Commission of the European Communities

environment and quality of life

THE MACROECONOMIC IMPACTS OF THE EC LARGE COMBUSTION PLANTS DIRECTIVE PROPOSAL

Economic aspects of controlling acid rain in Europe

Volume I

Report

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Economic aspects of controlling acid rain in Europe

Volume I

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ABSTRACT

This study assesses the costs and ensuing macroeconomic impacts of the proposed Directive on large combustion plants for each EC country including proposals made up to the end of 1986.

The study focusses on macroeconomic indicators such as gross domestic product or GDP (value of total production within a country), employment, private consumption, current balance of payments account, consumer prices and the balance of government budget (revenue less expenditures).

In addition to interactions within the separate national economies, analysis of the interdependancies between them is examined by the use of an international model.

VOLUME 2 contains the Technical Document I: "Assessment of Investments, costs and emission reduction" and Technical Document II: "INTERLINK - modification and detailed results".

KEYNOTE

The Brussels Commission began to broach
the idea of a common approach
uniting European forces
to reduce pollution from all sources
Some draft Directives formulated
are now intensiviley debated
the final outcome's still unclear
but may evolve within a year
Let's hope these efforts do not fail,
so history can tell the tale
of rising PH, healthy trees
and other happy trends like these

(part of a poem written by Ian. M. Torrens of the OECD)

ACKNOWLEDGEMENTS

'To link or not to link', that is the question. Not only is this true for the process of negotiating between EC countries on a coordinated policy to reduce acididifying emissions. It is also true for our efforts to simulate the macroeconomic impact of such a policy, with the help of the OECD INTERLINK model, since serious problems had to be overcome to obtain the results of a co-ordinated policy in a so called 'linked mode'.
Such results would not have been possible without the support of the Econometric Unit of the Economics and Statistics Department of the OECD which enabled us to use, an adapted version of, INTERLINK (version E041). Special mentioning deserve Portia Eltvedt, Rik Ford, Douglas Paterson and Pete Richardson for their cooperation in producing the simulations. We should not forget that such calculations need input on costs and investments of controlling emissions as well. We are especially indebted to Marcus Amman and Jean Paul Hettelingh from IIASA's RAINS project for their support on emission projections and the format of the costs model. We are also grateful for the support recieved from many persons from the CEC (DG Environment, DG Energy), the Netherlands Environment Ministry (especially Directorate Air), Agricultural University Wageningen (vakgroep Staathuishoudkunde), the Umweltbundesamt and DG Environment of the OECD.
In a sense computer output is just a starting point since a report needs writing and typing as well. We appreciate the skillful typing and decoding of the IVM secretariat and the assistence of Ms. Alison Gilbert in translating the typoscript.

DISCLAIMER

The technical views expressed in this report are the sole responsibility of the authors. In neither way do they reflect the view of the CEC, the OECD, or any other person or organisation who assisted us, on the results obtained.

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EXECUTIVE SUMMARY

I. Introduction

'Acid-rain' is one of the major environmental problems in the European Community. Power plants, refineries and industries, through their sulphur and nitrogen oxides emissions, are to a large extent causing the problem. Presently the European Community is negotiating on strategies to control these acidifying emissions. Recent discussions have focused on the draft Directive on large combustion plants, proposed by the Commission of the European Communities. The costs and expected economic effects for the EC countries constitute one of the major elements in these discussions.

This study assesses the costs and ensuing macroeconomic impacts of the draft Directive on large combustion plants for each EC country. It incorporates proposals made during discussions towards the end of 1986 on the contents of the Directive.

The study focuses on macroeconomic indicators such as gross domestic product, or GDP (value of total production within a country), employment, private consumption, current balance (the current account of the balance of payments), consumer prices and balance of government budget (revenues minus expenditures). The extent and direction of the macroeconomic impacts of the Directive was not clear at the outset; pollution control costs generally have a negative impact but investments in pollution control equipment are likely to exert a positive influence on the economy.

A method to assess the net overall influence is to use a macroeconomic model. A special feature of the pollution control program evaluated here is the fact that it is to be carried out simultaneously in all EC member countries. In addition to interactions within the separate national economies, analysis of the interdependencies between these economies is also at issue. This warrants the use of an international model.

This summary has the following contents:

- introduction to the macroeconomic model INTERLINK of the OECD,
- description of abatement strategies in each country,
- presentation of emission abatement costs and investments and the impact on electricity prices,

- presentation of macroeconomic impacts, as simulated with INTERLINK,
- discussion on elements of uncertainty,
- main conclusions and recommendations for further research.

II. INTERLINK of the OECD

The International Linkage model, or INTERLINK, of the OECD was used to assess the macroeconomic consequences. INTERLINK is generally used for forecasting ('OECD Economic Outlook'), simulating and targeting economic variables. It is for example being used for the simulation of the impact of equalising VAT rates within the EC.
INTERLINK is a medium-term world model in which the economies of 23 OECD countries, including 11 EC countries (Belgium and Luxembourg are modelled jointly) and 8 non-OECD regions, are modelled separately. These separate models can be linked via world trade and financial flows. In this way the influences of one country or region on the rest of the world economy, and resulting feedback effects, are taken into account.
INTERLINK was adapted for the purpose of this study. The major modifications are related to:

- the insertion of pollution control investments as a special form of fixed business investments,
- the inclusion of the impact of pollution control investments and costs on the gross domestic product,
- the reflection of pollution control costs in rising prices.

This adapted model was used as follows:

- a projection was made of the economic development without pollution control measures (base-line projection),
- a projection was made of this development including the exogenously determined costs and investments of emission abatement,
- the differences between these projections were reported as annual differences in economic indicators over the baseline projection.

III. Abatement strategies in each country to meet the Directive

The draft Directive pertaining to SO_2 and NO_X emissions stipulates that:

1) new plants larger than 50 MW thermal capacity must comply with emission standards which are related to the size of the plant;
2) EC member states are to reduce total emissions from large combustion plants by the end of 1995.

The following percentage reductions (which use 1980 as a base year) reflect discussions from late 1986:

- SO_2 emissions are to be reduced by a minimum of 45% except in

Greece, Ireland and Luxembourg (allowed a standstill), Portugal (allowed an increase) and Spain (at least a 10% reduction),
- NO_X emissions are to be reduced by a minimum of 30% except in Ireland, Luxembourg and Portugal (granted a standstill), Greece (allowed an increase) and Spain (at least a 10% reduction).

Assumptions on the strategy in each country

Strategies to control emissions may range from technical measures, such as flue gas desulphurization, to a switch in fuel mix or additional energy conservation measures. In this study however, only technical abatement measures are examined.

Due to a lack of data it was not possible to make a firm estimate of the abatement measures needed to meet the proposed EC emission standards for new, large industrial plants. Consequently the emissions from large plants (power as well as industrial) are reduced as follows:

- measures are taken to meet emission standards for new, large power plants,
- if this does not lead to the required percentage reduction, additional measures on existing power plants or more stringent ones on new power plants were assumed to be taken.

Some EC countries have already legislation to control SO_2 and NO_X emissions. If these policies are more stringent than the EC Directive the abatement measures of the national legislation are incorporated in the analysis. If the national policy is less stringent, additional measures are assumed to meet the requirements of the Directive.

Strategies to control sulphur dioxide in each EC country

Denmark, the Federal Republic of Germany and the Netherlands are implementing their own national strategies which will effect a reduction in emissions greater than that of the Directive. France, Luxembourg and Portugal do not have to take measures. Belgium, Greece, Ireland, Italy, Spain, and the United Kingdom are assumed to install flue gas desulphurization on new power plants and, if needed, flue gas desulphurization on existing power plants.

Strategies to control nitrogen oxides in each EC country

Germany, in carrying out its national policy, more than meets the required reduction. The Dutch national policy is insufficient to meet the total reduction required by the Directive and additional combustion modification is assumed. France, Greece and Luxembourg do not have to take measures. Belgium, Denmark, Ireland, Italy, Portugal, Spain and the United Kingdom initially implement combustion modifications to meet emission standards for new power plants. If this is insufficient to meet the total reduction additional measures are taken in the most cost effective way. This involves selecting among two stage combustion, combustion modification and selective catalytic reduction.

IV Costs and investments

Absolute volume of costs and investments

The volume of emissions being abated and the costs per ton of emission abated, determine the costs for each country. Generic and country specific factors, such as the selected abatement technologies, determine differences in costs among countries.

SO_2 abatement technologies distinguished are: flue gas desulphurization, fluidized bed combustion, dry sorbent injection, low sulphur coal and low sulphur, heavy fuel oil. The accent is on flue gas desulphurization since this technique is expected to be used on new power plants.

Table I. Factors determining abatement costs

Country specific data	Generic data
* Emissions to be abated	* Relation size and investment (economies of scale)
* Abatement strategy in each EC country	* Life time new and existing plants
* Type and specifications of fuel	* Fixed operating cost (% of investment)
* Capacity of combustion plants (size, new, existing)	* Wagesum per man year
* Energy efficiency of plant	* Direct exploitation employment
* Interest rate	* Prices of water, ammonia, limestone and catalyst
* Operating hours	
* Electricity price	

Table II. Investments and costs (in million ECU's in 1985 prices)

Country	CEC minimum reduction (% of 1980)		Investments (1985-1995)		Annual costs (1995)		Emission abated (kton) (1995)	
	SO_2	NO_X	SO_2	NO_X	SO_2	NO_X	SO_2	NO_X
Belgium	45	30	238	26	46	2	67	21
Denmark	45	30	436	65	103	7	201	78
France	45	30	0	0	0	0	0	0
FRGermany**	45	30	4769	1620	977	667	1716	727
Greece	0	0*	31	0	11	0	25	0
Ireland	0	0	168	22	40	3	64	20
Italy	45	30	2319	577	439	189	753	460
Luxembourg	0	0	0	0	0	0	0	0
Netherlands***	45	30	633	83	129	7	256	52
Portugal	0*	0	0	149	0	29	0	63
Spain	10	10	500	51	93	4	180	95
United Kingdom	45	30	3160	289	628	28	1344	339
EEC	< 45	< 30	12253	2882	2455	935	4606	1878

* granted an increase

** actual reduction higher than the required target for both SO_2 and NO_X. Costs and emission abated correspond with these higher reductions.

*** actual reduction for SO_2 higher than required target. Costs and emission abated correspond with the higher reduction.

NO_X abatement technologies selected are: selective catalytic reduction, combustion modification, two stage combustion and fluidised bed combustion. The accent is on combustion modifications.
Table II. shows that, in an absolute sense, the Federal Republic of Germany, Italy and the United Kingdom bear most of the costs of controlling SO_2 emissions. Germany and to a lesser extent Italy will face substantial costs in connection with the control of NO_X emissions.

Costs as percentage of the gross domestic product
Germany's high costs relative to its 1985 GDP (see figure I) reflect that country's stringent national policy. Denmark, due mainly to its domestic SO_2 control policy, and Ireland, due to the absolute amount of emissions to be abated, also face high costs. Costs in Belgium, France, Greece, Luxembourg and Spain, are relatively small chiefly because the volume of emissions to be abated is small. The need to apply selective catalytic reduction to control NO_X emissions explains the relatively high costs for: Germany (as a consequence of its national policy), Italy, and Portugal. Generally, NO_X control costs are negligible.

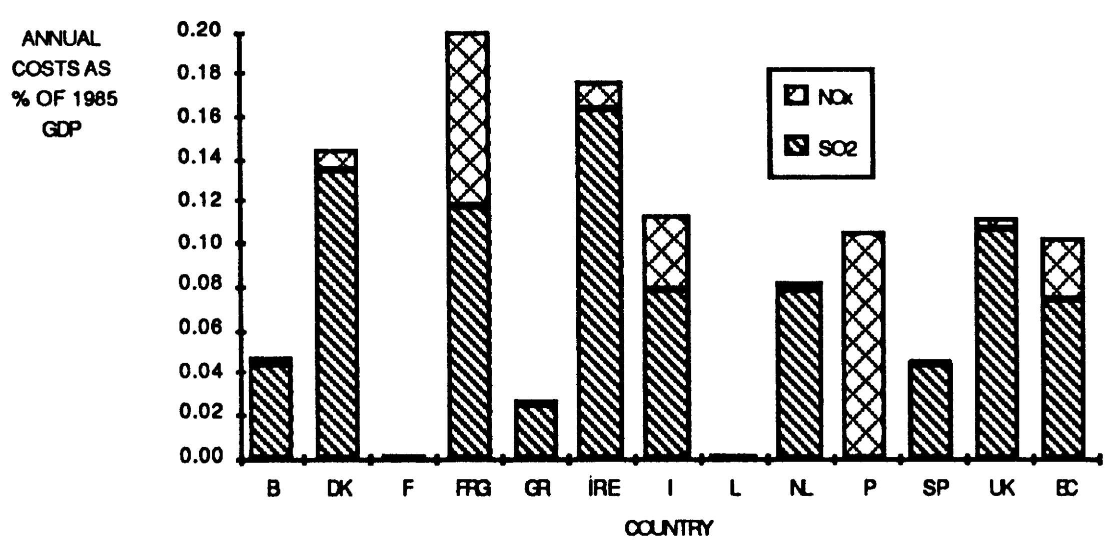

Figure I. Abatement costs in 1995 as percentage of GDP in 1985

Impact on the industrial electricity price
The pollution control costs borne by power plants lead to an increase in electricity production costs and therefore in the price of electricity. The increase in price that might result from pollution abatement is shown in figure II. The extent of the impact is influenced by the share of non-fossil fuels in electricity generation, electricity intensity (electricity consumption/GDP) and, of course, the volume of emission abatement costs.

