Fondazione Eni Enrico Mattei

# Green National Accounting: Synthesising and Extending the Welfare Based and Sustainability-Standard Based Approaches

Anil Markandya, Pamela Mason and
Marialuisa Tamborra

**NOTA DI LAVORO 94.2000**

Corso Magenta, 63, 20123 Milano, tel. +39/02/52036934 – fax +39/02/52036946
E-mail: letter@feem.it
C.F. 97080600154

# Green National Accounting: Synthesising and Extending the Welfare Based and Sustainability-standard Based Approaches.

Anil Markandya[1], Pamela Mason[1] and Marialuisa Tamborra[2]

1 : Department of Economics
University of Bath
Claverton Down, Bath, BA2 7AY, UK
emails: hssam@bath.ac.uk, hsspjm@bath.ac.uk

2 : Fondazione Eni Enrico Mattei (FEEM)
Corso Magenta 63
I-20123 Milano, Italy
email: tamborra:@feem.it

This paper was presented at the Workshop on "Green National Accounting in Europe: Comparison of Methods and Experiences, Milan, 4-7th March 2000 organised in the framework of the EVE concerted action, co-ordinated by the University of Cambridge and financed by DG Research.

## Summary

This paper examines the theoretical foundations of green national accounting, noting that their assumptions have led to green national income measuring *welfare-based* income, which is not necessarily equal to *sustainable* income. We review two major approaches to estimating green accounting: the welfare-based GARP approach provides the values of environmental damage to estimate the net welfare generated by economic activity and the GREENSTAMP approach calculates the economic output compatible with achieving environmental sustainability.

Both approaches deliver policy-relevant information and a comparison of the results obtained using both methods illustrates this. The GARP approach facilitates the identification of efficient level of environmental protection, while the GREENSTAMP approach identifies the costs of meeting sustainable standards. These distinct advantages suggest that the two approaches could be fruitfully synthesised, and this paper outlines how this could be achieved. The appropriate choice is likely to be informed by the results of the current revision of the UN SEEA.

# *1. Introduction*

The purpose of this paper is to review two alternative approaches to calculating environmental national accounts with which to assist policymakers with environmental and sustainability policies. These two approaches are firstly the welfare based income GARP approach, and secondly the sustainability standards-based GREENSTAMP approach, both of which are the result of EC-funded projects[1]. The GARP approach is in the tradition of the welfare-based national accounting framework, and involves calculating the physical and monetary damages of the environmental side-effects of economic activity in order to estimate more accurately the net welfare provided by economic activity, including the effects of current economic activity on the economy's future prospects. Both studies discuss the viability, usefulness and relevance of using environmentally adjusted national income aggregates, and address the problem of identifying the appropriate way to value environmental goods and services.

The theory underlying the GARP methodology, and more generally the use of NNP as a measure of an economy's welfare and the correction of NNP for environmental effects, is due to Weitzman (1976). Weitzman proved that NNP defined as consumption plus the value of net investments, including the value of depleted stocks of natural resources, is a measure of an economy's income. Section 2 describes how this framework has been used in the development of the methodology of green national accounting. It discusses some theoretical problems with the framework including the fact that it has not so far been developed to account for the effect of capital gains on the long-term prospects of open economies. It also points out that there is a distinction between income in the Weitzman tradition and sustainable income, in that income calculated in the Weitzman tradition cannot necessarily be sustained over time.

The welfare-based framework is the basis of the GARP methodology, which has been used to calculate the physical and monetary damage associated with economic activity, and thus provids the information required to measure environmentally adjusted national income in the Weitzman tradition. Section 3 gives a short description of the work that has been done under the GARP project, and goes on to describe two other methodologies, namely the Hueting methodology and the GREENSTAMP methodology, which have arisen due to the theoretical and practical drawbacks of the welfare-based income measure, and in particular the fact that it does not relate sufficiently to issues of sustainability. Moreover, this section includes an analysis of the type of information delivered to policy makers as well as some considerations on valuation issues using both the GARP and the GREENSTAMP approaches. Section 4 provides a comparison of the empirical results obtained using the GARP and the GREENSTAMP methodologies.

In section 5 we argue that, while this criticism of the welfare-based approach is accepted, there are positive features of the welfare-based approach that are missing from the sustainability-standards approach. The most important of these is that it is possible that the sustainability-standards approach would not measure the "efficient and sustainable" level of income, since it does not account for the possibility that, for some environmental effects, it may not reveal the correct binding constraint to environmental resource use. That is, the socially efficient level of environmental control could be more stringent under a welfare-based approach, in which case the sustainability standards approach would be inefficient.

The second point is that the welfare-based GARP approach to calculating Green NNP is valuable per se as a measure of the actual net welfare generated by the economy and in highlighting the welfare costs of economic activity. The sustainability standards-based approaches do not supply this information. Thus, on the basis of these observations, we argue that the two approaches could be profitably combined. Section 5 outlines three potential means by which this could be achieved. The first involves constraining the welfare-based approach to account for the net welfare costs of respecting sustainability standards. The second consists of extending the GREENSTAMP approach, where necessary, to account for the possibility that welfare-based standards might be the relevant constraints. The third is similar and is based on extending Hueting's sustainability standards-based model to account for welfare-based standards.

Section 6 provides an overview of the most recent proposed revisions to the UN System of Economic and Environmental Accounting (SEEA) in the light of the future use of the methodology developed under both GARP and

[1] The GARP approach was developed in a two-stage research project funded by the European Commission: the GARP I project, supported by the Joule programme of the European Commission during 1994-1996 (JOU2-CT93-0316) and the GARP II project, supported by DG XII-Environment and Climate Programme (ENV4-CT96-0285) during 1996-1998. The GREENSTAMP approach, after the DGXII-funded project GREENSTAMP (EV5V-CT94-0363) was carried out in the period 1994-1997.

GREENSTAMP, and section 7 concludes.

