1. Introduction and project objectives

Anil Markandya and Marialuisa Tamborra

1.1 THE CONTEXT

As countries become richer, a heightened interest in the environment comes from two sources. Individuals have a greater concern for the quality of the ambient environment, as more pressing needs are satisfied. At the same time the pressures on that ambient environment increase, with a higher loading of pollution from transport, power, industry and household consumption. One way in which this increased awareness of environmental problems manifests itself is through the demand for better information on what is happening to the environment and what that means for us as citizens and human beings. It is not surprising therefore that there has been an explosion of work on measuring impacts in terms of the *pressures* on the ambient environment, the *state* of that environment and the *responses* of society to these pressures (Adriaanse, 1993).

This work has been carried out almost exclusively in physical units, with little attention paid to the economic implications of the environmental changes. At the same time, it is clear that there is an economic dimension to the changes. The environment provides an economic function and it is at our peril that we ignore that function. But, in drawing up traditional measures of economic activity, such as Gross Domestic Product, that is precisely what we do. We do not take account of damages done to the stock of natural capital, nor of the losses of welfare that economic activities cause through increased pollution.

In response to these concerns, a literature has developed on the monetary value of environmental changes caused by economic activity. This literature has several strands. One looks at the depletion in mineral and renewable resources and asks whether conventional measures of GDP have paid enough attention to this depletion. If a country is maintaining its level of economic activity by running down its mineral resources but is not fully replacing them with alternative income generating assets, then its present level of welfare may be unsustainable. A second strand examines the expenditures undertaken by citizens in protecting themselves from the consequences of

increased pollution. These so-called 'defensive expenditures' are subject to some controversy. Should we deduct them from measures of national income? Some argue that if money is spent on such items, and it used to be spent on things that directly gave welfare, then society is indeed worse off. The problems lie in knowing what the relevant point of comparison is, and identifying and measuring these expenditures. Nevertheless this is an important area of work and much remains to be done to achieve satisfactory systems of accounting for defensive expenditures. The third area of work relates to the damage caused by the pollution. Can that damage be measured in money terms? If so, how much is it worth? And how do the values of the damage compare to other measures of economic activity, such as GDP (gross domestic product) or National Wealth?

This book presents the results of a two-phase project and deals with environmental accounting within an economic framework, focusing on the second and third issues raised above, but specially the third. Its point of departure is a project called GARP I, a study by researchers in Germany, Italy, the Netherlands and the UK, and published as a book (Markandya and Pavan, 1999).¹ A summary was published by the UK Office of National Statistics in 1998 (Markandya and Milborrow, 1998). Essentially what this research attempted was to use spatially disaggregated data on measures of pollution to derive economic damage estimates for those pollutants. The objective was to see what could (credibly) be done at a national level, what was the degree of uncertainty in the estimates and whether it was possible to make inter-country comparisons of damages within the European Union. The project also looked at whether these measures could be constructed on a routine basis, so that the task of preparing them could be handed over to statistical offices.

GARP I (Markandya and Pavan, 1999) considered only airborne pollutants, where a spatially disaggregated analysis was undertaken focusing on different *receptors* (such as human health, crops, the built and natural environment). Inevitably, the coverage and approach were not fully consistent. The degree of spatial disaggregation varied by country, as did the availability of data on pollution concentrations and estimates of stocks at risk. These differences accounted for a significant part of the differences in the resulting damage estimates.

In spite of these difficulties, the experience of the first phase confirmed that it is possible to make monetary estimates of the impacts of pollutants on human health, materials and crops with some credibility, although considerable further work is required before these tasks can be carried out routinely and in a comparable format for all countries. Health impacts accounted for the greatest damages, particularly chronic mortality from exposure to particulate pollution. Assessing damages incurred by forests and ecosystems

proved much more difficult due to both a lack of appropriate data and the underlying complexity of the natural systems. Some estimates of global warming damages were presented that reflected the limited consensus among certain sections of the scientific research community. However, these figures were regarded as highly uncertain and possibly subject to major revisions. The initial estimates were presented in numerous academic and policy-making fora and stimulated considerable discussion. Although several researchers are convinced of the usefulness of this exercise, it should be noted that there are still many commentators who are strongly opposed to this kind of valuation exercise, particularly when expressing life expectancy and other health issues in money terms.