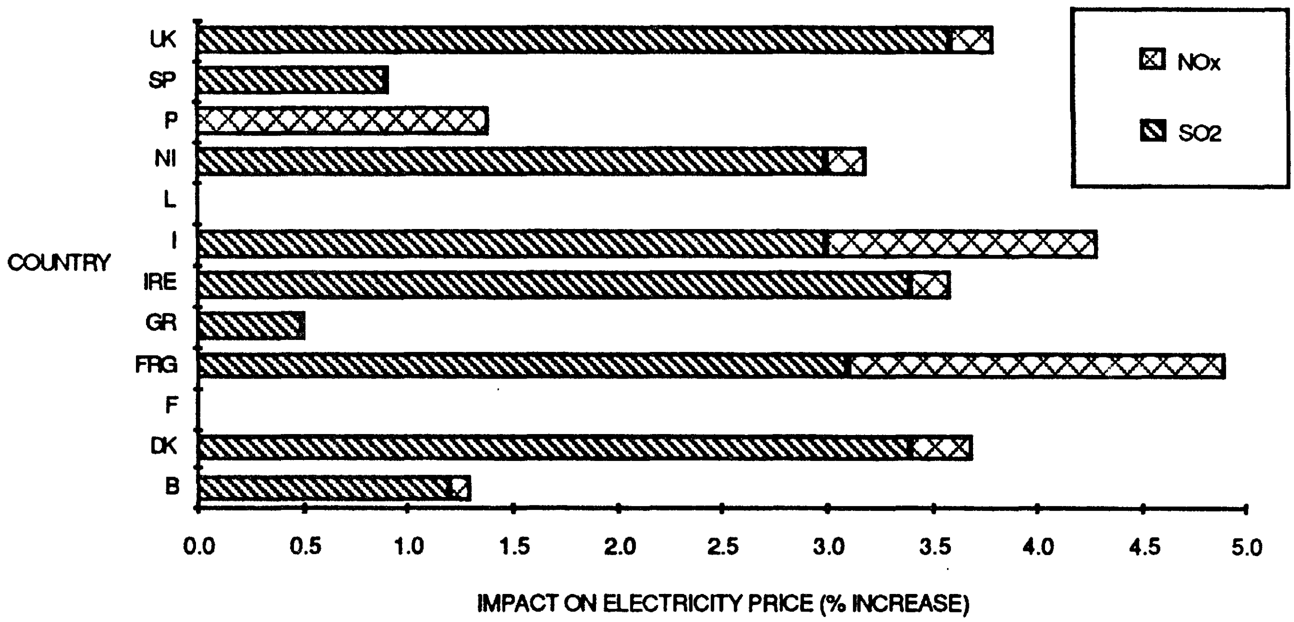

Figure II. Impact on the industrial electricity price (% increase 1995)

V. The macroeconomic impacts with INTERLINK

V.1. Introduction

The database of the OECD model allowed a simulation for a maximum period of 10 years (1988-1997). It was assumed that the investments in emission abatement were to take place in the period 1988-1993. This permitted simulation of the macroeconomic impact for a period following such investments, i.e. 1994-1997. Only in the longer term can the negative impacts of pollution control costs be fully reflected in the economy.

The impacts are presented on those key indicators which are closely related to main targets of economic policy: economic growth, prevention of inflation, equity on the balance of payments and full employment. These impacts are presented as differences between an economic development with and without pollution control. For example, in country X consumption is projected to grow with 2% annually during the coming decade. As a result of the pollution control, such as that required by the Directive, consumption is expected to grow only 1.95% annually over the same period. The difference in consumption over the baseline, caused by pollution control, thus is 0.05%. These differences are discussed here and are generally presented as (average) annual percentage differences in the specific period: 1988-1993 and 1994-1997.

Results are presented for the abatement of:

- SO_2 emissions,
- NO_X emissions,
- simultaneous abatement of both emissions.

V.2. Results for SO_2: Similarities among countries

Although the macroeconomic impacts differ across countries the results (table III and IV) display a similar pattern.
During the period in which the investments take place (1988-1993) economic activity, as reflected in the gross domestic product (GDP), increases in all countries due to the additional expenditures on pollution control investments. Since production is raised, employment increases as well. Investments increase not only in response to pollution control investments; because the level of production is raised, business sectors are stimulated to raise other investments as well. The higher level of investments and GDP cause imports to rise. As a result the current balance deteriorates. Consumer prices rise slightly, and private consumption decreases as a consequence of the gradual increase in pollution control costs. Government financial balances improve chiefly because the rise in the level of output and national income generate higher tax revenues.

TABLE III Macroeconomic impacts of controlling SO_2 emissions for large EC-countries

	FR	GER	ITA	UKM
Gross domestic product				
1988 - 1993	0.04	0.13	0.08	0.06
1994 - 1997	0.03	-0.06	0.03	-0.05
Private consumption				
1988 - 1993	..	-0.01	-0.03	-0.03
1994 - 1997	..	-0.06	-0.02	-0.11
Current balance[1]				
1988 - 1993	0.10	-0.21	-0.18	-0.22
1994 - 1997	-0.11	-0.06	-0.08	-0.13
Employment				
1988 - 1993	0.02	0.13	0.02	0.03
1994 - 1997	0.02	-0.11	0.01	-0.05
Consumer prices				
1988 - 1993	..	0.34	0.34	0.43
1994 - 1997	..	0.24	0.10	0.20
Government financial Bal.[2]				
1988 - 1993	..	0.13	0.10	0.08
1994 - 1997	..	0.06	0.12	0.10

All changes expressed as average annual percentage changes from baseline levels
[1]) billion $
[2]) % of baseline gross domestic product
.. not available

In the next period (1994-1997) the macroeconomic impacts are more negative: pollution control investments cease and the pollution control costs induce a decline. Consumer prices and export prices are generally at a higher level as a result of higher pollution control costs. Consequently consumption declines and, in countries whose competitive position deteriorates, exports decline as well. The decrease in investments, exports and consumption causes a decrease in GDP. In this period investments not only decrease due to the fact that no pollution control investments take place but also since production decreases and pollution control costs increase. The lower level of production explains the lower level of employment. In most countries the current balance remains more negatively influenced; although imports are reduced, due to the lower level of output, exports decrease as well. Government financial balances remain positively influenced since nominal income and thus tax revenues increase; the decrease in real national income in this period is offset by an increase in prices.
In almost all countries the positive macroeconomic impacts during the investment period exceed the negative impacts in the subsequent period.

TABLE IV Macroeconomic impacts of controlling SO_2 emissions for small EC countries.

	BLX	DEN	GRE	IRE	NET	POR	SPA
Gross domestic product							
1988 - 1993	0.12	0.17	0.06	0.12	0.12	0.08	0.09
1994 - 1997	-0.03	0.00	0.05	-0.21	-0.08	0.03	0.03
Private consumption							
1988 - 1993	0.02	0.01	0.01	0.00	0.01	..	0.03
1994 - 1997	-0.08	-0.15	0.00	-0.29	-0.03	..	-0.02
Current balance[1]							
1988 - 1993	0.02	-0.06	0.00	-0.05	-0.03	-0.01	0.00
1994 - 1997	0.03	-0.03	0.00	-0.09	-0.09	-0.02	0.02
Employment							
1988 - 1993	0.06	0.05	0.03	0.05	0.09	0.03	0.05
1994 - 1997	0.01	0.04	0.02	-0.03	-0.04	0.01	0.02
Consumer prices							
1988 - 1993	0.15	0.20	0.07	0.45	0.21	..	0.14
1994 - 1997	0.33	0.36	0.13	0.56	0.48	..	0.19
Government financial Bal.[2]							
1988 - 1993	0.06	0.10	0.01	0.01	0.09	..	0.03
1994 - 1997	0.04	0.06	0.00	-0.16	0.01	..	0.01

All changes expressed as average annual percentage changes from baseline levels
1) billion $
2) % of baseline gross domestic product
.. not available

V.3. Results for SO_2: Differences between countries

Despite the similarities in impacts from abating SO_2 emissions, there are also differences between countries: a predominantly positive influence is realised in France, Portugal, Spain and Greece but a more negative influence is exerted upon Ireland.
The most important factors which explain differences are:
- the absolute amount of pollution control costs and investments,
- the degree to which EC countries are dependent on exports and imports especially intra-EC trade,
- the reflection of pollution control costs in prices, of prices in money wages and, of money wages in prices.

France and Portugal
France and Portugal have no SO_2 abatement costs. They benefit via an improvement in competitive position and world trade volume. In both countries GDP and employment are raised due to the increase in exports.

Greece and Spain
For Greece and Spain the economic impact of abating SO_2 emissions is unmistakably positive, mainly due to the low level of pollution control costs. This low level of costs causes prices to rise only modestly. As a result the relative export price improves and exports increase. This increase in exports accounts for the positive long term impact on gross domestic product and employment.

Ireland
For Ireland the macroeconomic impact is rather negative. The high level of pollution control costs, the high import coefficient and the large share of imports from EC countries, particularly the United Kingdom, are the causes. The high import leakage dampens the positive impact of the expenditures in pollution control investments in the period 1988-1993. Moreover price increases, resulting from the domestic pollution control programme, are reinforced by the sharp increase in import prices. Consequently competitiveness deteriorates, exports decrease and the impact on the current balance is exacerbated.

Belgium and the Netherlands
For the Netherlands and Belgium impacts closely resemble the basic pattern although the macroeconomic impact is slightly better in Belgium, especially in the period 1994-1997. Performance is better in Belgium since pollution control costs in the Netherlands are twice as high as in Belgium. Consequently export prices rise more in the Netherlands, exports decrease more and gross domestic product, employment and current balance are less favourably influenced. An exception is the level of consumption in the Netherlands which declines less than in Belgium.

Denmark
For Denmark the macroeconomic impacts are more positive than for the Netherlands. Gross domestic product and business fixed investment initially rise more sharply since pollution control investments are higher. In the second period the impact on consumption is more negative than in the Netherlands. This results from price increases being reflected less in the increase in money wages (wage indexation): real wages decline so that consumption declines as well. The Danish economy, however, is less influenced by increasing import prices since Denmark is less dependent on the EC for imports. As a result price increases are only modest and the Danish competitive position deteriorates less and the impact on gross domestic product, employment and current balance is more favourable in Denmark.

Federal Republic of Germany
The macroeconomic impacts for Germany are more or less neutral: positive during the investment period and negative thereafter. The positive impacts are relatively large due to the large size of the pollution control programme. The rise in consumer prices is modest, if related to the abatement costs, since prices are less reflected in wage changes.

Italy
Results for Italy are more positive than for Germany: employment remains positive whereas consumer price increases are smaller. The size of the abatement programme in Italy is about two-thirds of the German efforts so the initial positive impact on gross domestic product is proportionally lower. Italy's competitive position is less affected than Germany's due to the lower pollution control costs. As a result exports are less negatively influenced, consumption declines only slightly in the period 1994-1997 and the decrease in the gross domestic product in the second period is only small.

United Kingdom
For the United Kingdom the macroeconomic impacts are more negative than for Germany: the positive impacts are smaller and the unfavourable impacts, e.g. on the current balance and the price level, are larger. This occurs even though the costs and investments for abating SO_2 emissions, as percentage of GDP, are about the same size in both countries. The differences are chiefly caused by the sharper, but more temporary, increase in export prices in the UK. As a result the competitive position of the UK economy, and consequently exports, deteriorate more than in Germany. This has a negative, but declining impact on the gross domestic product and employment.

V.4. RESULTS FOR NO_X

The macroeconomic impact of abating NO_X emissions for most countries is smaller than that for the abatement of SO_2 emissions due to the relatively low costs of abating NO_X emissions. The basic pattern for both emissions is similar: a positive impact during the investment period and a slightly negative impact thereafter.
Results for most countries are insignificant and fairly neutral due to the very small volume of costs. For France and Greece the impact is positive since these countries do not need to control NO_X emissions and benefit from the increase in demand in other EC countries. Consequently exports, employment and GDP increase. Only prices go up slightly as a result of increasing import prices. For Germany, Italy and Portugal the impact is somewhat more important (see table V) since NO_X control costs are somewhat higher.

TABLE V Macroeconomic impacts of controlling NO_X emissions for a selection of countries

	DEN[3]	POR	GER	ITA	UKM[3]
Gross domestic product					
1988 - 1993	0.02	0.08	0.06	0.03	0.01
1994 - 1997	-0.01	0.02	0.00	0.02	-0.01
Private consumption					
1988 - 1993	0.00	0.03	0.00	-0.01	0.00
1994 - 1997	-0.03	-0.02	-0.02	0.00	-0.02
Current balance[1]					
1988 - 1993	-0.01	-0.01	-0.15	-0.05	0.00
1994 - 1997	0.00	-0.02	-0.21	-0.03	0.02
Employment					
1988 - 1993	0.00	0.03	0.05	0.01	0.01
1994 - 1997	0.00	0.01	-0.03	0.01	-0.01
Consumer prices					
1988 - 1993	0.03	0.08	0.15	0.09	0.06
1994 - 1997	0.06	0.13	0.12	0.04	0.06
Government financial Bal.[2]					
1988 - 1993	0.01	0.02	0.06	0.03	0.01
1994 - 1997	0.00	0.00	0.04	0.04	0.01

All charges figures expressed as annual average percentage changes from baseline levels
1) billion $
2) % of baseline gross domestic product
3) both countries are included to compare their (insignificant) impacts, with impacts for Portugal, Germany and Italy

The macroeconomic impacts are more negative for Germany than for Italy. In the first period exports from Italy rise due to the increase in demand in other EC countries, e.g. Germany. This is also due to the improving competitive position of Italy which results from it's relatively smaller abatement costs. As a consequence exports fall less and employment and production remain more positive in the subsequent period. For Portugal the impacts are positive. This is due to the high level of pollution control investments and to the increase in exports in the first period, resulting from increased EC demand. Although domestic pollution control costs do negatively affect the impacts, the positive impacts on GDP, employment and consumption dominate.

V.5. Results for the simultaneous control of SO_2 and NO_X emissions

A major conclusion of the analysis is that even the simultaneous abatement of SO_2 and NO_X emissions has only marginal macroeconomic impacts for all EC countries. Only for a few indicators and for a few countries, are the impacts of the proposed Directive higher than one tenth of fluctuations in macroeconomic indicators, as observed over the past ten years. In general the impacts of the simultaneous abatement of both emissions, summarised over both periods, are positive for gross domestic product, investments and employment; negative for consumption, current balance, and consumer prices (which are higher).