## *2. Correcting Standard National Accounts for environmental and other externalities*

The shortcomings of the standard national accounts as a measure of wellbeing have long been discussed. In the last thirty years, however, there has been growing public concern as to the extent to which environmental damage may offset the positive effects of economic growth on wellbeing, and the extent to which economic growth may be unsustainable due to the depletion of productive environmental resources. The first concerted call for standard national accounts to be corrected to account for environmental issues came in 1989 with the publication of "Environmental Accounting for Sustainable Development", edited by Ahmad, El Serafy and Lutz. This publication reflected the concern among researchers that standard measures of national income provide neither an accurate reflection of welfare, nor an accurate indicator of the long-term prospects of the economy. This section surveys the theoretical work that has been done in the fields of national accounting and economic valuation to correct for these problems.

### *2.1 Green NNP in the Weitzman - Hartwick tradition*

The analysis in Weitzman's seminal (1976) article showed that the Hamiltonian of an economy's optimisation process can be used to measure its welfare income, since the current-value Hamiltonian represents current utility plus the utility value of net investment in manmade and (ideally) natural stocks of capital. Several authors have used this result in models of resource depletion and pollution to calculate an environmentally corrected net national product known as Green NNP.

One of the early theoretical explorations of correcting the national accounts for environmental and other non-market goods was made by Mäler (1991), who provided a theoretical rationale for deducting certain items of expenditure from national accounts. This was done using a model of an economy in which utility is dependent on a produced good as well as on environmental quality and leisure. Output is a function of invested capital, labour, environmental quality and the harvest from a natural stock. He noted that, since an accurate measure of welfare involves adding to conventional NNP the welfare provided by environmental goods, current defensive expenditures should not be deducted, since this would be double counting. However, the goods used to enhance the stock of environmental resources do not contribute to current welfare, and their value should be deducted. Likewise, the value of changes in the stock of environmental resources should be deducted in the same way as depreciation on manmade capital is deducted.

In a similar vein, Hartwick (1990) suggests netting out the value of decreases in the stocks of renewable and non-renewable resources. Both of these contributions involve using Weitzman's (1976) result that the Hamiltonian of an economy's optimal trajectory represents the utility level that, if kept constant, would constitute a utility path with the same net present value as the optimal path. Thus, using the assumption of a constant discount rate, the Hamiltonian represents the "return" on the economy's capital stock and in this sense can be thought of as the economy's income, or NNP.

### *2.2 Theoretical problems with Green NNP as an indicator of welfare*

One problem with Green NNP calculated in this way is that it does not account for capital gains or losses resulting from exogenously changing prices, or from exogenous technical progress. This problem derives from the fact that Weitzman's (1976) model, on which Green NNP in the Weitzman-Hartwick tradition is based, is a closed economy model with no technical progress, so that there are no exogenous effects and thus no capital gains.

Usher (1994) pointed out that “the Hamiltonian measure of income is the sum of current consumption and discounted future consumption generated by the activity in the economy during the current year.” A more complete definition of income would include the effects of economic activity exogenous to the economy. Sefton and Weale (1996) develop such a measure of income, accounting for the effects on an economy’s wealth of future paths of resource prices and rates of interest. This means a deduction for an increasing resource price path if the economy is a net resource importer and vice versa. However, while capital gains should in theory be included in measures of national income, in practice this is very difficult since it involves estimates of future price paths.[2]

[2] Further work in this area is being made possible by the EC-funded SAUNER project, which provides long-term paths of non-renewable resource prices and extraction paths compatible with sustainability of resource use.

A second problem with the interpretation of NNP, and the one dealt with in this paper, is that, even if all of the relevant factors could be measured and included, there is no guarantee that the result would be a measure of *sustainable* consumption or welfare. Pezzey (1994) and Asheim (1994) show that if an economy is not on a sustainable path and switching to a sustainable path would alter the prices at which assets are valued then the income level that is attainable as sustainable consumption is lower than the income level that would be measured by NNP in the Weitzman tradition.

One of the reasons for the lack of clarity in the interpretation of national income is that the word "income" in the national accounting literature has at least two distinct meanings. The first meaning corresponds to welfare-based income, the theoretical foundations for which have been discussed above. This measure of income corresponds to the assumption of a path of economic growth that maximises the net present value of consumption using a constant discount rate. This path will not necessarily be sustainable, in that under certain circumstances the PV-maximising path may involve decreasing utility at some point in the future[3].

The second main definition of income is “sustainable income”. This is income in the sense of the maximum that can be consumed without reducing the capital stock, and thus reducing future consumption possibilities. This has also been referred to as Hicksian income, since it is based on Hicks's (1946) definition of income as "the maximum amount …(an economy or individual) … can spend this week, and still expect to be able to spend the same amount in each ensuing week."

Pezzey (1994) and Asheim (1994) showed that, in general, welfare-based income and sustainable income are not equal. If the PV-maximising path is unique and not constant, then welfare-based income in the tradition of Weitzman is not attainable as sustainable income. Rather, welfare-based income identifies an “upper bound” on sustainable income, and is *attainable* only if an unsustainable consumption path can be switched to a sustainable path without changing the supporting prices, that is, if prices are exogenous. This condition would hold for the small open economy facing given international prices. It would not hold for the closed economy of Weitzman's analysis.

This distinction has caused some difficulty in interpretation of national income, in that income is often thought of as being the amount that one can consume without diminishing the productive capacity of the capital stocks, and thus as being the amount that can be consumed sustainably. For instance, Ahmad, El Serafy and Lutz (1989) note that "income is sustainable by definition: if it cannot be sustained, then it is wrongly estimated". This statement is an interpretation of income as sustainable income. The fact that welfare-based NNP does not correspond to sustainable income, even in theory, is one of the objections that has been raised to adjusting the national accounts for environmental factors. We will return to this problem below.

## *3. The major distinctions between the GARP and the GREENSTAMP approaches.*

This section discusses the development and application of two major methodologies whose aim is to contribute to the development of environmental accounts and ultimately to the measurement of environmentally adjusted national income, namely the GARP and GREENSTAMP methodologies. The GARP project is a major example of an empirical study that gathers the type of information that could be used to estimate a Green NNP, or could be provided as satellite accounts to be interpreted alongside standard national accounts. The project has been conducted in two phases, GARP I and GARP II, both funded by the EC DGXII. The aims of the first phase were to use an advanced methodology developed under the EXTERNE project to provide estimates of the monetary value of environmental damages for the EU countries Germany, Italy, the Netherlands and the UK. The aims of the second phase were to extend the method in terms of the range of pollutants covered, the attribution of the damages to different pollutant sources, and to assess the levels of defensive expenditure on various sources of damage.

