Sustainable National Income and Multiple Indicators for Sustainable Development [1]

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Abstract

Developing indicators for sustainable development is discussed in the context of a view on sustainability based on experiences with environmental economic modelling. This view coincides with an explanation of a specific indicator, sustainable national income (SNI).

The goal of publishing the SNI is to put into perspective the significance of gross national product (GNP) in political opinion-forming and policy-making. We summarise the place of both indicators in economic theory. To this end, sustainability is defined as non-declining welfare. This is almost equivalent to a non-declining volume of national income, or non-declining availability of environmental functions (possibilities to use our physical surroundings). The relevant environmental economic aspects of sustainability are thus incorporated in the SNI. Social aspects are limited to the conditions that employment and income distribution must remain unaffected and a subsistence level of income must be guaranteed. Sustainability thus defined takes the form of a development path that can be achieved in future if at least two conditions are satisfied: people must have dominant preferences for sustainability and blockages, such as the prisoner's dilemma, must be overcome by some form of concerted action. The sustainable path used here is the path with maximum non-declining income under current technology, which is the SNI. This path is not instantaneously achievable, but the difference in income between the actual path and this sustainable path is a measure of the current degree of unsustainability of the country considered. Moreover, under the assumed preferences the SNI is an improved monetary welfare measure in comparison to standard national income.

A calculation method for the approximation of this theoretical SNI has been set-up by dividing the theoretical model in separate approximate steps involving no feedback loops. First, the state of the environment on the sustainable path with maximum production (income) is estimated for each environmental problem taken into account. Second, this state is transformed in maximum allowable levels of emissions and the other forms of use of the environment, such as land use, by employing a model for each environmental problem. Third, these so-called sustainability standards are used as constraints in a dedicated general economic equilibrium model which maximises national income, thus

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producing the approximate SNI in the year considered. This model reduces the use of the environment down to the imposed sustainability standards by employing changes in production and consumption processes, varying from adding technical appliances via process adaptations to shifting production capacity to environmentally less damaging activities. The SNI can increase and its distance to GNP can decrease by technological progress.

Indicators of sustainable development

Like most of our colleagues, we characterise the system of our concern as the interacting social, economic and environmental subsystems of the world, a country or a region. The interactions between these subsystems can be described by variables representing human or physical actions (flows) from one subsystem to another and reactions. Actions and reactions can be investments, changes in employment, changes in types of use of the environment by economic activities such as resource use and emissions, et cetera. The reactions are to a large extent determined by characteristics of the stocks (the state, the condition) of the environmental, social and production-consumption subsystems, labelled as the stocks of natural, human and produced capital. Variables representing these (re)actions and characteristics of stocks can be labelled action and state variables, or flow and stock variables. The central question is apparently, how to measure whether the system is heading for sustainability, in other words, whether it tends towards sustainable development?

An approach to sustainable development

The question how to measure sustainable development can of course only be answered after having stated what one means by sustainability. Pezzey (1994) for instance inventoried a large variety of definitions. Yet, the theory these authors developed inspired us to make a cautious delimitation of the concept that might be useful in developing indicators. We do so by making use of some insights that we gathered from working with environmental economic theory on sustainability, more specifically from the theory of sustainable national income (SNI), and give some practical examples, including the application of the SNI. The following reasoning depicts our view on sustainability.

The interdependence of the environmental, social and production-consumption subsystems makes sustainability a characteristic of the system as a whole: the social subsystem cannot be sustainable while the environmental subsystem is not (the opposite holds true in the short term but not in the long term, see Hueting, 2003*),* and so on. It follows directly that the system's behaviour (or development) is either sustainable or it is not.

The development (or behaviour) of the social-economic-environmental system can be said to be sustainable if the development does not threaten the existence of the system itself, nor the elements and characteristics of the system that people (as elements of the system) want to preserve for whatever reasons. A sustainable development therefore requires the preservation of vital elements and characteristics of the system. These essential variables include human health and vital environmental functions *i.e.* possibilities to use our physical surroundings (specifically to withdraw space, substances and organisms and to emit substances) (Hueting 1980, Pezzey 1994, Goodland 1995 and Hueting and De Boer 2001). Examples are the function 'air for physiological functioning of humans, plants and animals (breathing)' of air, the function 'drinking water' of water and the function 'soil for raising crops' of soil. It is clear that a sustainable development according to this "definition" is not unique, but that does not need to be a problem.

