

Chapter 10

MACROECONOMIC COST-BENEFIT ANALYSIS OF ENVIRONMENTAL PROGRAMMES

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1 INTRODUCTION

In the evaluation of environmental projects and programmes two traditions can be discerned. The first is the applied welfare economics of social cost-benefit analysis. The second, stemming from quite a different origin, is macroeconomic evaluation. Both approaches have their strengths and their weaknesses. In this article I shall critically survey both methods and propose a synthesis.

Public investments are seldom directly profitable for the authority undertaking it. Generally financial proceeds are far below the expenditures and the investment projects do not meet the criterion that is usually applied in private economic calculations. A major reason for the growth of social cost-benefit analysis is the need for a method and a criterion that can be used to assess whether a public investment can be justified from a broader economic point of view, looking at the costs and benefits for society as a whole. In a social cost-benefit analysis welfare losses and gains to all members of society are included in the costs and benefits, no matter whether the cash flow of the public investor is affected or not. The investment proposal is accepted if it meets the criterion that the present value of all future benefits, no matter whom they accrue to, should exceed the present value of all costs of the investment. The criterion implies that a social cost-benefit analysis, narrowly defined, only covers those welfare changes that can be brought under the measuring rod of money [Pigou, 1921].

Since the nineteen-thirties social-cost benefit analysis has been used in public decision-making. Originally the method of social cost-benefit analysis was applied for the assessment of public investments in economic infrastructure; e.g. flood-control dams, roads, land reclamation, airports. Since the early nineteen-seventies the analysis of monetary environmental damage and the cost-benefit analysis of projects aiming at environmental improvement and nature conservation have emerged. A body of knowledge has evolved and environmental cost-benefit analysis is growing into a flourishing branch of environ-

mental economics. A review of the "state of the art" has been given by Freeman [1979] and by Dixon and Hufschmidt [1986]. Earlier surveys include Mäler and Wijzga [1976], Pearce [1978] and Abelson [1979].

The strength of environmental cost-benefit analysis is its methodology for analyzing the details of a specific environmental improvement and the paradigm it offers for constructing shadow prices, in terms of money values, for goods and services which have no market price because no explicit markets exist for them. A major weakness is the neglect of the macroeconomic context and its impact on the costs and benefits of environmental projects.

Macroeconomic evaluation of environmental programmes goes back to the Keynesian revolution in macroeconomic policymaking. Empirical macroeconomic models were constructed to provide a scientific base for macroeconomic forecasts and for predicting the consequences (in terms of income, employment, balance of payments, government budget) of changes in fiscal policy, e.g. the impact of a rise in government expenditure, aiming at macroeconomic stabilization.

From the early sixties on the simple Keynesian expenditure models have been succeeded by a class of models which include supply and cost equations. This progress in model building has made it possible to simulate specific investment programmes and to assess long-run structural impact on macroeconomic variables, next to the short-run expenditure impacts. Examples of macroeconomic evaluations are studies that are concerned with seaport industries [Van den Beld and Middelhoek 1971], nuclear energy and energy saving. Since the early nineteen-seventies the macroeconomic evaluation of environmental programmes has been added to this list.

Macroeconomic evaluations take the macroeconomic conditions into account by definition. The impacts of an environmental programme (and any other programme or project) are identified by calculating the divergences of the macroeconomic variables from a reference path of macroeconomic development that is expected to occur if the investment project is not carried out. The reference path will take account of the relevant economic regime, e.g. underemployment. A methodological weakness of the macroeconomic evaluations is that up to now the specific effects, especially the benefits of environmental investment, have been dealt with either rather cavalierly or not at all.

It can be concluded from the above that both methods - social cost-benefit analysis and macroeconomic analysis - have their strengths and weaknesses. In section 2 they will be discussed at length. One might ask whether a unified approach can be developed which

combines the strengths of both methods, and excludes their weaknesses. In section 3 an attempt will be made to achieve this. The elements of a "macroeconomic cost-benefit analysis" will be discussed. In section 4 the components will be put together. Section 5 recapitulates what such a macroeconomic cost-benefit analysis adds to the existing methodology for evaluating the environment.

2 TWO TRADITIONS IN ECONOMIC EVALUATION

2.1 Social cost-benefit analysis

A key problem in social cost-benefit analysis is how to value the positive and negative impacts of a public investment. The conventional solution of the problem is to take the Walrasian model of general equilibrium as a point of reference. In Walras's conceptual model of a market economy all markets are in equilibrium and consumers and producers have adjusted to market prices in such a way that the welfare of each participant is maximized.¹ Under these conditions the prices that prevail indicate exactly what value the economic agents attach to (marginal) increments in resources and in producible goods. Consequently market prices coincide with their social value. When a number of markets is in disequilibrium the set of existing market prices does not reflect their true social value. The cost-benefit analyst should then look for an adequate set of shadow prices.

For practical cost-benefit analysis the important question is whether in the real world, where the public investment has to be carried through, the economic situation during the lifetime of the project will correspond to Walras's blueprint of a market economy to such an extent that actual prices can be accepted as adequate indicators of marginal social value.

Actually some major markets frequently are not in equilibrium. Labour markets and foreign exchange markets are the most glaring examples. The price on capital markets is heavily affected by tax distortions, causing a divergence between the demand price and supply price of capital, even if demand equals the supply of capital. But if one looks at practical cost-benefit analysis as it is actually applied in practice in the developed countries one sees that in most cases market prices are used rather uncritically in the calculations of costs and benefits. The question how the existing economic situation

¹ Of course one should bear in mind the well-known provisos that there is perfect competition, that external economies or diseconomies and collective goods are absent and all property rights are fully specified.

relates to Walras's general economic equilibrium is not taken into consideration. It is implicitly assumed that there is a close enough correspondence between the real world and the model.

This is a fortiori true of practical environmental cost-benefit analysis. The specialists working in this area are concentrating their efforts on valuing the environmental spillovers. In cases in which a market good is a close substitute for the unmarketed and unpriced environmental good the market price is generally taken as a proxy for the marginal social value of the environmental good. In consequence of the fixation on the environmental aspect the environmental economist is inclined to ignore the problem that in reality the economic regime diverges from the Walrasian general equilibrium and that market prices do not reflect social values. The studies reviewed in Freeman 1979 illustrate this point. By using market prices he is implicitly assuming that a competitive general equilibrium actually prevails and will continue to exist during the lifetime of the project.