The aim of the GARP welfare-based approach is to develop a practically measurable estimate of the net welfare that an economy generates. This is based on the Weitzman foundation as described above. The problems with this approach can be summarised as follows:

---

[3] Dasgupta and Heal (1974) illustrate a case in which the consumption path that maximises the net present value of utility is eventually decreasing. This case involves the use of a non-renewable resource with manmade capital in production, the decreasing flow of the resource being compensated by an increasing stock of manmade capital. Beyond the point at which the interest rate on to manmade capital falls below the constant utility rate of discount, the efficient consumption and utility path falls.

- The welfare-based measure is not, even in theory, a measure of sustainable income, because it is derived from the assumption of a present value-maximising intertemporal equilibrium. It is not equal to sustainable income unless the PV-maximising path happens to be constant.
- Unless the economy is actually at the efficient level of environmental damage implied by the derived environmental values, the prices at which environmental damages are valued will not be the correct prices, and the measure of welfare will be incorrect, even if the aim is to measure welfare-based income rather than sustainable income.
- Some environmental assets provide services essential to the sustainability of human wellbeing, but that are not traded in markets and thus do not have market prices. The depletion of these assets often does not impact directly on current welfare and is not therefore amenable to economic valuation. The sustainability implications of this depletion are not reflected in a welfare-based valuation approach.

The theoretical basis for a second approach to calculating Sustainable National Income (SNI) was developed by Hueting (1989) in response to these difficulties, and in particular to the fact that welfare-based green national income is not a measure of sustainable income. Hueting's suggested methodology is built on the idea of strong sustainability[4], in contrast to the welfare-based approach, and takes environmental sustainability as a starting point. The basic premise of the SNI concept is that national income can only be sustainable if essential environmental services are themselves sustainable. Thus, sustainable income is defined as the maximum level of net economic output that is compatible with respecting scientifically identified standards of environmental sustainability. This, given publicly declared support for a policy of sustainable development, can be taken to be the "social demand" for environmental goods.

The Hueting method estimates an adjusted GDP, compatible with undertaking the abatement necessary to reach sustainability standards, using existing market prices. This partial equilibrium approach however does not account for the general equilibrium effects of the non-marginal changes in economic activity that would be associated with implementing environmental sustainability standards. Therefore, while the GREENSTAMP team were in sympathy with the aims of Hueting in measuring sustainable national income, they proposed a third methodology that would account for the total price and quantity effects of imposing sustainability standards.

The GREENSTAMP methodology, like the Hueting methodology, is based on a requirement for strong, environmental, sustainability. This approach rejects the monetisation of the benefits of environmental goods in order to apply cost benefit analysis to identify the most efficient allocation of resources at a macroeconomic level. Rather, according to this approach, the appropriate way in which to express society's "demand" for environmental goods is by respecting environmental standards compatible with preserving the ecological base required for sustainability. The GREENSTAMP methodology avoids the problems associated with the Hueting methodology by estimating sustainable national income by empirically calibrating a multi-sector equilibrium model of a national economy and using this to estimate the economic output that is consistent with respecting environmental sustainability standards. However, the major disadvantage with this approach is, arguably, that the complexity of a real national economy is so great that the inaccuracies associated with attempting to model an economy would be so great as to result in inaccuracies at least as great as those associated with the other two methods.

## *3.1 Policy-relevant information provided by GARP and GREENSTAMP*

The basis of the GARP methodology is the integration of scientific knowledge into the economic framework. The central objective is to provide a scientifically robust method to calculate damages to human health, crops and materials. These are first calculated in physical units by applying the impact pathway analysis, based on consolidated exposure-response functions, and are subsequently transformed into monetary terms. Thus, information is delivered to policy makers in the form of both physical and monetary impact estimates.

This information is particularly important from a policy perspective because it constitutes a basis on which scientifically and economically justifiable environmental standards can be identified. However, these standards do not necessarily represent the standards required for environmental (or economic) sustainability, and moreover they are based on the monetary valuation of environmental damages, which is often considered to be controversial.

[4] Strong sustainability requires that stocks of "essential" environmental resources be maintained. This contrasts with weak sustainability, which requires that the value of aggregate capital stocks be maintained, so that increased manmade capital can substitute for depleted natural resources.

The GREENSTAMP project provides policymakers with information on the costs to be borne by society in meeting given standards of environmental protection. The idea behind the GREENSTAMP project is to adopt a cost-effectiveness approach, initially developed by Baumol and Oates (1971) in the context of the implementation of environmental quality standards for pollution control. The cost-effectiveness approach "takes a performance standard as given and aims to identify the way of attaining it that involves the least expenditure". As Brower, O'Connor and Radermacher (1999) point out, "the standard setting is partly dependent on the initial estimates about the probable magnitude of these costs". In GREENSTAMP environmental standards are assumed to arise from a political decision making process, and given the commitment of governments to follow a policy of sustainable development, are considered to correspond to environmental sustainability standards. Once the standards are set, the question is how these standards should be implemented within a decision making process. This question is addressed using scenario modelling, which results in the calculation of abatement cost curves.

The implementation of environmental standards is based on costs of abatement associated with the hypothesis envisaged in each scenario. This approach allows policy makers to choose cost-effective solutions. However, political and economic realities imply the possibility that the policy decisions on environmental standards will be based on budget constraints rather than on sustainability targets.

### *3.2 Object to be measured*

This section highlights the fact that the factor to be measured and valued differs between the GARP and GREENSTAMP approaches. GARP uses welfare measures to value benefits obtained or damages avoided, whereas GREENSTAMP uses actual or hypothetical "market" costs to measure the economic costs of protecting the environment. If the damage function (which measures benefits obtained or damages avoided) estimated under the GARP approach, can be compared to the avoidance cost curve estimated using the GREENSTAMP approach, the point at which they meet illustrates the efficient level of environmental protection. This point does not necessarily correspond to the environmentally sustainable level of damage which, as argued below, could be greater than or less than this level.