From the above it follows rather directly that a development is sustainable if the essential variables are constant or increasing, *i.e. never decreasing*. However, this condition results in a group of sustainable balanced development paths (such as path *s* in Figure 1) which generally do not coincide with the actual development path (*a* in Figure 1) at any time instant. Therefore, this type of sustainable development path generally cannot take-off from the actual development path immediately. This is why a sustainable balanced growth path can only be attained by an infeasible leap or approached in the course of time via a transition path.

Feasible transition paths (such as *f* in Figure 1) from the actual development path *a* to a sustainable balanced growth path such as *s* generally exist. On such a transition path, the essential variables gradually converge to a never-decreasing pattern on a sustainable balanced growth path such as *s*, but they never reach the path exactly. In stability theory, however, a transition path to a stable path is considered stable itself. Therefore, a transition path such as *f* may be considered a sustainable development as well, although the essential variables have diminished to sustainable levels only at the end of path *f*. [2]

A development of the social-economic-environmental system includes the reactions of people and their governments to their perceptions of this development, so an unsustainable development might turn into a sustainable one, or *vice versa*. This makes sustainability a time-dependent criterion. At first sight it might seem odd that the whole system's survival would be at stake in a certain period and not in the next period, or *vice versa*, while the system still exists. The reason is that the system is dynamic and threats to its existence are therefore not immediately effective and may consequently be averted before they would become effective. So, a development of the social-economic-environmental system can be called sustainable if the extrapolation of the development into the future with the best of our knowledge shows that all essential variables converge to non-decreasing patterns or close ranges around those patterns. Therefore, if the development changes, it may also change from being unsustainable into being sustainable, or *vice versa*.

[2] Stability theory shows that the group of sustainable development paths can be broadened further. Like a stable path, a path may still considered sustainable if it ultimately stays circling within a constant range around the balanced growth path *s*, where this range should of course be acceptable according to the preferences of the people. Thus, stochastic fluctuations, stable limit cycles and limited chaotic system behaviour around the balanced growth path may be incorporated in the sustainability concept. We shall not use this extended sustainability concept here.

