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Use of macroeconomic models in analysis of environmental problems in Norway and consequences for environmental statistics

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Key words: Linkage of environmental statistics to economic statistics; Estimation of emissions on the basis of economic data; Macroeconomic evaluation of damage caused by pollution.

Summary

This paper advocates the following strategy: First define the environmental problem, then decide on the analyses and methods needed to bring forward information to decision makers, and only when this demand is relatively clearly defined - collect the necessary data.

The point is of course to avoid putting much resources and efforts into detailed modelling of "inessential" phenomena, while at the same time making certain that the statistics gathered are useful and treated in a disciplined manner. There is almost no limit to the amount of environmental and economic statistics or analyses "needed" by someone somewhere. All too often data are collected in an unsystematic and too ambitious way.

Many countries' planning procedures are rather fragmented, with responsibilities for economic development, environmental standards etc. distributed among several more or less independent ministries and agencies. These procedures might be improved if they are based on a common understanding of the functioning of the economy. Macroeconomic models can be used to ensure consistency among the various planning activities with regard to behavioural assumptions of economic agents, as well as expectations about future development of key economic variables. At this stage of development, it is probably more important to be pragmatic and consistent within an integrated approach to the planning problem, than to be sophisticated with regard to more partial aspects.

Within the traditional economic statistics, more weight should be given to statistics on stock variables, to give a reasonably accurate picture of the total national wealth and its development over time. This information should ideally be based on an internationally accepted set of indicators, covering standard regions and sectors and presented in standard units. The information should, wherever possible, be compatible with the SNA definitions and classifications in order to facilitate analysis and forecasting.

This paper starts with a brief summary of the development of resource accounting in Norway. Section 2 is on the development of the analytical tools used in Norway for studies of interactions between economic activity and selected environmental problems. This section also contains a short description of one of the relevant macroeconomic models. A more technical description is presented in Appendix 2. Section 3 presents of a number of case studies carried out by the use of these tools, and finally section 4 sums up plans and recommendations for further work.

1 Resource accounting in Norway. Historical development

Analysis of methodological questions and the development of some experimental resource accounts started at the Central Bureau of Statistics of Norway (CBS) in 1978, and the first results were presented in 1980. From then on, parts of the accounts have been presented in a yearly report ("Natural resources and the environment") from the CBS. The main aim for resource accounting is to improve the management of natural resources and the environment, by making it possible to integrate resource and environmental issues in the social planning process. Social planning in Norway, as in most other countries, has focused on economic issues. Thus, priority has been given to make the resource and environmental accounts compatible with economic classifications and standards. The content and emphasis of the resource accounts have, however, shifted over time.

In the initial phase considerable efforts were made to establish resource accounts for *energy, fish and land use*, in addition to less detailed accounts for *minerals and forests*. The accounts covered *reserves*, *extraction*, *transformation* and *use* of the resources. At all levels, emphasis was put on the linkage to the national accounts. For some of the resources, input-output analysis of final deliveries were made. Thus, initially, the natural resource accounts covered a number of resources. The main reason for this was a growing concern for the scarcity of these resources, and a belief that the greatest stumbling block for a rational management of these resources was to be found in lack of adequate and systemized data.

These attitudes have changed somewhat over time. First of all, the oil price shocks of the 1970s and the reactions to these shocks seemed to indicate that there was no immediate danger of depletion of the non-renewable resources. It became clear that dooms-day prophecies brought forward by for instance the Club of Rome, disregarded important regulating factors brought about by responses to resource prices. Second, and perhaps more important, it emerged that the problem of attaining a rational management of natural resources was only partly due to lack of data. Rather, the problem appeared to be the inertia of the established planning apparatus and its resistance to the introduction of new and partly unknown resource and environmental considerations in the planning procedure.

The gradual recognition of these facts led to two major changes in the Norwegian system of natural resource accounting. One is concerned with the coverage by the accounting system. After a period with extended accounting of many resources, priority is now given to the development and operation of natural resource accounts which have clearly defined end users or which have been used extensively over a period of years. The main emphasis is on two resources only; *energy (oil, gas and hydro power)* and *air*, with less detailed accounts being made for *fish*, *minerals* and *forests*. Air is covered by compiling information on environmental problems regulated in international treaties (e.g. sulphur dioxide, nitrogen oxides, CFCs), or problems where international agreements seem necessary in the not too distant future (e.g. volatile organic components and the greenhouse gases carbon dioxide, methane and nitrous oxides). Second, and equally important, priority is now given to the compilation of information in a form suitable for use in macroeconomic models and other analytical tools. Thus, over the years, the macroeconomic models employed by the Ministry of Finance for medium and long term economic projections have been extended to include relatively detailed energy and air pollution variables. Integrated forecasts are now made of economic development, demand for energy and emissions to air of polluting compounds, based on a consistent set of assumptions. For more details, refer to the yearly report "Natural Resources and the Environment" (CBS, 1990), Miljøstatistikk 1988 (CBS, 1988), and special reports on Norwegian experiences in natural resource accounting (Alfsen, Bye and Lorentsen, 1987, Alfsen and Bye, 1990, Alfsen and Lorentsen, 1990).

2 Development of analytical tools

2.1 On the need for planning

Economic planning has generally been motivated by factors such as the need for macro-economic stability and full employment, equity goals with regard to income distribution, and the increasing proportion of collective or public consumption with increasing income level. The possible adverse effects of serious mismanagement of the global and local environment now makes it tempting to state that concern for the environment is the main reason for long term economic planning. Today, there exists procedures for economic planning or policy analysis in most of the industrialized countries, while systems for environmental planning is only beginning to emerge. Hence, the most practical and efficient approach to the problem of establishing an environmental planning system may be to adapt to the already established economic planning apparatus, including its modelling tools.

There are several reasons why a planning system based on macroeconomic models is particularly useful:

- One aim in employing models is clearly to simulate real social systems in order to be able to predict possible future development. After all, it is better (and generally cheaper) to envisage and prevent damage to the environment than to detect and repair the damage (where repair is possible). Model forecasts may provide "early warning" signals about emerging problems, e.g. as to which pollutants might be difficult to control in the future.

- Another aim is to make sure that economic and environmental planning is utilizing a consistent set of assumptions in the planning effort. Models make it possible to analyze the environmental and economic effects of control policies in a coherent and consistent manner.

- A model is necessary to evaluate the direct and indirect (i.e. allocation) effects of different policies on the economy itself as well as on the environment.