In the theory of cost-benefit analysis, which should be distinguished from the practical applications discussed above, the restrictions on the use of market prices were recognized at rather an early date. Large and persistent unemployment, taxation which affects marginal valuations, price controls and imperfect competition, public goods and externalities disturb the Walrasian-Paretian conditions of general equilibrium and maximum welfare. These discrepancies between blueprint and reality are most glaringly visible in the developing countries: massive unemployment, price controls of foreign currency, to mention two outstanding examples. The theoretical literature on cost-benefit analysis of development projects has taken the lead in adapting cost-benefit analysis rules to such non-optimum and non-equilibrium regimes [Lal 1974, Lal 1980, Kuyvenhoven and Mennes 1985, Unido 1972, Little and Mirlees, 1974]. Progress has been slower in the literature on project analysis for the developed world. In the first stage ad hoc partial solutions were proposed to handle such problems as unemployment [Haveman and Krutilla, 1968] or distortions in capital markets [Hufschmidt c.s. 1961, Marglin 1963]. This is also the approach in modern textbooks on cost-benefit analysis [Sugden and Williams 1978, Dasgupta and Pearce 1978, Lesourne 1975, Mishan 1982]. A major weakness of the partial equilibrium approach is that it does not take into account the relations between markets which could affect shadow prices in a systematic way.

A recent development is the derivation of disequilibrium cost-benefit rules in the context of a general Walrasian framework. Johansson [1982] has developed rules for assessing the costs and benefits of investment projects under different regimes: Keynesian

unemployment, classical unemployment and repressed inflation. In a mathematically rigorous way he shows which corrections have to be made in market prices under different regimes of disequilibrium. In this volume [Johansson and Löfgren 1988] the general disequilibrium approach of social cost-benefit analysis is further explored.² It surely is an important step ahead in the theory of cost-benefit analysis and it is interesting to observe that in their contribution to this volume the general disequilibrium approach is, to my knowledge, for the first time applied to an environmental project, in this case a natural resource project.

In environmental cost-benefit analyses in general, however, the state of the art is such that there exists a developed body of methodological knowledge capable of being applied to evaluate the environmental dimensions of actual projects. At the same time there is a lack of applicable methods which enable us to take account of the actually existing economic regime in all those cases in which the state of the world diverges from general equilibrium.

2.2 Macroeconomic evaluation

Macroeconomic evaluation has developed from Keynesian macroeconomics and macroeconomic model building: areas of economic investigation that are far removed from welfare economics and its application in cost-benefit analysis. Macro-economic models have been used for purposes of economic forecasting, but also and increasingly for policy simulations. The simple short-run expenditure models of the first and second generation developed into full-blown medium-term structural models, incorporating the supply side. The new generation of models offered the opportunity to progress from simulating the expenditure impacts of short-term stabilization policies to the simulation of structural policy measures, which have major impacts on the supply side by changing factor productivities, costs and other variables.

During the past two decades the macroeconomic evaluation of structural policies has been extended to cover environmental programmes. National studies have been made for several countries. OECD [1978] surveys Japan, Italy, the Netherlands and the United States. The OECD 1985 publication discusses recent results for the US and the Netherlands and adds Austria, Finland, France and Norway. Christansen and Haveman's survey [1981]

² See also their references to the literature on disequilibrium cost-benefit rules following Johansson's pioneering article.

of studies concerning the impact of environmental regulation on economic growth contains a number of macroeconometric studies for the US-economy. Recently a macroeconometric analysis of an international environmental programme has been made: Klaassen et al. [1987] discuss the macroeconomic impact of a program of acid rain abatement, carried out simultaneously by all EC-member countries.

In most of these studies use has been made of existing macroeconometric models that have been adapted to capture the impacts of environmental programmes on variables such as national output and income, employment, consumption, balance of payments and balance of the government budget. These studies take a historical or 'projected' future time path of macroeconomic variables as a starting point. Then the environmental investments are inserted into the macroeconometric model and other adaptations are made to take account of the costs and other specific characteristics of the programme. Next a second model run is made. The macroeconomic impact of the environmental programme is presented by the differences between the time paths of the macroeconomic variables with and without the environmental programme.

In these macroeconomic policy simulations the actual economic regime is taken into account. When the reference time path is characterized by unemployment and excess capacity the macroeconomic impact of environmental expenditure will differ from the macroeconomic consequences that would have resulted under a regime of full employment.

In macroeconomic evaluation the state of the art is just the opposite of that in cost-benefit analysis. A general economic point of view is chosen, contrary to the partial view in practical cost-benefit analysis. The relations between markets for output, labour and money are modelled. The information about the relevant economic regime is contained in the quantitative data about excess capacity and unemployment. On the other hand the macroeconomic modelling of the specific characteristics of environmental programmes and projects is hardly developed. This is especially true of the evaluation of the environmental benefits. Actually the macroeconomic benefits of reducing environmental damage have not been incorporated in the programme simulations. Only the macroeconomic consequences of the pollution control investment expenditure and of the ensuing costs of pollution control are analysed. We shall elaborate this point further in section 3.5. An additional shortcoming of macroeconomic evaluation, from the point of view of cost-benefit analysis, is that the economic impacts of the environmental investments are expressed in terms of the macroeconomic variables instead of a common measure of welfare (see section 4). The

explanation for these deficiencies is the lack of a sound welfare economic underpinning of the macroeconomic evaluation technique, which again points to its Keynesian origin.

3 ELEMENTS OF A MACROECONOMIC COST-BENEFIT ANALYSIS

Table 1 contains the gist of a comparison of the two methods of economic evaluation. The table shows that it can be interesting to investigate whether the two methods can be combined in such a way that use can be made of the strong elements of both approaches.

TABLE 1

Strengths and weaknesses of social cost-benefit analysis and macroeconomic evaluation.

| | cost-benefit analysis | macroeconomic evaluation |
|---|--------------------------|-----------------------------|
| modelling of the economic regime | no | yes |
| welfare economic foundation | yes | no |
| modelling of environmental characteristics | yes | no |

In this section an attempt will be made to accomplish such a synthesis of cost-benefit analysis and macroeconomic evaluation. I shall do this by taking macroeconomic evaluation as a starting point and by investigating:

- a. in what way macroeconomic evaluation can be given a welfare economic foundation (section 3.1 to 3.4);
- b. in what way environmental specific characteristics can be introduced in a macroeconomic evaluation based on welfare economics (section 3.5).