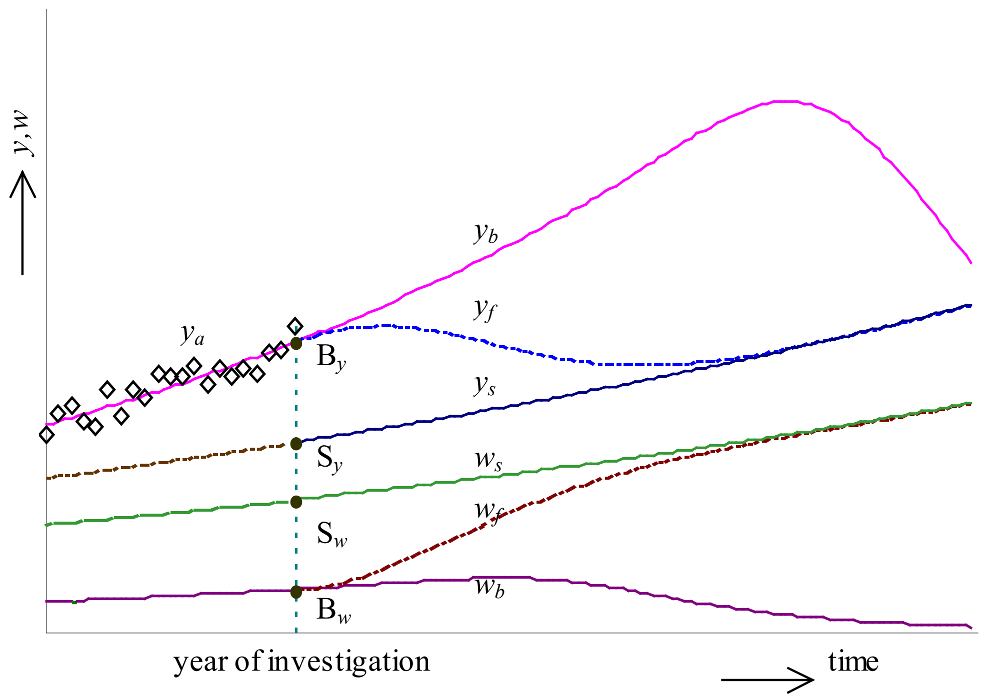


Figure 1. Actual standard national income observations (y_a, fictitious example) compared with the net national income (y) and a welfare indicator (w) on three optimal paths, calculated with a dynamic environmental economic model. The business-as-usual path (index b) approximates the actual path (index a) by assuming incomplete expression of preferences for the environment. These preferences are assumed to be completely expressed on the infeasible sustainable path (index s) and the feasible transition path (index f). The points B_y and B_w indicate the levels of national income y and the welfare measure w on the business-as-usual path b in the year of investigation; S_y and S_w are the corresponding points on the infeasible sustainable path.

Sustainability clearly puts society in control: the system is not autonomous but human decisions are vital for the continuation of its existence. People may threaten the system's survival, including that of people in the future, by maintaining an unsustainable development, and only people can turn it into a sustainable development.

The well-known definition in the report "Our common future" (WCED, 1987) summarises the reasoning so far quite well by saying that the world economic development is sustainable if it takes care of the needs of the present generation without damaging the possibilities of future generations to satisfy their needs.

Some conditions to sustainable development indicators

The next step is how to develop from these still rather abstract notions a set of indicators for the "degree of", "distance to" or "movement towards" sustainability of actual system development.

From stability theory it also follows that the notion of a set of stable or sustainable paths defines at each time instant a region of initial points of these paths, the border of which can be considered as the sustainability boundary (Perrings, 1996). This boundary consists of points of no return. If a point on the actual development path at a certain time lies within the sustainability boundary of that moment, a sustainable balanced development path still can be reached and the actual development still can be deemed sustainable. This elegant concept could be turned into a great instrument along with a satellite accounting system monitoring the actual developments of the (most important) essential physical or monetary action (flow) and state (stock) variables. It could even be used to develop sustainability indicators. Unfortunately, the assessment of this boundary must be considered practically impossible and practical criteria for sustainability must be developed.

To that end, consider a set of action and state variables of the social-economic-environmental system. What makes these variables sustainability indicators? Of course, the variables must be calculated correctly in accordance with the conventions of the system of national accounts. It can then be established for instance whether a variable is increasingly "uncoupled" from the growth of production. But even if such uncoupling is observed, it still cannot yet be established whether this fact guarantees sustainable development if it is not clear in which direction the variable must change to this end. For instance, remaining at the same level can be insufficient to attain sustainability because of the persistent and cumulative character of the burden. In such cases only a slowing-down of the deterioration would have been attained. It is therefore paramount to have a notion of the closest sustainable balanced growth path of the system as a whole (*s* in Figure 1), *i.e.* the set of sustainable levels of all monitored variables that is the closest to the actual situation. Because this dictates in which direction and at what pace the variables must change. Only then, can one judge if the monitored development is a sign of a transition towards sustainability (such as *f* in Figure 1). More importantly, only then can one see whether sustainability is still far away or relatively close for the essential variables.

The sustainable levels of the essential action and state variables are mutually dependent and must in theory be estimated by modelling the whole system. Below we give an example of how this can be done. From this exercise it follows that certain action and state variables must change with certain rates at least in order to achieve that other state variables reach sustainable levels. For example, the (equivalent) emission of greenhouse gases (an essential action variable) should be reduced with a rate of at least about 0.5% of last year's emission each year world-wide during the next centuries in order to prevent unsustainable global warming (temperature at ground level is an essential state variable). That is, according to a set of different global warming models. These conditions to the rates of change of some key action or state variables are even less accurate than the estimates of the sustainable levels of these variables, but they provide important additional information for judging the "degree" of sustainability of the monitored course of these in the course of time.

Summarising, we propose to judge the degree of sustainability of the actual development by comparing the actual levels and the development of the monitored variables with the levels they must ultimately attain on an estimated sustainable path. From this comparison may follow demands on the rates of change of some variables. Such a sustainable path is the one corresponding with maximum sustainable national income, the SNI.

Sustainable national income

We illustrate the process just explained using the calculation of the sustainable national income (SNI) according to Hueting (1980) and Hueting and De Boer (2001), performed by the Institute for Environmental Studies in co-operation with Statistics Netherlands for the statistical years 1990 and 1995; see Verbruggen *et al.* (2000), Hofkes *et al.* (2002) and Gerlagh *et al.* (2002).