- Models make it convenient to assess the direct and indirect economic costs and benefits of alternative policies.

- Models can play a constructive role in imposing the necessary discipline in data collecting. Models that can be used to answer questions which are important to the planning authorities will also define precisely which data sets are needed for management purposes.

- Empirical models are useful in the process of accumulating knowledge; personal skills are not easy to inherit whereas a well documented model is "common property".

2.2 Present status

Social planning in Norway has traditionally focused on economic issues, and central in the planning process has been the application of macroeconomic models. These models can relatively easy be revised and extended to make them useful for analysis of environmental issues, by including energy variables and indicators of emissions of emission of air pollutants. This makes it possible to provide scenarios and policy analyses of environmental issues consistent with macroeconomic forecasts used for other purposes such as the government's Long term programmes, energy forecasts etc. The approach has been rather pragmatic; to integrate some important environmental issues in existing planning procedures, instead of constructing sophisticated additional environmental models.

Simultaneous forecasts of emissions to air are now routinely made along with long-term projections of economic growth. The air pollution components covered at present are: *Sulphur dioxide* (SO_2), *Nitrogen oxides* (NO_x), *Carbon monoxide* (CO), *Carbon dioxide* (CO_2), *Volatile organic components* (VOC), *Particulate matter*, *Lead* (Pb), *Methane* (CH_4) and *Nitrous oxide* (N_2O). Four different types of emission sources are specified for each of some thirty economic sectors: emission from *stationary combustion*, *mobile combustion*, *process (i.e. non-energy) related emission* and *evaporation*.

The economic foundation for the emission forecasts is the medium term model *MODAG* and the multi-sectoral general equilibrium model *MSG*. The models are constructed, maintained and operated by the Central Bureau of Statistics of Norway and frequently used by the Ministry of Finance. Approximately 30 economic sectors are specified in the models.

Forecasts of emissions are basically ex post calculations to the economic models employing constant emission coefficients calibrated in a base year. However, exogenous adjustments of the coefficients are made in order to take account of planned environmental control measures in the forecasting period, e.g. catalytic cleaning of exhausts from private cars, further cleaning of emissions from polluting industries etc.

In order to determine the emission coefficients in the base year, information from the energy accounts of Norway and data on emissions in the base year are employed. These data provide information on fuel use and emissions in approximately 140 sectors (see Appendix 1 for a list), specified on 8 different types of fossil fuels and 9 types of polluting components. Data on process related emissions (i.e. emissions not related to combustion of energy commodities) is obtained from the State Pollution Control Authority (SFT). It is essential for this application of the emission inventories that they are categorized according to a classification that permit comparison with economic statistics. Table 1 and 2 show emission levels by type of source and some aggregate sectors in 1987.

Below follows a brief description of some of the main elements of the model MSG-4 model, which has been used extensively for analysis of air pollution problems. For further elaborations and details, see Appendix 2 and Johansen (1974), Bjerkholt et al. (1983), Offerdal et al. (1987), and Longva et al. (1985).

Table 1 Emissions to air by type of source. 1987. 1000 metric tons.

	SO_2	NO_x	CO	CO_2*	VOC	Particu-lates	Pb**	CH_4[1]	N_2O[1]
TOTAL	74.7	231.8	652.6	34.2	188.2	25.4	277.0	286.4	12.6
STATIONARY COMBUSTION	24.4	27.5	123.9	14.0	26.2	13.0	4.1	7.9	1.8
- Industrial combustion	17.9	22.6	4.8	10.0	2.9	1.2	0.4	0.1	0.5
- Non-industrial combustion	6.0	3.8	118.8	3.9	23.1	11.7	0.2	7.8	1.3
- Incineration of waste	0.6	1.1	0.4	0.1	0.3	0.1	3.5	-	-
INDUSTRIAL PROCESSES	31.2	7.9	36.1	5.0	5.4	0.0	5.0	273.7	10.0
- Paper and paper prod.	3.3	-	-	-	-	-	-	-	-
- Industrial chemicals	5.8	4.3	32.3	0.5	0.7	-	-	-	6.0
- Mineral products	1.9	-	-	1.1	-	-	-	-	-
- Petroleum refining	3.4	-	-	-	3.6	-	-	-	-
- Metals	16.8	3.6	3.8	3.3	1.1	0.0	5.0	-	-
- Agriculture	-	-	-	0.2	-	-	-	105.0	4.0
- Waste dumps	-	-	-	-	-	-	-	160.0	-
EVAPORATION	-	-	-	-	73.2	-	-	8.8	-
- Storage of gasoline	-	-	-	-	3.0	-	-	-	-
- Filling stations	-	-	-	-	5.0	-	-	-	-
- Solvents	-	-	-	-	50.0	-	-	-	-
- Oil- and gas extraction	-	-	-	-	15.2	-	-	6.2	-
- Gas terminals	-	-	-	-	-	-	-	0.4	-
- Mining	-	-	-	-	-	-	-	2.2	-
MOBILE SOURCES	19.0	196.5	492.6	15.3	83.4	12.5	267.9	4.7	0.8
- Automobiles	4.6	79.6	406.4	7.8	49.7	4.5	252.4	3.1	0.3
-Light vehicles	1.7	44.7	370.3	5.3	43.2	2.2	234.6	2.6	0.2
-Gasoline	1.1	42.5	367.1	4.9	41.6	1.4	234.5	2.6	0.1
-Diesel	0.6	2.2	3.2	0.4	1.6	0.7	0.0	-	0.1
-Heavy vehicles	3.0	34.9	36.1	2.5	6.5	2.4	17.8	0.5	0.1
-Gasoline	0.1	3.9	25.9	0.4	2.7	0.1	17.8	0.3	-
-Diesel	2.9	31.0	10.2	2.1	3.8	2.3	0.1	0.2	0.1
- Motor cycles, mopeds, tractors etc.	1.4	13.7	65.6	1.1	24.3	2.0	15.2	0.2	0.1
- Railways	0.1	0.5	0.2	0.1	0.1	0.1	0.0	-	-
- Air traffic	0.2	4.1	10.6	1.8	2.2	0.2	0.0	0.1	0.1
- Coastal water transport	9.6	52.1	5.2	2.4	3.7	3.0	0.2	0.7	0.2
- Fishing fleet	2.2	32.8	3.3	1.5	2.3	1.9	0.1	0.4	0.1
- Oil well drilling	0.9	13.7	1.4	0.6	1.0	0.8	0.0	0.2	-

*) Million tons
**) Tons
1) Preliminary figures.