In GARP I it was concluded that, for this kind of exercise, a hybrid approach is appropriate, where monetary values and physical impacts are presented, with the latter being in the form that is closest to the 'end point' that affects human welfare. The project team also agreed that the data are more usefully presented alongside the national income accounts rather than deducted from GDP. The primary reason for this is that it is unclear to what extent the damages have already been internalised. Hence, if they were subtracted some double counting would result. The second is that by far the greatest benefit of the data is to guide policy on the economic and environmental interface, and the aggregation of damages into GDP is of little value in this regard.

1.2 PROJECT OBJECTIVES

To develop the research further it was recognised that the coverage of existing impacts should be extended as far as possible across the study countries. This is important for policy-making within the EU, where cross-country resource allocation and regulatory decisions have to be taken. Second, *damages need to be attributed to sources*, since this is an essential linkage if the approach is to have real policy relevance. Third, other forms of pollution media need to be investigated such as damages to water and land. Specifically, the main objectives of the work programme which this book reports on were:

- (a) To review the credibility of monetary valuation of environmental damage, as well as that of other indicators of environmental impacts and pressure. The review examines the strengths and weaknesses of the different measures, particularly with reference to their role in developing accounts and in their usefulness to decision-makers. In many areas, the methodology has been updated in the light of advances in other areas.

- (b) To enhance the valuation of environmental damages in the EU in the light of new data. In GARP I the team found a number of gaps in the data required for the valuation of environmental damages. These missing data varied across countries, with some having better information than others. GARP II fills these gaps as much as possible and obtains valuations that are both credible and comparable to the maximum extent.
- (c) To extend the range of pollutants covered by the analysis. In particular, careful consideration was needed of the relationship between primary and secondary pollutants, and the effects of heavy metals on human health was also to be investigated. Impacts on water and land contamination are also evaluated.
- (d) To attribute the spatially disaggregated damages to different sources of pollution using a 'multi-source' version of the ECOSENSE model developed by IER, University of Stuttgart. This model allows damages to be assigned to countries and economic activities (sectors), identifying crucial transboundary impacts.
- (e) To review critically the main methodological approaches for the estimation of defensive expenditures, together with any estimates that were available. For each stressor (source of damage) there are a number of defensive expenditures that are undertaken. This issue was identified as important in the first phase, but very sparse data were available. Comment is made on how these should be integrated into an accounting system.
- (f) To evaluate the replicability of the methodology to other countries in the EU and consider the feasibility of preparing such estimates on a regular basis so as to form an impression of the changing state of the environment over time. In this regard, the final presentation of the data was an important issue with the prime objective being to maintain a high degree of policy relevance.

Progress has been made in all of these areas and it is the purpose of this report to show that the basic methodology has been consolidated and certain limits to the work recognised.

1.3 OVERVIEW OF APPROACH

An overview of the key stages in the work is given in Figure 1.1. As can be seen, the second phase of this project, called GARP II, still maintains a major focus on the impacts of air pollution. Airborne pollutants can be distinguished as either primary or secondary. A primary pollutant is directly emitted from a source (usually a combustion process such as a power

Figure 1.1 Schematic representation of the GARP approach

station, factory or motor vehicle). Examples include sulphur dioxide (SO₂) and total suspended particulates (TSP). Secondary pollutants (such as ozone (O₃), nitrates and sulphates) are formed by chemical reaction in the air. In this analysis, we are concerned with pollution concentrations. Data on *all* these can either be measured (that is, supplied by monitoring stations) or modelled via computer dispersion models.