The SNI is defined as the maximum attainable national income under absolute preferences for sustainability, while technology and societal essential variables as employment remain as observed, except the size of the population. The reasons for these choices are:

- the SNI is designed to show the trade-off between production and the sustainable levels of environmental functions (the levels to which the environment can be used), taking the effects of changing technology and sectoral employment into account
- the effects of expected *future* technological progress and of expected *future* population growth on *present* sustainable national income must not be incorporated in the SNI
- effects of reaching sustainability on employment and other social variables, and thus on national income, are not incorporated in the SNI, because these effects cloud the indicator
- many societal essential variables *may* correlate positively or negatively with the level of production and the levels of environmental functions, and may therefore be monitored separately (Goodland 1995, Hueting 2003).
- the size of the population is an essential element in the ultimate sustainable state and it is therefore an outcome of the SNI calculation (although family planning was not used as one of the measures to attain sustainability in the practical calculations).

The income maximisation selects only one sustainable balanced growth path as the vehicle for the SNI and as the goal of transitions to sustainable development. We illustrate this below. Further, we explain how this path is approximated for essential variables and how the SNI is calculated.

Theoretical environmental-economic model

Like before, we start with the theory, in which we use a reliable model of the relevant processes in production, consumption and the environment. Remember that we assume all societal elements to be constant, except population size. The model takes care of the interactions, the resulting volume and price changes and consequently maximises national income properly.

The interactions in production and consumption are taken care of by production functions and welfare functions, at least one function per activity, where each function has multiple inputs. The use of the environment, or possibilities to do so, appear in both the production and the welfare functions. The model simulates the changes of state and action (flow) variables in the economy, the environment and society in their mutual dependence. The model has time dependent solutions, which form a path in variable space vs. time. We discuss those paths by means of two important aggregate output variables, plotted on the same vertical axis. One of them is the volume of national income as a measure of production and consumption, the other one is a welfare measure.

The model can produce different paths by providing it with different inputs. A crucial input is the structure of the preferences for using the vital functions of our physical surroundings for increasing production in the short term on the one hand and for safeguarding these functions in the long term on the other. This welfare function can – for a large part – only be assumed, because these preferences can be measured only very partially (Hueting 1980, Hueting and De Boer 2001).

One may assume for instance that the people prefer the actual state of affairs in production, consumption, society and the environment. If the parameters of the model are estimated (calibrated) well, the model approximates the present development of national income (path *a* in Figure 1) by path *b*. Far extrapolation of path *b* might indicate a collapse of welfare and income because of depletion of vital environmental functions.

Assumed stronger preferences for the environment produce a model path with lower income, but higher welfare, and a probably postponed collapse.

If dominant preferences for sustainable use of the environment are assumed, two paths may be calculated.

If the state of the environment as well as the technical and other measures in the economy are optimised directly in the first year of calculation so as to maximise SNI, the sustainable balanced growth path (*s* in Figure 1) will be calculated. Its characteristic is that environmental functions do not decline in future due to their use for production and consumption, because this use is limited. The sustainable path starts from an already sustainable state. The initial point lies on the 'permanently' sustainable path with maximum income (the SNI), here called *the* sustainable path. As no transition occurs following the initial state, it is a 'balanced growth' path. The path is infeasible in that it cannot be reached directly, but only by a transition path as just mentioned. Again the availability of environmental functions will not decrease on this path, but now national income does not decrease either. It may increase, but in theory, "as far as the model reaches into the future", this national income never decreases (technically, the collapse is shifted to infinity). Moreover, because national income is still maximised under the presumed preferences, this sustainable development path produces *the* sustainable national income.

If the state of the environment and the technical and other measures in the economy are chosen as they are in the first year of calculation, the model produces a theoretically feasible transition path (*f* in Figure 1), departing from the actual development path in that year. During the transition, environmental functions will not be exhausted beyond the levels reached in the sustainable equilibrium, but income will drop gradually when more and more measures are taken to reach the equilibrium.

