krueger (1991). They apply a decomposition analysis to interpret the potential effects of North American Free Trade Agreement (NAFTA) on the environment.

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

2. Model setup and calibration

SNI-AGE Model

In order to be able to calculate a sustainable national income (SNI) indicator, we constructed an applied general equilibrium (AGE) model for the Dutch economy. This 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, although capital is actually produced. The model distinguishes three consumers: the private households, the government, and the Rest of the World (ROW). In addition to these producers and consumers, there are several auxiliary agents that are necessary to shape specific features of the model. In order to capture non-unitary income elasticities in the model, the consumption of the private households is split into a 'subsistence' and a 'luxury' part. There is an 'investor' who demands investment goods necessary for economic growth, and a 'capital sector' which produces the composite capital good. Trade is modelled using the Armington specification for imports and a Constant Elasticity of Transformation (CET) production structure for sectors producing for both the domestic and the world market. The CET production structure is analogue to the CES production function but then with multiple outputs. Besides the common AGE model elements mentioned above, 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.

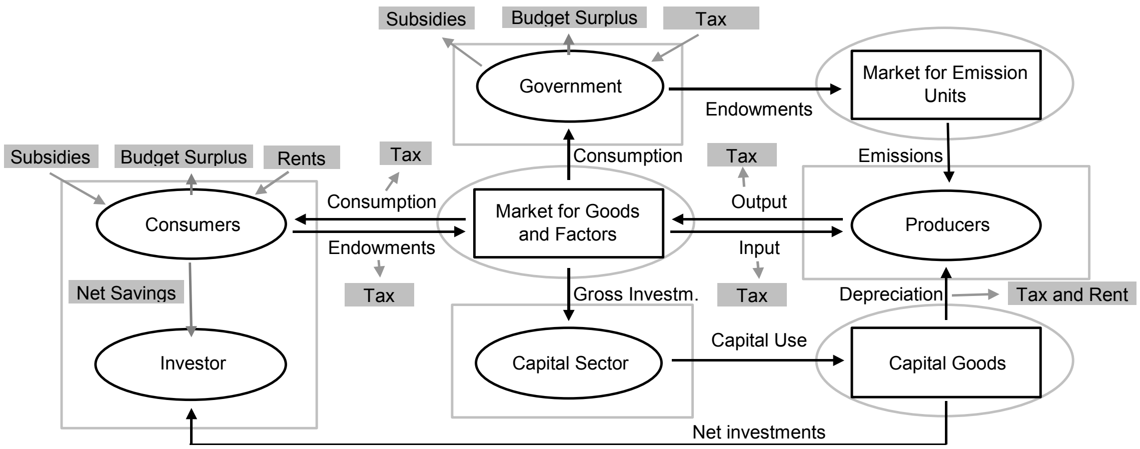

Figure 1 Overview of SNI-AGE model.

Figure 1 presents an overview of the relationships in the model. 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.

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.

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).

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 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 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. Hofkes *et al*. (2002) explicate the choices made. We have to be aware that results may significantly depend on the actual assumptions, so that we prefer to speak of a SNI calculation rather than the unique SNI.

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.

Calibration

The model is calibrated for 1990, 1995 and 2000 using historical data for the Netherlands for these years, provided by Statistics Netherlands. 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). Net National Income (NNI) at (current) market prices amounts to 213 billion euros in 1990, 268 billion euros in 1995 and 340 billion euros in 2000 as shown in Table 1. As the Consumer Price Index (CPI) has risen by 24.4% over the period, real income has grown by 28.2% between 1990 and 2000, or 2.5% annually.

Table 1 NNI and economic growth in period 1990–2000

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

To get a feeling for what the economy looks like, we present the condensed Social Accounting Matrices (SAMs) for these years in Table 2 to Table 4. The row entries represent goods, the column entries represent agents; a positive table entry denotes supply while a negative table entry denotes demand. Market equilibrium requires that supply matches demand. Consequently, rows sum to zero. For all sectors, the value of output equals the value of intermediate deliveries plus the value of production factors employed. Thus, the first five columns also sum to zero. The other column sums represent the trade surplus, X–M (note that a negative value means that exports exceed imports as a negative entry denotes demand for a good), net investments, I, consumption, C, and income from endowments, Y. The latter columns sum to zero according to the standard equation Y=C+I+X–M. To give an example, the value of goods produced by the agricultural sectors, both in 1990 and 1995, amounts to 17 billion euros, and 18 billion euros in 2000 (current prices). In 2000, more then half thereof, 11.2 billion euros, accounts for the value of intermediate deliveries by other sectors. The remaining 7.2 million euros is value added.