## *4. A comparison of the empirical results*

Having compared the GARP and the GREENSTAMP methodologies, we will now compare some of the results obtained from applications of these methodologies.
The main sources for this empirical analysis are:

- The final report of the GARP II project, finished in November 1999 (DG XII ENV4-CT96-0285) which extends the scope and results obtained in a first round of work during the GARP I project (see Markandya, Pavan, 1999);
- The draft final report “Natural Resources and Environmental Accounting in the Czech Republic” of August 1999 (Phare OSS No. 85.2200.10);

The GARP II report provides results on damage estimates (especially those caused by air pollutants) for four countries, whereas the first empirical results of the GREENSTAMP methodology were obtained from a study in the Czech Republic.

Ideally we would compare damage estimates with avoidance costs for different pollutants, but it seems that the two sources are not sufficiently compatible and/or do not contain enough quantitative information to allow such a detailed comparison. The comparison would have compared the order of magnitude of two pollutants, $NO_x$ and $SO_2$, that have been studied by both projects.

In the Czech study abatement cost curves were estimated both for $NO_x$ and $SO_2$. These were calculated from stationary sources only. This affects the results, since emissions from stationary sources have reduced in the last few years, whereas those from mobile sources are increasing rapidly. Therefore, the net effect of total $NO_x$ and $SO_2$ emissions to air is not clear. The Czech study presents $NO_x$ and $SO_2$ results for 1996 (stationary sources emissions and total emissions) and estimates for 2000 and 2010 (only from stationary sources). They are estimated using the Czech register of emissions and air pollution sources (REZZO). These results are presented in Table 1.

**Table 1:** $NO_x$ and $SO_x$ emissions in the Czech Republic: Costs in Euros per Kilotonne of pollutant abated per year.

| | $NO_x$ emissions | $SO_x$ emissions |
|---|---|---|

| | Stationary | Total | Stationary | total |
|---|---|---|---|---|
| 1996 | 205 kt/y | 430 kt/y | ? | |
| 2000 | 160 kt/y | / | 336 kt | |
| 2010 | 85-90 kt/y | | 186 kt/y | |

Source: O'Connor (1999)

Reductions in emissions are obtained using both primary and secondary measures. The costs associated with these measures are 100 Euro per tonne of $NO_x$ abated using primary measures, and in the range of 200-400 Euro per tonne of $NO_x$ abated using secondary measures. For sulphur oxides, costs depend on whether the type of measure is primary or secondary, and on the solutions adopted. Estimates of $SO_x$ abatement and the associated costs require assumptions regarding technologies and techniques adopted. In fact, costs range from 300-400 Euro per tonne of $SO_2$ for use of low sulphur fuel to 400 - 1100 Euro/t SO2 for flue gas desulphurisation. The use of low sulphur gas oil seems to be particularly expensive (more than 2000 ECU per tonne of $SO_2$).

In GARP II results are reported for damages caused to human health (both in terms of morbidity and mortality), crops and materials caused by these air pollutants: sulphur oxides ($SO_x$), ozone, and $PM_{10}$. The most detailed results are available for health impacts, as they rely on the existing epidemiological literature and exposure-response functions. These damages are calculated using the ECOSENSE model, developed at the IER research institute (Stuttgart, Germany). These estimates cover four countries: Germany, Italy, Netherlands, and United Kingdom. The main results on damage costs are presented in the synthesis table below (table 2). This table shows results obtained using monitored concentration data, combined with dispersion modelling. This procedure has the advantage that it accounts directly for import and exports of pollutants. In fact, the monitored data register the actual air pollution in a given country, regardless of its origin. However, GARP II also adopted a second method for estimating damages, which allows their calculation on the basis of the emissions caused by a given country, obtained from CORINAIR data and modelling. Finally, a conversion table is provided in order to eliminate exports and add imports of pollution for each EU country. This procedure not only has the advantage of being more compatible with the GREENSTAMP results, which are based on emission data, but is also suitable for calculating the source of damages by country and by sector of activity.

**Table 2:** Damage Costs caused by the pollutants $SO_2$, $PM_{10}$ and $O_3$ in Germany, Italy, the Netherlands, and UK in prices of 1995. The background levels considered were $PM_{10}$: 10 µg/m$^3$, $O_3$: 20 ppbV (AOT40 crops: 0 ppbVh), $SO_2$: 1ppbV.

| | GERMANY | ITALY [a] | NETHER-LANDS [b] | UNITED KINGDOM [c] |
|---|---|---|---|---|
| | Damage Costs [Million ECU[d]/a] unless otherwise stated | | | |
| ***Human Health*** | | | | |
| Mortality | 22191 | 22564 | 5084 | 7952 |
| Morbidity | 21157 | 21936 | 4926 | 7932 |
| Subtotal | 43348 | 44500 | 10010 | 15884 |
| Percentage of GDP[e] [%] | 2.73% | 4.41% | 3.61% | 1.75% |
| Costs Per Inhabitant [ECU/(person*a)] | 532 | 778 | 651 | 272 |
| ***Crops*** | | | | |
| Subtotal | 1611 | 2.2 | 154 | 754 |
| Percentage of GDP [%] | 0.10% | 2 e-4% | 0.06% | 0.08% |
| Costs Per Inhabitant [ECU/(person*a)] | 20 | 4e-2 | 10 | 13 |
| ***Material*** | | | | |
| Subtotal | 136 | N.A. | 10 | 1250 |
| Percentage of GDP [%] | 0.01% | N.A. | 4 e-3% | 0.14% |
| Costs Per Inhabitant [ECU/(person*a)] | 2 | N.A. | 1 | 21 |
| **Total** | 45094 | 44502 | 10174 | 17888 |
| **Percentage of GDP [%]** | 2.8% | 4.4% | 3.7% | 2.0% |
| **Costs Per Inhabitant [ECU/(person*a)]** | 554 | 778 | 662 | 306 |

Source: GARP II executive summary of the final report to the European Commission, Nov. 1998.