One could ask how it is possible that we assume strong preferences for sustainability, while it is obvious that currently the world follows a non-sustainable development path. It is obvious, however, that individuals generally do not have the power to prevent large-scale damage to the environment. It is also obvious that, when they have the power to change their conduct in a sustainable way, they have objections to being the first ones to take such steps, even if they have strong preferences for the result. This is because it would cause them disproportional costs, while they expect the effect to be close to zero because they doubt that others will follow suit (prisoner's dilemma). Because of the existence of these and other 'blockages' (or 'barriers'), it suffices to assume one set of preferences to explain both the actual development where the blockages are effective and the assumedly preferred more environmentally benign path where the blockages are overcome (Hueting and De Boer 2001). This construction has the additional advantage that the comparison of national income on both paths is less problematic than with two different welfare functions.

The distance between the sustainable path and the actual development path in terms of national income is the distance to sustainability we have to bridge as a country in terms of the required opportunity costs. If we recalculate the expected future SNI trajectory in each year or each couple of years with the same model on the basis of new information on production, consumption and environmental protection technology, the starting point of the trajectory provides the SNI of that year in the statistical sense. The SNI's at these starting points in the consecutive years of calculation form the time series of SNI we are looking for (Figure 2).

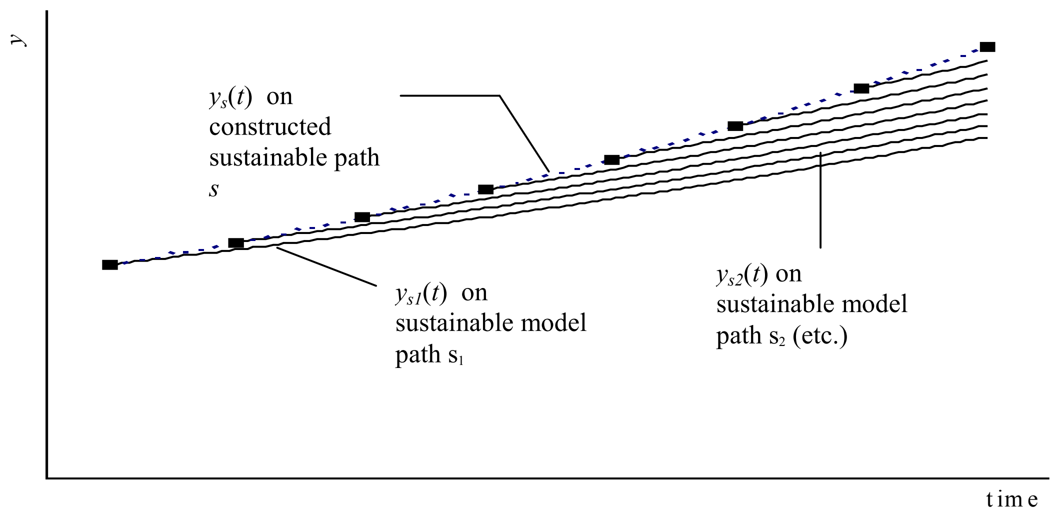


Figure 2. Construction of the unfeasible sustainable path s and the corresponding sustainable national income y_s,. In the calculation of the sustainable national income according to Hueting, technological progress is *ex ante* assumed zero on each model path. In that case national income on these paths ($y_{s1}(t)$, $y_{s2}(t)$ et cetera) are constant and their graphs are horizontal lines (not shown in the figure). National income on the *ex post* constructed sustainable path s, however, may still rise due to technological progress.

Practical SNI model approach

Generally, a sufficiently accurate integral economic-environmental model is so large and complex that a sustainable solution providing the SNI cannot be found. Therefore, we have decided to approximate the sustainable path by using a set of models that co-operate in a sequential fashion, without the mutual feedback that would make the model collection generally valid.

The case of sustainable development, however, offers a possibility to make this simplification without generating a large error. Remember that the necessary condition for sustainability is that environmental functions are maintained forever, at the lowest levels of availability that enables the environment to stay supporting these levels. Put less technically, we seek the maximum levels of use of the environment that may be sustained forever, in other words, levels above which the very possibilities to continue with this use would disappear in the future. Three conditions are set up that are assumed to hold if the environment is used sustainably. These conditions must be satisfied both in the present and in the future.