3.1 Measure of costs and benefits

A first question concerns the definition of costs and benefits in the context of a macroeconomic model. All costs and benefits have to be classified in terms of the well-known macroeconomic output aggregates: consumption, investment, government expenditure, exports and imports. In most empirical macroeconomic models further subcategorization may be required.

The costs of the (environmental) project should be conceived of as opportunity costs, that is the output foregone by allocating factors of production to the public investment project and not using them in an alternative direction. The benefits consist of the

increase of output, e.g. additional production in agriculture resulting from an air pollution abatement programme. A second category of benefits is made up by the welfare gains, e.g. the value attached to better visibility when air pollution is reduced.

As welfare can best be measured in terms of consumption it is the appropriate unit to express all output variables. But which conversion factors should be used in converting a unit of investment into a unit of consumption? In the macroeconomic calculations of the national income the components consumption, investment and so on are added up by using their market prices. But this procedure must not be followed to calculate economic welfare if market prices do not reflect the true social value. In such cases a guilder of investment is not equivalent to a guilder of consumption in terms of the satisfaction it gives.

One important reason why the shadow price of investment - that is the multiplication factor that is used to convert the value of one dollar allocated to investment into consumer goods - diverges from 1 is formed by the taxes levied on business and personal income. Because the investor receives only a part of the return on capital his rate of time preference is considerably below the rate of return on capital. In other words the value of one dollar of investment - that is the present value of the consumer goods to be produced by this dollar of investment during its lifetime - exceeds the value of one dollar of present consumption. The shadow price of investment (relative to consumption) is greater than 1.³ In order to be converted into consumption the value of investment has to be multiplied by the appropriate shadow price.

Identifying the conversion factor for exports and imports boils down to finding a shadow price of foreign currency which truly reflects its scarcity. It is particularly relevant when the official exchange rate deviates from the rate which would have prevailed in a free competitive market for currency.

By multiplying the (changes in) macroeconomic variables with their appropriate shadow prices and adding up these consumption equivalents the costs and benefits for subsequent years over the lifetime of the project can be calculated.

3.2 Modelling the finance decision

Musgrave [1969] and Feldstein [1974] have propounded the idea that the level of opportunity costs is affected by the financing of the project. The source of finance may

³ Zuidema (1982) calculated a shadow price of capital for the Netherlands of 4.

be a tax increase, capital market loan, additional bank credit or a combination of these. Another possibility is that the government "finances" a project by reducing its expenditure on other items of public expenditure. In the view of the authors mentioned the financial instrument is of importance because capital market loans, for example, will reduce investment to a greater extent than a rise in income taxes. Given the different shadow prices of consumption and investment the financial instrument that is chosen will affect the level of opportunity costs. Even in a state of full employment equilibrium, like Musgrave and Feldstein implicitly assume, such differences will be manifest. In our macroeconomic evaluation of costs and benefits it is a fortiori true that the choice of the financial instrument affects the macroeconomic variables; its ultimate impact being determined by the economic regime that is implied by the structure of the model and the numerical values of the parameters.

3.3 Modelling environmental expenditure

The environmental project or programme is introduced into the model by raising the relevant expenditure variable. In a programme to abate industrial air pollution the compliance investments of industry are modelled by increasing business fixed investment; if three-way catalysts are to be installed in motor-cars part of the expenditure will constitute a rise in consumption. An increase in bank credit or a rise in taxes, necessary to procure the finance for the programme, can be incorporated in most models by increasing the money supply or the tax rate.

In most cases the private sector has to make the environmental investments on its own account. This asks for equations which model the impacts of pollution abatement costs during the lifetime of the equipment. A direct impact of rising costs will be a fall in profits. This, possibly together with a rise in the rate of interest, discourages investment. The costs of pollution abatement push up prices; among them are export prices. The deterioration of international competitiveness will reduce exports. The ultimate impact of the environmental project expenditure consists of a combination of expenditure impacts during the period the environmental investments are made, and cost impacts which only carry their full weight after the completion of the investment programme. Consequently, almost all macroeconomic evaluations of environmental programmes show a rise in national output and employment during the years of investment and subsequently a decline, caused by the costs of pollution control. It should be reminded, however, that the macroeconomic results depend on the general economic state of the world.

A weakness of macroeconomic models is the aggregative nature of the output variables and of the technical and import coefficients attached to them. By disaggregating and adding variables the model can be adapted further. Such refinements are particularly in place when the environmental investments and costs have specific technical or import coefficients which diverge substantially from the macroeconomic average coefficients.

3.4 Economic regime and opportunity costs

We pointed out that the macroeconomic impacts of an environmental programme or project, and consequently its costs and benefits, greatly depend on the economic state of the world and the financial instrument. This dependence can best be illustrated with a simple model. The appendix contains such a didactic model in which different "pure" economic regimes can be represented. A host of assumptions are made to raise the transparency of the model and its solution. The project asks for governmental expenditure only and it is finished within one period. The impacts of the benefits are not studied; only the opportunity costs of the project are analyzed. The macroeconomic model represents a closed economy with markets for products, labour and money.⁴ The demand functions for consumer goods, investment, public goods and money are specified, as well as the demand for labour. The structure of output is characterized by decreasing marginal productivity of labour and increasing marginal costs of aggregate supply.

From the basic model four specific models are derived for the following economic regimes: neoclassical equilibrium, neoclassical unemployment, Keynesian unemployment and Keynesian inflation. For each of these states of the world the opportunity cost formulae are calculated, taking into account the instrument that has been used to finance the project. By comparing the formulae it is possible to isolate the impact of the economic regime and the impact of the financial instrument on the level of opportunity costs.

In a regime of neoclassical equilibrium demand equals supply in every market. Total output is determined by the supply of labour coming forth at the equilibrium price of labour. Any increase in output would cause excess demand in the labour market. When a public investment project is undertaken full employment equilibrium can only be maintained by reducing private sector output. In the model the reduction of consumption and investment is realized by a rise in the rate of interest. When the project is financed by taxes consumption relative to private investment will decrease to a larger extent than

⁴ The model is closed with a market for securities.

would have been the case if the financial needs had been met by capital market loans. The shadow price of investment in terms of consumption units being greater than one, tax finance will minimize opportunity costs under a regime of neoclassical full employment equilibrium.