Notes

[a] Results for Italy do not include damages due to $O_3$ and material impacts

[b] Results for the Netherlands include morbidity impacts of CO at 1.8 million ECU/a (assumed background for CO: 0.15 ppbV), Wet acid deposition was assumed to be the average of 100 meq/m$^2$a

[c] Results for the UK include material damages due to Acidity

[d] In 1995 prices

[e] [European Commission 1997a, Eurostat 1997]

Unfortunately, a systematic comparison of these results is not possible for various reasons:

1. *Differences in geographical coverage*: GARP II produced results for 4 countries: Germany, Italy, Netherlands, United Kingdom, whereas GREENSTAMP has produced empirical results only for the Czech Republic.
2. *Differences in the treatment of the pollutants*: Basically both projects focus on the valuation of air pollution. However, they do not consider the same pollutants: GREENSTAMP focuses on $SO_x$ and $NO_x$, whereas GARP II does not estimate damages for $NO_x$, because there is little evidence that $NO_x$ causes direct damages (e.g. to health). Data for ozone (as the main effect of $NO_x$ damages) are available in GARP II, but the relationship between $NO_x$ emissions and ozone levels is difficult to establish. Moreover, damage calculations based on $NO_x$ as an ozone precursor would lead to problems of double-counting, given that particles ($PM_{10}$) and $SO_2$ are also involved in ozone formation. The different treatment is due to the fact that GARP refers to the impacts, whereas the GREENSTAMP analyses the emissions. In a Driving-forces - Pressure - State - Impact - Response framework (DPSIR framework) they refer to a different stage of the chain: pressures for GREENSTAMP and impacts for GARP;
3. *Differences in the conceptual foundations*: these differences have been outlined in previous sections.

Both studies have hitherto concentrated on air pollution. For the GARP project this is due to difficulties in applying the impact pathway analysis to media other than air. For GREENSTAMP it appears conceptually less problematic, although in practice, time series data for the construction of abatement curves are lacking.

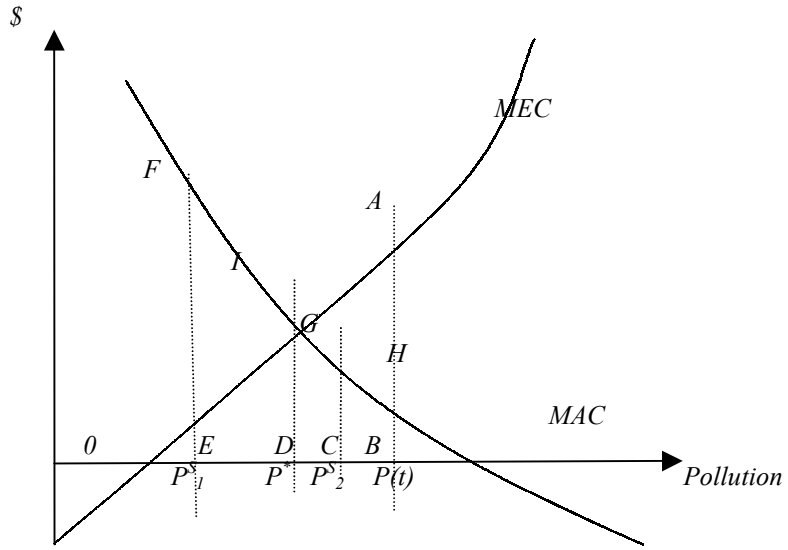
GARP also furnishes detailed and disaggregated damage estimates by industrial sector. In addition, because of the relevance of transboundary effects of air pollution, imports and exports of air pollution are calculated for each EU Member State by the ECOSENSE model, so as to determine net exporter and net importer countries.

Other media are taken into account in GARP II. In some cases, such as forests and eco-systems, a review of the existing literature on valuation is provided. For water, in contrast, because of the difficulty in applying the impact pathway analysis with a model which has a general applicability (dispersion models for water are site-specific), an alternative methodology has been presented at an "embryonic stage", which is similar in some respects to the avoidance cost approach. In fact, it considers water purification costs as a proxy of damage costs and attributes them to industrial sectors according to their polluting potential and the number of employees in each sector. GREENSTAMP also uses past investment costs and operational costs of water treatment per population equivalent as a basis for calculating abatement cost curves.

## *5. Outline of 3 potential synthesised and extended approaches.*

We argue here that, while there are clearly both theoretical and practical limitations to the welfare-based approach to calculating national income, it has significant advantages that are missing in the Hueting and the GREENSTAMP approaches. Moreover, a drawback of the GREENSTAMP approach is the one mentioned earlier, namely that the complexity involved in calibrating a model of a real national economy may be prohibitive. A second drawback that applies to both the GREENSTAMP and the Hueting methodologies is that while they account for the problems of meeting sustainability standards, and thus avoid the major drawback of Green NNP, they do not account for the welfare effects of environmental damage, and thus for the possibility that the welfare effects might be stronger than the sustainability effects. This point is particularly relevant for the case of environmental effects that do not have sustainability implications, in that they do not result in natural resource depletion or the accumulation of damaging stocks of pollutants etc., an example being noise. It is also conceivable that some types of environmental damage that have sustainability implications could have welfare implications that imply stricter limits, an example being biodiversity loss. These concepts are illustrated in figure 1 below:

**Figure 1**: Efficient and Sustainable Environmental Protection: the GARP and GREENSTAMP methodologies




In figure 2, the *MEC* curve shows the marginal economic cost of pollution, while the *MAC* curve shows the marginal cost of abating pollution. The socially efficient level of pollution is $P^*$ where the marginal cost of abatement is equal to its marginal benefit. Two potential sustainability standards are shown, $P^S_1$ and the less stringent $P^S_2$. The actual current level of pollution is *P(t)*.

Under the prevailing green national accounting framework, the amount to be deducted from green GNP and NNP for current welfare effects of pollution is the area OAB. Under the sustainability standards approach, the amount to be deducted from output is *HBEF* if the standard is $P^S_1$ and *HBCG* if the standard is $P^S_2$.