The first condition is that the extinction of biological species at the global level may not be accelerated by human influence. The second condition is that any changes in the state of the environment may have only a minor, acceptable impact on human health. The third condition is that vital environmental functions must be present all over the world, that is, not equally spread but within reach for human use. These three conditions impose bounds on the acceptable variation in the state of the environment, however imprecise. Think of maximum allowable pollutant concentrations, minimal ozone column, maximum global warming et cetera. We call these bounds sustainability standards for *the state* of the environment.

These bounds to the state of the environment are used as inputs in models of the environmental problems concerned, such as the use of natural resources and space, climate change, acidification, eutrophication, dispersion of harmful substances and desiccation. Iteration with such a model yields limits to the use of the environment by production and consumption mentioned before. We call these limits sustainability standards for *the use* of the environment, and they are actually approximations of the use of the environment on the sustainable path (which we cannot compute directly). The standards represent both the assumed preferences for sustainable use of the environment (the vertical demand line in Figure 2.7, Hueting and De Boer 2001) and the knowledge we have of the 'behaviour' of the environment under (or close to) that sustainability, however approximate this knowledge sometimes may be. Table 1 shows the most important standards as developed in the project.

Table 1. **Sustainability standards for the Netherlands, 1990**

Environmental Theme	Units	Emission	Sustainability standard	Required Reduction (%)	
Greenhouse effect	Billion kg CO_2 equivalents/yr	254.5	53.3	201.2	(79.1%)
Ozone layer depletion	Million kg CFC 11 equivalents/yr	10.4	0.6	9.8	(94.2%)
Acidification	Billion acid equivalents/yr	40.1	10.0	30.1	(75.1%)
Eutrophication	Million P-equivalents/yr	188.9	128.0	60.9	(32.3%)
Smog formation	Million kilograms NMVOC/yr	527.1	240.0	287.1	(54.5%)
Fine particles	Million kilograms/yr	78.6	20.0	58.6	(74.6%)
Dispersion to water	Billion AETP-equivalents/yr	196.8	73.5	123.3	(62.7%)

CFC 11: chlorofluorocarbon 11
NMVOC: volatile organic compounds excluding methane
AETP: aquatic ecological toxicity potentials
kg AETP-equivalents: kg 1,4-dichlorobenzene

These standards are used as inputs to a dedicated applied general equilibrium model (AGE) of the country's economy. We have chosen to use a static model; this means that the dynamics of production and consumption, caused by changes in capital stocks and so on, are neglected. Again, this assumption is acceptable by virtue of the intended comparison between the actual development path and the permanent sustainable development path. The model calculates the sustainable equilibrium of the maximum national income in the year involved. This maximum is the - practically approximated - sustainable national income.

In this general equilibrium model, it is necessary to make additional assumptions *e.g.* regarding time scale, regarding reactions to price changes due to internalisation of costs to eliminate environmental burdens and regarding what will happen to international trade when all the countries in the world simultaneously take sustainability measures (which is one of the – logical – basic assumptions of the SNI estimate). This too introduces uncertainty margins in the results. Of course, these margins do mean that there are different possible results, but principally that different SNI's do not exist.

The SNI in combination with standard NI indicates the distance to sustainability as it develops in time, or in other words, as an indicator of how far we live beyond our means, or how fast we proceed in correcting it. This distance can decrease by an increase of SNI because of technological progress and by changes in production and consumption patterns.

Numerical results

Table 2 presents the macro-economic results for SNI variant 2 in comparison with the reference net national income (NNI) situation, for 1990. SNI2 assumes that world market prices change proportionally as domestic prices when world-wide sustainability constraints are implemented. SNI1 assumes the world market prices do not change; this variant, which is in 1990 42,5 % lower than NNI*,* is not presented in the table. SNI2 is 56% below NNI in the base situation. In Table 2 income is partitioned by sectors. The row entry 'Other VA' in corresponds to the capital and abatement sector, and to taxes and emission permits paid for directly by consumers. SNI has to be corrected for double counting, which describes the part of value added spent on reduction of dehydration and on soil clean up.