Sources: CBS, SFT.

Table 2 Emissions to air by sector. 1987. 1000 tons

		SO_2	NO_x	VOC[1)]	CO	CO_2*	Particu-lates	Pb**	CH_4[3]	N_2O[3]
	Total	74.7	231.8	115.0	652.6	34.2	25.4	277.0	286.2	12.8
11	Agriculture	1.0	5.4	3.6	11.3	0.7	0.8	1.9	105.1	4.1
12	Forestry	0.1	0.7	1.1	3.1	0.1	0.1	0.8	0.0	0.0
13	Fishing etc.	2.2	32.8	3.6	6.3	1.5	1.9	1.0	0.4	0.1
14	Manufacture of food, beverages and tobacco	4.2	2.5	0.4	1.8	0.8	0.3	0.8	0.0	0.1
18	Man. of textiles, wearing apparel etc.	0.2	0.2	0.0	0.2	0.1	0.0	0.1	0.0	0.0
26	Man. of wood and wood prod.	0.5	0.8	0.2	1.0	0.1	0.1	0.3	0.1	0.1
28	Printing and publishing	0.0	0.2	0.1	0.7	0.0	0.0	0.4	0.0	0.0
29	Man. of non-ind. chemical and mineral products	6.1	6.3	0.5	2.0	2.9	0.4	0.7	2.2	0.1
34	Man. of pulp and paper prod.	6.6	1.6	0.1	0.6	0.5	0.3	0.2	0.2	0.3
37	Man. of ind. chemicals	7.0	6.0	0.8	32.4	1.4	0.1	0.0	0.0	6.1
40	Petroleum refining	4.1	1.9	3.6	0.0	1.1	0.1	0.0	0.0	0.1
43	Man. of metals	19.5	5.2	1.3	4.2	3.8	0.2	5.1	0.0	0.1
44	Man. of metal products, machinery, building of ships,.	0.9	1.2	0.3	1.7	0.3	0.1	1.0	0.0	0.0
55	Construction	0.9	8.2	1.2	4.8	0.6	0.6	1.5	0.1	0.1
63	Financing and insurance . . .	0.1	0.5	0.5	4.0	0.1	0.0	2.6	0.0	0.0
64	Oil and gas extraction	0.2	11.3	2.4	3.3	4.3	0.0	0.0	8.7	0.3
68	Oil well drilling	1.2	13.7	1.0	1.4	0.6	0.8	0.0	1.3	0.0
71	Prod. of electricity[2)]	0.6	1.1	0.3	0.4	0.2	0.1	3.5	0.0	0.0
74	Domestic transp. and comm.	12.2	76.4	12.3	49.8	5.9	5.1	16.9	1.0	0.4
81	Wholesale and retail trade . .	1.2	11.7	7.0	57.2	1.3	0.6	35.8	0.5	0.1
83	Housing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	Other private services	0.6	3.4	2.8	24.2	0.7	0.1	15.4	0.2	0.1
92	Defence	0.4	3.7	0.4	2.3	0.6	0.2	0.6	0.1	0.0
93	Education and research	0.3	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.0
94	Health and social welfare services	0.7	0.2	0.0	0.1	0.3	0.0	0.0	0.0	0.0
95	Other public services	0.1	0.7	0.1	0.8	0.1	0.0	0.5	160.0	0.0
P	Private households	3.9	36.1	71.4	439.1	6.0	13.1	188.0	6.3	0.6

*) Million tons
**) Tons
1) Evaporation not included. (Evaporation: see table 6.4.)
2) Includes emissions from waste incineration plants.
3) Preliminary figures.

Sources: CBS, SFT.

2.3 Economic structure of the MSG-4 model

The MSG model was constructed in order to study the overall long-term prospects of the Norwegian economy and also more specifically the long-term interactions between economic growth and energy supply and demand. The model is mainly used by the Ministry of Finance as a quantitative tool in macroeconomic planning, but other government bodies and research institutes also make use of it. The dimensions of the model, 32 production sectors and 42 commodities, reflect a compromise between the ambition of applying detailed sector information and the Ministry's need for a manageable model.

In most industries the input aggregates - labour, capital, energy and materials - are substitutable according to neo-classical production functions. In addition, inter-fuel substitution is assumed within the energy aggregate within each sector. The development of the total production capacity of the economy is determined by the exogenous growth of the labour force, sectoral assessments of technical change, and rates of return to capital. The composition of production also influences the total productive capacity since sectors are not equally efficient.

The model is closed by letting the level of household consumption be endogenously determined such that full capacity utilization is ensured. Thus, total private consumption is what is left of production capacity over gross investments, government consumption, and net exports.

The model calculates the equilibrium prices for commodities and real wages, and will trace out paths of balanced growth in the sense that there is a continuous balance between supply and demand of goods and factors of production within the limits of available capacity. Some price indices such as nominal wages, the prices of non-competitive imports, oil, gas, electricity, government fees and commodity taxes are exogenous to the model and determine the nominal price level.

The substitution parameters of the model are most properly interpreted as long-term elasticities. In an equilibrium model with no lags, as in MSG, economic agents react immediately to adjust their allocations to changes in prices or other incentives. In the real world, it necessarily takes time for economic agents to adopt to changed incentives. Thus, the model predicts the average development over a period where changed incentives have persisted long enough to allow agents to adjust.

<u>Emission submodel</u>

As already mentioned, sectoral emissions of nine pollutants from four types of sources are presently modelled. Emissions from industries and private households due to stationary combustion are associated with the use of fuel oils, mobile combustion emissions are associated with the demand for petrol, process emissions are associated with demand for intermediate materials other than energy commodities, while evaporation is associated with both industry specific use of materials (proxy for use of solvent), total demand for gasoline (evaporation from storage and handling of gasoline) and private consumption of housing (proxy for use of paints etc.), see table 3. Waste generation in private households is assumed to follow total private consumption. Emissions from waste dumps (mainly methane) and incineration of waste are determined by exogenously given factors determining the relative amount of waste generated going to dumps and incinerated, respectively.

Emission factors are calibrated in a base year, and are projected by taking into account the effects of planned and implemented environmental control policies like emission standards for new vehicles, limits on sulphur content of heating oils, direct regulation of emissions from specified firms, etc.