The share of the agricultural sector decreases from about 4 per cent of NNI in 1990 (8 billion euros divided by 213 billion euros) to about 3 per cent of NNI in 1995 (8 billion euros divided by 268 billion euros) to 2% in 2000. The share of industries in value added decreases from about 29% in 1990 to 25% in 2000, while the services share in value added increases form about 61 in 1990 to approximately 65% in 2000. In the period 1990–2000, gross investments amount to 56, 63 and 91 billion euros respectively, about half of which is for maintenance; net investments amount to 29, 30 and 35 billion euros respectively. Capital goods are mainly produced by industry. About half of total income (after taxes) is attributed to labour, capital returns account for 30 per cent, and taxes (excluding income taxes), account for the remaining 20 per cent of income.

Table 2 *Reference Social Accounting Matrix* 1990 *(billion Euros, current prices).*

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	17	-13	-1	-0		-2		-2		0
Industries	-5	117	-30	-41	-0	6		-47		0
Services	-2	-33	175	-11	-0	-6		-123		0
Capital	-2	-8	-16	56			-29			0
Abatement	-0	-0	-0		0			-0		0
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 3 *Reference Social Accounting Matrix* 1995 *(billion Euros, current prices).*

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	17	-11	-1	-0		-4		-2		-0
Industries	-5	134	-38	-44	-0	-4		-44		0
Services	-2	-40	227	-13	-0	-6		-166		0
Capital	-2	-10	-21	63			-30			
Abatement	-0	-0	-0		0			-0		0
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

Table 4 *Reference Social Accounting Matrix* 2000 *(billion Euros, current prices).*

	Agr.	Ind.	Serv.	Cap.	Abat.	Trade	N.Inv.	Cons.	Endw.	Sum
Agriculture	18	-10	-1	-0		-4		-2		-0
Industries	-5	170	-52	-60	-0	1		-54		0
Services	-3	-57	313	-23	-0	-11		-220		0
Capital	-3	-18	-40	91			-30			
Abatement	-0	-0	-0		0			-0		0
Labor	-2	-42	-123		-0				166	0
Profits	-5	-27	-59						91	-0
Taxes	-0	-17	-38	-8				-20	83	0
Sum	0	0	0	-0	0	-14	-30	-296	340	0