Table 2. **Macro-economic results (billion euros)**

Variant 2 : Fixed Trade Patterns	NNI, 1990	SNI2, 1990	
National Income	**213.0**	**94.2**	**(-56%)**
Agricultural Production	7.6	16.0	(111%)
Industrial Production	61.8	46.7	(-24%)
Services Production	128.9	27.2	(-79%)
Other VA	14.8	14.9	(1%)
Double counting	0.0	-10.7	

At first sight perhaps remarkably, we find the sharpest decrease in value added in the services sector, which is the sector with the lowest burden on the environment. The industrial sector with its much greater burden on the environment decreases far less. The agricultural sector with its intensive use of natural resources even shows an increase in value added. This can be explained as follows.[3]) The labour productivity in the latter sectors decreases substantially because environmentally benign production methods require more labour per unit of output. This leads to an increase in real prices and consequently to an increase in value added per unit of output. However, the increase in prices causes a relatively small decrease in the total output of the sectors because of the low price elasticity of the demand (change in demand resulting from change in price), especially for food. In the services sector real prices increase far less, because the production of services such as culture, education and the administration of justice cause much less of a burden on the environment. However, the price elasticity of the demand for these products is much higher than for products such as food and shelter. This causes a decrease in the value added of the services sector, mainly caused by a move of labour from this to the other sectors.

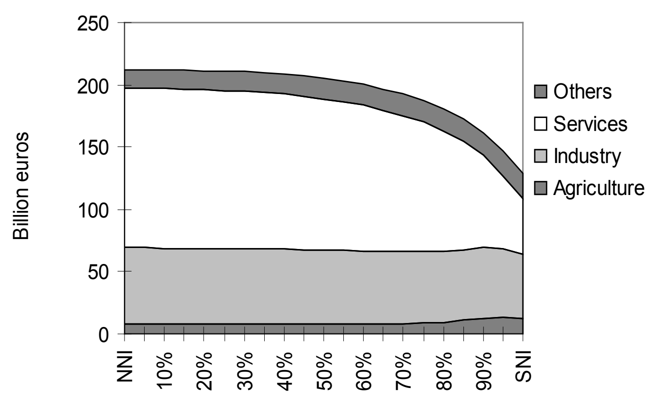
This course of affairs is exactly what could be expected according to the theory on which the SNI is based (e.g. Hueting and De Boer 2001). This theory is in line with

3 Another explanation is possible as well; see Gerlagh *et al*. (2002) and Hofkes *et al*. (2002).

standard economic theory and with the conventions of the System of National Accounts (SNA). According to this theory both income distribution and employment level will remain unaltered when the costs of decreasing environmental burdens are – gradually – internalised in the products (remember that the infeasible leap to sustainability in the model will in reality take quite some adaptation time, otherwise substantial frictions will occur). The assumption of unaltered income distribution and constant employment level (see above) seems to be logical and realistic. Because of the price rise of the environment burdening products the income ratio (the ratio of the values added) between (1) the workers in the sectors producing these products and (2) the workers in the services sector can remain unaltered. Because of this and because of the difference in the price elasticity of the demand, workers in the services sector can move to the other sectors, so that the overall employment level can remain constant.

The just described mechanism will not occur in SNI1, because in SNI1 in the rest of the world relative prices of environmentally burdening and not burdening products remain unaltered, so that the Netherlands can import environmentally burdening products cheaply from abroad. This also explains why SNI1 is higher than SNI2. However, another process occurs in SNI1, affecting domestic prices of imported and exported goods and causing effects analogous to the effects occurring via the mechanism just described in SNI2, be it to a limited extent (Figure 3).

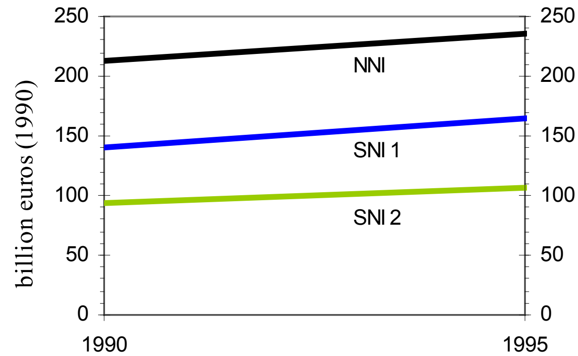
Figure 3. **Break up of income in value added, from NNI to SNI1.**



A trend decomposition for 1990 - 1995

The SNI-indicator has been calculated for the Netherlands for 1990 and 1995. For each year, the calculated value of SNI is sensitive to various assumptions, so that for a set of possible assumptions, we find a range of SNI values, as opposed to a unique point calculation. Yet, since assumptions typically affect the calculated SNI value in about the same way for different years, the trend between the two periods will be less sensitive to the assumptions, as the following figure portrays.