There are two main elements to the analysis: *damage calculation* and *damage attribution*. Damage calculation involves a restricted impact pathway analysis, whereby concentration data is interpolated to national grid maps and overlaid with population data. This is essentially what was done in GARP I and is in contrast to a full ‘bottom-up’ (engineering) approach that considers in detail the emissions from site-specific sources. The impact pathway analysis is discussed in more detail in Chapter 3.

The damage attribution exercise, however, does allow emissions to be allocated by economic sector. This is achieved through the ECOSENSE model, an integrated computer tool that incorporates modules for technology, emissions, exposure–response functions and valuation data (see Chapter 8, Section 8.1 for an introduction to the ECOSENSE model). Both damage calculation and damage attribution sets of calculations have been undertaken for impacts on human health, crops and building materials. It is for these receptors that exposure–response functions have been established with most confidence.

The analysis allows both physical and monetary indicators of damage to be generated. Where possible one of a number of valuation techniques can be applied to derive estimates for specific ‘endpoints’ that are closely related to human welfare. Wherever possible the valuation is based on the theoretical foundation of willingness to pay (WTP) or willingness to accept (WTA). Valuation techniques and issues arising are discussed in more detail in Chapter 5.

Figure 1.1 shows that for forest and ecosystem impacts the complexity of these systems does not permit a comprehensive valuation exercise. Hence the approach discussed above cannot be applied. The broad framework for assessing these impacts was a critical load approach, with nitrogen being the main pollutant considered. The natural environment is classified into eight vegetation classes and used in conjunction with land cover data at a European level. Forest assessment identifies three main types of damage from air pollution: loss of timber, reduced recreational benefits and decreased existence value. All these categories present methodological difficulties, although the situation has improved since Markandya and Pavan (1999). It is now possible to make sample valuations (for example, for specific biotopes) and obtain some implicit values from related studies. These are reported in Chapter 11.

Global warming impacts are also a distinct module. The debate on appropriate quantification of these impacts has advanced considerably in recent years. In Markandya and Pavan (1999) the estimates were made of the present value of future climate change damages in the study countries as a result of global carbon dioxide (CO₂) emissions in 1990. This was undertaken on the basis of published studies. The results have been updated, drawing on more recent literature, especially relating to regional impacts.

In Figure 1.1 'other impacts' assessed include water pollution and land contamination. In the case of water the approach involves linking data sets on river water quality, recreational activities and monetary values that exist for these activities, to provide estimates of recreational damage costs. The analysis has been undertaken, in the first instance, only for the UK. Land contamination issues are likely to be very specific. In accordance with the approach taken in the rest of the project, the ideal approach would be to create 'flow' accounts to assess the change in the value of contaminated land over time. However, initial investigations of the data indicated that this would not be possible. Hence, data on the stock of contaminated land together with illustrative figures on the costs of remediation were collected. For both these types of impacts it has only been possible, at this stage, to make some sample valuations. It is hoped, particularly in the case of water impacts, that the methodology will be expanded to become more comprehensive – expanding the quantification of the impact pathway so that the analysis is more in line with that for air pollution.

Under the heading 'other issues' are concepts that the project team believe to be relevant to the concept of environmental accounting but that were not covered in the core activity of the project GARP II. Defensive expenditures (also referred to as environmental protection expenditures) are understood to be an indicator of the total monetary burden which society bears annually for the regulation of environmental degradation and damages induced by the economic use of the environment in the past and present periods. These expenditures can involve environmental protection and restoration activities, damage avoidance and treatment. Estimates have been made as part of this project and many published studies have been reviewed. Chapter 7 discusses the methodological issues concerning defensive expenditures, and the results obtained, in more detail.