Under neoclassical unemployment, caused by downward rigidity of the real wage rate, the level of opportunity costs equals the opportunity costs in a situation of neoclassical equilibrium on all markets. Total employment and the output produced by labour are fixed by the rigid wage rate. The reservoir of unemployed labour will not be used to increase output. Consequently the public investment will crowd out private sector output in quite the same way it does under a regime of full employment equilibrium.

Even under a regime of Keynesian inflationary disequilibrium, with positive excess demand in the product market, the opportunity costs can be equal to the costs in neoclassical states of the world, given specific assumptions about rationing. The constraint on output set by full employment of labour causes reactions in the economic system more or less comparable to the crowding-out effects under the neoclassical regimes.

The important exception is the regime of Keynesian unemployment. Opportunity costs are at a lower level than they are under the three other regimes. When a public investment is made output can be increased by absorbing unemployed labour. Consequently the working of the crowding-out mechanism is reversed. The rise in the rate of interest can be limited and consequently the decrease of private investment can be small. The increase of output and income will even induce a rise in consumption. At low levels of employment, where the elasticity of supply is high, opportunity costs can turn out to be a boon: the sum of consumption and private investment increases instead of showing a decline. In such a situation opportunity costs are not represented by output foregone but by output won.

For each economic regime a least-cost financial instrument can be found. Under Keynesian unemployment bank credit gives the lowest level of opportunity costs, because it minimizes the crowding-out effects of a rise in the rate of interest. In the other states of the world a lump-sum tax is to be preferred. Such a tax decreases consumption relative to investment to a larger degree than bank credit or a capital market loan would; with a shadow price of capital in terms of consumption units greater than 1 this implies a lower level of opportunity costs.

The didactic model shows four pure regimes. Such pure forms will seldom or never be found in the real world. In practical macroeconomic cost-benefit analysis (cba) it is necessary to derive opportunity costs and benefits from an empirical macroeconomic model

which gives a true and quantitative picture of the existing situation in a specific economy during a specific time period. The cba analyst has to specify the relevant economic regime carefully; neoclassical equilibrium is only a special case. This makes the task of the cba analyst more difficult and hazardous. Fortunately it will very often not be necessary to construct completely new models because existing models can be used. Some of these models have a more or less official status (e.g. the model of the Dutch CPB, or the OECD Interlink model) and they reflect the view of policy makers on the existing economic situation and on the most relevant economic interdependencies. By taking such a model as a starting point for macroeconomic cost-benefit analysis consistency is attained between macroeconomic planning and project evaluation; nowadays such a consistency is often lacking.

3.5 Macroeconomic impacts of environmental benefits

In section 3.4 I have stressed the importance of the general economic context. Environmental cost-benefit analysis which concentrates on the ecological-economic linkages really runs the risk of losing sight of the relevance the existing economic regime has for the economic values that have to be attached to the impacts of environmental projects and programmes.

Having said this we shall concentrate in this section on the environmental aspects of macroeconomic environmental cost-benefit analysis. The beneficial impacts of environmental measures affect economic welfare by the following routes:

- a. a rise in economic performance because of reduction of environmental damage;
- b. technical spin-off resulting from new or larger markets for pollution abatement equipment;
- c. direct impact of environmental improvement on the utility of persons.

A. Effects of reduction of environmental damage to output.

The valuation of environmental damage constitutes the core of practical environmental cost-benefit analysis. Detailed empirical micro studies have been made of the impact of pollution on the productivity and/or prices of crops, forests, human labour, houses and recreational facilities.⁵ The strategic questions are how to detect the physical impact of

⁵ Compare Freeman [1979].

pollution and how to value the quantities of goods affected. In those cases in which the goods have a market price it is usually assumed in practical benefit analysis that the price reflects the social value of the products. In this way the benefits that are expected to arise from the environmental measure are expressed in monetary units.

Such a calculation, which proceeds in accordance with the established methodology in environmental benefit analysis, implicitly assumes that the growth in output will be absorbed by an equal expansion of demand. In other words the assumption is made that Say's law - "supply creates its own demand" - holds true and that the economic system reacts as if a regime of neoclassical equilibrium exists. Apparently there is a lack of studies which assess the consequences of different economic regimes for the benefits.

A way to fill this gap is to start from a macroeconomic model and to introduce environmental benefits. In macroeconomic models of the most simple kind the benefits of air pollution abatement (which for example improves agricultural output) could be inserted as an exogenous increase in the output of consumer goods. In more sophisticated models the productivity coefficients can be raised or the factor-input coefficients reduced. Next a run with the macroeconomic model has to be made to pinpoint the impact of environmental improvement on output variables and on aggregate national product. Results can be refined and made more specific by disaggregating the output variables in such a way that the environmentally relevant sectors are sorted out.

A rise in productivity will reduce the costs of production. This may induce reductions in prices; exports may increase; profits will increase too, which in turn may stimulate investments. Such positive impacts on national income will be reinforced by a rise in consumption. In this way and through other linkages within the macroeconomic model, output and expenditure variables will increase. It should be noted that the increase of the national product may be above or below the level of benefits that was calculated in the separate environmental benefit analysis. The ultimate outcome will be largely determined by the structure and parameters of the macroeconomic model (which again express a view on the prevailing economic regime). Very crucial is the way and the degree in which total expenditures are assumed to react to increases in productivity. If the economic regime is such that additional output is absorbed by a corresponding rise in effective demand, the potential environmental benefits will be fully realized. But one can also imagine an economic regime of Keynesian unemployment where lack of effective demand forms a constraint on the rise in income. The increase in productivity would only increase

the amount of unused productive resources. In "partial" environmental cost-benefit analysis this problem is overlooked.

Research on the impact of environmental benefits on macroeconomic growth has been a sadly neglected area.⁶ This lack of research interest is in stark contrast to the many sophisticated studies in partial environmental benefit analysis.