Figure 4. **Trends for NNI, SNI1, and SNI2 (different assumptions on trade).**



We explain this picture by decomposing the changes in the SNI into a scale effect, a composition effect, an emission effect, and a technology effect (Table 3). Whereas NNI increased by 10.4% over the period 1990-1995, SNI (variant 2) increased by 13.9%. The table shows that the increase in sustainable income is mainly due to (i) the composition effect, that is the change in the structure of the Dutch economy, with a slightly decreasing share for industries and an increasing share for services, and (ii) an emission effect, that is a decrease in the emission intensity of all sectors, on average. An extensive trend analysis is given in Hofkes *et al.* (2002). It falls beyond the scope of this presentation.

Also, we notice that we cannot claim that the economy has become more sustainable, though SNI grew faster than NI, since the gap between NI and SNI increased, in absolute terms, from 135 to 146 billion euros. To become more robust, we would need to extend the trend analysis to, at least, a ten-year period.

Table 3. **Decomposition of changes in NNI and SNI2 (billion euros, 1995 prices).**

	NNI		SNI2	
1990	242.8		107.4	
Scale effect	268.4	(+10.5%)	110.1	(+2.5%)
Composition effect	268.4		113.1	(+2.7%)
Emission effect	268.4		122.8	(+8.6%)
Technology effect	268.4		122.2	(–0.5%)
1995 relative to 1990	268.4	(+10.5%)	122.2	(+13.9%)

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

Concluding comments

The main emphasis of the research was on the construction of an applied general equilibrium (AGE) model to calculate a sustainable national income indicator for the Netherlands. We have been successful in the sense that we have shown that an AGE model can be extended with a list of environmental themes, and that abatement costs can be included explicitly in the model to account for the costs associated with emission reduction measures.

Our calculations indicate that climate change, caused by emissions of greenhouse gases, is currently the most pressing environmental issue, in terms of costs involved to meet the sustainability standards. Whether the gap between net national income and the SNI level will increase or decrease over time largely depends on the greenhouse gas policies that will be implemented in the coming years.

There are still many improvements and refinements to be made to our modelling analysis. Without being exhaustive, we recall some features that deserve special attention. First, the coverage of relevant environmental functions (themes) can be extended. For the Netherlands, land use and waste disposal beg for inclusion. Moreover, there is need for a discussion about what level of resource use can be called sustainable. We also note that the list of environmental themes included is biased to 'sink' functions of the environment, as opposed to the environmental 'source' functions associated with forests, mineral deposits, topsoil, fish stocks, and water resources. Our focus is typical for current Dutch environmental concerns. If the calculations would be repeated for other countries, one should consider including other natural resources. For many poorer countries, the sustainable use of the environmental 'source' functions is of more immediate importance then the sustainable use of the 'sink' functions.

Second, the modelling of international trade can be worked out further. Third, the information on technical options of abatement and their costs needs to be kept up to date. Fourth, in the present model, emissions are linked to outputs. Part of the emissions can better be linked to certain types of inputs, for instance, CO2 emissions to fuel inputs. Modelling emissions through links with (fuel) inputs will allow a better reflection of substitution possibilities. Fifth, the model might benefit from a differentiation of the abatement cost curves between sectors and a differentiation of the expenditure effects of technical abatement. In short, changing and modifying assumptions that underlie the SNI calculations means that a whole gamut of sensitivity analyses can be done.

Though sensitive to several assumptions and qualifications, we have a measure of the part of income that depends on an excessive use of resources. For the Netherlands, for 1990, we calculated that about half of its income could be attributed to resource use that exceeds a sustainable level. In the midst of the many theoretic analyses on sustainable income levels, policy makers may find it useful to have a numerical result.

Presenting an SNI does, in our view, not rule out disaggregated indicators on the pressure and the state of the production and consumption system, society and the environment. On the contrary, these indicators add considerable detail and explanation to an aggregated indicator such as SNI, just like the detailed results of an SNI calculation do. In fact, many of those indicators are used in an SNI calculation. However, the discussion on the obtained results points out that the SNI should always be compared to the actual NI. Likewise, disaggregated indicators for the actual environmental pressure and state can in our experience only have meaning as sustainability indicators if they are compared with the relevant sustainability standards, however roughly these are estimated.

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