3. Some case studies

3.1 Forecasts of emissions to air and the effects of fluctuating energy prices

Table 3 Emission compounds, sources and indicators

	Type of sources	Indicators
1	Stationary	Fuel oil consumption
2	Mobile	Petrol consumption
3	Process	Raw materials, intermediate goods
4	Evaporation	Various variables
	Emission components	
1	Sulphur dioxide	SO_2
2	Nitrogen oxides	NO_x
3	Carbon monoxide	CO
4	Carbon dioxide	CO_2
5	Volatile organic components	VOC
6	Lead	Pb
7	Particulates	Prt
8	Methane	CH_4
9	Nitrous oxide	N_2O

As previously mentioned, emission projections are elaborated on a regular basis in connection with governmental white papers on economic perspectives, plans for energy use and other ad hoc reports. The projections, which usually only incorporate environmental control measures already decided on, serve as indicators of likely development of emissions to air. As such they provide early warning signals on whether targets, like international obligations to reduce emissions, are likely to be met, and if not, the order of magnitude of the gap. Figure 1 shows one such set of projections, based on a macroeconomic growth path similar to the last government's Long Term Programme (Stortingsmelding 1988-1989, Bye et al., 1989).

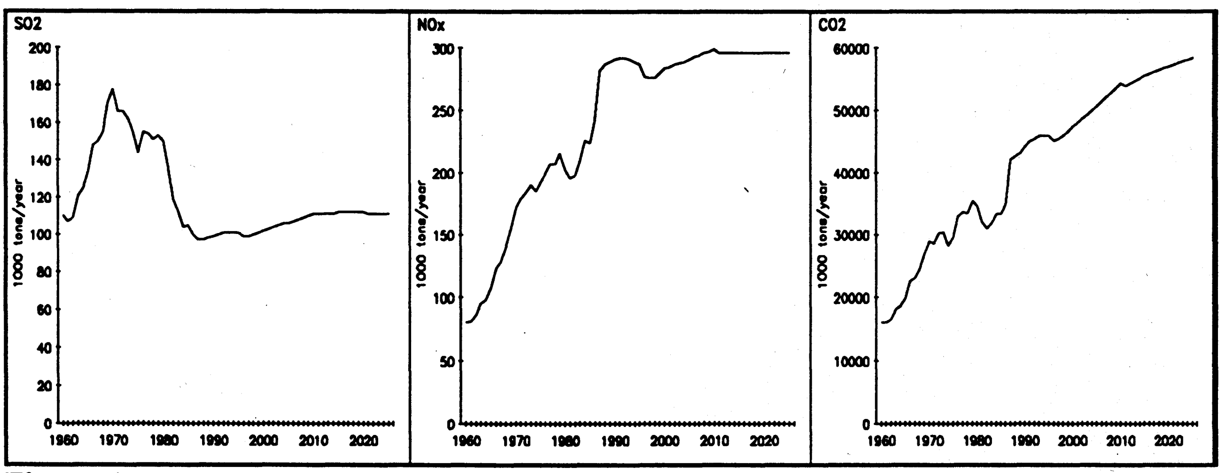

Figure 1 Emission projections

The forecast indicates that a more or less stable level of SO_2 emissions is expected under the prevailing assumptions of the economic scenario. NO_x emissions are expected to increase sharply, before they level off early in the next century as new regulations of automobile exhaust gases are coming into force. Most worrisome is perhaps the continuous growth in CO_2 emissions, although the growth rate may decline somewhat in the long run. Note that all projections are based on the assumption that no additional efforts in combating emissions are going to be initiated.

Any forecast is contingent on a number of more or less uncertain assumptions. Due to its close link to emissions to air, the world market price of oil is crucial in this respect. Table

4 shows calculated emission elasticities for several compounds with respect to the world market oil price. In the calculation of these numbers assumption of world market as well as domestic market reactions to changes in oil price are incorporated. Emissions of compounds stemming mainly from transportation activities show the greatest sensitivity to changes in the oil price. The results are further commented on and documented in Alfsen (1987).

Table 4 Emission elasticities with respect to world market price on crude oil

Component	Estimated emission elasticity (lower	upper)
SO_2, VOC	-0,15	-0,25
NO_x	-0,25	-0,35
CO, Pb, Particulates	-0,35	-0,40

The long term equilibrium price of electricity is, among other factors, dependent on the rate of return to capital in the electricity generating sector. Table 5 shows the percentage change in emissions of various compounds when this rate is varied from a reference level of 6 per cent. The perhaps surprising sign of the NO_x emission elasticity, is due to the power intensive industry in Norway.

These are but two examples of sensitivity calculations aimed at mapping the possible environmental effects of alternative development paths for variables deemed to be important in the modelling effort of future emissions to air. A general equilibrium approach is a quite appropriate tool for this type of study, since it at least in principle capture also the indirect effects of changes in important exogenous variables. These may be important in estimating the total effects of alternative development paths.

Table 5 Per cent change in total emissions when rate of return to capital in the electricity generating sector is varied from 6 to 5 and 7 per cent

Components	Estimated change in emissions Rate of return 5%	7%
SO_2	0,0	0,0
NO_x	0,4	-0,6
CO	-1,8	2,3
Pb	-0,1	0,1
VOC	-0,6	0,8
Particulates	-2,4	3,1

3.2 Emission tax on SO_2

In a study based on the MSG-4E model, the effects on economic activity of introducing an emission tax on sulphur dioxide (SO_2) were calculated (Alfsen, Glomsrød and Hanson, 1986, 1987, Alfsen and Hanson, 1987, Hanson and Alfsen, 1986, Alfsen, Hanson and Lorentsen, 1987). Emissions from fuel combustion in 13 manufacturing sectors were taxed according to the sulphur content of the fuel. According to the model, which has empirically estimated relations with predominately energy-capital complementarity, taxation of SO_2 emissions reduces long term economic growth. The reduction in GDP inferred from the model calculation was considerably greater than the tax payment from sectors directly affected. Although substitution possibilities can be expected to reduce the total impact of the tax on the economic result of a sector, the capital-energy complementarity leads to less investment when the price of energy increase, thus reducing the long-term growth of that particular sector. Although taxation is a cost-effective mean to lower emissions from polluting sectors, the indirect allocation cost of the control policy should be recognized from the outset, as these costs may dominate the more easily calculated direct costs of the taxed sectors.