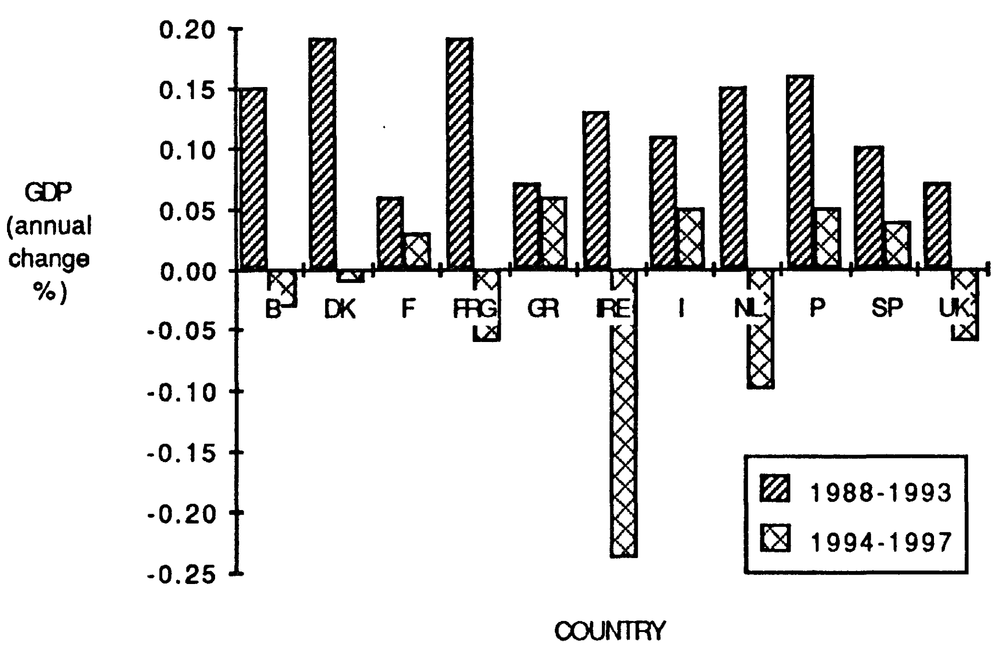

Figure III Impact of combined control of SO_2 and NO_X emissions on GDP

Within the boundaries of these small impacts the combined control of SO_2 and NO_X has a predominantly negative impact, on GDP (illustrated in figure III) and employment, for only one country: Ireland. In the United Kingdom employment is negatively affected but the gross domestic product, over both periods, is hardly affected. Net impacts are positive for Spain, Portugal and Greece and to a smaller extent Italy. The eventual impact for the remaining countries is generally neutral to positive although somewhat more negative for Germany and the Netherlands and more positive for Belgium, and Denmark. The impacts for France are positive as well.

VI. Elements of uncertainty

Volume of abatement costs and investments

A sensitivity analysis indicated that for most countries costs, for the abatement of SO_2 emissions, would not be altered substantially if an estimate of the impact of emission standards for new industrial plants were to be included. Except for France, Greece, Portugal and Spain, where costs would probably be higher, and for Ireland, where costs could be lower. These results however depend very much on the assumed volume of new industrial plants larger than 300 MWth.

Costs could be higher as well if countries strongly prefer to buy domestic, instead of cheaper imported, pollution control equipment. In doing so abating SO_2 emissions could be more expensive for Ireland, Spain and the United Kingdom. This preference would not only strengthen the negative macroeconomic impacts of pollution control costs but would enlarge the positive impacts of the investments as well. The latter being resulting from the higher investments and the lower import leakage.

Costs for SO_2 as well as NO_X could be lower if abatement measures such as fuel switches, the use of lower sulphur coal and combustion modifications on new industrial plants and energy conservation were included.

Constant versus flexible interest rates

An analysis with INTERLINK showed that the Directive would have more negative macroeconomic impacts, for virtually all countries, if interest rates were floating instead of being fixed, as was assumed. Employment, GDP, government financial balance would be less positive due to the increased interest rate but consumer prices would be slightly lower.

A flexible instead of a fixed exchange rate

A flexible, instead of the assumed fixed, exchange rate is expected to cause a more positive impact on most macroeconomic indicators, although prices could increase somewhat more. The main reason for this is that exports decrease less.

The direct import coefficient of investments in emission abatement

This study assumes that the direct import share of investments in pollution control corresponds with that for total fixed investments. This assumption could imply an underestimation of the positive impacts for Germany, since this country has a leading position in Europe with respect to the control of SO_2 and NO_X emissions.

Exclusion of damage reduction
Since it was impossible to include the macroeconomic impacts of reductions in environmental damage, potentially positive macroeconomic impacts of the draft Directive were excluded.

VII. Conclusions

Despite these elements of uncertainty the major conclusion of this study is not affected. The proposed Directive on large combustion installations is likely to have only small, but positive macroeconomic impacts during the period in which the investments in air pollution control take place. In the subsequent period the proposed Directive is expected to have small but negative impacts on the economies of most EC member states.
Given this conclusion the Directive is expected to have a predominantly positive influence for France, Portugal, Spain and Greece and to a lesser extent Italy. A more negative influence is exerted upon Ireland. For the remaining countries effects are more or less neutral although more positive for Denmark and Belgium and less positive for the United Kingdom, the Netherlands and Germany. Several elements of uncertainty however could affect this distribution of positive and negative impacts among countries.

VIII. Suggestions for further research

The following research items, partly related to the main elements of uncertainty, are suggested:

- inclusion of other abatement strategies such as fuel switches, energy conservation, low sulphur fuels and measures for new industrial plants;
- extension of the study to other sectors: transport, industrial processes, domestic sectors and small industries;
- development of abatement scenarios for other, related pollutants, i.e. volatile organic components and ammonia;
- analysis of the macroeconomic impacts with alternative assumptions regarding the main elements of uncertainty;
- evaluation, where feasible in monetary terms, of the present and future damage ("benefits") of emission abatement strategies in the EC.

Since the macroeconomic impacts of the Directive are only small, and since the resulting emission reductions are probably insufficient to lead to a full recovery of forests and to a standstill in acidification of soils and surface waters, it could be worthwhile to analyse the impacts of more stringent abatement of 'acid-rain' in the European Community.

1

INTRODUCTION

1.1. Introduction

The urgency of the environmental problems associated with acidification is acknowledged by the European Commission. The various EC member states are affected by acidification in different ways. The damage is to a large extent caused by sources throughout Europe which emit sulphur- and nitrogen oxides to the air: a shared resource. Clearly, the European Community constitutes a suitable 'supra-national' body of administration to formulate and direct environmental management strategies.
Presently within the Community negotiations take place on strategies which imply that national governments select policy measures so that national emissions are reduced by a percentage over the 1980 level. Discussions within the EC focus especially on the proposed council Directive on large combustion plants. But the Europarliament also expressed its view in a resolution. In order to set the percentage reductions, it can be meaningful to know the efforts required from different EC member states, in terms of additional investments, costs and resulting macroeconomic effects.
This study aims to assess these economic impacts of policy measures for the reduction of acidifying emissions in the EC. It is an internationalisation of a comparable study that was performed in the Netherlands (LMO, 1985; Klaassen and Nentjes, 1986) in cooperation with the Netherlands Central Planning Bureau)[1].

1.2. Scope

The aim of the study is to assess the (macro)-economic impact of control strategies for sulphur and nitrogen emissions as proposed and discussed by the Commission of the European Community, in its Directive on large combustion plants.
In addition it was proposed to assess the macroeconomic impact of a more stringent scenario, provisionally termed 'Europarliament'.

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[1] References are to be found after chapter 7.

This aim was approached by addressing the following questions:

1) What is the 'most-likely' strategy adopted by the EC countries to meet the emission reductions required?
2) What additional investments and costs are associated with this strategy?
3) What are the second and higher order economic effects caused by the strategies selected?

During the study it proved impossible to tackle the proposed strategy of the Europarliament. Due to time constraints the study was necessarily limited to the proposed Directive on large combustion plants.
The study takes the draft Directive on large combustion plants, as formulated end 1983, as a starting point. However, discussions within the Council of environmental ministers, reflecting the situation end 1986, are taking into account as well and formulated as additional assumptions on the contents of the Directive.
In principle reduction strategies might range from technical measures such as flue gas desulphurization and selective catalytic reduction to a switch in fuel mix, or additional energy conservation measures. After a feasibility study, however, the scope was limited to technical abatement measures. The question of additional energy conservation was dealt with in a separate feasibility study (Becht, 1987).
The question on second and higher order economics effects deals in particular with effects on:

- macroeconomic key indicators such as gross domestic product, employment, imports, export, inflation, government budget deficit,
- prices of energy.

This study focuses, however, on the impact of macroeconomic key indicators since this part of the study was expected to reveal aspects which were not already addressed in other studies (Schulz, 1987; Arthur D. Little, 1984; Rentz, 1986; Cambridge Decision Analysis/Environmental Resources Limited, 1986). The principal usefullness of the approach is its comprehensiveness and analytical soundness since it asseses the net overal influence exerted upon the economy. In a sense it is more accurate than a mere accounting of costs and benefits since it takes into account the interdependencies in and between national economies which might reveal unexpected 'costs' and 'benefits'.
Still a certain modesty is needed since the assessment is not complete. Due to lack of data questions regarding the extent of the damage prevented by the reduction of the emissions are only partly addressed and no macroeconomic analysis was possible.
In addition to this macroeconomic assessment the impact on the electricity prices was addressed.
Summarizing the focus of this study is the assessment of costs, investments and ensueing macroeconomic impacts of the proposed and discussed Directive large combustion plants.

These impacts are studied for the first stage of the Directive, up to 1995, for both sulphur as well as nitrogen oxides. To assess the macroeconomic impact use was made of an existing macroeconomic model: INTERLINK of the OECD.

1.3. Remainder (Reading guide)

Conclusions are dealt with in chapter 7. The macroeconomic results of the simulations with the OECD INTERLINK model are the subject of chapter 6. The preceding chapter 5 describes the costs and investments of the abatement strategy in each country. The question on the abatement strategy in each country is tackled in chapter 4. Theoretical aspects of the assessment of macroeconomic impacts are dealt with in the chapters 2 and 3. Chapter 3 describes the main features of the modified version of the OECD INTERLINK model used in this study. An introduction to macroeconomic effects of pollution control is to be found in chapter 2.
More details on the feasibility of estimating the (monetary) value of the damage prevented when reducing acidifying emissions are to be found in appendix A. Detailed background information is included in two separate, technical documents:

TECHNICAL DOCUMENT I : Assessment of investments, costs and emission reduction

TECHNICAL DOCUMENT II: INTERLINK: modifications and detailed results.

2. MACROECONOMIC IMPACT OF POLLUTION CONTROL: A TYPOLOGY

2.1. Introduction

Abatement measures for (air-)pollution act upon the economy through various channels and may have a contractionary or expansionary impact (Rose, 1983; OECD, 1984). One methodology to capture such a broad range of impacts is to use an existing macroeconomic model and, where necessary, adapt it in order to include the specific characteristics of pollution control. The principal usefulness of such an approach is its comprehensiveness and analytical soundness; it assesses the net overall influence exerted upon the economy. Such a 'macro' general equilibrium assessment is more accurate that a mere accounting of costs and benefits since the former takes account of the interdependencies in an economy.
In this chapter four main categories of macroeconomic impacts of pollution control are distinguished:

1) Effects of additional expenditures,
2) Impact of additional pollution control (environmental) costs.
3) Consequences of avoided environmental damage,
4) Technological spin-off.

Generally macroeconomic studies concentrate on the first two, neglecting the remaining, categories. The approach is reasonably firm. Yet the firmness depends on the quality of the model and its ability to include the various relationships between environmental expenditures, costs and the economy.
In section 2 (expenditures and costs) the methodology is described, the various channels of impact are discussed and the key factors that determine the eventual outcome of the analysis are presented. Consequences of avoided environmental damage and technological spin-off are more uncertain and estimates so far are only very tentative. Section 3 indicates the problems and potential of including the effects of reducing damage. Section 4 describes the difficulties in assessing the impact of technological spin-off. Conclusions are presented in section 5.

2.2. Effects of expenditures and costs

Methodology

The starting point of the macroeconomic evaluation is the time path of the additional investments and the net annual costs of the pollution control or environmental program. These investments and costs are disaggregated into relevant categories such as capital costs (interest and depriciation), labour costs, costs of raw material and energy and direct import coefficient of the investments. They are presented in constant prices using a recent price level. In addition, data may be needed on the mode of financing the investments (capital market, internal business financing from current cash flows, government subsidies), the type of management (government, private sector) and who pays the costs.

The second step involves making a base or reference projection for the economic development without the additional costs and investments of pollution control. Next a projection is made including the effects of the pollution control program. Differences in impact on economic variables between both projections that then arise can be ascribed to the environmental policy (CPB, 1982).

Main causal relations

After this brief outline of the methodology the main causal relations and dynamics of the impact of pollution control are discussed. A more detailed typology of macroeconomic channels of impact, as included in INTERLINK, is presented in the next chapter (section 3.5.).

The main causal relations can be illustrated as follows.

Additional environmental investments cause rising expenditures so that imports, but also domestic sales increase. Due to additional supplies (intermediary deliveries) direct employment and additional imports are generated. Operating the pollution control equipment has similar consequences. These positive effects of additional expenditures influence the result especially in the period in which the environmental investments take place. In the same period, however, the environmental investments may cause a direct crowding out of (traditional) investments due to financial constraints. This has a negative influence on production capacity, level of output and employment. The environmental investment may cause additional demand on the capital market and an upward pressure on the interest rate depending on the way investments are financed. Rising pollution control costs for households will, other things being equal, reduce other private consumption. Consequences of pollution control costs are especially important after the investment period.

The polluting industry, confronted with rising abatement costs which partly depend on government subsidies, will, depending on the market position, raise market prices and see business profits decline. This deterioration in competitiveness may cause a decrease in exports. Lower business profits may cause a reduction in the volume of new investments, production capacity and related jobs and may also cause an early scrapping (retirement) of existing capacity.