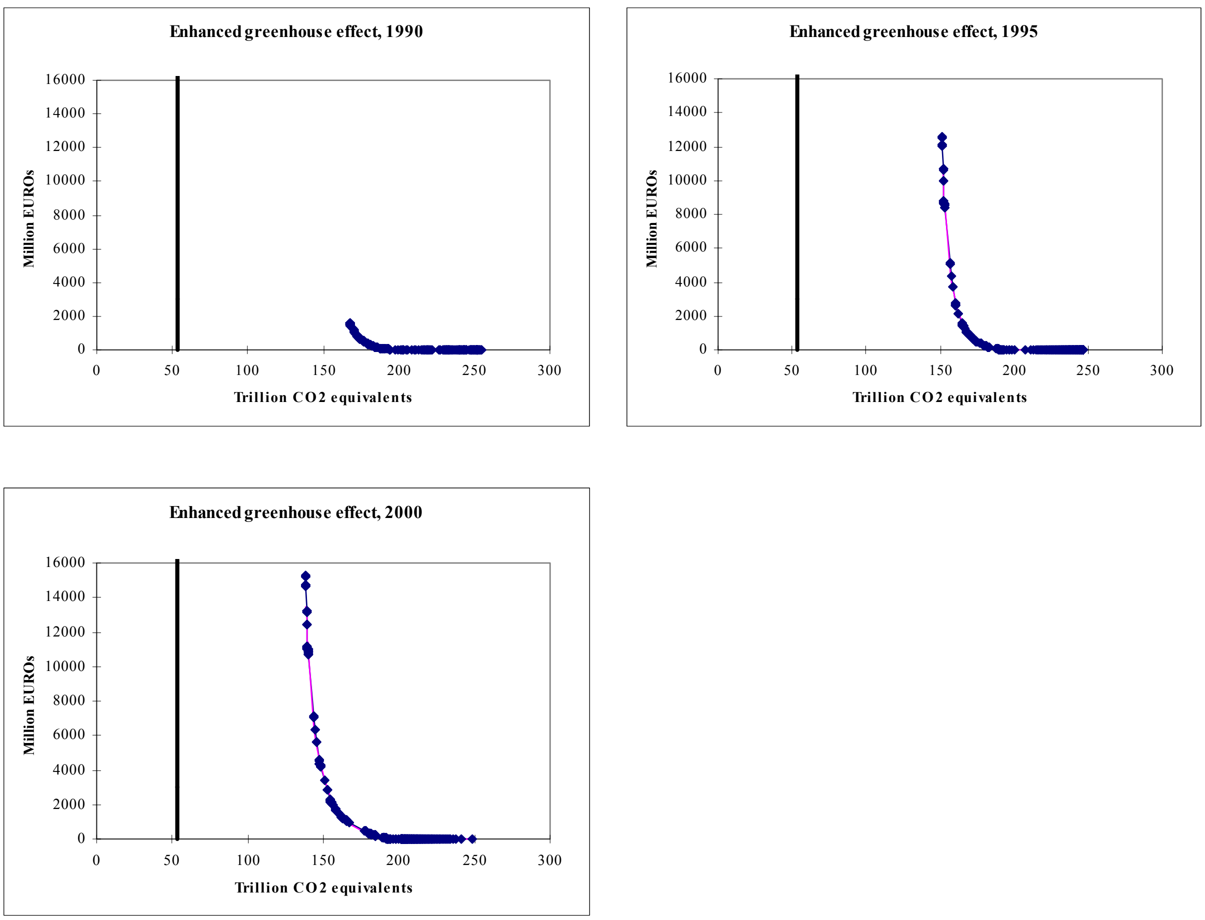

Figure 2 *Abatement cost curve GHG emissions 1990, 1995 and 2000. The vertical line represents the sustainability target of emissions*

Emission units are treated as production factors, similar to labour and capital, since an enforced reduction of emissions decreases output (see Hofkes et al., 2002). 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[1] 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 instance, Figure 2 shows the abatement cost curves of GHG emissions for 1990, 1995 and 2000 respectively. The level of emission reduction that can be reached through identified abatement measures increases substantially between 1990 and 2000, mainly due to more credible information on renewable energy sources (see Menkveld, 2002).

Table 5 presents the emission levels per year and the sustainability standards for the various environmental themes. The sustainability standards are exogenous to the model calculations, and remain unchanged during the period 1990–2000. There is some debate about whether the sustainability standards can be objectively assessed. In this study we take the sustainability standards as assessed by Hueting and de Boer. These standards are described extensively in Verbruggen (2000).

From Table 5 we can learn that except for greenhouse gases the required reductions (level of emissions minus sustainability standard) considerably decrease for most themes in the period 1990 and 2000. Along this period, greenhouse gases (GHG) make the most costly environmental theme to reach the sustainability standards. Figure 2 shows that only part of the required reductions for GHG emissions can be realized through technical measures. The remainder of the reduction has to be realized through a restructuring of the economy. Although not shown, in the case of smog formation and dispersion of fine particals to air, the potential emission reductions of technical measures in 2000 suffice to meet the sustainability standards. For the theme ‘depletion of the ozone layer’, actual emissions in 1995 are already at a sustainable level (see Table 5). The sharp fall in emissions is caused by the strict ban on sales of ozone emitting appliances.

[1] 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.

Table 5 Base emissions and sustainability standards for the environmental themes in the period 1990-2000.