3.3 Reduced corrosion when emissions are lowered

Reducing SO_2 emissions leads to several benefits not considered in the previous case study. Among these benefits are reduced material damage, and probably also increased productivity of the labour force. The effects on human health are difficult to quantify. Beneficial effects in terms of reduced corrosion rates are easier to estimate, and this has been done in a separate study (Glomsrød and Rosland, 1988). Employing empirically determined functions of damages from SO_2 concentration on building materials, relations between national SO_2 emission and cost of maintenance were obtained. By extracting these costs in simulations using the MSG-4E model, it was possible to estimate some of the benefits accruing from cleaner (less acid) air. The direct outlays due to SO_2 generated corrosion on materials included in the study amounted to approximately NOK 200 millions per year in 1985 and NOK 300 millions in year 2000 in fixed prices. Removing SO_2 emissions altogether would directly yield this benefit to firms and households. However, total benefits for the economy as a whole, including allocation effects caused by the reduced price of capital, was calculated to be NOK 400-500 millions per year around the turn of the century. Thus, again the repercussions in the economy of changing the operating conditions for some sectors proved to be of the same order as the more easily accessible direct effects. The lesson is that general equilibrium effects of environmental control policies must be included when the overall costs and benefits of such policies are to be assessed.

3.4 Environmental taxes or regulations?

A comprehensive study of possible developments of the Norwegian economy, energy use and emissions to air through year 2000 has recently been carried out (Bye et al., 1989). The study, which was based on a medium term macroeconomic model called MODAG (see Cappelen and Moum (1987) for a description), was motivated by the need to reconcile international agreements on reduction in SO_2 and NO_x emissions with national policies of the economy and energy use. In addition, a growing concern for global environmental problems like the greenhouse effect, has generated a demand for studies of future emission of CO_2 and scenarios attempting to reduce these emissions. Three of the scenarios developed in the study are illustrated in figures 2-4 by way of projected emissions to air.

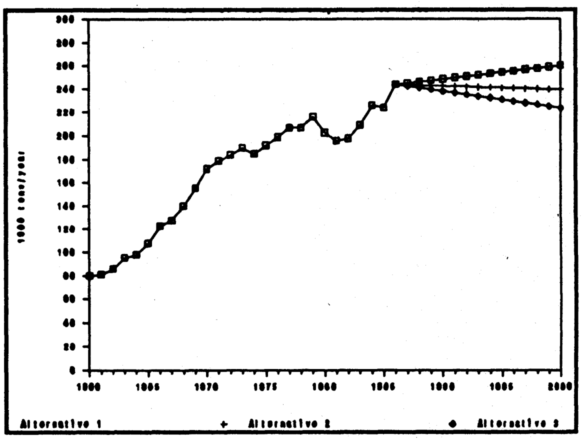

Figure 2 Emission of NO_x

Alternative 1 is a reference scenario where no special consideration is given neither to energy use nor emissions to air. Alternative 2 is a scenario where the traditional policy of direct regulations of emissions from single firms together with stricter limits on emissions from automobiles is employed. Neither of these approaches fulfil the obligations of the present or expected future international agreements. For this reason an additional alternative, alternative 3, was developed where the entire taxation scheme in Norway was restructured to stabilize CO_2-emissions at the 1989 level by the year 2000. Heavy taxes on use of fossil fuels were imposed, increasing the real price of all oil products by 75 per cent, and the tax revenue used to reduce income taxes. As can be seen from the figure, a combination of a new tax policy and some measures of direct regulations looks promising from an environmental viewpoint, although the political difficulties with this approach should not be underestimated.

In the calculations, the total effects on main macroeconomic variables in alternative 3 were small. There are several reasons for this:

- The budget share for energy is relatively low in most sectors; on average 5 per cent of total variable costs.
- Reductions in direct income taxes were assumed to modify nominal wage increases, thus reducing the increase in production costs. International competitiveness was on average retained.
- Higher energy prices were further assumed to increase the productivity of energy.
- Finally, higher prices on fossil fuels increased the domestic demand for electricity, and thus increased investments and construction activities. This also increased the domestic activity level.

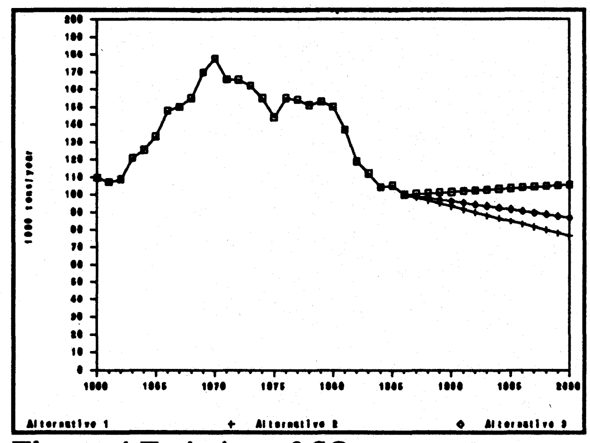

Figure 4 Emission of SO_2

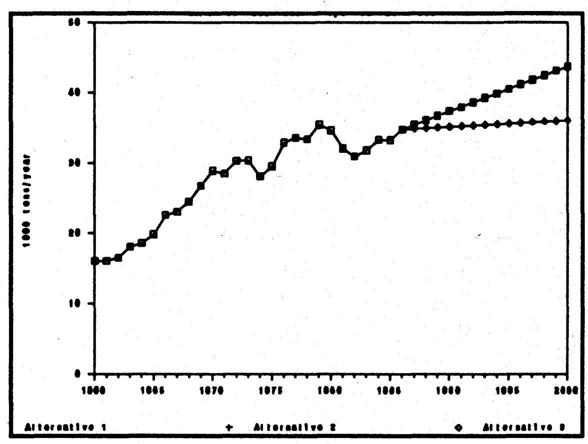

Figure 3 Emission of CO_2

Overall, GDP and household consumption were lowered by 1-2 per cent in year 2000 compared to the reference alternative (alternative 1). Total domestic consumption of electricity was increased by 5 per cent, while demand for heating oils was reduced by 35 per cent and gasoline demand declined by almost 20 per cent.

3.5 <u>Alternative tax scenario; marginal damage tax rate, endogenous purchaser price on oil products.</u>

In a closely related study to the previous one (Brendemoen and Glomsrød, 1989), tax rates were determined from estimates of local marginal damage to health, materials and nature. The overall economic effects of this approach were not very different from the previous study. Emissions of SO_2 and NO_x were both reduced by approximately 25 per cent in year 2000 compared to the reference path, while CO and particulates were reduced by roughly 20 per cent. Information on marginal damages from emissions of SO_2, NO_x, CO and particulates also allows preliminary estimates of some of the benefits accruing from the reduction of emissions to be made. Benefits included less damage to river systems and forests, reduced health damages from NO_x, CO, SO_2 and particulates, reduced damages to materials, and also non-environmental benefits from a reduction in traffic (fewer accidents, less congestions, less deterioration of road surfaces and less noise). Estimated benefits amounted to roughly 1,5 per cent of GDP in year 2000. This is of the same order of magnitude as the reduction in GDP due to the fuel tax.