Factors influencing the final impact

Not only these channels of impact but also a number of dominant factors influence the eventual impact of a pollution control program and thus constitute a tool to explain differences in impact between countries:

* The absolute and relative size of the environmental investments and costs
* the ratio of factor demand for capital, labour and import goods of the pollution control programme
* the mode of financing the investments (capital market, government subsidies, internal business financing)
* the transmission of:
  - pollution control costs into prices for final demand categories (e.g. consumer prices)
  - prices into wage changes (wage price indexation)
* the monetary, exchange rate and budgetary (fiscal) policy
* the prevailing economic circumstances (e.g. unemployment, over capacity)
* the extent of 'openness' of a national economy and it's dependence on international trade

The above factors can be adstructed as follows.
The larger the investments and costs the more serious the consequences will be. Not only the direct effects on quantities but also the indirect impacts, through effects on prices, are affected. The relative size of the domestic environmental programma, compared to foreign policies and compared to the activity level of the home economy, is also important. A proportionally larger foreign program causes more import inflation but also lessens the deterioration of home competitiveness. This depends, among other things, on the sensitivity of the different prices of final demand categories for changes in foreign and domestic prices induced by the pollution control costs.
A high direct import share implies a less favourable domestic impact whereas a labour intensive pollution control program results in a higher direct employment level. Capital intensity is reflected in the initial amount of investments and the amount of other, traditional investments crowded out.
The mode of financing the environmental measures can vary among a strict application of the 'polluter-pays-principle', a more equal distribution using pollution charges, to financing via government subsidies. Financing may take place on the capital market or from internal business revenues (cash flows). These differences are reflected in the final impact.
The transmission of costs is also of importance. Wage earners may have

their wages indexed for changes in prices, taxes and social security contributions. Industries may partly be able to transmit costs increases into market prices.
An accomodating monetary policy can reduce or prevent the upward pressure on the interest rate resulting from the environmental programme. The government's budget policy also influences the impact since its budget deficit may be raised, borrowing on the capital market may increase, other expenditures may decrease or tax revenues may increase in order to compensate for additional subsidies for environmental investments. Of course the budget deficit may also improve. The exchange rate policy modifies the initial impact on the balance of payments. A flexible exchange rate can induce an increase in exports which may partly compensate for a decrease in exports; this decrease resulting from the raised price level caused by pollution control costs.
The prevailing economic conditions influence the attractiveness of an environmental programma as well. In a situation of over capacity and unemployment the environmental programme reduces this surplus, thus mitigating price impacts and causing positive second and higher order effects. Whether or not reallocation occurs also depends on qualitative discrepancies of the labour market and the sectoral distribution of surplus capacity.
In this international, European context it is important to note that if a country is strongly dependent on international trade the results of an internationally coordinated pollution control policy have a stronger impact on the home economy. Not only may exports benefit more from the increased world trade volume (due to foreign environmental expenditures); the domestic price level will be influenced stronger through a more severe increase in prices of import goods.
Various channels of impact and key factors thus determine the final impact of a pollution control program on macroeconomic indicators. The analysis so far suggests that macroeconomics is able to deal with all relevant categories of impact. This is somewhat misleading since the analyses of costs and expenditures have also received some criticism in the past (Rose, 1983; OECD, 1984; Klaassen, 1986). Moreover two categories of impact - damage reduction and technological spin off - have not yet been discussed; they are not included in conventional macroeconomic analysis.

2.3. Effects of avoided environmental damage

The main aim of the abatement of acidifying emissions is to reduce their negative impact on the environment. Although a vast amount of literature exists on this subject the available scientific knowledge at present does not allow a reliable estimate of the quantity of (monetary) damage that will be avoided as a result of reducing acidifying emissions (see Appendix A for details). This implies that a macroeconomic analysis of this impact is impossible due to lack of empirical data.

Damage reductions or benefits, according to the OECD (1984) can be classified as follows: "cost-reducing", "output-increasing" and "utility-increasing". It is in principle possible to use macroeconomic models to evaluate the impact of the first two categories since these are reflected in the gross national product. An example of "cost-reducing" benefits is a reduction in the costs, for producers, of adding additional lime to lakes and forests. An example of "output-increasing" benefits is an increase in yields in agriculture or forestry, due to an increase in physical production, resulting from a decrease in ozone. Depending on the distribution of benefits over industries, consumers and government it can tentatively be elucidated that such a damage reduction, not surprisingly, is likely to have a positive impact on the economy (Nentjes, 1985; Klaassen, 1987). Still the major problem is to isolate this beneficial impact, of environmental improvement on gross domestic product and other economic indicators, from other factors that affect the level of productivity and output.
For "utility-increasing" benefits, resulting from a decrease in acid deposition, this macroeconomic approach remains impossible since these benefits are not reflected in the gross domestic product. Examples of such benefits are: a reduction in expenditures of consumers on medical care due to a decrease in the corrosion of water supply systems or a reduction in the cost of home painting or car washing. These benefits result in a reallocation of the household expenditures and do not have an (remarkable) effect on the gross domestic product. The benefits however do lead to an increase in welfare. Other examples of "utility-increasing" benefits are the increase in welfare which directly results from an increase in recreational facilities in forests, reduced mortality and morbidity and aesthetical improvements of historical buildings. Econometric models do not account for these "utility-increasing" benefits and a macroeconomic assessment remains impossible.
The main argument not to include the impact of damage reduction however is the lack of data on the extent of the damage. It seems to make more sense to direct research on the quantification, were possible monetary evaluation, of the reduction in damage, and its geographic distribution under different abatement scenario's, than to try and asses its macroeconomic impacts.

2.4. Technological spin-off

Another omission is the exclusion of technological spin-off. As a result of additional domestic or EC-wide demand for pollution control equipment, the domestic suppliers will obtain the opportunity to implement, and extend, their experience and improve their production process. This 'learning-by-doing' may cause cost savings and lead to better quality products. As a result, exports from these countries are expected to increase, certainly if, at a later stage, comparable measures are taken in other countries. Although numerous examples exist of this technological spin-off, such as the strong position of Japanese suppliers of catalysts, empirical data are not sufficiently firm to allow a quantitive estimate of the additional export resulting of such a spin-off. Simulating the macroeconomic impact of such additional exports is reasonable straightforward (see Houweling, 1987) and tentative calculations for a specific Dutch case study (Nentjes, 1985; Klaassen, 1987) did show a positive macroeconomic impact. But the order of magnitude remains questionable and can be challenged (Cope, 1987). The relation between stricter environmental standards, innovation, cost reductions and additional exports would need some more research efforts (Nentjes and Wiersma, 1987) to quantify the impact in a firm manner.

2.5. Conclusions

Measures to control (air-) pollution act upon the economy through various channels and may have a contractionary or expansionary impact. One methodology to capture these impacts is to use an existing macroeconomic model. Four main categories of macroeconomic impacts of pollution control can be distinguished:

1. Effects of additional expenditures.
2. The impact of additional pollution control (environmental) costs.
3. Consequences of avoided environmental damage.
4. Technological spin-off.

Generally macroeconomic studies of the impact of pollution control concentrate on the first two categories, neglecting the remaining ones. The starting point of the macroeconomic evaluation of expenditures and costs is a time path of the additional investments and annual costs of the pollution control program. The second step involves making a reference projection for the economic development without the pollution control program. Next to that a projection is made including the pollution control program. Differences in economic variables that then arise can be ascribed to the environmental policy.
A number of dominant factors such as the absolute size of the environmental investments and costs, may explain differences in impact between countries.
A macroeconomic analysis of the impact of avoided damage at present is impossible due to lack of empirical data on the amount of damage. Macroeconomic models are in principle only able to capture "cost-reducing" and "output-increasing" benefits. A macroeconomic evaluation of "utility-improving" benefits is impossible since these benefits are not reflected in the gross domestic product.
Empirical data are neither sufficiently firm to allow a quantitive estimate of the additional impact of technological spin-off. Hence these impacts hence cannot be included in the evaluation which implies a too negative picture of the macroeconomic impact.

3. INTERLINK: A MULTI-COUNTRY MODEL

3.1. Introduction

For the analysis of the macroeconomic impacts of pollution control measures one can make use of an existing macroeconomic model. To study the economic consequences of a coordinated EC acid deposition abatement programme the policy simulations have to be made with a model which takes into account the economic interactions between the countries in the EC, which simultaneously carry out the abatement programme. Such a model has to be modified in order to deal with the specific characteristics of the pollution control program.
This chapter, after explaining why the INTERLINK model of the OECD was selected, describes the structure and basic equations of INTERLINK (section 3.2). Secondly the modifications to the INTERLINK model, introduced for the purpose of this study, are discussed (section 3.3). Subsequently the way in which investments and costs of pollution control are inserted into the model is presented (section 3.4). The suitability of the model, after the modifications, is evaluated in section 3.5. Conclusions are the subject of the final section (3.6).

3.2. Description of OECD's INTERLINK

3.2.1. Introduction

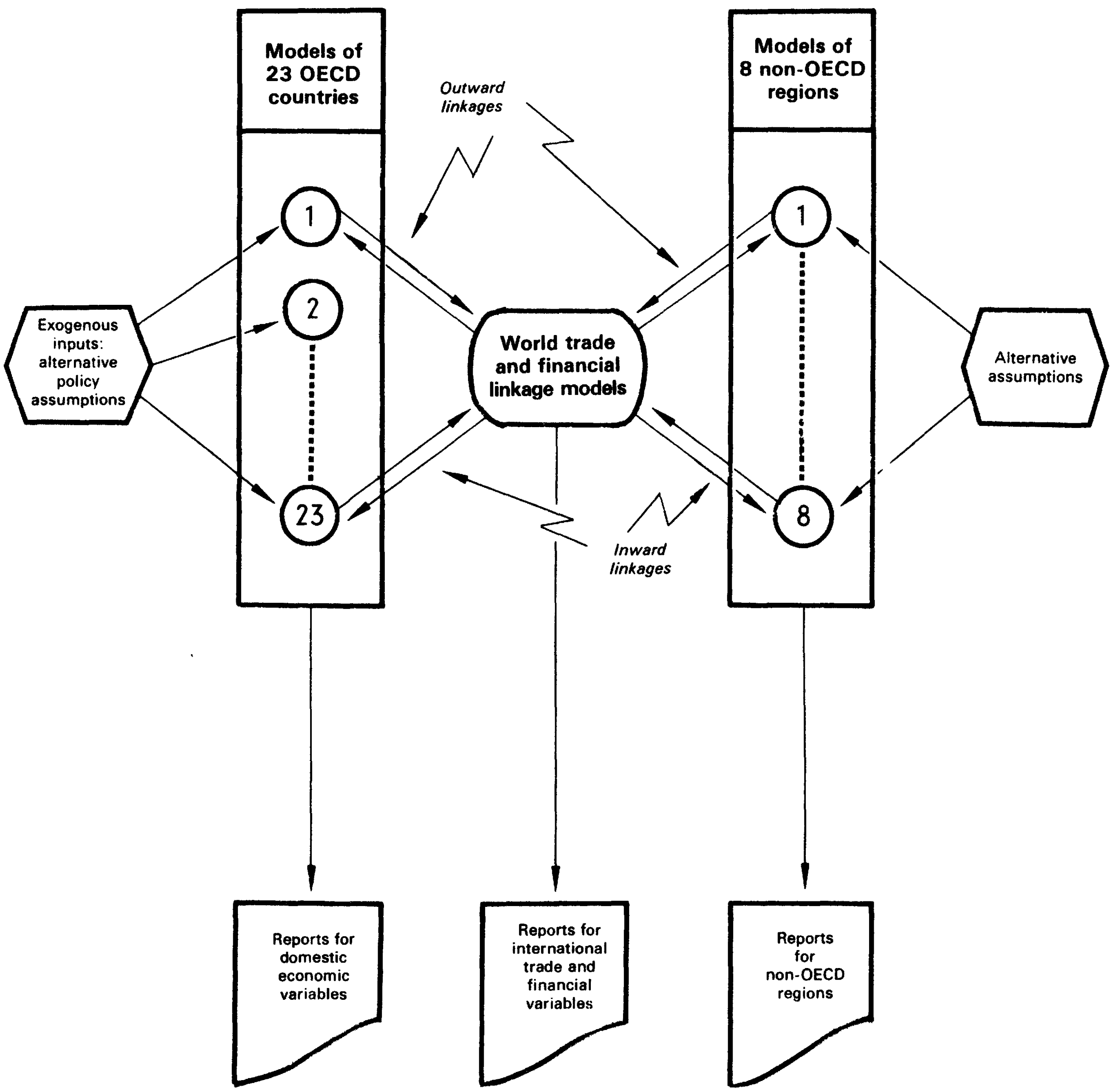
In a feasibility study the suitability of four macroeconomic models for this project was evaluated: COMET and HERMES (both EEC models), CHASE INTERNATIONAL MODEL (Chase Econometrics inc.) and INTERLINK of the OECD. INTERLINK proved to be the most suitable model. It is able to capture almost all relevant macroeconomic impacts of pollution control and the quality of the model is seen as being comparitively very high. The model is updated continuously to reflect new theoretical insigths and in addition results of the model are published frequently and are free for verification. Moreover and in contrast to e.g. HERMES, the model is operational and it is also being used for various types of studies. Due to the structural similarity of the different country models INTERLINK is more transparant and results are more easily comparable. Finally the model is cost-effective, although users of the model are required to carry out the analysis themselves but with the assist-

ance of the OECD in operating the model.
Generally INTERLINK is used for forecasting (semi-annual 'OECD Economic Outlook'), simulating and targeting economic variables. One example is the impact of equalisation of VAT rates within the EC which is presently being carried out by the CEC. An other example is the impact of an oil price shock.
For this study INTERLINK is used to obtain baseline forecasts and to simulate the effects of additional pollution control investments.

3.2.2. Main features of the model

Basic structure.
INTERLINK is a short to medium term, semi-annual world model in which the economies of 23 OECD countries and 8 non-OECD regions are modelled seperately. These seperate models can be linked optionally via world trade and financial flows. In this way the influence of one country or region on the rest of the world economy, and feedback effects following from this interaction, are taken into account (see figure 1). After this overview of the basic structure the OECD area block, the non-OECD area block and world trade and financial linkages are presented.

OECD-area block
Each country model comprises approximately 50 behavioural relations and some 100 identities. The models for the seven major OECD-countries (United States, Canada, Japan, Germany, France, Italy and the United Kingdom) are considerably more detailed than those for smaller countries, although there is a high degree of structural similarity.
Models for the major economies include detailed supply blocks based on production decisions. The production structure for these countries is based on a nested double CES production function of the putty/semiputty type in which capital, differentiated by vintage, energy and labour are combined. This long-run production structure is used to define a concept of normal output. The actual level of output is specified with the factor utilization rate (the ratio of actual to normal output) as the dependent variable. Independent variables are: costs, final sales (domestic demand plus exports), non-energy imports of goods and services, and inventories. Derived factor demand equations are specified as dynamic adjustments to desired factor inputs, in which the speed of adjustment is influenced by a unit cost or profitability variable and/ or the prevailing factor utilization rate. Business energy demand adjusts instantly to optimal levels.
The supply structure, via input costs, is linked to the determination of output prices. The cost mark-up is influenced by the prices of foreign competitors on prices and aggregate demand effects which operate via the intensity of factor utilization. Endogenous labour supply, and hence unemployment, through behavioural participation rate equations is a final element of the supply blocks for the seven largest OECD-economies.