Environmental Theme	Units	Sustainability Standard	Emission levels 1990	1995	2000
Greenhouse effect	Billion kg. CO_2 equivalents	53.3	254.5	246.9	248.3
Ozone layer depletion	Million kg. CFC11 equivalents	0.6	10.4	0.3	0.1
Acidification	Billion acid equivalents	10.0	40.1	34.0	31.3
Eutrophication	Million P-equivalents	128.0	188.9	173.9	137.5
Smog formation	Million kilograms	240.0	527.1	385.5	280.3
Fine particles	Million kilograms	20.0	78.6	59.2	53.2
Dispersion to water	Billion AETP-equivalents	73.5	196.8	99.6	88.3
Dehydration	Percentage affected area	0	100.0	100.0	90.0
Soil contamination	Thousands contaminated sites	0	600.0	598.5	590.0

3. Decomposition analysis

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

In the decomposition analysis we distinguish four underlying forces of economic development, overall economic growth, changes in the composition of the economy, changes in technologies used for production, and changes in available but unused technologies. These first three forces are commonly referred to as the scale effect, the composition effect and the technique effect. A similar approach can be found in Grossman and Krueger (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, who focus on changes in actual emissions, 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) but not used for reaching a sustainable economy. We label these technologies 'available abatement technologies'. Changes in the SNI indicator that are due to changes in the available abatement technologies are labelled the abatement effect. Second, we do not use the decomposition to interpret changes in emissions, but changes in the sustainable income level. Recall that the sustainability standards do not change between 1990 and 2000. Instead, we use a parallel approach, comparing changes in the actual economy with associated changes in the sustainable economy that defines the SNI indicator. Figure 3 presents the scheme of our decomposition analysis.

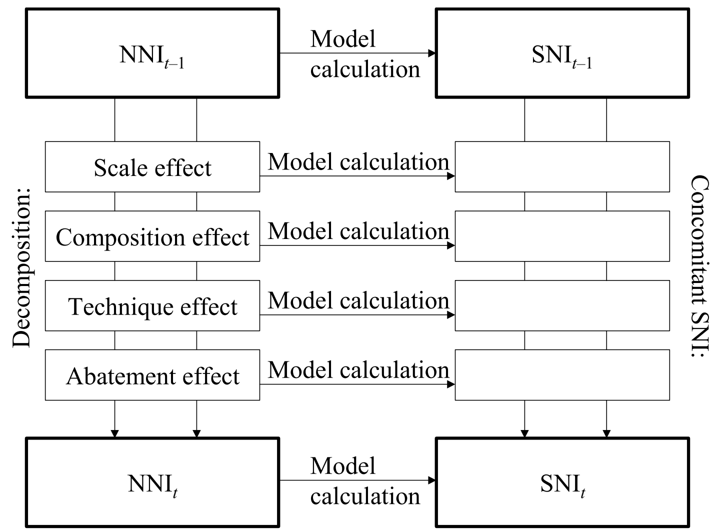

Figure 3 Decomposition scheme in the period t-1 to t for t=1995 *and* 2000.

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 t–1 to t. Starting from the reference economy in t–1, 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. The trend analysis for t–1 to t consists of a decomposition of the changes in the reference economy, i.e. we move from NNI at time t–1 (upper left) to NNI at time t (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 t–1 and t. We applied this procedure for the periods 1990–1995 (see Hofkes *et al*., 2002) and 1995–2000 (this paper).

4. Numerical results

Trend of NNI and SNI in the period 1990–2000

Table 6 presents the macro-economic results of the two SNI variants for the Netherlands in the period 1990–2000 as discussed in Section 2. We consider all prices and values at the 1990 level. It appears that the extent to which SNI drops is quite significantly determined by the specification of international trade. In 2000, SNI variant 1 (with constant relative world market prices) is 25% below net national income, while SNI variant 2 (with world market prices changing proportionally to domestic prices) is 48% below net national income. Furthermore, both variants show a relatively improving SNI during the period 1990–2000 in the sense that its shortfall relative to the NNI declines significantly. In particular, SNI variant 1 moves from 34% below NNI in 1990 via 30% in 1995 to 25% in 2000. SNI variant 2 is 56% below NNI in 1990, 54% in 1995 and 48% in 2000. For both variants, we thus observe the trend that SNI moves closer to the actual NNI.