Natural resource depletion is also an important issue and is often viewed as being an important parameter in any debate about 'sustainable' development, an issue which this study does not address directly. This subject has, however, received increased attention in recent years (see, for example, Vaze, 1996) and it is an area that we believe should be explored in subsequent research projects. It is also the subject of a project on Sustainability and the Use of Non-renewable Resources (SAUNER) which combines a theoretical

appraisal of sustainable development in the presence of non-renewable resource depletion, with empirical estimates of current resource stocks, and future resource use.² The output of SAUNER will include suggested policies to narrow the gap between anticipated resource-use paths and those which are efficient and sustainable. It is anticipated that this may be relevant to the methodological development of resource depletion accountancy.

1.4 METHODOLOGICAL ISSUES

The main purpose of the research reported in this book was to estimate the environmental damages sustained as a result of economic activities and to offer an insight about how the information generated can be used in conjunction with conventional economic accounts, principally estimates of GDP. In this context, it is recognised that there is much controversy as to the suitable definition and interpretation of GDP itself, let alone environmentally adjusted GDP. In view of this and many other uncertainties concerning the estimates themselves, the project team do not advocate subtracting the damage estimates from national income figures. Instead, the team believes that the GARP methodology complements the direction taken in the development of international environmental accounting frameworks and sheds new light on the feasibility of aspects of these frameworks. It is therefore hoped that the future evolution of environmental accounting will benefit from the findings of this project.

The research does take a favourable view on another controversial question, namely whether environmental damages or burdens should be monetised. Our view is that valuation is important since it allows environmental costs to be integrated with traditional costs and benefits using a single denominator. As a result of this work, we hope that the significance of economy–environment linkages will become better understood and that resource allocation decisions will be made on a more efficient basis. The approach to valuation is based on welfare principles as defined in neo-classical microeconomics. For further discussion of underlying principles see European Commission (1999, volumes 1–2).

At the outset we should reiterate that, as for the project GARP I published in Markandya and Pavan (1999), what is being valued is the *total damage* caused by the economic activity. This is done (in most cases) by taking the unit value of the damage and multiplying it by the number of units of the environment lost or damaged. This necessitates defining what the ambient environment would be in the absence of anthropogenic activity, an issue which is discussed further in Chapter 8. In this respect the treatment of environmental services is not different from that of other goods and services,

which are valued using market prices times the number of units bought/sold. We should also point out, however, that the unit values reported here *can* also be used for a *marginal valuation*, that is, to look at the damage caused by a small increase in pollution levels. We have focused on total damage because it provides estimates broadly comparable with the components of national income accounts.

The valuation method described above, where we take unit values based on existing prices, is also referred to as the partial equilibrium method of valuation, as it is based on taking existing prices as given and valuing damages by multiplying the changes in quantities by the prices. This has come under some criticism on the grounds that partial-equilibrium assumptions are unlikely to hold at the aggregate level, thus reducing the credibility of the valuation. As a general criticism this is not valid; all measures of national activity such as GDP are based on taking prices as fixed and the welfare basis of such measures has been shown to be sound (Weitzman, 1976). At the same time, there can be some cases where policy makers will want to know whether a major reduction in pollution will bring about a given set of benefits as estimated by the partial equilibrium method. The answer is that there are cases where such an assumption will not be valid and major changes in environmental impacts will cause a substantial change in relative prices and corresponding structural shifts within the economy. Consequently, we have indicated in the report the environmental impacts for which this valuation issue arises in a practical context. In such cases we have also provided some examples of valuation methods that are not based on the partial-equilibrium approach.

As we noted earlier, the monetary valuation in general does not command universal approval. This also applies to the particular form of monetary valuation used in this book – that is, damage estimation based on willingness to pay to avoid the damage or willingness to accept payment as compensation for the damage. Hence it is important to put this work in a broader context and to see what the arguments for and against this approach are. This is done in Chapter 2, where other developments in the area of environmental accounting are reviewed. One project in particular, the ‘Green Stamp’ project funded by the European Commission – Research Framework Programme, has made an important contribution to this discussion. The focus of this project is an investigation into the feasibility of using avoidance cost data in monetising environmental effects rather than willingness-to-pay measures, favoured in GARP II. Green Stamp also promotes an alternative set of indicators to the satellite national income accounts. These indicators would be in the form of avoidance cost curves, developed though input-output and general equilibrium modelling, which provide estimates of the cost of meeting specified environmental standards.