Note: *Outward linkages* correspond to domestic variables that directly affect partner countries. These include import volumes, export prices, net capital inflows, wage rates, interest rates, and exchange rates.

Inward linkages correspond to external variables that directly affect the domestic economy. These include export volumes, import prices and net capital outflows.

Figure 1. INTERLINK, basic structure (OECD, 1983).

For the smaller OECD-countries no consistent production function based, supply blocks are present; supply factors operate chiefly through price and wage equations. Labour supply is determined outside these models. Inside the smaller models the demand for labour is a function of the demand-determined production level and of real wages. Business fixed investment is dependent on output changes and long-term real interest rates. The concept of price formation is comparable with the one for major OECD-economies.
In INTERLINK, government deficits are endogenous for all OECD-countries though modelled in rather less detail for the smaller economies. Private consumption is a function of real disposable income, prices and real interest rates. The export volume is dependent on world trade (market growth) and on relative price competitiveness. The import volume is determined primarily on the basis of aggregate world demand. Relative prices of imported and domestically produced goods are also a determinant of countries' imports. Wage rates have been modelled primarily as a function of labour market conditions (rate of unemployment), trend productivity and prices. Oil prices are treated as an exogenous variable.
For the seven largest OECD-countries money demand is modelled endogenously and the short-term interest rate is an exogenous variable. Short-term rates can however be determined endogenously by the setting of monetary targets and the implicit inversion of the demand for money functions. The short-term rates in the other OECD-countries are determined as a function of these interest rates and of exchange rates. Long-term interest rates are determined through a distributed lag of short-term interest rates.

Non-OECD-area block
For non-OECD-areas, INTERLINK contains rudimentary reduced-form models. An important role is played by the external purchasing-power of exports; how much a region is able to import given its export proceeds and import prices.

World trade and financial linkage model
This block of equations provides a description of the principal mechanisms through which the OECD-economies interact with each other and with eight non- OECD-regions (see figure 2). The principal aim of this block is to take account of feedback effects from this interaction and to ensure global consistency of multi-country projections and simulations.

Trade flows
Within each country and non-OECD regional model, import volumes and export prices are endogenously determined for given values of exchange rates, import prices and world trade. These values are passed on to the world trade block where they are converted to a common numeraire, taken

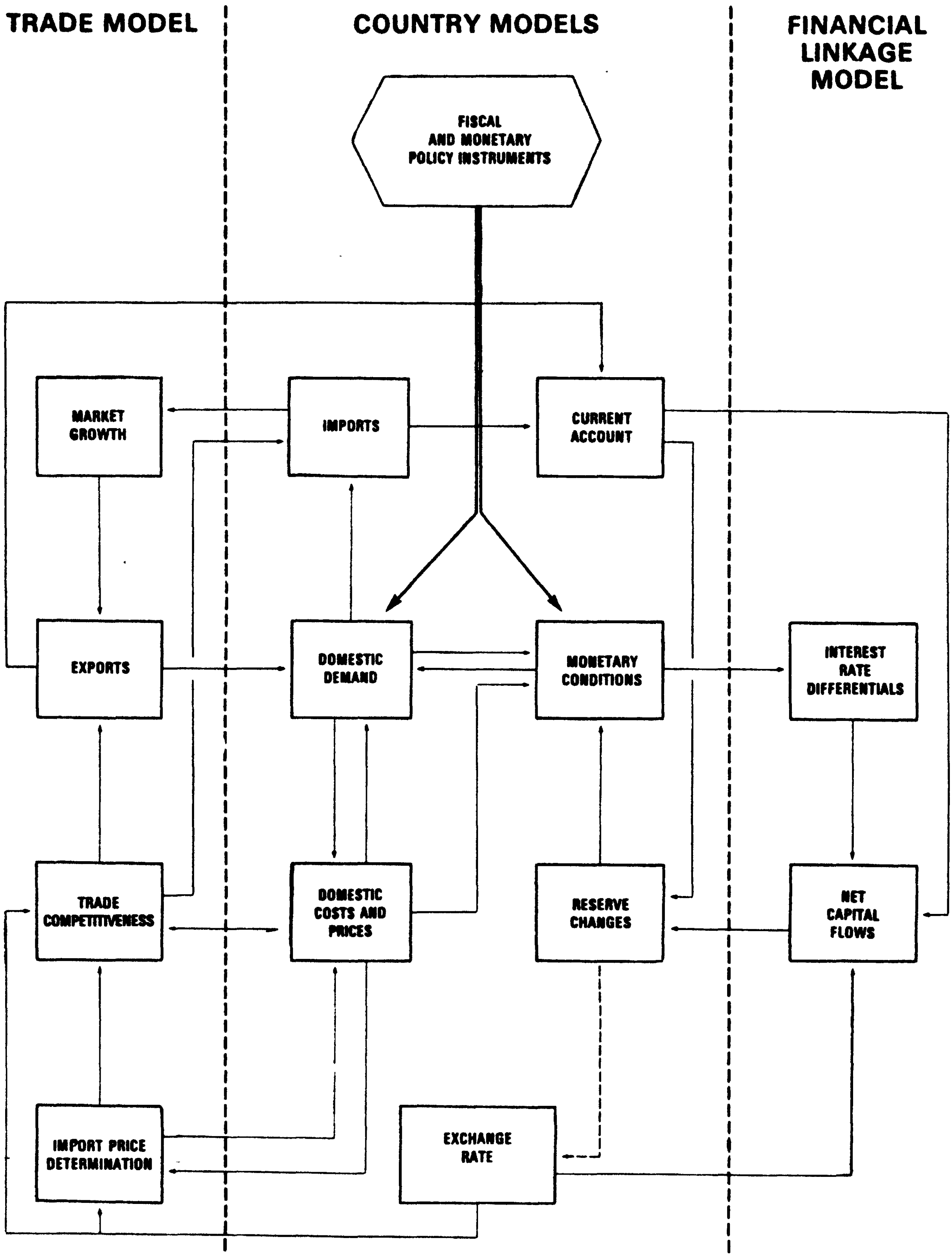


Figure 2. INTERLINK, trade and financial linkages (OECD, 1983).

to be the U.S. dollar. Next a consistent set of export volume and import price estimates is determined through a weighting with market shares of the import volumes and export prices. These are in turn passed back to the country models and on repeated iteration a convergent and internationally-consistent model solution is achieved: the sum of changes in countries' imports correspond to the sum of changes in countries' exports and changes in countries' export prices have their full counterpart in partner countries' import prices.

Financial flows
The financial linkages (capital flows) between the world economies are modelled as explicit equations for the effective exchange rate. Net capital flows are obtained from the balance of payments identity. International financial linkages are based on a portfolio balance model of exchange rate determination. International consistency is ensured by cross country restrictions on parameters imposed during estimation.

3.3. Modification of INTERLINK

Introduction
Additional pollution control investments cause rising expenditures, so that domestic sales increase. Due to additional supplies (intermediary deliveries) the related direct employment is increased. Operating the pollution control equipment has similar consequences. The polluting industry, confronted with rising abatement costs, the level also being influenced by government subsidies, will raise market prices. Deterioration in competitiveness causes a decrease in exports. In the production block the availability and utilisation of factors of production are described. If prices changes, resulting from 'passed on' pollution control costs, give rise in changes in the relative prices of factors of production (labour, capital, energy and materials) substitution and the selection of other production techniques may appear.

Adjustments in INTERLINK
INTERLINK has been adjusted to make the model suitable for dealing with the above specific characteristics of environmental expenditure. Environmental expenditure can be classified into two main macroeconomic categories:

- expenditure on pollution control, or environmental, equipment;
- expenditure on exploitation requirements of pollution control, or environmental equipment.

Environmental investments
The first category is termed environmental investment. Data for this variable are determined outside INTERLINK. Inside the model these data are transformed from factor prices to market prices; i.e., on the basis of the model equations for indirect taxes and subsidies, environmental

investment inclusive of indirect taxes minus subsidies is calculated. By adding this new investment category to private fixed investment, environmental investment is treated in the same way as the already existing private fixed investment categories of INTERLINK. These endogenous mechanisms need no correction.
However, to ensure that environmental capital costs are calculated, adjustments are necessary. In the models of the large countries environmental investment is therefore added to business fixed investment in the equations determining the growth rate of normal longrun costs and of actual weighted costs. The environmental capital stock, determined in a new relationship, is added to business capital stock in the equations determining the inverse profitability variable and average normal costs. In this way the calculation of environmental capital costs (interest and depreciation) in the cost relationships of the large country models of INTERLINK is guaranteed. These costs then enter the price equations automatically. In the models of the small economies explicit cost relationships are not present. Capital costs are therefore determined outside these models. These data are added directly to the equations determining consumer prices. Via the private consumption deflator the capital costs enter automatically the other price relationships of the models for the small countries.

Environmental exploitation expenditure

The second category, environmental exploitation expenditure, consists of expenditure on:

- energy used by environmental capital (pollution control equipment);
- labour to exploit environmental capital;
- material to exploit environmental capital.

Employment figures and energy and material expenditures are determined outside INTERLINK. Adjustments are made to ensure that exploitation employment influences total employment and productivity. By multiplication of the employment figures with the real wage rate, labour exploitation expenditure is determined inside INTERLINK. After transformation to market prices environmental exploitation expenditure is added to the equation determining final domestic demand.
"Demand-pull" effects on inflation are ensured by adding the environmental exploitation expenditures to the equation of the price for total or final domestic demand. "Cost-push" effects on inflation are established by adding the environmental expenditure categories to the consumer price equation of the small country models and to the cost relationships of the models for the large countries.
Environmental exploitation expenditures are also added to the equations determining indirect taxes and subsidies.
Finally, adjustments are made to ensure that expenditure on energy and material for the exploitation of environmental capital influences industrial production, imports of energy, investments in stocks and the intensity of factor utilization.

3.4. Investments and costs of pollution control into INTERLINK

This section starts with a description of general conversion of costs into input data for INTERLINK. Subsequently an adjustment in time horizon is discussed. Finally, the insertion and modification of annual costs is presented.

Conversion of costs into input data

The costs submodel (see chapter 5, section 5.2) calculates the investments and costs of the Directive on large combustion plants in constant prices of 1985[1]). Moreover costs and investments are expressed in market prices, including Value Added Tax (VAT). Eventually however, both costs and investments are inserted into INTERLINK in national valuta, in prices of the INTERLINK base year (generally 1983) and at factor costs (excluding VAT). Costs and investments are converted into national valuta using the 1985 exchange rate and in addition are expressed in base year prices applying price indexes of the OECD data base. In addition (generic) VAT is substracted to express costs and investments at factor costs. INTERLINK then calculates, country specific, VAT and subsidies endogenously (within the model).

A shift in time horizon

With respect to the time horizon the following transformation is made. In this study the first stage of the Directive on Large Combustion Installations is observed, viz. the plan period 1/1/1985 until 1995. The majority of the air pollution control investments resulting from the Directive is expected to take place in the period 1988-1993. For a complete picture it is necessary to simulate the macroeconomic impact also for some years (say four) after the investments take place since the negative impact of the costs generally only floats to the surface after the investment period. The database of the OECD INTERLINK model however, does not allow the projection of macroeconomic impacts beyond 1992. Only for the period 1983-1992 a projection is possible.
Therefore the following transformation is made. Investments take place in a period of six years: 1988-1993 in reality and 1983-1988 in the model. The economic impact is calculated for the period 1988-1997 in reality (which corresponds with 1983-1992 in the simulation), including a period of four years (1993-1997) in which no investments take place. This transformation is not expected to have a considerable impact since the results are not extremely sensitive for changes in the macroeconomic base line or reference projection. Moreover the macroeconomic situation i.e. unemployment in both periods; 1988-1997 (in reality) and 1983-1992 (in the model), is not expected to be too diverging.

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[1]) Cost module calculates figures in German Deutschmarks.

Furthermore it was assumed that environmental investments, taking place from 1988-1993, are equally distributed over that period (each year 1/6 of total investments). For Germany this procedure results in a small overestimate of the impact especially during the investment period since in reality investments are distributed over a longer period. This offers the advantage however, that efforts before 1988 (but after 1/1/ 1985) are taken into account.

Annual costs
For the annual costs the same transformation of periods and conversion in national valuta, OECD base year and in factor costs take place. In reality these costs (in constant prices) increase from 1988-1993 and stabilise in the periods thereafter (1994-1997). In the model these periods are 1983-1988 and 1989-1992.
The costs submodule distinguishes the next categories of annual costs:

* capital costs (interest and depreciation)
* operating costs:
  - fixed (insurance, local taxes, administration, maintenance and repair)
  - materials (gypsum, catalyst, ammonia, water)
  - energy (electricity, steam)
  - wage sum.

For the large country models capital costs are endogenously calculated from the environmental investments, using country specific interest rate and life time of the INTERLINK model. For the small country models these costs are exogenously calculated using specific lifetime and real interest rates (1985) of the OECD data base (see technical document I for details).
Annual operating costs are treated as follows. Fixed operating costs and costs of materials are aggregated into one category and inserted into the model, while energy costs remain a separate subcategory. This facilitates linkage with prices distinguished in INTERLINK. The direct employment during exploitation is calculated exogenously. This employment constitutes the input for the model. Thus total wages are calculated endogenously using the country specific wage sum in the model. All these annual costs (in constant prices) increase and cumulate gradually from 1988 to 1993 and stabilise from 1994 to 1997.

3.5. Evaluation of the suitability after modification

INTERLINK country models take account of the following macroeconomic impact of pollution control.
In the expenditure block the different categories of demand are modelled. Traditional consumption declines if costs of pollution control for consumers rise. More indirectly consumption is affected by changes in the national income.