B. Effects of technical spin-off

Environmental programmes will increase the market for specific pollution abatement equipment; new programmes may even create completely new markets. The familiarity with national legislation and the vicinity of potential customers will give home producers a head start on foreign competitors. A growing market will stimulate "learning by doing". The increase in knowledge and experience will enable producers to reduce costs. By strengthening their competitive position producers will have better chances to export environmental equipment when at a later stage the same environmental policies are adopted in other countries.

It should be noted that the macroeconomic impacts of technical spin-off are affected by the economic regime. An increase in the export of environmental technology will have a powerful multiplier impact on national income when the general economic situation is one of large excess capacity and Keynesian unemployment. Under a regime of market equilibrium the increase in exports of environmental technology will have considerable crowding-out effects on other sectors and the net gain in income may be relatively modest.

Examples of growth in the home market followed by a strong export position are air pollution abatement equipment in Japan and waste water treatment technologies in the Netherlands. Although technical spin-off impacts may materialize in time, their occurrence and magnitude are very uncertain. These uncertainties do not differ, however, from other uncertain benefits in conventional cost-benefit analysis and they can be dealt with in the usual way.

⁶ The only study I know of, Nentjes and Klaassen (1985) and Nentjes (1987), is rather elementary. The analysis of macroeconomic benefits is based on the assumption that a damage reduction of x billion guilders in agriculture and forestry arising from air pollution abatement will cause the export of the sectors to increase by the same amount.

C. Direct utility impacts

In macroeconomic models the national account definitions of output and income are used. Unmarketed goods are not included in these concepts, with the exception of public sector outputs. It would be a mistake to insert a money equivalent of human satisfactions into the macroeconomic model, for example the joy of beautiful scenery, because they will not affect output and income. Only if utility impacts are assumed to affect things like labour productivity, which in turn would induce a change of income, the model should be adapted.

The best way to deal with direct utility impacts is to calculate them separately; express them in terms of the macroeconomic consumer good equivalents by using a willingness-to-pay measure and add this figure to the increase of consumer goods that has been calculated with the macroeconomic model.

4 A USER'S GUIDE TO MACROECONOMIC COST-BENEFIT ANALYSIS

In section 3 the steps which have to be made in drafting a macroeconomic cost-benefit analysis of environmental programmes or projects have been discussed. The logical order of the elements of the complete procedure is as follows:

1. Select an appropriate empirical macroeconomic model and calculate a reference path.

A. Cost impact

2. Calculate the expenditures of the environmental project. The expenditures are split up into expenditure on durable equipment and expences of operating the equipment during its lifetime. Durable equipment is split up into government investment, private investment and durable consumer goods.⁷ It can be useful to divide operating expenses into wages and other factor incomes.
3. Insert the project expenditure variables in the macroeconomic model and make other model adaptations: e.g. in the cost and price equations and in the import equations.
4. Find out from which source(s) the environmental project has to be financed.
5. Adapt the macroeconometric model to take account of the finance choice.
6. Make a model run to determine the opportunity costs of the environmental projects in terms of foregone consumption, investments, exports and so on in subsequent years.

⁷ More refinement can be obtained by calculating the output variables, expressed in value added, with the aid of a separate input-output model.

B. Benefit impact

7. Calculate the benefits of the damage prevented by the environmental project. Very often a detailed economic model or ecological-economic model of the sector(s) involved will be needed to make a reliable estimate of the benefits.
8. Adapt the macroeconometric model to take account of the impact of damage prevention (direct environmental benefits) on macroeconometric parameters.
9. Make an estimate of the benefits of technical spin-off.
10. Adapt the macroeconometric model to take account of technical spin-off.
11. Make a model run to determine the benefits of the environmental project in terms of additional consumption, investments, exports and so on.

C. Valuation

12. Calculate the shadow price of private investment (and of foreign currency).
13. Multiply the macroeconometric output impacts of the project expenditure with their shadow prices and add up.
14. Multiply the macroeconometric output impact of the benefits (prevented damages and technical spin-off) with their shadow prices and add up.
15. Calculate the direct utility impacts in terms of consumer goods.
16. Discount the opportunity cost (sub 13) and the benefits (sub 14 and 15) in successive years, using a rate of discount equal to the social rate of time preference.
17. Calculate the benefit-cost ratio.

A comparison of the above-mentioned procedure for a complete macroeconomic environmental cost-benefit analysis with standard macroeconomic evaluations of environmental projects or programmes reveals that in the usual macroeconomic evaluations only parts of the total procedure are performed. Steps 1 to 6 are carried out. Next the output variables are added up, using market prices instead of shadow prices. Benefit evaluation (7 to 11) is not undertaken at all.⁸ Expressing costs (and benefits) in one number and in a way which satisfies the demands of welfare economics (12 to 16) has not been tried. Actually

⁸ In Nentjes and Klaassen [1985] and Nentjes [1987] steps 7 to 11 have been performed in a tentative way.

macroeconomic environmental project evaluation boils down to some primitive and incomplete sort of cost-effectiveness analysis in which the options of implementing and not implementing the environmental programme are compared. In such analyses the implicit assumption is made that all shadow prices are equal to 1 and a present value of the cost impacts over subsequent years is not calculated.

5 CONCLUDING REMARKS

In section 3 the intention was announced to develop a full-blown macroeconomic cost-benefit analysis of environmental policies by giving a welfare economic foundation to macroeconomic evaluation and by introducing the attainments of environmental benefit analysis into it. In summary the welfare economic underpinning consists of the following elements.

- All relevant impacts of the environmental programme are taken into account; costs as well as all benefits.
- Costs are interpreted and modelled as opportunity costs.
- The shadow prices of capital and foreign currency are introduced to correct market prices in cases of market failure.
- (Future) costs and benefits are expressed in one unit of measurement (consumer goods) and discounted at an appropriate discount rate.
- The general economic context in which the environmental programme is carried out (the economic regime) is explicitly taken into consideration.

The macroeconomic cost-benefit analysis uses the methods developed in microeconomic environmental cost-benefit analysis to estimate the direct benefits of reducing pollution. On top of that the indirect benefits of technical spin-off are taken into consideration, as well as the specific characteristics (the technical and import coefficients) of the investment in environmental equipment, and its costs.

The transformation of macroeconomic policy simulation into a macroeconomic cost-benefit analysis in my view adds a useful tool of analysis to the existing methods of evaluation. Its main strength compared to microeconomic cost-benefit analysis is that it offers a practical solution to the problem of how to model the impact of the economic regime on the costs and benefits of environmental programmes.