Figure 5 shows benefits from reduced emissions by type of damage. A reduction of national emissions has only small effects on damages on nature. This is due to the fact that most of these damages are caused by transboundary pollution. Benefits from reduced corrosion also turn out to be relatively small according to the calculations. Reduced health damages, however, are quite substantial. In particular, benefits from reduction in NO_x emissions seems to be important. Perhaps surprisingly, economic gains from reduced road traffic are estimated to be of the same order of magnitude as the benefits from a reduction in health damages. This may provide a purely economic incentive for increasing the effective price of transportation, in addition to the environmental concerns.

The estimated benefits from reductions in emissions, are of course highly uncertain and almost speculative at present. They should therefore be interpreted with great care. These uncertainties come in addition to the more traditional sources of uncertainty associated with forecasting economic growth and its structure. Nevertheless, it should be recognized that only a small fraction of possible benefits from a reduction in emissions to air has been looked at in this analysis. A rough balance of marginal costs and benefits in the model calculations therefore indicates that a reduction in projected emissions levels may be warranted. Moreover, control policies to reduce emissions to air at some level may even be justified for pure economical reasons, e.g. by increasing the efficiency of the road traffic. Although several questions remain, the study indicates an important option for integrating economic and environmental policies.

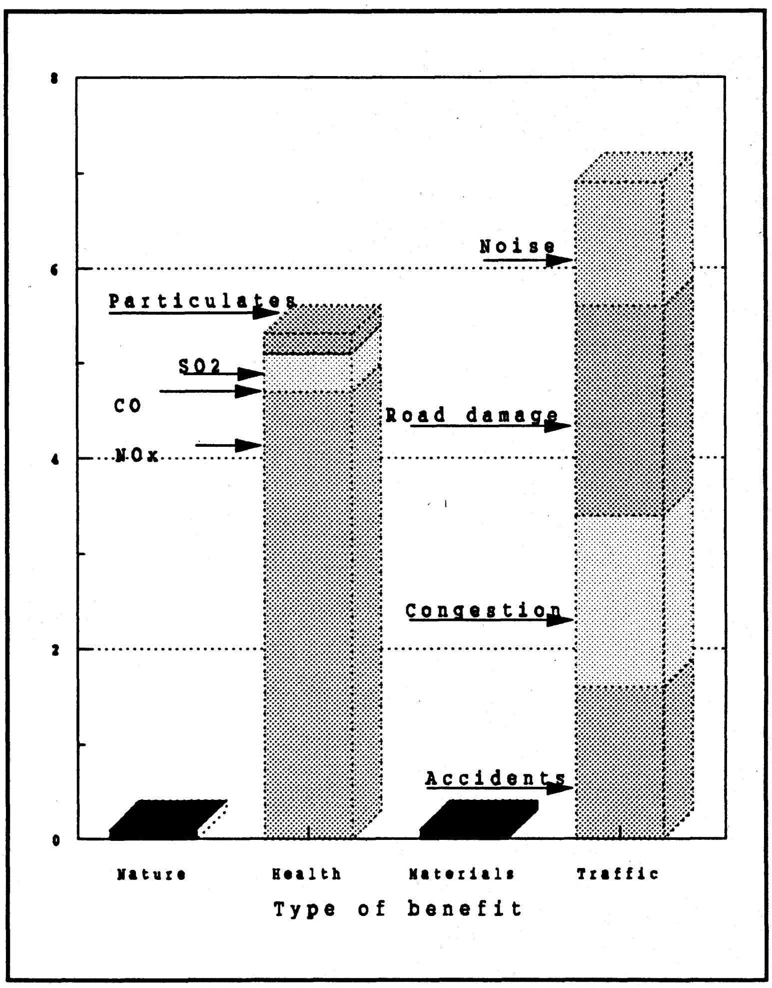

Figure 5 Yearly benefit of emissions reductions in year 2000. Fixed 1985-NOK

Distributional consequences of the tax increase has been analyzed, assuming fixed budget shares of the consumption goods. Increases in expenditures in year 2000 vary between 9,3 per cent in cities to 10,4 per cent in rural areas. On average expenditure as measured by the

Laspeyre index increases by 9,7 per cent. Similarly, families with low total expenditures are expected to experience an increase of approximately 11 per cent, while high income families are expected to meet an increase of 9,5 per cent. Hence, distributional consequences are expected to be small.

3.6 Life under a CO_2 ceiling

Limits to CO_2 emissions seem to be an important element in future strategies to combat the excessive greenhouse effect. As for many other important air pollutants, CO_2 emissions mainly stem from combustion of fossil fuels. But unlike most others, CO_2 can not be treated or removed from exhaust gases by economically viable means. Thus, only a reduction in the consumption of fossil fuels remains as a control strategy. A recent study (Glomsrød et al., 1990) looks at the economic consequences of a rather modest approach in this direction; i.e. a stabilization of Norwegian fossil fuel related CO_2 emissions after year 2000. The price of oil products is treated as an endogenous variable in this study which primarily focuses on the period 2000-2010. Again, this is a topic which clearly require a macroeconomic approach, and is most suitable for analysis within a general equilibrium modelling framework.

In addition to providing information on the required price of oil products (table 6, note that solid and gaseous fuels for combustion are almost absent in Norway), and the economic effects of a higher price path, the study also established a set of new benchmarks for further control policies against the emissions of other pollutants, most notably SO_2, NO_x and VOC, see table 7.

Table 6 Changes in price on, and use of, energy relative to reference scenario. Year 2000. Per cent.

	Price on oil products	Use of Gasoline	Use of Fuel oil	Use of Electricity
Production sectors	107	-35	-30	-8
Private households	130	-36	-53	17
Total		-35	-32	-4

Effective control of consumption of fossil fuels is also an effective policy against emissions other than CO_2, thus reducing the need for costly investments in cleaning technology. This illustrates the need for linking studies of economic growth, energy use and for instance CO_2, and also to include other pollutants of concern to the general welfare of the society.