Gross business investments (exclusive of environmental investments) are influenced through rising pollution control costs and decreasing profitability as well as by changes in national income and interest rates. Additional import is generated due to the environmental investments and operating costs as well as increasing national income.
In the wage and price block changes in wage and price levels are causally related to other factors such as environmental costs. Increasing pollution control costs are partially reflected in rising prices for final demand categories. Moreover, through wage indexation, these price changes might be reflected in wage changes which may result in price changes, etc.
The social security and government block describes the most important allowances and contributions. Financing of pollution control investments affects the government budget deficit. Tax revenues, as well as lower allowances, resulting from additional expenditures and employment counterbalance this.
In the block of capital transactions and trade the environmental investment and costs cause world trade volume to rise. Relative export prices of the different EC countries change as well as a result of foreign and domestic pollution control costs, resulting in an alteration of the export position. Existing patterns of trade are thus modified.
In addition to these incorporated macroeconomic impacts two other transmission mechanisms might be relevant. However, these are not incorporated in the simulations that have been made with INTERLINK:

1. The environmental investment may cause a direct crowding out of traditional business investments due to limited financial means.
2. A decrease in business profit may, in case it arises, speed up the scrapping of old capital vintages (and complementary labour). This may happen in putty clay models, but the INTERLINK supply model of the large countries is of a putty/semi-putty type.

It is concluded that INTERLINK is in principle a suitable model for studying international economic aspects of national control strategies to reduce acidifying emissions in the EC. INTERLINK involves considerable detail for individual countries. This gives a richer set of results but implies a larger and more considered data input. The models for Germany, France, Italy and the United Kingdom are more detailed than those for other EC-countries.

3.6. Conclusions

In this project the OECD INTERLINK model was selected to simulate the macroeconomic impact of pollution control. The model was selected since its quality is high, the model is 'up to date', operational, transparant and cost effective. After modification of the EC country models INTERLINK was able to capture almost all relevant macroeconomic impacts of national control strategies to reduce acidifying emissions in the

EC. Only the impacts of direct 'crowding-out' of traditional investments and of additional scrapping were not incorporated. Adaptation of the country models was necessary in order to take the specific characteristics of pollution control into account. In spite of a high degree of structural similarity, country models were more detailed for larger than for smaller EC countries, which necessitated different modifications. Also the pollution control investments and costs as endogeneously determined had to be converted to constitute as inputdata for INTERLINK.

4. DIRECTIVE AND ABATEMENT STRATEGIES

4.1. Introduction

The strategies EC countries adopt to meet the Directive on large combustion plants are the subject of this chapter.
First a brief description is given of the Directive and its main components (section 4.2) viz.:

- emission standards for new, large combustion plants;
- prescription of percentages reduction in the total emissions of large combustion plants (overall emission target or bubble concept) per country.

Secondly a projection of unabated, reference emissions in 1995 is compared with the overall emission targets (section 4.3) to determine which amount of emissions should be abated to meet the percentage reduction required in the Directive. Subsequently the question on the abatement strategy in each country is tackled (section 4.4) as follows:

- Some countries have already national legislation to control emissions. If this legislated national policy is sufficient to meet the Directive this national policy is taken to calculate costs.
- In the absence of a national control strategy, or if the national strategy does not lead (fully) to the emission targets, (additional) abatement measures are needed. Countries without national strategies must first comply with the emission standards for new, large (power) plants. If that is not sufficient to meet the bubble concept existing power plants are to take abatement measures or new plants need to take more stringent measures.

The conclusions are presented in section 4.5.
The following limitations should be noted. Costs are calculated only for the period 1985-1995 (stage one of the Directive) since it was technically impossible to simulate the macroeconomic impact of the second stage (period 1995-2000) of the Directive.
The amount of emissions to be abated under the bubble concept includes emissions from large power stations as well as large industrial plants. However, no assesment was feasible of the technical abatement measures and emission reduction for new industrial plants due to a lack of data

on the size distribution of these plants[1]). One should note however that the emissions from large industrial plants (as well as large power plants) are abated; not by means of abatement measures on new industrial plants, but by additional measures on existing or new power plants. The possible error introduced by this procedure is discussed in the next chapter (section 5.4).

4.2. The directive on large combustion plants

The Commission of the European Community, at the end of 1983, has proposed a Directive to limit the SO_2 and NO_x emissions from large combustion plants. This draft Council Directive applies to combustion plants with a heat input of more than 50 MWth. The original Directive contains two components:

1) New plants (for which an operating license is granted after 1st January 1985) have to comply with emission standards. These emission standards depend on the size of the installation (> 300 MWth, 100-300 MWth and < 100 MWth).
2) A bubble concept according to which member states are to draw up programmes for the reduction of total annual emissions from large combustion plants. This in order to reach by 31st December 1995 at the latest the following overall reductions of emissions from large combustion plants (using 1980 as a base year):
   60% for SO_2
   40% for NO_x

Presently within the Council discussions are still taking place on the contents of the Directive. This discussion did not yet result in a final solution. Therefore for the purpose of this study the following assumptions have been made, reflecting discussions in late 1986:

* the emission standards proposed for the first stage (1985-1995) are the same as in the original proposal.
* in 1995 each EC country, as well as the EC as a whole, is to reach in principle a minimum reduction of 45% for SO_2 and 30% for NO_x.
* the following exceptions are made:
  With respect to SO_2: Greece, Ireland and Luxembourg are allowed to maintain emissions at the 1980 level (a standstill). Portugal is allowed an increase. Spain should reduce its emissions by at least 10%.
  Regarding NO_x: Ireland, Luxembourg as well as Portugal are to maintain their emissions at the 1980 level. Spain is to reduce emissions by 10%. Greece is allowed to increase its NO_x emissions.

[1] Only for the present abatement policies of Denmark, the Federal Republic of Germany and The Netherlands data allowed a estimate of their emission standards for industrial plants.

4.3. Future emissions (reference case)

4.3.1. Introduction

Future emissions, percentage reduction and emissions of large combustion installations in 1980 determine to a large extent the costs of the Directive for each country. To project future (reference) emissions an emissions submodule was set up. Input data for this module are:

* scenarios for fuel use in industry and electricity generation in 1995.
* data on emission factors for sulphur dioxyde, depending on heat value, sulphur retained in ash and sulphur content.
* data on emission factors for NO_x.
* data on 1980 emissions for large combustion plants.

The emissions submodule results in a projection of 1995 emissions of large combustions plants and an estimation of emissions to be abated to meet the bubble part of the Directive.

4.3.2. Energy consumption

In this study the energy use in electricity generation for 1995 was based on UNIPEDE (1987) and energy use in industrial plants was based on CEC projections as put forward in the "Energy 2000" study (Guilmot et. al., 1986) and IEA (1986) for Spain and Portugal. Table 1 summarises some of the characteristics of this energy scenario.

Table 1. Characteristics of the energy scenario for 1995

	Power Plants					Industry	
Country	Electricity consumption (1980=100)	Electricity production (Twh)	Shares(%): non-fossil	oil	coal	Fuel consumption Index (1980=100)	Total (PJ)
Belgium	140	67.5	61	9	26	85	480
Denmark	163	35.7	2	0	98	127	154
France	177	490.0	94	1	4	80	1475
Germany	128	446.0	40	3	50	81	2295
Greece	190	41.3	17	8	75	140	209
Ireland	183	18.1	6	37	57	150	109
Italy	161	272.3	18	25	37	92	1377
Luxembourg	134	1.0	58	0	0	94	82
Netherlands	117	66.7	5	0	48	104	641
Portugal	203	31.4	40	14	46	176	205
Spain	162	169.6	55	5	40	167	1001
U.K.	117	305.6	23	3	74	102	1833

Note: non-fossil include hydro and nuclear; total of shares may differ from 100% since gas is not included.

In view of recent information the share of oil in industrial energy demand, and related SO_2 emissions, might be somewhat higher as expected in the 'Energy 2000' study[2]). The energy scenario used for electricity generation tends to overestimate the expected growth in electicity demand as well as the share of oil and solid fuels. This implies an overestimate of future emissions certainly of SO_2.
It must be noted that for several countries there are major uncertainties in the future of nuclear energy and the penetration of coal[3]).

4.3.3. Emission coefficients

Sulphur emission coefficients were based on various international and national sources: (Amann et. al, 1986; CEC, 1984; de Ryck, 1983; Department of the environment, 1986; Beck, 1986; CITEPA, 1983; Schultz, 1986).
For nitrogen oxides emissions, available information allowed only an aggregated approach: no distinction was possible of different types of combustion installations. Emission factors only differ per fuel type and per sector. A large share of data was based on CITEPA (1986), supplemented with various national sources (Hoogervorst,1985; Department of the Environment; CITEPA, 1983; Beck, 1986; CEC; 1984). Technical document I (section 3) supplies more details on these data.

4.3.4. SO_2 emissions to be abated to meet the bubble

The energy scenario in combination with the emission coefficients lead to a projection of unabated, reference emissions of large combustion plants in 1995 (see table 2). The amount of emissions to be abated results from the percentage reduction required and the reference emissions. Table 2 does not yet incorporate the impact of already legislated national control strategies in several EC countries. National control strategies are discussed in section 4.4.

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[2] In view of recent oil price developments the 'Energy 2000' study (Guilmot, 1986), used for the projection of industrial emissions is probably based on a too high oil price. Recent scenario's indicate a lower oil price, which stimulates economic growth and energy demand in the EC, and moreover reduces the interest of industry in energy conservation (CEC, 1986). Against that however slower growth rates for the iron and steel industry and more rapid change towards higher value added products in combination with ongoing improvements in the chemical, paper- and pulp industry counterbalance this. As a result the projection of future industrial energy demand is hardly affected although the share of oil will be somewhat higher at the expense of natural gas and oil.

[3] Especially in the case of Italy the near energy future seems unpredictable due to siting problems of coal fired power plants and discussions on the extension of nuclaer capacity. (ENEA, 1987.)

Differences in emissions to be abated per country resulting from differences in reference emissions can be explained as follows.
In Belgium some reduction in emissions is expected due to an increased share of nuclear and low sulpur coal in the production of electricity. However, the reduction is not sufficient, since industrial emissions will decrease only slightly and high sulphur fuel oil will continue to be used in power plants.
Without a national control strategy emissions in Denmark would increase with the growth in electricity consumption. This growth will be met by increased coal use in power plants. Industrial emissions tend to stabilise.
In France growth in nuclear power and a shift away from high sulphur oil cause SO_2 emissions to decrease enough to meet the bubble. Apart from measures on new industrial plants France does not need to take action.

Table 2. SO_2 emissions to be abated in 1995

Country	Emissions 1980 (kton)	Reference (unabated) 1995 (kton)	EEC target 1995 (%)	EEC target 1995 (kton)	To be abated 1995 (kton)
Belgium	530	359	45	292	67
Denmark	323	365	45	178	187
France	1910	782	45	1051	0
Germany	2225	2277	45	1224	1053
Greece	250	273	0	250	23
Ireland	99	163	0	99	64
Italy	2450	2101	45	1348	753
Luxembourg	3	0	0	3	0
Netherlands	299	324	45	164	159
Portugal	280	360	0*	360	0
Spain	2290	2243	10	2061	182
United Kingdom	3600	3324	45	1980	1344
EEC	14259	12571	<45	7842	4792

Note: National abatement policies are not included in reference emissions. 1980 emissions based on country submissions to the EEC (CEC, 1987). Reference emissions based on the emissions model except Greece and Portugal based on CEC submissions.
*:granted an increase.

Emissions from electricity generation in the Federal Republic of Germany tend to stabilise, even if Germany's legislated abatement policy is not considered. The growth in electricity demand is met by nuclear and

coal-fired capacity at the expense of oil. Industrial emissions tend to decline since final energy demand drops and the share of hard coal and gas grows.
In Greece SO_2 emissions increase only slightly, despite the doubling of electricity demand and consequent tripling of the use of domestic brown coal with a very high SO_2 emission. This is due to the high calcium content in the Northern Greece brown coal which leads to a higher sulphur retention is ash[4]). Without additional costs, Greece can comply with the emission standards for most of its new plants.
In Ireland the growth in emissions is mainly caused by the increase in coal for electricity generation while the use of high sulphur fuel oil stabilises.
In Italy SO_2 pollution decreases as a result of a shift from high sulphur oil to low sulphur coal and nuclear energy for electricity generation. Moreover a reduction in the use of fuel oil causes industrial emissions to decline as well.
In the Netherlands power plants emissions would stabilise as the increase of coal emissions is offset by a decrease in fuel oil and an increase in natural gas. Industrial emissions increase slightly.
In Portugal sulphur emissions are raised since the rapid increase in electricity demand is met by new coal-fired capacity. Although industrial emissions grow as well, Portugal does not need to take abatement measures to meet the bubble since it is permitted an increase.
In Spain power plants emissions decrease due to the decrease in use of high sulphur fuel oil and stabilisation in use of brown coal. Industrial emissions however almost double.
In the United Kingdom emissions show a downward trend; the industrial use of fuel oil declines in favour of hard coal and natural gas.

4.3.5. NO_X emissions to be abated to meet the bubble

Table 3 shows the amount of NO_X emissions that needs abatement in order to comply with the bubble concept.

One should note that compared to the data on SO_2 emissions for large combustion plants, NO_X emissions for 1980 are less well accepted, both politically and scientifically[5]). The same holds for the projection of future emissions due to the less firm database of NO_X emission factors. The level of reference emissions can be explained as follows.

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[4] That is to say if appropriate steps are taken to reduce these emissions during combustion

[5] For Italy for example the 1980 emissions refer to all emissions from all power and industrial plants irrespective of the size. This implies an overestimate of the required reduction.

Table 3. NO_x emissions to be abated in 1995

Country	Emissions 1980 (kton)	Unabated Reference 1995 (kton)	EEC target 1995 (%)	EEC target 1995 (kton)	To be abated 1995 (kton)
Belgium	136	115	30	95	20
Denmark	124	165	30	87	78
France	368	190	30	258	0
Germany	1062	925	30	743	182
Greece	24	38	0*	38	0
Ireland	24	44	0	24	20
Italy	649	913	30	454	459
Luxembourg	1	1	0	1	0
Netherlands	110	128	30	77	51
Portugal	23	85	0	23	62
Spain	450	500	10	405	95
United Kingdom	954	1006	30	668	338
EEC	3925	4110	< 30	2748	1363

Note: National abatement policies are not included in reference emissions based on the emissions submodel. 1980 emissions based on emission inventory (CEC, 1987), not confirmed by memberstates.
* : granted an increase.