APPENDIX¹

Opportunity cost rules under alternative economic regimes

In the following it will be shown that it is possible to construct opportunity cost formulae for other states of the world than neoclassical equilibrium. First the characteristics of the economic situation have to be specified by constructing a mathematical model of the economic regime. Next the opportunity cost equation can be derived from the model. The costs will differ according to the state of the economy. Four different regimes will be modelled:

- neoclassical equilibrium, with zero excess demands in all markets;
- neoclassical unemployment, arising from downward rigidity of the real wage rate;
- Keynesian unemployment, arising from a lack of effective demand;
- Keynesian inflation with positive excess demand in the product markets.

Under any of the four regimes the level of the alternative costs will be influenced by the way the project is financed. The following options will be considered:

- issue of government bonds;
- (lump sum) taxes;
- bank credit;
- reduction of other government expenditure items;

The basic model

The starting point for the construction of opportunity cost rules is a basic or trunk model from which the models for the four regimes will be derived.

$$X_D = C_D + I + G \quad (1)$$

$$X_S = C_D + S + T \quad (2)$$

$$S = s(X_S - T) - \bar{C} + ar, \quad 0 \leq s < 1 \quad (3)$$

$$I = -ir + \bar{I}, \quad 0 \leq t < 1 \quad (4)$$

$$T = tX_S + \bar{T} \quad (5)$$

¹ I thank Ide W.H. Nentjes for his assistance in working out the mathematics.

$$G = \bar{G} \quad (6)$$

$$N_D = nX_S^2 \quad (7)$$

$$\frac{dX_S}{dN_D} = \frac{0,5}{n^{0,5}} N_D^{-0,5} = \frac{w}{p} \quad (8)$$

$$N_S = \bar{N} \quad (9)$$

$$M_S = \bar{M} \quad (10)$$

$$M_D = l_1 pX_S - l_2 r \quad (11)$$

$$pX_S + wN_S + M_S + B_S = pX_D + wN_D + M_D + B_D \quad (12)$$

$$X_D > < X_S \quad (13)$$

$$N_D > < N_S \quad (14)$$

$$M_D > < M_S \quad (15)$$

$$B_D > < B_S \quad (16)$$

Definition of the symbols:

C_D = demand for consumer goods

I = demand for capital goods

G = government expenditure

S = savings

T = taxes

X_D = demand for aggregate output

X_S = aggregate supply

N_D = labour demand

N_S = labour supply

$\frac{w}{p}$ = real wage rate

w = money wage rate

p = general price level

r = rate of interest

M_D = money demand

M_S = money supply

B_D = demand for bonds

B_S = supply of bonds

$a, i, l_1, l_2, n, r, s, t$ are coefficients

$\bar{C}, \bar{I}, \bar{G}, \bar{M}, \bar{N}, \bar{T}$ have a predetermined value

Neoclassical equilibrium model

The neoclassical equilibrium model is derived from the trunk model by transforming (13) to (16) into market equilibrium conditions:

$$X_D = X_S \quad (13a)$$

$$N_D = N_S \quad (14a)$$

$$M_D = M_S \quad (15a)$$

$$B_D = B_S \quad (16a)$$

From the model for the product and labour market, which consists of 11 equations (1 to 9, 13a, 14a) and 11 endogenous variables ($C_D, I, G, S, T, X_D, X_S, N_D, N_S, \frac{w}{p}, r$) the reduced form

equations for consumption and investment can be derived. Aggregate output is calculated from (7), (9), (13a) and (14a).

$$\frac{\bar{N}^{0,5}}{n^{0,5}} = X_D = X_S = \bar{X}$$

From (1) and (2) it follows $I = S + T - G$. Substituting (3), (4), (5) and (6) into this equation gives:

$$I = \frac{i}{a+i} \{(1-c)\bar{X} - A\} + \bar{I} \quad (22)$$

$$C_D = c\bar{X} + \bar{C} - (1-s)\bar{T} + \frac{a}{a+i} \{(1-c)\bar{X} - A\} \quad (23)$$

$$c = (1-s-t+st)$$

$$A = \bar{I} + \bar{G} + \bar{C} - (1-s)\bar{T}$$

Assume that the project is financed with bond loans. The change in government expenditure arising from a public investment project is ΔG . From (22) and (23) it follows:

$$\Delta I = - \frac{i}{a+i} \Delta G \quad (24)$$

$$\Delta C = - \frac{a}{a+i} \Delta G = -(1 - \frac{i}{a+i}) \Delta G \quad (25)$$

In neoclassical equilibrium the opportunity cost-components are determined by the interest elasticities of the savings and investment functions. The idea, often encountered in practical cost benefit analysis, that the public investment fully crowds out private investment, holds only in the special case of a completely interest-inelastic savings equation ($a = 0$).

If the project is financed with lump-sum taxes $\Delta G = \Delta T$.
From (22) and (23) it can be derived

$$\Delta I = - \frac{si}{a+i} \Delta G \quad (26)$$

$$\Delta C = - \frac{sa}{a+i} \Delta G - (1-s) \Delta G = -(1 - \frac{si}{a+i}) \Delta G \quad (27)$$

If the project is financed with lump-sum taxes private investment will diminish with a smaller amount than in the case of financing with loans.

Financing with bank credit is not consistent with a neoclassical model. Increasing the money supply would imply a switch of economic regime. The money market only affects the product and labour market in a situation of market disequilibrium. This case will be investigated in the context of the inflation regime.

If the government decides to 'finance' the public investment project by cutting other government expenditures then the level of G is unchanged and the opportunity cost is $-\Delta G$ for any of the four regimes.

Neoclassical unemployment model

To transform the trunk model into a model generating neoclassical unemployment equations (13) and (15) have to be changed into equilibrium equations and downward rigidity of the real wage rate has to be postulated.

$$X_D = X_S \quad (13a)$$

$$M_D = M_S \quad (15a)$$

$$\bar{\frac{w}{p}} = \left(\frac{w}{p}\right) \quad (17)$$

Moreover the definition of unemployment may be added.

$$U = N_S - N_D \quad (18)$$

The model for the product and labour market consists of 12 equations (1 to 9, 13a, 17, 18) and 12 unknowns (C_D , I , G , S , T ,

$X_D, X_S, N_D, N_S, \frac{w}{p}, r, U$). The endogenous variables can be solved from this model. We shall concentrate on I and C_D .