While NNI has increased by 60.1 million euros (28.2%) between 1990 and 2000, sustainable national income has increased by 64.8 billion euros (46.4%) in variant 1 and by 46.8 billion euros (49.7%) in variant 2, respectively. Figure 4 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.

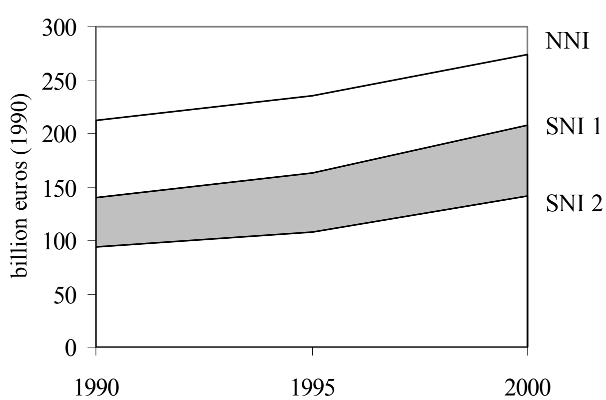

Figure 4 Trend in NNI, SNI variant 1 (SNI 1) and SNI variant 2 (SNI 2), 1990–2000.

	1990	1995	2000
NNI	213.0	235.4	273.1
SNI variant 1	139.8	163.8	204.6
SNI variant 2	94.2	107.2	141.0
Index			
NNI	100.0	110.4	128.2
SNI variant 1	100.0	117.2	146.4
SNI variant 2	100.0	113.8	149.7
Share of SNI below NNI			
SNI variant 1	–34%	–30%	–25%
SNI variant 2	–56%	–54%	–48%

Table 6 Macro economic results for NNI and SNI 1990–2000 (billion Euros, 1990 prices).

The gap between SNI and NNI measures the dependence of the economy on that part of natural resource use that exceeds the sustainable exploitation level (c.f. Gerlagh *et al.*, 2002).

Figure 4 shows that under both variants SNI has improved in the period 1990 to 2000. In other words the fall in national income necessary to obtain a sustainable economy decreases slightly between 1990 and 2000. Independent of the variants, the Dutch economy tends to decrease its over-dependence on natural resource exploitation.

Decomposition

To give an interpretation of the trend in the development of SNI between 1990 and 2000 we apply the decomposition analysis as described in Section 2 distinguishing a scale effect, a composition effect, a technique effect, and an abatement effect. We elaborate upon the decomposition of NNI stage by stage for each separate effect, as done by Hofkes *et al*. (2002) for the period 1990–1995. Below, we discuss the decomposition in 1995–2000 separately, and we compare the decomposition analysis for both periods.

Table 7 summarizes the decomposition for both periods. It shows that, whereas net national income has grown by 28.2% between 1990 and 2000, GHG emissions have decreased by 1.4%. The level of GHG emission actually decreased between 1990 and 1995 from 254.5 to 246.9, but then slightly increased to 248.3 billion kg. CO_2 equivalents in 2000. In the period 1990–2000, SNI increased by 46.4% and 49.7% for variant 1 and 2, respectively. The largest increase in SNI was realised between 1995 and 2000. Below, we discuss the underlying mechanisms of the SNI developments in more detail.

Table 7 Decomposition of changes in NNI, SNI1 and SNI2 (billion Euros, 1990 prices), and GHG emissions (billion kg. CO_2 equivalents).

	NNI	(change)	GHG emissions	(change)	SNI1	(change)	SNI2	(change)
1990	213.0		254.5		139.8		94.2	
Scale effect	235.4	(+10.4%)	281.0	(+10.4%)	148.7	(+6.4%)	96.6	(+2.6%)
Composition effect	235.4		265.8	(–5.4%)	151.3	(+1.8%)	99.2	(+2.7%)
Technique effect	235.4		246.9	(–7.1%)	164.1	(+8.4%)	107.8	(+8.6%)
Abatement effect	235.4		246.9		163.8	(–0.1%)	107.2	(–0.3%)
1995 (relative to 1990)	235.4	(+10.4%)	246.9	(–3.0%)	163.8	(+17.2%)	107.2	(+13.9%)
Scale effect	273.1	(+16.0%)	286.5	(+16.0%)	177.1	(+8.1%)	108.6	(+1.3%)
Composition effect	273.1		289.4	(+1.0%)	185.5	(+4.7%)	111.3	(+2.5%)
Technique effect	273.1		248.3	(–14.2%)	196.2	(+5.8%)	128.0	(+15.0%)
Abatement effect	273.1		248.3		204.6	(+4.3%)	141.0	(+10.2%)
2000 (relative to 1995)	273.1	(+16.0%)	248.3	(+0.6%)	204.6	(+24.9%)	141.0	(+31.5%)
2000 (relative to 1990)	273.1	(+28.2%)	248.3	(–1.4%)	204.6	(+46.4%)	141.0	(+49.7%)