Table 7 Changes in emissions relative to reference scenario. Year 2010. Per cent

Sulphur dioxide (SO_2)	-25
Nitrogen oxides (NO_x)	-23
Carbon monoxide (CO)	-28
Carbon dioxide (CO_2)	-26
Particulates	-20

4 Summary and future work

In Norway, the use of slightly extended economic models has made possible the elaboration of *consistent* projections for the long term development of the economy, future energy use and indicators of the air quality. Thus, a common framework has been developed where representatives for the Ministry of Finance, the Ministry of Oil and Energy, and the Ministry of Environment can discuss priorities and measures. Also, building environmental models on more traditional economic planning tools facilitates the introduction of environmental issues into planning bodies, which until recently have not been overly concerned with issues outside their traditional (economic) domain.

In addition, establishing a model apparatus for environmental studies creates a useful framework for the data gathering in the field of environmental statistics. It is all too easy to collect large amounts of data on the state of the environment without due attention to where and when the data are going to be used and whom it will serve. A more detailed discussion is provided in Alfsen (1988).

The framework described above is still partial, not treating other environmental problems like water pollution or generation and transportation of hazardous waste. Without a multi-pollutant framework, the danger of transferring air pollution problems to other recipients exists. The aim must be to extend the traditional concept of national capital to include important natural and environmental resources, and to provide planning tools, e.g. models, making it easier to manage the total wealth of the nation, including the environment, in a sustainable manner.

The direction of future work in Norway is partly on improved sectoral modelling and partly on the incorporation of feedback mechanisms from the environment to the economy (damage functions) in the macroeconomic models.

One high priority is to get a better understanding of transportation as an economic activity within a macroeconomic and multisectoral framework. This is partly due to the rudimentary treatment this activity gets within this activity gets within the present models, but also a response to a trend where more of the recognizable environmental damages come from diffusive sources like automobiles. Present plans include further disaggregation of the transport sector, as well as introducing transportation as a fifth input factors in some of the more transport intensive production sectors. Costs of transportation will be linked to amount of infra-structure capital like roads, harbours, etc., and maintenance costs will be dependent on traffic volume.

The electricity producing sector is extended from covering only hydro power production to also include production based on natural gas. Distribution of power is modelled as a separate economic activity.

The consumer block of the models are to be extended to include some 13 different consumer groups. This will facilitate studies of distributional questions raised by proposals of far reaching environmental control policies.

Further work on the estimation of the economic costs (benefits) of a deteriorated (improved) environment is going to be undertaken. The aim is to identify the main components of these feedback mechanisms, and to include these in the modelling framework. This will make it possible to capture some of the benefits associated with environmental control policies.

The main stumbling block in the path described above is probably going to be data. Large uncertainty in, and sometimes absence of, data will make the first versions of a new model highly "experimental". By developing such models we will, however, contribute to the clarification of what data are needed for the next generation of general equilibrium models, and thus provide input to the ongoing international work on standards and priorities for environmental statistics.

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Appendix 1: Sector classification in the compilation of emission inventories

23 100 Agriculture, crop production

121 Agriculture, livestock production, hunting, trapping and game propagation

131 Agriculture, own-account capital formation, agricultural services

145 Forestry and logging

150 Fishing, sealing and whaling, breeding of fish

159 Coal and metal ore mining

176 Other mining and quarrying

201 Slaughtering and other production of meat products, meat canning

210 Manufacture of diary products

215 Canning and preservation of fruits and vegetables

220 Preserving and processing of fish

225 Canning of fish

230 Manufacture of fish oil and fish meal

235 Manufacture of vegetable oils

240 Refining and hardening of animal oils

245 Manufacture of margarine

250 Manufacture of grain mill products

255 Manufacture of bakery products

260 Manufacture of cocoa, chocolate and sugar confectionary

265 Manufacture of other food products

270 Manufacture of prepared animal feeds

275 Manufacture of spirits and wines

280 Manufacture of malt liquors

285 Manufacture of soft drinks and carbonated water

290 Manufacture of tobacco products

295 Manufacture of yarn

300 Manufacture of fabrics, narrow fabrics and elastic fabrics

305 Manufacture of made-up tecxtile goods, except wearing apparel

310 Manufacture of knitted goods

321 Manufacture of other textiles

333 Manufacture of other wearing apparels

346 Manufacture of hats and caps, fur clothing, leather and leather products

350 Manufacture of footwear

355 Sawing and planing of wood

360 Manufacture of particle board

365 Prefabrication of wooden houses

370 Manufacture of doors, windows, etc., other building materials, wooden containers and other wood products

375 Manufacture of furniture and fixtures of wood

380 Manufacture of mechanical pulp

385 Manufacture of sulphate and sulphite pulp

390 Manufacture of paper and paperboard

395 Manufacture of fibre board

400 Manufacture of packing materials and other paper and paperboard articles

405 Printing and bookbinding

410 Publishing of newspapers

415 Other publishing

420 Manufacture of basic industrial chemicals, except fertilizers

425 Manufacture of fertilizers and pesticides

430 Manufacture of basic plastic materials and man-made fibres

435 Manufactures of paints, varnishes and lacquers

446 Manufacture of drugs, medicine, soap, cleaning and toilet preparations

450 Manufacture of explosives and ammunition

455 Manufacture of other chemical products

465 Manufacture of products of petroleum and coal

470 Manufacture and repair of rubber products

475 Manufacture of plastic products

486 Manufacture of ceramics, glass and glass products
495 Manufacture of cement and lime
501 Manufacture of structural clay products, concrete and concrete products
505 Stone cutting, polishing and grinding, and manufacture of other stoneware and earthenware
510 Manufacture of iron and steel
515 Manufacture of ferro-alloys
520 Iron and steel founding
525 Manufacture of aluminium
530 Manufacture of other non-ferrous metals
535 Rolling of non-ferrous metals and non-ferrous metal founding
546 Manufacture of cutlery, hand tools and general hardware
555 Manufacture of structural metal products
566 Manufacture of metal containeres, netting, wire, nails and screws
570 Manufacture of other metal products
575 Manufacture of turbines and engines and agricultural machinery
580 Manufacturing of machinery for manufacturing, mining and quarrying and construction
582 Manufcturing and repair of oil drilling rigs and ships, oil production platforms etc. and specialized spare parts
591 Manufacture of officeand household machinery
595 Repair of machinery
600 Manufacture of other machinery
605 Manufacture of electric motors and equipment for electricity production
610 Manufacture of radio, television and communication apparatus
615 Manufacture of electrical household appliances
620 Manufacture of insulated wire and cables
625 Manufacture of other electrical apparatus and equipment
630 Building of ships
635 Building of boats
640 Manufacture of ship and boat engines and components and fixtures for ships and boats
645 Manufacture and repair of railway and tramway eqipment
651 Manufacture of motor vehicles, motor cycles, bicycles, aircraft and other transport equipment
681 Other manufacturing industries
700 Construction, exclusive oil well drilling
717 Oil and gas exploration and drilling
721 Wholesale and retail trade
760 Hotels and reastaurants
801 Railway, tramway and subway transport
805 Scheduled motor bus transport
815 Provision of taxi and other unscheduled passanger transport by road
821 Other land transport and supporting services to land transport
824 Pipeline transport for oil and gas
830 Ocean transport
835 Coastal and inland water transport
840 Supporting services to water transport
845 Air transport
850 Services allied to transport and storage
855 Postal services
860 Telecommunication services
865 Banking
869 Imputed service charges of banks
872 Operation of other financial institutions, imputed service charges and financial services
876 Insurance
885 Dwellings
891 Commercial buildings and other real estate services