Under a regime of neoclassical unemployment the level of production is not determined by the available supply of labour, as it is under neoclassical equilibrium, but by the rigid wage rate. According to (7) and by solving X from (8) by integration we obtain

$$X_S = \frac{0,5}{n \cdot 0,5} \left(\frac{\bar{w}}{p}\right)^{-1} = \bar{X}$$

If $\frac{w}{p}$ is fixed at a level above the full employment wage then \bar{X} represents a level of output that is below full employment output.

The equations for I and C_D are derived in quite the same way as was done for a regime of neoclassical equilibrium. The formulae only differ in that \bar{X} has to be replaced by \bar{X} . From these formulae we calculate the opportunity cost components ΔC and ΔI . The results are completely identical to the opportunity cost rules under a regime of neoclassical full employment equilibrium for the four financial instruments that have been distinguished. This outcome demonstrates that the existence of unemployment as such does not guarantee that public investment projects will diminish unemployment, even if the project is financed by government bonds. From (24) and (25) it follows:

$$\Delta C + \Delta I = -\frac{a}{a+1} \Delta G - \frac{i}{a+1} \Delta G = -\Delta G \quad (28)$$

Public works will not increase employment. Any increase in employment would decrease marginal productivity, which in turn asks for a lower real wage rate. The real wage rate rigidity blocks this adjustment. Total output remains constant and consequently a public investment project can only absorb workers by driving them out of their jobs in the private sector.

Keynesian unemployment model

The trunk model transforms into a Keynesian model with unemployment by specifying market equilibrium in the product and money market and by postulating rigidity of the money wage:

$$X_D = X_S \quad (13a)$$

$$M_D = M_S \quad (15a)$$

$$w = \bar{w} \quad (19)$$

Again the unemployment equation can be added

$$U = N_S - N_D \quad (18)$$

The number of equations is 15 (1 tot 11, 14, 13a, 15a, 18, 19) from which the 15 endogenous variables (C_D , I , G , S , T , X_D , X_S , N_D , N_S , w , p , r , M_D , M_S , U) can be solved.

From (1) to (6) and (13a) it follows:

$$r = - \frac{(1-c)}{a+i} X_S - \frac{A}{a+i}$$

and from (7), (8) and (19)

$$p = 2n\bar{w} X_S$$

Substituting the equations for r , p , (10) and (15a) in (11) gives:

$$X_S = \frac{1}{4l_1 n\bar{w}} \{Z + Y^{0,5}\} \quad (29)$$

$$Z = -l_2 \frac{(1-c)}{2(a+i)}$$

$$Y^{0,5} = \left[\left\{ l_2 \frac{(1-c)}{2(a+i)} \right\}^2 + 8l_1 n\bar{w} \left\{ \frac{l_2 A}{a+i} + \bar{M} \right\} \right]^{0,5}$$

By substituting X_S in the equation for r and next the equation for r in (4) we get:

$$I = \frac{i}{a+i} \left\{ \frac{(1-c)}{4l_1 n\bar{w}} (Z + Y^{0,5}) - A \right\} + \bar{I} \quad (30)$$

The reduced form equation for consumption is solved by substituting the equation for r in (13) and substituting (3) in (2) and X_S (29) in that equation.

$$C = \frac{c}{1-c} A + \bar{C} - (1-s)\bar{T} + \left\{ \frac{c}{(1-c)} + \frac{a}{a+i} \right\} \left\{ \frac{(1-c)}{4l_1 n\bar{w}} (Z + Y^{0,5}) - A \right\} \quad (31)$$

If the project is financed with bond loans the impacts on the opportunity cost components are calculated by differentiating (30) and (31) to G .

$$\Delta I = - \frac{i}{a+i} \Delta G + R \frac{i}{a+i} \Delta G = - \frac{i}{a+i} (1-R) \Delta G \quad (32)$$

$$\Delta C = - \frac{a}{a+i} \Delta G + \left\{ \frac{a}{a+i} + \frac{c}{1-c} \right\} R \Delta G = - \frac{a}{a+i} (1-R) \Delta G + \frac{c}{1-c} R \Delta G \quad (33)$$

$$\Delta I + \Delta C = - \Delta G + \frac{1}{1-c} R \Delta G$$

$$R = \frac{(1-c)l_2}{a+i} \cdot \frac{1}{Y^{0,5}} \quad R \geq 0$$

Compared with the results of the neoclassical model it appears that under the Keynesian unemployment regime the neoclassical (negative) cost component is compensated by a positive component (R). For consumption the positive component is larger than for investment. For plausible values of the coefficients and predetermined variables the range of R is $0 < R < 1$. If $R > 1-c$ then private sector output ($\Delta I + \Delta C$) will increase instead of falling off. Depending on the shadow price of investment the opportunity cost will be negative, but very small, or even be positive.

Let us consider financing with lump-sum taxes. Differentiating G and T in (30) and (31) and set gives ΔT equal to ΔG .

$$\Delta I = - \frac{si}{a+i} (1-R) \Delta G \quad (34)$$

$$\Delta C = - \frac{sa}{a+i} (1-R) \Delta G + \frac{sc}{1-c} R \Delta G - (1-s) \Delta G \quad (35)$$

In comparison with financing out of loans under Keynesian unemployment the decline in investment is smaller; the increment of consumption is smaller too. Compared with financing with taxes under neoclassical (dis)equilibrium regimes the decrease of investment is lower and consumption might even show an increase, where under neoclassical (dis)equilibrium consumption decreases.

Next consider financing with bank credit. When the project is financed with bank credit $\Delta G = \Delta M$ We derive from (30) and (31):

$$\Delta I = - \frac{i}{a+i} \left\{ 1 - \left(1 + \frac{a+i}{l_2} \right) R \right\} \Delta G \quad (36)$$

$$\Delta C = - \frac{a}{a+i} \left\{ 1 - \left(1 + \frac{a+i}{l_2} \right) R \right\} \Delta G + \frac{c}{1-c} \left(1 + \frac{a+i}{l_2} \right) R \Delta G \quad (37)$$

$$\Delta I + \Delta C = - \Delta G + \frac{1}{1-c} \left(1 + \frac{a+i}{l_2} \right) R \Delta G$$

The results show that under a regime of Keynesian unemployment monetary financing induces a smaller reduction of investment than

would have occurred if the project had been financed with bond loans; an increase of investment even is possible (if $R > 0,5$). Consumption increases more than under bond loan finance.