Scale effect

Based on the economic growth between time *t*-1 and *t*, we enlarge the economy at time *t* by the economic growth in the period, such that NNI reaches the same level as at time *t*. We maintain all other characteristics such as the sectoral composition of the economy, the emission intensities per sector and the abatement cost curves. So, emissions increase proportionally with the economy. For the resulting economy, we reiterate the procedure for calculating the two variants of the SNI indicator.

In the period 1990 and 2000, NNI grew by 28.2%. Table 7 shows that in both periods, both SNI variants increased due to the scale effect. The growth in SNI was smaller than in NNI, and the reason is that, when economic production, consumption, and emissions grow uniformly, it becomes increasingly difficult to meet the sustainable standards because of the increasing emissions and sustainability standards remain unchanged. In addition, the growth in SNI variant 2 was smaller than the growth in variant 1, as variant 2 is more stringent.

The scale effect of SNI shows a similar trend for both periods, as shown in Table 7. Between 1990 and 1995, NNI grew by 10.4%, while SNI variant 1 and 2 grew by 6.4% and 2.6% respectively. Whereas NNI grows by 16.0% between 1995 and 2000, the SNI level only grows by 8.1% in variant 1. The scale effect leads to an increase of sustainable income in variant 2 by 1.3%. So, the SNI growth rates due to the scale effect in both periods are well below the economic growth. In addition, the SNI growth rate of variant 2 is well below the growth rate of variant 1.

Composition effect

The next step of the decomposition consists of the inclusion of the changes in the economic structure. The economy has the same size and composition at time *t*, but the emission intensities of economic activities and the abatement technologies from time *t*–1 are maintained. Depended on whether the economy specialises in relatively more environment intensive sectors or in relatively less environment intensive sectors, emissions might increase or decrease, respectively, due to the composition effect.

The composition effect of GHG emissions is ambiguous, as the economy first shows a shift towards less emission intensive sectors, but then shows a shift towards more emission intensive sectors. In the period 1990–1995, the GHG emissions declined by –5.4% due to compositional changes. In the 1995 and 2000, GHG emissions increased by 1.0% due to compositional changes in the economy, from 286.5 to 289.4 billion kg CO_2 eq., relative to a uniform blow up of the economy, see Table 7.

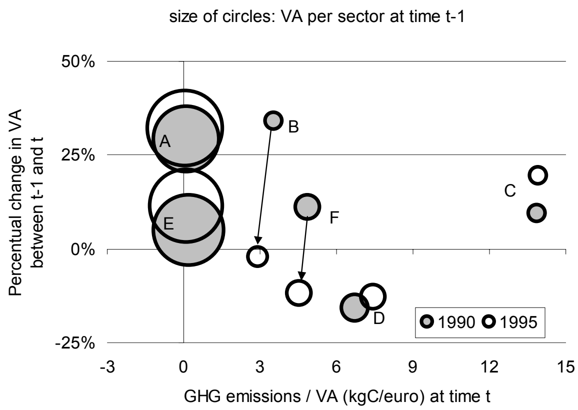

Figure 5 *Change in Value Added (VA) for 1990–1995 and 1995–2000 per GHG emission intensity between 1995 and 2000.*