In Belgium the reduction in NO_x pollution, resulting mainly from the use of nuclear power is not sufficient to meet the bubble. In France the growing share of nuclear capacity causes a sharp decrease and additional abatement measures are not needed. Denmark must take steps due to the growing share of coal fired capacity. In Germany, even without national abatement strategy, NO_x emissions are expected to decline since fuel use is decreasing in industry and in electricity generation.
In Greece NO_x pollution increases sharply due to the increase in brown coal use and despite the very low emission factor. No reduction however is required since NO_x emissions per ton fuel combusted are

already very low (100 gr/GJ). Additional reduction would imply after treatment of the flue gases at prohibitive costs per ton emission abated.
In Ireland emissions will double as a result of new coal fired power plants coming on stream. Italian NO_x pollution enlarges rapidly as a result of the increased use of coal for electricity production. In Luxembourg these emissions stabilise. In the Netherlands they would increase: the increasing use of coal being responsible. In Portugal the expected increase stems mainly from the incline in coal use for electricity generation.
In Spain this type of pollution remains at the 1980 level for power plants. However industrial emissions rise, making abatement measures inevitable.
In the United Kingdom NO_x pollution will nearly stay at the same level due to the stabilisation of fuel use in electricity generation as well as in industry.

4.4. Control strategy and abatement measures per country

4.4.1. Introduction

This section describes the assumed reaction of the various EC Countries on the proposed Directive.

4.4.2. Sulphur dioxide

Countries with a national control policy: Denmark, Germany and the Netherlands

Denmark, implementing its own policy, reduces its emissions by means of an extensive program of applying FGD (flue gas desulphurization) on new and existing power plants. In addition the sulphur content in fuel oil is reduced from 1.5% to 1.0% S. and the sulphur content in hard coal is limited to 1.2%.
In the Federal Republic of Germany an intensive program of FGD on new as well as existing plants has and will result from the Ordinance on large firing installations. Part of the emission standards set fort in the Ordinance can be met by the use of low sulphur fuels. Costs estimates for the use of these fuels however were not included since the volume of these low sulphur fuels was not available.
In the Netherlands a comparable ordinance came into force in spring 1987 and incorporates earlier legislation. All new and existing coal-fired plants (> 300 MWth), with some exceptions, require FGD. For other, existing coal-fired power plants, 0.8% S in coal is required. Industrial standards can be met by the use of fuel oil with a sulphur content of 1.0%, in existing as well as new installations, or the application of fluidised bed combustion for new coal fired installations. Special standards for refineries are to be met by combining

a reduction in process emissions and, if necessary flue gas desulphurization.
These three countries do more then meet the bubble (see technical document I for details.)

France, Luxembourg and Portugal
France has no costs due to its large share of nuclear energy. Sulphur emissions in Luxembourg, already negligible, would decrease anyway making abatement measures superfluous. Portugal is granted an increase in its emissions and can confine with the use of free, low sulphur coal up to 1995. All these countries meet the Directive without measures.

Belgium, Greece, Ireland, Italy, Spain and the United Kingdom
The most likely strategy of these countries are not known. Therefore the following strategies were assumed.
Belgium installs FGD on some recently commissioned coal-fired plants and in addition some existing oil-fired units. A new fluidised bed combustion unit will inject additional lime.
Greece can confine with the application of sorbent injection instead of FGD on one new brown coal power plant. The need for abatement is already low due to the expected reduction of emissions during combustion of most new brown coal-fired plants.
In Ireland all new or recently commissioned coal-fired units and moreover a small oil-fired unit apply FGD to reach the standstill requirement.
All new Italian fossil fueled power plants apply FGD. This is still not enough to reach the 45% reduction. In addition FGD is installed on part of the existing capacity.
Spain installs FGD on all new coal-fired plants and one existing coal plant to comply with the 10% reduction of the bubble.
In the United Kingdom some 23000 MWe, of which more then 19000 MWe involves retrofitting, would need FGD to meet the 45% reduction.

4.4.3. Nitrogen oxides

Countries with a legislated national policy: Germany and the Netherlands
In Germany the Conference of Federal and State Environment ministers accepted stringent emission standards for NO_x. As a result new and part of the existing large (>300 MWth) plants in electricity generation as well as in industry, have to install SCR (Selective Calatytic Reduction). Other plants are expected to instal CM (Combustion Modification). Although data on the extent of the abatement program are less certain for NO_x than for SO_2 an estimate was possible (see technical document I, for details).
The Netherlands policy is less strict. New coal fired units can implement TSC (Two stage combustion). Converted unit as well as some new gas fired units will apply CM. Furthermore an extensive program of retro-

fitting gas-fired power plants with CM is expected. CM and fluidised bed combustion is expected for industrial installations to meet the overall reduction of the Directive. In view of available information (see technical document I) the conclusion is warranted that the present Dutch policy is not sufficient. Therefore extra CM on some existing plants is assumed.

Remaining countries

These countries start with CM to meet the emission standards for their new power plants. If this is insuffiecient to meet the bubble extra measures are taken in the most cost effective way.
Belgium installs TSC on some recently commissioned coal plants. In addition some existing units use CM and one fluidised bed plant will also contribute to the Belgium efforts. In Denmark all recently converted or new coal-fired plants need TSC or CM. Moreover three-quarters of the existing coal capacity needs CM as well to meet the bubble. In Ireland all coal-fired Moneypoint units need TSC. Also retrofitting of all brown coal and part of oil fired capacity with CM is needed. Spain can sustain with the application of TSC on its new coal fired plants and CM on a small part of existing capacity. For all these countries efforts and costs are small.
The United Kingdom needs a more stringent program. Despite the stabilisation of NO_x emissions the 30% reduction requires an intensive program of retrofitting 95% of the existing coal-fired capacity and TSC on all new coal-fired units.
For Italy and Portugal however TSC and CM is not enough and SCR is inevitable. Italy has to equip practically all its new coal- and oil-fired power plants with SCR, except for some coal units that have to apply only TSC. Moreover all existing oil, gas and coal fired units would require CM. Portugal applies CM on the existing plants followed by, a least-cost-combination of SCR and TSC on all new or recently built coal-fired power plants.

4.5. Conclusions

Sulphur dioxide

Denmark, the Federal Republic of Germany and the Netherlands carry out their already legislated national control strategies and do more then meet the bubble. France, Luxembourg and Portugal do not have to take abatement measures. The most likely abatement strategy of Belgium, Greece, Ireland, Italy, Spain and the United Kingdom is not known. Therefore it was assumed that these countries generally will install flue gas desulphurization on new power plants and, if unsufficient to meet the bubble, apply FGD on existing power plants.

Nitrogen oxides

The Federal Republic of Germany and the Netherlands will carry out their own legislated policy. For the Netherlands this is insufficient and additional combustion modification is expected. France and Luxembourg are not to take any measures and neither is Greece since it is granted an increase in its emissions. Belgium, Denmark, Ireland, Italy, Portugal, Spain and the United Kingdom start with combustion modifications to meet the emission standards for their new power plants. If insufficient additional measures are taken in the most cost-effective way, selecting between two stage combustion, combustion modification on existing power plants and, if inevitable selective catalytic reduction.

5. COSTS AND INVESTMENTS

5.1 Introduction

This chapter deals with the costs and investments of the abatement strategy in each country.
Section 5.2 presents the structure and major elements of the costs module used to calculate abatement costs. This costs module describes the different abatement technologies, their costs as well as the country specific and generic elements taken into account to calculate the costs for each country. The results of this calculation method are presented in section 5.3. The same section not only includes the absolute size of the pollution control investments and costs, but also depicts and describes the efforts as percentage of the gross domestic product and the impact on electricity prices. A discussion on sensitivity is the subject of section 5.4. Conclusions are made in section 5.5.

5.2. Costs submodule

5.2.1. Introduction

This submodule calculates the costs and investments of the abatament strategy of each country. It takes into account country specific as well as generic factors that influence the cost and investments of the abatement of sulphur dioxyde and nitrogen oxides emissions. Table 4 shows its main features.
The possibility to incorporate country-specific data on detailed fuel characteristics and on the capacity of plants is an important characteristic of the module [1]). The United Kingdom for example uses a domestic hard coal with a high chlorine content which leads to additional investments before flue gas desulphurization of power plants can take place.

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[1] Through incorporating fuel characteristics such as heat value, sulphur content, SO_2 retention in ash and specific fluegas volumes a more accurate calculation of abatement costs is possible. Size and age of plants are important when it comes to assessing the costs specific limit values for SO_2 and NO_X in fluegas.

Table 4. Input and output of the costs module

INPUT	
Country specific data	**Generic data**
* Emissions to abate * National abatement strategy * Type and specifications of fuel * Capacity of combustion plants (size, new, existing) * Interest rate * Operating hours * Energy efficiency plant * Electricity price	* Relation size and investment for a specific abatement technique * Life-time new, existing * Fixed operating cost (% of investment) * Wagesum per man year * Direct employment during exploitation * Prices of lime(stone), water, ammonia and catalyst
OUTPUT	
* Investments * Capital costs (interest and deprecation) * Operating costs (fixed, materials, energy and wages) * Employment during exploitation * Emissions abated	

A basic assumption of the costs module is that costs related to a specific abatement technique, taking into account only generic data, are in principle equal for each EC country. Costs however will differ between countries due to differences in country specific factors such as size, fuel type, interest rate and electricity price. The existence of a free accesible market for abatement technologies and know-how tends, on the long run, to minimise differences in costs, for a specific technology, which are due to generic factors. According to this principle e.g. the investment in a new 300 MWE unit burning imported hard coal with the same sulphur content will be the same in Ireland, Portugal or Germany. Data on investments and costs are mainly based on German data since these data are based on large scale, relevant Western European experience.
The costs module consists of two submodules:

- sulphur dioxyde
- nitrogen oxides

For more details reference is made to technical document I.

5.2.2. Sulphur dioxide control options

The techniques for SO_2 emission control which have been considered are:

- Flue gas desulphurization (FGD) (gypsum processes)
- Fluidized Bed Combustion (FBC)
- Dry Sorbent Injection (DSI)
- Use of low sulphur coal (0.60-0.75 %S)
- Use of low sulphur heavy fuel oil (0.5-1.0 %S)

Table 5 summarises the control possibilities and gives an impression of the costs presently derived from the costs module.

Table 5. SO_2 control options: costs and removal efficiencies

Control option	Investment (ECU/KWe)	Annual costs (ECU/ton SO_2)	Removal efficiency
* flue gas desulphurization	74-226 *	340- 960 *	90%
* low sulphur coal	0	0	#
* low sulphur heavy fuel oil	0	400-1120	#
* fluidised bed combustion	0	0 0	50-70%
* sorbent injection	103 *	965 *	50%

* Resulting costs depend on generic and country specific factors
# Depends on reference case.
Technical document I (section 2) contains further details.

Use of low sulphur fuels is a straightforward way to achieve abatement. The emission standards for large (>300 MWth) plants however can not be met. Coal with the necessary very low sulphur content is not available, while the costs of very low sulphur fuel oil (< 0.1 %) are prohibitive compared with those of other abatement techniques.
In the case of oil combustion, emission standards of plants with capacities in the range of <100 MWth and 100-300 MWth can be met using oil with a sulphur content of 1.1 %. Costs depend on the initial sulphur content. For economic reasons, fuel oils are used with sulphur contents up to 3.5 % at present within the EC.
Coal with a sufficiently low sulphur content (some 0.7%) for use in smaller plants, is available on the world market with little sulphur premium (Sulphur premium: extra costs of fuel oil per percent sulphur). However, coal use is often connected with local reserves which will continue, thus prohibiting use of imported low sulphur coal.
Dry sorbent injection, a recently developed technique, refers to the injection of cheap SO_2 absorbing chemicals (limestone, lime) into the furnace. The efficiency of the process is around 50 %. Investments are

relatively low, while operating costs are high compared with FGD, a well known alternative.
Fluidized bed combustion (FBC) is a new, not yet fully developed combustion technique. From an air pollution point of view it is attractive since it is a cheap alternative for abating SO_2 emissions and at the same time NO_X emissions. At this moment it is only used in smaller (<300 MWth) plants. It is not considered as an important technique for large scale power production in the coming decade (this applies as well to all other techniques, as for instance integrated coal gassification gasturbine systems).
The proposed emission standards in the EC-directive for large plants (> 300 MWth) therefore can only be met by using FGD: flue gas desulphurization. In the use of this technique a considerable experience, especially in Germany, exists. German data have been used to construct a mathematical relation between investment and:

* size (MWe)
* sulphur content (% S)
* specific fluegas volume (m3/Kwh)

Next, equations were constructed for the annual costs:

* Capital costs (depreciation and interest)[2])
* Exploitation costs:
  - Fixed: tax, insurance, administration, maintenance and repair
  - Variable: materials (limestone, water), electricity and wages

It is concluded that in the period up to 1995 new large (>300 MWth) plants will be fitted with FGD installations in order to meet the EC-directive. Smaller plants (100-300 MWth) are preferably fitted with dry sorbent injection (if nessecary) because of too high sulphur contents of the fuel which makes FGD more expensive.

5.2.3. Nitrogen oxides control options

The technologies considered are:

- Selective Catalytic Reduction (SCR)
- Combustion Modification (CM)
- Two Stage Combustion (TSC) [3])
- Fluidised Bed Combustion (FBC)

Some key information is given in Table 6.

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[2]) Capital costs are calculated with country specific market interest rates and the generic economic lifetime of new and existing plants. This approach might differ from depreciation schemes and internal interest rates used by national electricity producers.

[3]) An important subcategory of combustion modification.

Selective Catalytic Reduction removes nitrogen oxides from fluegas: ammonia reacts with NO_x producing nitrogen and water. A catalyst is needed. Practical removal efficiency is ca 80 %.

Table 6. NO_x control options: costs and removal efficiencies.