Keynesian inflation model

The trunk model can be extended to a Keynesian model with excess demand and inflation. The money market is in equilibrium and output is determined by the maximum of available labour:

$$M_D = M_S \quad (15a)$$

$$X_S = \bar{X}_S = \frac{1}{n^{0,5}} \bar{N}^{0,5} \quad (20)$$

If $X_D > X_S$, national labour demand is determined by the demand for output. Equations (8) and (7) transform into:

$$N_D = nX_D^2 \quad (7a)$$

$$\frac{dX_D}{dN_D} = \frac{w}{p} \quad (8a)$$

As in the former Keynesian model the money wage is rigid in the period concerned.

$$w = \bar{w} \quad (19)$$

By definition

$$p = \frac{p}{w} w \quad (21)$$

From the model of 15 equations (1 to 6, 7a, 8a, 9 to 11, 15a, 21) and 15 unknown variables

$(C_D, I, G, S, T, X_D, X_S, N_D, N_S, \frac{p}{w}, w, p, r, M_D, M_S)$

the reduced form equations of investment and consumption can be derived by substituting the other equations in (11).

$$I_D = - \frac{i}{I_2 Q + (a+i)} \{ c\bar{X}_S + A + \frac{(a+i)}{I_2} \bar{M} \} + \frac{i}{I_2} \bar{M} + \bar{I} \quad (38)^2$$

² I_D, I_S investment demand resp. supply. Under a regime of inflation is $I_D > I_S$ and $C_D > C_S$.

$$C_D = c\bar{X} + \bar{C} - (1-s)\bar{T} - \frac{a}{1_2 Q + (a+i)} \{ c\bar{X} + A + \frac{(a+i)}{1_2} \bar{M} \} + \frac{a}{1_2} \bar{M} \quad (39)$$

$$Q = \frac{1}{2n1_1 \bar{w}\bar{X}_S}$$

Consider the case of financing out of bond loans. From (30) and (31) we derive:

$$\Delta I_D = \frac{-i}{(a+i)+Q1_2} \Delta G \quad (40)$$

$$\Delta C_D = \frac{-a}{(a+i)+Q1_2} \Delta G \quad (41)$$

$$\Delta I_D + \Delta C_D = - \frac{1}{1 + \frac{Q1_2}{a+i}} \Delta G \quad (42)$$

Under a regime of Keynesian inflation the consumption demand and investment demand both decrease less than they would have done under full employment equilibrium or under neoclassical unemployment. (Note that G in (40) and (41) is multiplied with a fraction that is smaller than in (24) and (25). Consequently private sector demand decreases less than the increase of government expenditure. Aggregate excess demand will increase and the public project financed by loans adds to inflationary pressure.

The decrease of the production of investment and consumer goods can only be determined by making additional assumptions about the reactions of suppliers. It should be noted that the public investment project can only be carried out if the reduction of private sector output exceeds the reduction of private sector demand. Assuming such a rationing mechanism and assuming that the reduction in the private sector is proportional to the decrease in consumer and investment demand the resulting rationing fraction f is determined by the equation:

$$\Delta C_S + \Delta I_S = f \frac{-i}{(a+i)+Q1_2} \Delta G - f \frac{a}{(a+i)+Q1_2} \Delta G = - \Delta G \quad (43)$$

$$\text{where } f = 1 + \frac{Q1_2}{a+i} \quad (44)$$

The increase in the supply of investment and consumption is

$$\Delta I_S = f \Delta I_D = - \frac{i}{a+i} \Delta G \quad (45)$$

$$\Delta C_S = f \Delta C_D = - \frac{a}{a+i} \Delta G \quad (46)$$

Under these specific assumptions the opportunity cost equation is equal to the results obtained under a regime of neoclassical equilibrium or unemployment disequilibrium.

Let us now pay attention to financing with (lump-sum) taxes. The reduction of consumption and investment demand is calculated in the usual way:

$$\Delta I_D = - \frac{si}{a+i+Ql_2} \Delta G \quad (47)$$

$$\Delta C_D = - \frac{sa}{a+i+Ql_2} \Delta G - (1-s) \Delta G \quad (48)$$

$$\Delta I_D + \Delta C_D = \frac{-1 - \frac{(1-s)}{(a+i)} Ql_2}{1 + \frac{a}{a+i}} \Delta G$$

The reduction of investment demand and of consumer demand is smaller than it would have been under a neoclassical regime (cf. (26) and (27)).

The reduction of total private sector demand is larger than it would have been if the project had been financed through the capital market under a regime of Keynesian inflation. This is so because consumption demand shows a relative large reduction. Contrarily the investment demand reduction is smaller than it would be if the project was financed by loans.

In the case of financing with bank credit ($\Delta M = \Delta G$) the changes in private sector demands are

$$\Delta I_D = \frac{-i(1-Q)}{a+i+Ql_2} \Delta G$$

$$\Delta C_D = \frac{-a(1-Q)}{a+i+Ql_2} \Delta G$$

$$\Delta C_D + \Delta I_D = \frac{-(1-Q)}{1 + \frac{a}{a+i}} \Delta G$$

Again total demand for private output will decrease less than the increase in demand of the public sector. The demand reduction will be smaller than the demand reduction in case the project was financed by loans under a regime of Keynesian inflation.

Proportional rationing of investment and consumption just enough to produce the additional government output, makes for the same result as under a neoclassical regime with loan finance

$$\Delta I_S = - \frac{i}{a+i} \Delta G \quad \text{and} \quad \Delta C_S = - \frac{a}{a+i} \Delta G.$$

From the above analysis it appears that under regimes of neoclassical equilibrium and neoclassical unemployment the lowest possible level of opportunity costs is attained if public projects are financed by raising lump-sum taxes. Under a regime of Keynesian unemployment opportunity costs are minimized if the projects are financed with bank credit. Under Keynesian inflation the minimum opportunity cost alternative will depend on the rationing decisions of producers. If rationing is proportional to the reduction in demand then tax finance should be preferred.

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