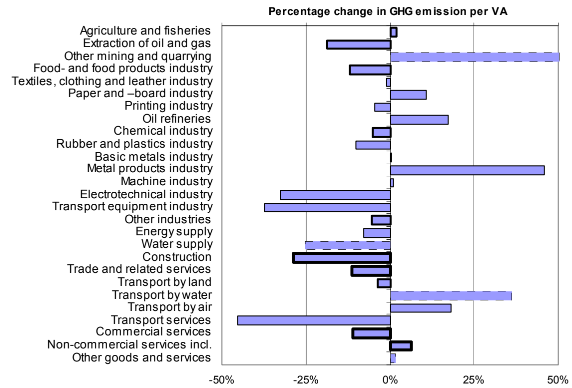

Figure 6 *Percentual changes in GHG emissions per VA for all considered sectors, 1995–2000.*

Note: In Figure 6, the thickness of the bar borders represent the value added of a sector. The thickest border represents sectors with a VA above average. The next thickest border represents a VA between half times average and average. The normal sized border represents a VA between one eighth and a half time average, while the dotted line represents a VA below one eighth of average VA.

Figure 5 illustrates the relation between the intensity of GHG emissions per value added at time *t*–1 on the x-ax and the relative change in value added between *t*–1 and t on the y-ax. The size of the circles represents the value added at time *t*–1. The figure pictures 6 different sectors denoted by A to F. The circles with a grey surface represent the relative change in sectoral VA between 1990 and 1995, which is linked to the GHG emission intensity of the sector in 1990, while the size of the circle reflects the VA of the sector in 1990. The transparent circles are similarly defined for the next period.

The sector 'commercial services' (A) is the largest sector in VA terms and has a low emission intensity. Despite the low emission intensity of this sector, 'commercial services' sector contributes to higher GHG emission levels due to its high growth rates in the 1990s, see Table 8. The sector 'oil refineries' (B) is a relative polluting sector. Between 1990 and 1995, this sector grew sharply, but then it has shrunk. Table 8 shows that 'oil refineries' contribute considerably to the increase of GHG emissions. The 'energy supply' sector (C) has the highest emission intensity of all sectors, and it continues to grow at a high rate in the period 1995–2000. This sector contributes to the increase of GHG emissions by 2.7 (billion kg CO_2 eq). The agricultural sector (D) shows an increase in emission intensity, but this sector is shrinking at a higher past during the 1990s. As a result, the agricultural sector contributed to a more sustainable composition of the economy. The non-commercial services sector (E) is one of the largest sectors. It has a low emission intensity, and the growth rate of VA increases during the 1990s. Finally, the chemical industry (F) is relatively emission intensive. Although its share in total VA increased in the first half of the 1990s, its share in VA has decreased in the second half. Ultimately, the GHG emissions of the chemical industry declined between 1990 and 2000.

Table 8 Changes in contribution (in absolute terms) to GHG emissions (billion kg CO_2 eq) of six economic sectors in the period 1990–2000

		Changes in contribution to GHG emissions		
		1990-1995	1995-2000	1990-2000
Commercial services	A	0.37	0.68	1.05
Oil refineries	B	4.01	4.63	8.63
Energy supply	C	1.11	1.61	2.72
Agricultural sector	D	–3.42	–5.23	–8.65
Non-commercial services sector	E	–2.90	1.00	–1.90
Chemical industry	F	0.91	–4.44	–3.54

In the period 1990–1995, the change in composition of the economy lowered the emission intensity of production, and consequently, lowered the burden of economic growth on sustainable income. The SNI variant 1 increased by 1.8% and SNI variant 2 increased by 2.7% (see Table 7). In contrast to the previous period, between 1995 and 2000, GHG emissions increase due to the composition effect, and we would expect an increase in the burden of economic growth on sustainable income, that is, a negative effect of composition on SNI. However, the sustainable income level increases due to the composition effect by 4.7% under variant 1, and by 2.5% under variant 2. The simultaneous increase of GHG emissions and the SNI indicators seems counterintuitive. One possible explanation for this counterintuitive development is that those economic sectors that have increased their share in the economy are characterised by relatively high emission intensity but also with cheap opportunities to reduce emissions. A full understanding of the mechanisms requires further analysis and is delayed to a future paper.