The diagram illustrates the point made above regarding the role of the binding environmental constraint. If the sustainability standard is $P^S_1$ then this is the binding constraint, being more stringent than the social efficiency condition that *MEC = MAC*. However, if the sustainability constraint is $P^S_2$ then the binding constraint is the welfare-based one. In this case, the efficient and sustainable level of pollution is $P^*$ and the cost to output of achieving this is *HBDI*.

The possibility that welfare standards can constitute the binding constraint for some environmental issues while sustainability standards are the relevant constraint in others suggests the potential for combined measures of efficient and sustainable welfare, and efficient and sustainable output. Moreover, for given sustainability and welfare-based standards, welfare-based demand curves for environmental standards could be used to implement the binding constraint cost-effectively. That is, emissions reductions could be targeted to where the reduction in welfare costs will be highest.

The remainder of this section outlines three methods by which the welfare-based approach could be combined with the sustainability-standards-based approach in order to identify indicators of efficient and sustainable output and welfare. The measure of efficient and sustainable output would consist of the GREENSTAMP or Hueting approaches, extended to account for welfare issues, as explained below. The measure of efficient and sustainable welfare would consist of the GARP, national accounting approach, constrained to represent sustainability standards. These proposed measures are described in turn.

## *5.1 The sustainability-constrained GARP approach.*

The first possible methodology is the development of a sustainability-constrained welfare-based approach. We have already noted that that there is a positive role for the existing welfare-based approach in revealing the extent to which human welfare changes over time when the negative side-effects, in particular the environmental effects, of economic activity are accounted for. A second role for the welfare-based framework is to use economic valuation techniques to estimate the net value of the welfare that would be foregone if the economy were to respect sustainability standards. The aim of the sustainability constrained GARP approach would be to develop an indicator of sustainable economic welfare. An advantage of this approach would be that it could be related to the standard measure of GDP and NNP, and would indicate the welfare that would have to be given up if sustainability standards were to be respected.

The standard measure of Green NNP assumes that the underlying model of the economy is one of maximising the Present Value of the net utility provided by economic activity. The problem for the sustainability-constrained welfare-based approach is to develop a measure, without necessarily assuming that the underlying model of the economy has changed, to represent the net welfare that would be provided by economic activity if the economy's path were to be shifted to one that is sustainable.

The first stage in this approach would therefore be to identify the rules for strong economic and environmental sustainability that must be adhered to if the economy is to follow a sustainable path. Thus, in the case of pollutants, the rule must limit emissions. In the case of biodiversity, the rule will limit habitat destruction. In the case of renewable and non-renewable resources that are used as inputs to production, sustainability rules of the type developed by the SAUNER project must be applied. In developing an indicator of strong sustainability, we could think in terms of specific types of investment, so that we calculate not only the amount of output that is feasible while respecting certain environmental standards, but also the amount and types of investment that must be undertaken in compensation for depleting natural resources. The second stage would be to calculate the economic cost of attaining these standards. This cost should be calculated if possible in a general equilibrium framework, so that the benefits of satisfying each sustainability standard in terms of reduced effort required to satisfy other standards are accounted for.

Consider a green national accounting model in which the following three constraints apply:

$$\dot{K} = F(K,R) - \delta K - C - D$$

$$\dot{P} = -\gamma(S)P - h(D) + E(R)$$

$$\dot{S} = g(S) - R$$

That is, investment in manmade capital $K$ is equal to output (a function of manmade capital and a natural resource) minus depreciation on manmade capital, minus consumption, minus expenditure on pollution control. The stock of pollution $P$ changes according to its natural rate of deterioration, the amount spent on pollution control and the amount of the natural resource used. The resource stock $S$ grows or is depleted according to the difference between natural growth and extraction.

Let us assume that there are two sustainability constraints in this model. The first is that the natural resource must be allowed to regenerate over time to what is considered its long term sustainable level. The second is that the pollution level must be decreased over time to the scientifically identified sustainable level. There is clearly an interdependence between the two sustainability constraints. The decrease in resource extraction and use means that less pollution is produced. Moreover, any increase in the resource stock improves the capacity of the environment to assimilate pollution. Both of these factors mean that the amount spent on pollution abatement to meet the sustainability standard for pollution is less than it would otherwise be. Thus, to calculate the cost to output of respecting each sustainability standard separately would be an overestimation.

Economic sustainability constraints as well as environmental sustainability constraints must be imposed. This involves prescribing the amount, and in some cases the type, of investment that must be made in order to ensure that the capacity of productive stocks to generate wellbeing does not decrease over time. An obvious example of this is the possible requirement to undertake investment in alternative energy generating capacity to compensate for the depletion of non-renewable energy resources.

The value of welfare on the sustainability-constrained path would be estimated by deducting from current consumption the consumption that would be foregone to meet the economic and environmental sustainability standards, and by adding the value of the welfare gains e.g. from lower pollution.

Insofar as the sustainability standard means lower pollution, this will increase welfare. If the model included the contribution to utility of the natural resource stock, then the second sustainability constraint would also have a positive welfare effect. These compensating effects on welfare are not accounted for under the other two approaches proposed. Thus, the advantage of this approach over the welfare-extended Hueting approach outlined below is that it provides a *net* measure of the economic effects of applying sustainability rules. That is, it accounts not only for the output and consumption that would have to be sacrificed in order to invest for sustainability, but also for the increase in welfare that would accompany improved environmental standards, and potentially also from the increased security that would be associated with sustainability.

The problem still to be addressed is that, while the economy is on an unsustainable path, the prices at which environmental assets, and the welfare effects of reduced pollution, are measured are not the correct sustainability prices. Moreover, it will be extremely difficult to measure the second and third-order effects of environmental measures on the effort required to meet other sustainability standards. Using current market and derived non-market values is bound to be an approximation. It is possible that, because of these problems, this measure and the welfare-extended Hueting approach outlined in section 5.3 will be less theoretically coherent than the welfare-extended GREENSTAMP approach outlined in section 5.2. However, we would argue that they are also likely to be more practicable.