These goals are referred to as 'sustainability norms'. The models proposed (but not implemented) would then develop cost estimates for various scenarios that move the economy from its present condition to one which respected a specified set of environmentally sustainable standards.

We take the view that the Green Stamp approach is useful to policy makers but it does not obviate the need for damage estimation. First, the costs of meeting specified standards do not tell the policy maker whether those standards should be met. That requires a comparison of the costs of avoidance as well as the environmental damages reduced. Second, the costs of meeting standards that are set by policy makers, *but that are not met*, are only an indication of what society would have to pay to achieve certain environmental goals. If society is not paying this price, it may be suffering more, or less, than the cost. Again, only damage estimation will reveal that. Hence the Green Stamp Approach, while useful, is not by itself a guide to policy. Furthermore its costs are not directly comparable with the GDP estimates of the value of goods and services actually produced.

1.5 SPECIFIC ISSUES FOR GARP II

As stated at the beginning, GARP II had a number of key broad objectives that have been identified. In addition, the project explored a number of specific issues relating to the environmental impacts and environmental accounts and these are contained later in this book. These can be summarised as follows:

- (a) The measured concentration data for primary pollutants varies substantially in quality, both between countries and pollutants. This strongly influences the credibility of the interpolation and the resulting confidence in the damage estimates. The underlying chemistry describing the formation of secondary pollutants is also highly complicated. Valuation of impacts is also highly sensitive to background levels of pollution. In this study, a range of background levels has been taken and tests for linearity carried out.
- (b) The literature on valuation of damages is still strongly dependent on US studies, although this situation has improved since Markandya and Pavan (1999). Many studies are not transferable to the European context and care has to be taken to ensure that functions and values that are used are realistic to European conditions. The valuation work updates estimates on the basis of some recent European studies.
- (c) It was evident from Markandya and Pavan (1999) that impacts on human health dominate the overall impacts of air pollution. The key

parameter underlying the valuation for health is the Value of a Statistical Life (VSL), on which there is little agreement. This issue has been debated extensively in recent years. The project team concluded, however, that the related concept of Value of Life Years Lost (VLYL) is more appropriate for the type of impact being experienced. This is principally due to the fact that (a) most mortality cases will be for individuals with already severely reduced life expectancy (see Chapters 8 to 15), and (b) the key effects of chronic mortality are best measured in terms of changes in life years lost. A major effort has been made to consolidate the valuation approach as a whole and efforts have been especially directed to the quantification of chronic mortality impacts.

- (d) Detailed reviews of the epidemiological literature revealed considerable doubts over some of the health endpoints adopted in Markandya and Pavan (1999). The causal relationship in many cases proved inconclusive (that is, the pathway could not be fully defined) or it was impossible to avoid double counting. These endpoints have been removed. Subsequently, a number of new endpoints have arisen and results prepared for these.

This book addresses many of the principal weaknesses identified in Markandya and Pavan (1999). We believe that in all of the areas mentioned above significant progress has been made in developing sound methodologies, given the many remaining uncertainties that are inherent in this field of research and policy.

NOTES

1. This earlier project was titled the *Green Accounting Research Project I (GARP I)* and was supported financially by the European Commission. The present volume is based on the results obtained during a second phase of this project, financed by the European Commission, titled *GARP II*, and builds on that work in ways that are elaborated in the chapter.
2. SAUNER is a European Commission financed project undertaken under the direction of Professor Markandya, with colleagues from Germany and Austria.

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