Technique effect

In the third step of our decomposition analysis, we adjust the economic input-output data and the emissions data to account for the change, in every sector, in emission intensity per value added. The technique effect considerably contributes to the decrease of GHG emissions in the period 1990–2000. The emission intensities of most economic activities have been lowered, and as a result, the technique effect results in considerable increases in SNI, see Table 7. This trend is consistent for the period 1990–2000.

Between 1990 and 1995, the improved technologies lowered the GHG emission level by 7.1%. Consequently, in both variants SNI increased by approximately 8.5% due to the technique effect. In the period 1995–2000, the average emission intensity has decreased by 14.2%. In the period 1995–2000, the technique effect largely compensates the scale effect and the composition effect, so that the GHG emission level of 2000 ends up just above the level of 1995. According to the large technique effect in GHG emissions in the period 1995–2000, Table 7 shows that SNI variant 1 increases by 5.8%, while under variant 2, SNI increases by 15.0%.

Similar to the compositional effect, the technique effect is not uniform over the various sectors – some sectors show an increase, other sectors a decrease in emissions per value added – but there is an unambiguous aggregate effect, as presented in Figure 6. It shows the relative change in GHG emissions per VA per sector between 1995 and 2000. The commercial services sector shows a decrease in emissions per value added, while the largest increase in emissions per value added is found in the other mining and quarrying sector. This sector accounts for 6% of national income.

Abatement effect

Finally, we calculate the abatement effect, which concerns the emission reduction potential of unused, available abatement technologies. Thus, NNI (in the left part of Figure 3) 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. If new abatement technologies have been developed, the sustainable income will rise, *i.e.* a positive abatement effect. On the other hand, if abatement technologies are actually implemented and there is no new set of abatement technologies available for further emission reduction, the abatement effect will be negative.

During the period 1990–2000, GHG emissions were the binding theme. During this period, the abatement effect has brought the SNI to a higher level. The split up of the period 1990-2000 in two sub-periods shows a clear change in trends. In the first half of the 1990s, the abatement effect was negligible, but in the second half of the 1990s, the abatement effect was substantial, see Table 7. Apparently, the set of abatement technologies for the reduction of GHG emission in 1995, in comparison with 1990, was not extended with many new low-cost abatement technologies, see Figure 2. In the period 1995–2000, however, the abatement cost curve shifts to the left. Many new low-cost abatement technologies have become available. The abatement effect is positive for both SNI variants, 4.3% and 10.2% for variant 1 and 2 respectively. Yet, we have to make a qualification to this result. Part of this abatement effect in the period 1995–2000 is due to the availability, in 2000, of more credible information (specifically on renewable energy sources) rather than to new available technical measures. Still, the calculations suggest opportunities for a delinking of economic growth and environmental pressure.

5. Conclusions

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

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

Second, the change in the composition of the economy is a powerful element for decreasing actual emissions. Yet, there are limitations to a further change in composition towards emission extensive sectors, and thus, it deprives the economy of part of its opportunities for meeting the sustainability standards in the concomitant sustainable economy. That is, the size of the composition effect on sustainable income is well below the size of the composition effect on actual emissions. On the other hand, if the economic restructuring contributes to an increase in actual emissions, it is likely that it becomes more difficult to meet the sustainability standards. Our results are inconclusive, as we found a simultaneous increase of the GHG emissions and the SNI indicator for the period 1995–2000. Probably, there are more underlying mechanisms at play which needs further analysis.

Third, a decrease in the emission intensity of production processes is the most direct way of decreasing actual emissions. Furthermore, since emissions on the margin require a more than proportional abatement effort for reaching a sustainable economy, the decrease in emissions also leads to a more than proportional gain in sustainable income levels. This explains that the magnitude of increases in sustainable income levels tends to be higher than the magnitude of the emission intensity decreases. Yet, the implementation of emission reduction measures can partly exhaust the set of measures available for further reductions, so that the abatement effect is (small but) negative, as is the case in the period 1990–1995. In the period 1995–2000, however, the set of emission reduction measures has been enlarged. Part of this enlargement might be due to more credible information on abatement technologies, especially in the case of GHG emissions. On the other hand, the enlargement of unused available abatement technologies in 2000 contains opportunities for a further trend of delinking of economic growth and environmental pressure.

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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