## *5.2 The welfare-extended GREENSTAMP approach*

The aim of the GREENSTAMP approach is to develop a theoretically coherent and practicable measure of the amount that an economy would produce if sustainable environmental standards were being respected. This is taken to be a measure of feasible "sustainable consumption", and is intended as a measure of strong sustainability. An extension of this approach would allow for the role of economic valuation, and the possibility that welfare-based values might represent the policy-relevant environmental standard.

The first stage in the welfare-extended GREENSTAMP approach would be to calculate the sustainability standards for each type of environmental impact, as described in section 5.1. The second would be to calculate welfare-based demand curves for environmental standards based on the cost data provided under the GARP approach, and use these together with the sustainability standards to identify the "efficient and sustainable" level of environmental protection. The use of impact costs identified under the GARP approach could also be used in this framework to ensure that sustainability standards are achieved in the most efficient way possible, by targeting emissions reductions to where the marginal impact reductions will be greatest.

These target reductions would be incorporated into the calibrated models of production used by GREENSTAMP. The result would be a measure of the economic output compatible with respecting both environmentally sustainable and economically efficient environmental standards. The method should incorporate a rule for sustainable use of renewable and non-renewable resources, which could be informed by the results of the SAUNER project. The drawback of this approach is the complexity of the modelling that would be required to achieve any degree of reality. Incorporating welfare into the calibrated GREENSTAMP models would make them more complicated still. Thus, the practicalities of this approach need to be discussed further.

## *5.3 The welfare-extended Hueting approach*

Hueting's approach is to subtract from current output the avoidance cost of meeting sustainability standards. It is, thus, similar in spirit to the GREENSTAMP approach. However, this approach involves deducting the costs of meeting sustainability standards from standard national accounts, rather than running models of sustainable production. In this respect, it resembles the GARP approach.

However, there are fundamental differences between this model and the welfare-based approach. Hueting's approach aims to measure the final output that would have to be sacrificed, given the current situation, to meet environmental sustainability standards. The welfare-based approach, on the other hand, aims to correct standard national accounts to provide a more accurate measure of the net benefit that economic activity yields. An extension of Hueting's methodology to account for welfare-issues would be to estimate the output that is compatible with respecting both environmental sustainability standards and economic efficiency.

The first stage in the process is, again, for each environmental stock/ asset, to derive a rule for strong sustainability. The second stage in the process is to use environmental valuation to ascertain whether or not the sustainability standard is the binding constraint. In the case of habitat and pollution standards, for instance, it may be that more conservation is justified on welfare grounds than is implied by the sustainability standard. Having identified the relevant standard for each environmental issue, the costs of reaching this standard must be deducted from national income. Again, as in the method described in section 5.1, this should be done as far as possible in a general equilibrium framework in order to account for the benefits of reaching each standard in terms of reduced costs of meeting other standards. The resulting measure would be of the economic output compatible with meeting both environmental sustainability and economic efficiency standards.

## 6. *Valuation methods used in the SEEA revision*

The United Nations System of Environmental and Economic Accounting (SEEA) is a monetary satellite system designed to be consistent with the System of National Accounts (SNA). This system is currently under revision by the so-called London Group, created in 1993 to provide an informed forum for practitioners to share their experience of developing and implementing the SEEA.

The SEEA revision integrates both valuation methods discussed in this paper, and refers to them as the cost-side approach and the benefit-side approach. The cost-side approach measures actual and hypothetical expenditures to achieve improvements in environmental quality, to avoid degradation in quality or replace environmental services. In principle, environmental valuation includes both restoration costs and avoidance costs. However, the latter have been used more extensively because, unlike restoration costs, they refer exclusively to impacts caused by human activities at the present time within the domestic boundaries. In the GREENSTAMP project the avoidance cost approach has been retained.

The benefit-side approach consists of the monetisation of environmental damage.
In the SEEA revision valuation can be accomplished using two different methods, defined as:

1. The one-step approach, which elicits individual WTP or WTA;
2. The two- step or dose-response approach, which involves the physical description of cause-effect relationships and subsequent monetisation of the environmental damage.

In the GARP I and GARP II projects the dose-response approach has been used to calculate air pollution impacts. For other impacts a review of contingent valuation studies was undertaken. However, for some environmental media, such as water and soil, the cost-side approach was used.

Chapter 5 of the SEEA revision, while recognising difficulties in estimating benefit-side figures because of the indirect nature of some benefit categories, and the complexity of the subject matter, also points out that "supply-side valuation is not as easy to come by as one might like to hope" (draft chapter 5 of SEEA revision, version of 28th October 1999). In fact, detailed empirical work on firm-level environmental expenditures and statistics-based sectoral estimations are very heterogeneous.

However, it seems that the revision of the SEEA, will take the view that benefit-side valuation techniques are concerned with limited, local and relatively small environmental questions (See also O'Connor and Steurer, 1999). The use of benefit transfer is considered to be problematic, since it requires corrections and weightings, although it appears that a final position on benefit transfer has not yet been reached. In fact, in paragraph 3.2 of draft chapter 5 "Accounting Aggregates Derivable from the SEEA", where environmentally adjusted aggregates are defined, both damage estimates to economic assets (buildings, forests, soils) and to human health are included. Whereas damage values to economic assets can rely on market prices, damages to health need to be calculated on the basis of dose-response functions and willingness-to-pay, and benefit transfer methods are seen as possible means where precise local estimates are unavailable.

The revised SEEA includes environmentally-adjusted aggregates such as the Eco-domestic product (EDP), defined as "the income measure derived from the SEEA. The Hicksian framework can be used to give this a precise definition. As suggested above, the key is to include in “capital accumulation” first the standard net investment in produced assets … and then the changes in asset values that can be related to the exploitation of natural resources or to pollution exposure" (draft chapter 5 of SEEA revision, version of 28th October 1999).