901 Business services, machinery and equipment rental and leasing
920 Sanitary and similar services
925 Education and research and scientific institutes
930 Health and veterinary services
935 Welfare services
941 Business, professional and labour associations, other social and related community services
950 Recreational and cultural services
955 Repair of motor vehicles, household appliances and goods for personal use
961 Laundries, laundry services, cleaning and dying plants, miscellaneous personal services
965 Domestic services

General government

21 825 Supporting services to land transport
840 Supporting services to water transport
845 Air transport
910 Public administration
915 Defence
925 Eduaction and research and scientific institutes
930 Health and veterinary services
941 Other social and related community services
991 Other production

Local government

22 825 Supporting services to land transport
910 Public administration
920 Sanitary and similar services
925 Education and research and scientific institutes
930 Health and veterinary services
935 Welfare services
941 Other social and related community services
950 Recreational and cultural services
PK Private households

Appendix 2: Structure of the MSG-4 model

Production structure

The model of producer behaviour includes substitution possibilities between five aggregate input activities; capital *(K)*, labour *(L)*, electricity *(E)*, fuels (petrol and fuel oils) *(F)*, and other materials *(M)*. Within each aggregate, fixed proportions are assumed. The substitution responses are formally represented by Generalized Leontief (GL) cost functions (Diewert, 1971). Electricity and fuels are assumed to be weakly separable from the other aggregate inputs, with total energy input denoted by *U*. The dual to the energy activity aggregate is a price index for energy, denoted P_U.

For industry *j* the unit cost structure is represented by the following relations (omitting the rather detailed tax parameters present in the actual implementation of the model):

$$\frac{Q_j}{X_j} = h_j(t)\sum_k \sum_l \alpha_{kl}\sqrt{P_{kj}P_{lj}}\,; \qquad k,l = K,L,U,M \tag{1}$$

$$P_{Uj} = \sum_m \sum_n \beta_{mn}\sqrt{P_{mj}P_{nj}}\,; \qquad m,n = E,F \tag{2}$$

where the P's are prices of input activities, X_j is total output and Q_j denotes total costs in sector j, $h_j(t)$ describes Hicks neutral technical change, and the α's and β's are estimated parameters. Applying Shephards lemma, factor coefficients may be derived as:

$$Z_{kj} \equiv \frac{\partial(Q_j/X_j)}{\partial P_{kj}}; \qquad k = K,L,U,M \tag{3}$$

$$Z_{Umj} \equiv \frac{\partial P_{Uj}}{\partial P_{mj}}; \qquad m = E,F \tag{4}$$

$$Z_{mj} = Z_{Umj}Z_{Uj}; \qquad m = E,F \tag{5}$$

where the Z_{kj}'s are input coefficients measuring aggregate input per unit of output, and the Z_{Umj}'s are energy coefficients measuring the input of electricity and fuels per unit of energy used. The factor demand equations for industry *j* may then be written as:

$$\zeta_j = Z_{kj}X_j; \qquad k = K,L,U,M; \ \zeta = K,L,M,E,F \tag{6}$$

The producers are assumed to be cost minimizers, which implies that marginal costs equal output price:

$$P_{Xj} = \frac{\partial Q_j}{\partial X_j} = \sum_\zeta Z_{\zeta j}P_{\zeta j}; \qquad \zeta = K,L,M,E,F \tag{7}$$

where P_{Lj} is an exogenous index of wage costs per unit of labour input, and P_{Kj} is the user cost of capital:

$$P_{Kj} = \sum_{i=1}^{M} \kappa_{ij}(R_j+\delta_{ij})P_i \tag{8}$$

R_j is the rate of return to capital, the κ's are fixed industry capital structure coefficients, the δ's are fixed rate of depreciation specified by kind of capital and industry (capital stock is assumed to follow an exponential survival curve), and M is the number of capital categories (usually three).

<u>Private investments</u>

Optimal capital stock per unit of output in each industry is determined by the cost-minimizing procedure described above. Demand for investments of type i is then determined as follows:

$$J_i = \sum_{j}^{N} \kappa_{ij}[K_j - K_j(-1) + \delta_{ij}K_j] \tag{9}$$

where N is the number of industries.

<u>Government consumption and external trade</u>

Goverment consumption is determined in the model as exogenously given gross total wage and material expenditures plus capital depriciation less marketed governmental services, in accordance with national accounting practice.

Export activities are exogenously determined, while import activity levels are determined from exogenous import share coefficients for various intermediate and final demand activities.

<u>Household consumption</u>

Total household consumption is determined residually as what is left of total output over gross investments, government consumption, and net export. The demand for consumption activity i is written as:

$$C_i = \eta_{Ci}(\Theta V)^{\xi_i}\prod_j P_{Cj}^{\gamma_{ij}} \tag{10}$$

where V is total expenditure, P_{Cj} is the price of consumption activity j, and η_{Ci}, ξ_i and γ_{ij} are parameters. The auxiliary variable Θ is introduced to insure that the budget constraint

$$\sum_i P_{Ci}C_i = V \tag{11}$$

is fulfilled for every combination of prices and demand (horizontal adjustments of Engel curves).

Want independence is assumed between the 18 consumption activities specified, except within a group consisting og housing services, electricity and fuel oil, and a group consisting og user costs of cars, petrol and car maintenance, and public transportation services. This means that the utility function is additive in the utilities of the two groups and each of the other goods. See Bjerkholt et al. (1983) for further details.

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