The accounting framework for EDP, as described in the draft chapter 5, is therefore as follows:

EDP = NDP (GDP – consumption of fixed capital)
- depletion of natural resources (minerals and biological resources)
- “negative land improvements” (excess deforestation)
- pollution damage to economic assets (buildings, forests, soils)
- pollution damage to human health (morbidity and mortality)

- value of increments to stock pollutants (CO2, ozone layer loss)
- final expenditures on environmental management (including abatement)

Another important aggregate described by the SEEA is constituted by Genuine Savings, which has been used widely by the World Bank as a measure including also investments in human capital formation and depletion of subsoil assets. The term 'genuine' is employed in order to distinguish this saving measure from the usual SNA93 definition of net saving.

## *7. Conclusion*

This paper has attempted to provide a broad overview of the recent developments in national accounting and the economic valuation of environmental damage. The aim has been to acknowledge the theoretical and practical drawbacks in all of the currently existing methods, and to make a preliminary proposal for alternative methodologies by means of which the existing methodologies could be synthesised.

The neoclassical theory behind the use of the values of environmental depletion and damage to estimate "welfare-based" national income presents various theoretical problems, in particular the fact that it is not, even in theory, a measure of sustainable income. These problems are reflected in the GARP methodology, which embodies these theoretical foundations. The methodologies discussed in this paper that were devised to remedy these problems are the Hueting method, and the GREENSTAMP method.

While there are clearly drawbacks to each of the existing methodologies, they each also have significant advantages, and so it seems worthwhile to discuss the possibility of synthesising the different approaches. Section 3.1 notes that both the GARP and the GREENSTAMP approaches deliver useful information to policy makers. The feasibility of GREENSTAMP seems to be higher in the medium run, especially for those media where dispersion models embodied in the impact pathway analysis cannot be applied. However, when applicable, damage evaluation as presented in GARP is scientifically robust and is a useful complement to information on abatement costs. Section 3.1 pointed out that information on the values of damages provided under the GARP approach is a basis on which policymakers can make scientifically justifiable decisions in setting priorities based on impacts to the environment.

The major drawback of the GARP approach is the fact that it does not account fully for the implications for sustainability, and in particular environmental sustainability, of environmental damage and depletion. The drawbacks of the other two approaches are, firstly, that they do not account for the role that economic valuation can play in helping to identify environmental standards that are both environmentally sustainable and economically efficient. The measures derived under these methodologies likewise do not account for the welfare effects of environmental damage. A further drawback that is common to the GARP and Hueting approaches is that the prices at which costs and damages are measured are current prices, as opposed to the prices that would hold if the desired environmental standards were to be imposed. However, the advantage of these approaches over the GREENSTAMP approach is that they do not rely on complex economic modelling.

Section 5 outlines ways in which the approaches could be synthesised. They are firstly a "sustainability-constrained GARP approach", which would use the GARP approach to measure the net welfare that would be consistent with meeting identified efficiency and sustainability standards. The second is a "welfare-extended GREENSTAMP approach", which would use the calibrated models developed under the GREENSTAMP project to measure the output compatible with adhering to sustainable and efficient environmental standards. The third approach would be a "welfare-extended Hueting approach" which would deduct from current output the estimated costs of meeting sustainable and efficient environmental standards. These methods are proposed at this stage as potential areas for further research. It is likely that the choice of the method will depend on the developments regarding the SEEA revision by the London Group, as a final decision on the valuation approach that should be given priority has yet to be taken.

## References


Ahmad, Yusuf J., El Serafy, Salah, and Lutz, Ernst (eds.) (1989) "*Environmental Accounting for Sustainable Development*" A World Bank Symposium Paper. Washington, D.C.

Asheim, G.B. (1994) "*Net National Product as an Indicator of Sustainability*." Scandinavian Journal of Economics, 96: pp 257-265.

Baumol, W. J. and Oates, W.E. (1971) "*The use of standards and prices for protection of the environment*", Swedish Journal of Economics, Vol. 73, pp. 42-54.

Brower, R., O'Connor, M. and Radermacher, W. (1999) "*GREEned National STAtistical and Modelling Procedure: the GREENSTAMP approach to the calculation of environmentally adjusted national income figures*", International Journal of Sustainable Development, Vol. 2, No. 1, pp. 7-31.

GREENSTAMP Project (1997) "*Methodological Problems in the Calculation of Environmentally Adjusted National Income Figures*" Final Report to the European commission DGXII.

Hartwick, J. (1990) "*Natural Resources, National Accounting and Economic Depreciation*". Journal of Political Economy 43 pp 291-304

Hicks, J.R. (1946) "*Value and Capital*" 2nd ed. Oxford University Press, Oxford.

Hueting, R. (1989) "*Correcting National Income for Environmental Losses: Towards a Practical Solution*." In Ahmad, Yusuf J., El Serafy, Salah, and Lutz, Ernst (eds.) (1989) "Environmental Accounting for Sustainable Development" A World Bank Symposium Paper. Washington, D.C.

Jesinghaus, J. (1999) Handbook of a European system of environmental pressure indices, http://esl.jrc.it/envind/theory/handb_09.htm

Mäler, Karl-Goran, (1991) "*National Accounts and Environmental Resources*" Environmental and Resource Economics Vol. 1 (1) pp 1-15.

Markandya, A. and Pavan, M. (eds) (1999) "*Green Accounting in Europe - Four Case Studies*" Kluwer Academic Publishers, Dordrecht

O'Connor, M. (1999) "Natural Resources and Environmental Accounting in the Czech Republic" Draft Report OSS 85.2200.10

O'Connor, M. and Steurer, A. (1999) "The 'Frontier of Monetisation' in Environmental Valuation", paper presented at the 6th London Group meeting on environmental accounting, 15-19 November, Canberra, Australia.

Pezzey, J. (1994) "*The Optimal Sustainable Depletion of Non-Renewable Resources.*" University College, London

SEEA revision (1999) "Draft Chapter 5", version of 28 October, internal document of the London Group.

Sefton, J.A. and Weale, M.R. (1996) "*The Net National Product and Exhaustible Resources- The Effects of Foreign Trade*", Journal of Public Economics 61(1) pp. 21-47.

Usher, (1994) "*Income and the Hamiltonian*." Review of Income and Wealth 40(2) pp 123-141.