Technique	Investment (ECU/KWe)	annual costs (ECU/ton NO_x)	efficiency %	Remarks
SCR	22-33	1000-1400	80	Large > 300 MWth plants
CM	4- 8	28- 30	20-40	Retrofit possible
TSC	5-10	50- 70	30-60	
FBC	0	0	50	

Combustion Modification optimizes the boiler operation to reduce the NO_x production. Parameters are operational (rates of air and fuel flows, mixing of combustion air with fuel etc.) as well as technical (burner design etc.). Some types of CM are useful in retrofit situations: Low NO_x Burners.
Two stage combustion is one of the older techniques for NO_x control. It is based on the principle of fuel rich burner operation achieved by inserting portions of the combustion air through separate ports. The technique is especially suited for (new), large, coal-fired installations.
Fluidized Bed Combustion of solid fuels is a combustion technique with several advantages, one being a relatively low NO_x production.
The operational costs of combustion modification techniques are nihil or low compared with those of SCR. Costs are only capital costs.
Ammonia and the catalyst needed to operate SCR lead to operational costs which form the majority of total annual costs. In the cost module German data was used in a relationship between investment in SCR, the size of the plant and the type of fuel (solid, oil, gas). Furthermore equations were developed for the different annual costs viz:

* capital costs (interest and depriciation)
* operating costs:
  - fixed: tax, insurance, administration, maintenance and repair
  - variable: materials (catalyst and ammonia)and energy costs (electricity and steam)

Compared to the data on costs for controlling SO_2 emissions data to control NO_x emissions are generally less well established.
In practice a combination of techniques is used in new plants to minimize or evade the use of SCR in complying with emission standards. SCR

will then only be used in plants with a capacity larger than 300 MWth if this is inevitable to meet stricter national standards (Germany) or to comply with the bubble concept.

5.3. Costs and investments

5.3.1. Introduction

The costs of the Directive for most countries are to a large extent determined by the requirement of the bubble; the emission standards for new power plants only would demand less efforts [4]).
But there are some exceptions. Several countries, Denmark, the Federal Republic of Germany and the Netherlands carry out their own national control policies. Other countries, France and Luxembourg, for example do not need to abate emissions at all. In this section first costs and investments of the control of SO_2 emissions are presented. Subsequently the costs and investments of abatement measures for NO_X are presented.

5.3.2. Sulphurdioxide

Absolute level of costs and investments

Table 7 summarizes the measures, costs, investments and emission reduction for those countries that are to take measures to meet the Directive. The annual costs are the final level of cost in 1995. The final level of costs results from the amount of emission abated and the (average) costs per ton abated. The amount of emissions to abate was explained in the previous chapter (Future emissions: reference case). Differences in costs per ton (see also table 8) can be explained as follows.
Compared to the EC average, costs per ton avoided are high in Belgium due to the small size of the coal-fired units, as well as the low operating hours and restricted lifetime of the oil fired plants.
Danish costs per ton abated are relatively low. Some 25% of the abatement is reached by low sulphur fuel oil (400 ECU/ton); the size (± 400 MWe) and operating hours of the coal fired units that use flue gas desulphurization are high.
Costs per ton of the German policy are slighty higher due to its large program of retrofitting power plants.
Despite the high operating costs of sorbent injection in Greece the very low capital costs of this technique result in low costs per ton

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[4]) Probably also for all new plants (including industrial installations). We remind the reader that no estimate was made for the abatement measures and costs of meeting the emission standards for new industrial plants.

Table 7. Measures, investments, costs and emission reduction for SO_2 (figures in million ECU of 1985).

Country	Measure	Size (MWe)	Investments (1985-1995)	Annual costs (1995)	Emission reduction (Kton)
Belgium	FBC + lime	105	0	0.5	3
	FGD existing	1540	238	45.5	64
	TOTAL	1645	238	45.9	67
Denmark	FGD new	928	143	28.3	55
	FGD existing	3147	292	55.3	95
	1% S fuel oil	-	0	19.5	44
	1.2%S in coal	-	0	0	2
	TOTAL	4075	436	103.1	201
Greece	S.I.new	300	311	0.9	25
Germany#	FGD new	16186	1567	306.8	733
	FGD existing	19447	2623	532.6	737
	FGD industry	6267	580	133.2	247
	TOTAL	41900	4770	972.6	1716
Ireland	FGD new	276	29	7.1	13
	FGD existing	953	139	32.5	51
	TOTAL	1229	168	39.6	64
Italy	FGD new	15280	1175	224.6	389
	FGD existing	5298	1144	214.2	364
	TOTAL	20578	2319	438.9	753
Nether-lands	FGD new	1800	152	29.6	67
	FGD existing	2681	332	59.0	100
	FGD industry	720	148	34.0	53
	0.8% S in coal	-	0	0	23
	1.0% S fuel oil	-	0	5.5	14
	TOTAL	5201	633	128.2	256
Spain	FGD new	2529	261	48.2	104
	FGD existing	2122	239	44.3	77
	TOTAL	4651	500	92.5	180
United Kingdom	FGD new	3552	439	79.9	201
	FGD existing	19450	2721	548.1	1143
	TOTAL	23002	3160	628.0	1344

note: FGD: flue gas desulphurization, S.I.: sorbent injection,
FBC: fluidised bed combustion.
\# : Measures before 1985 excluded. If the were included annual costs would be 1180 million ECU/annum and investments up to 1995 amount to 5.8. billion ECU.

avoided.
In Ireland costs per ton are high since most of the plants need retrofitting. This, the high interest rate and the high electricity price explain the relatively high capital and operating costs per ton abated.
Although capital cost per ton abated are relatively low in Italy, since most of the plants are new, operating costs per ton avoided are high due to the low sulphur content.
The cost per ton abated for the Netherlands are somewhat below EC average. This is mainly due to the large size (600 MWe) of new planned coal fired units and the use of cheap low sulphur fuels, despite the higher costs of FGD in refineries and some converted coal fired power plants. In spite of the higher investment, due to the high chlorine content in the British coal and retrofitting, costs per ton SO_2 avoided are below EC average. The main explanation is the relatively large size of the units (some 600 MWe). In addition the high sulphur content in the coal involves a large amount of emission abated per FGD unit leading to low costs per ton abated.

Table 8. Investments and costs of reducing SO_2 emissions (in million ECU's in 1985 prices)

Country	Investments (1985-1995)	Annual costs (1995)	Emission abated ton (kton)	Costs per abated (ECU/ton)
Belgium	238	45.9	67	685
Denmark	436	94.6	201	471
France	0	0	0	0
FRGermany*	4769	976.6	1716	569
Greece	31	10.9	25	436
Ireland	168	39.6	64	619
Italy	2319	438.9	753	583
Luxembourg	0	0	0	0
Netherlands	633	128.2	256	501
Portugal**	0	0	0	0
Spain	500	92.5	180	514
United Kingdom	3160	628.0	1344	467
EEC	12253	2455	4606	533

* excluding measures taken before 1985

** For Denmark, Germany and the Netherlands figures refer to their national control policy. These countries do more then meet the bubble.

Costs as percentage of the gross domestic product

Figure 3 depicts the total annual abatement costs in 1995 as percentage of the Gross Domestic Product in each country. Although crude it permits some analyses of the differences in macroeconomic impact for each country.

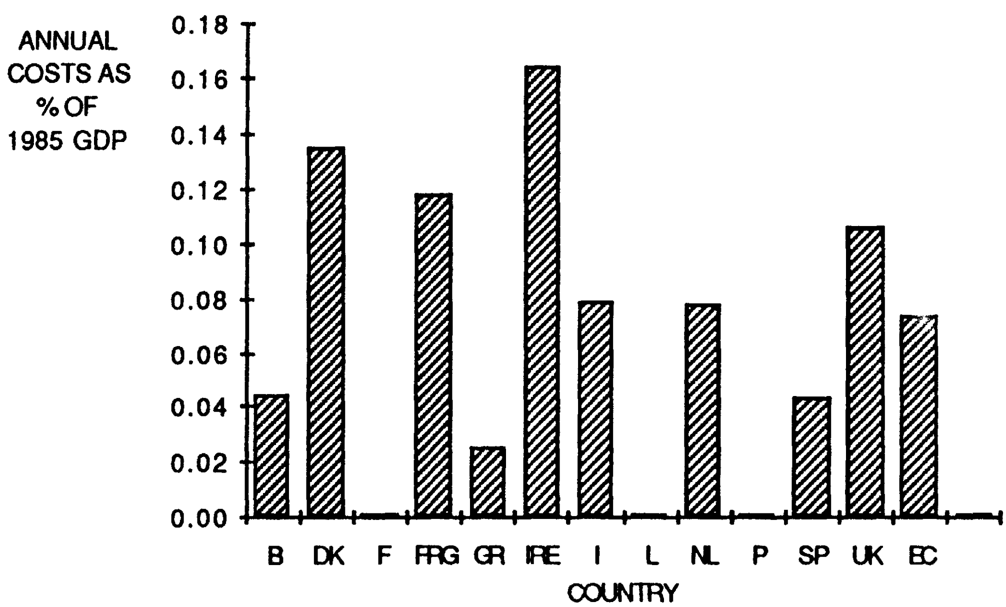

Figure 3. SO_2 abatement costs in 1995 (in constant prices of 1985) as percentage of the 1985 gross domestic product (GDP).

Average annual costs in the EC are not very high (0.074% of unweighted GDP in 1985) compared to the total environmental expenditures in some European countries which are in the range of 0.5 - 1.7% of GDP (OECD, 1984). Striking, compared to the EC average, are the high costs in Germany, Denmark and Ireland. In Denmark as well as in Germany this is due to their own stringent policy. If measures effectuated in Germany before 1985 are taken into account costs are even higher (0.14% instead of 0.12% of GDP). The costs for Ireland are high because their GDP is low and abatement costs are high with their increase in coal-related sulphur emissions.

Costs are high in the United Kingdom mainly as a result of the required 45% reduction. Will the additional exceptions of Italy and the Netherlands, all other countries costs have costs (far) below the EC average.

5.3.3. Nitrogen oxides

Absolute level of costs and investments

Table 9 summarises the measures, related costs and investments, as well as the emission reduction for NO_x.
The final level of NO_x control costs (in 1995), as well as the costs per ton abated for each country are presented in table 10. The amount of emissions to be abated to meet the bubble part of the Directive is the main determinant for the level of costs[5]). There is one exception. Germany carries out its own legislation and does far more then meeting the Directive. Differences in the costs per ton abated can be explained as follows.
The Directive leads to low costs for Belgium, Ireland the Netherlands and Spain since the amount of emissions to be abated is small and the necessary reduction can be reached by combustion modification in combination with two stage combustion. In Denmark and the United Kingdom costs are still low but more existing plants need retrofitting. Minor differences in costs per ton avoided are mainly the result of differences in emission factors as well as differences in operating hours and the share of retrofit versus newfit.
More striking are the results for Italy, Germany and Portugal. In these countries catalytic reduction is inevitable leading to relatively high average costs per ton abated. In Italy and Portugal costs per ton are below that of Germany. This is due to the relatively large amount of emissions abated by cheap techniques such as combustion modification whereas in Germany SCR is the main abatement technology.

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[5]) France and Luxembourg will have some, negligible costs for their new industrial plants. These have not been included due to insufficient data on the size distribution of industrial plants.

Table 9. Measures, investments, costs and emission reduction for NO_x (figures in million ECU of 1985)

Country	Measure	Size (MWe)	Investments (1985-1995)	Annual costs (1995)	Emission reduction (Kton)
Belgium	FBC	105	0	0.0	1
	CM existing	2348	19	1.9	15
	TSC	560	7	0.5	5
	TOTAL	3045	26	2.4	21
Denmark	TSC new	1506	7	0.8	22
	TSC existing	2570	30	2.7	38
	CM existing	3280	27	3.0	17
	TOTAL	7356	65	6.5	78
Germany	SCR + CM new	15278	455	186.7	230
	SCR + CM exist.	12955	495	267.6	221
	CM new + old	23839	183	17.6	13
	SCR industry	11754	365	177.8	112
	CM industry	-	132	17.2	54
	TOTAL	53826	1620	666.6	727
Ireland	TSC	1104	11	1.3	10
	CM existing	1399	11	1.5	10
	TOTAL	2503	22	2.8	20
Italy	TSC existing	2478	27	2.0	36
	CM new+old	27473	217	21.8	130
	SCR + CM	13820	333	165.0	294
	TOTAL	43771	577	188.8	460
Nether-lands	TSC new + old	2838	15	1.0	22
	CM new + old	8362	60	5.3	23
	FBC industry	-	0	0.0	1
	CM industry	-	3	0.3	2
	CM extra	615	5	0.4	4
	TOTAL	11815	83	7.0	52
Portugal	CM new+old	2838	15	2.5	27
	TSC existing	600	7	0.7	10
	SCR new+old	1800	120	25.6	26
	TOTAL	4238	149	28.8	63
Spain	TSC new	4101	22	1.5	64
	CM existing	3550	29	2.7	37
	TOTAL	7651	51	4.2	95
United Kingdom	TSC new	4802	26	1.9	56
	CM existing	32570	263	25.9	283
	TOTAL	23372	289	27.8	339

note: measures refer to power plants unless otherwise stated.

Table 10. Investments and costs of reducing NO_x emissions (in million ECU's in 1985 prices)

Country	Investments (1985-1995)	Annual costs (1995)	Emission abated (kton)	Costs per ton abated (ECU/ton)
Belgium	26	2.4	21	114
Denmark	65	6.5	78	83
France	0	0	0	0
FRGermany*	1620	666.6	727	917
Greece	0	0	0	0
Ireland	22	2.8	20	140
Italy	577	188.8	460	410
Luxembourg	0	0	0	0
Netherlands	83	7.0	52	135
Portugal	149	28.8	63	457
Spain	51	4.2	95	44
United Kingdom	289	27.8	339	82
EEC	2882	934.9	1878	498

* figures are those of the present national policy which is more than sufficient to meet the bubble.

Costs as percentage of the gross domestic product

Figure 4 depicts the annual costs as percentage of the Gross Domestic Product in each country.
Generally the costs as % of GDP are close to nil, except for Portugal and Germany where costs amount to 0.11% and 0.08% respectively of GDP. In Portugal the absolute level of costs may not be impressive but the 1985 GDP was not very large (28 billion ECU) whereas in Germany both abatement costs as well as GDP (827 billion ECU) are large. In Italy costs/GDP are slightly above EEC average of some 0.03% of GDP. In Ireland costs as percentage of GDP are not quite nil since GDP in Ireland is, also very low (24 billion ECU).

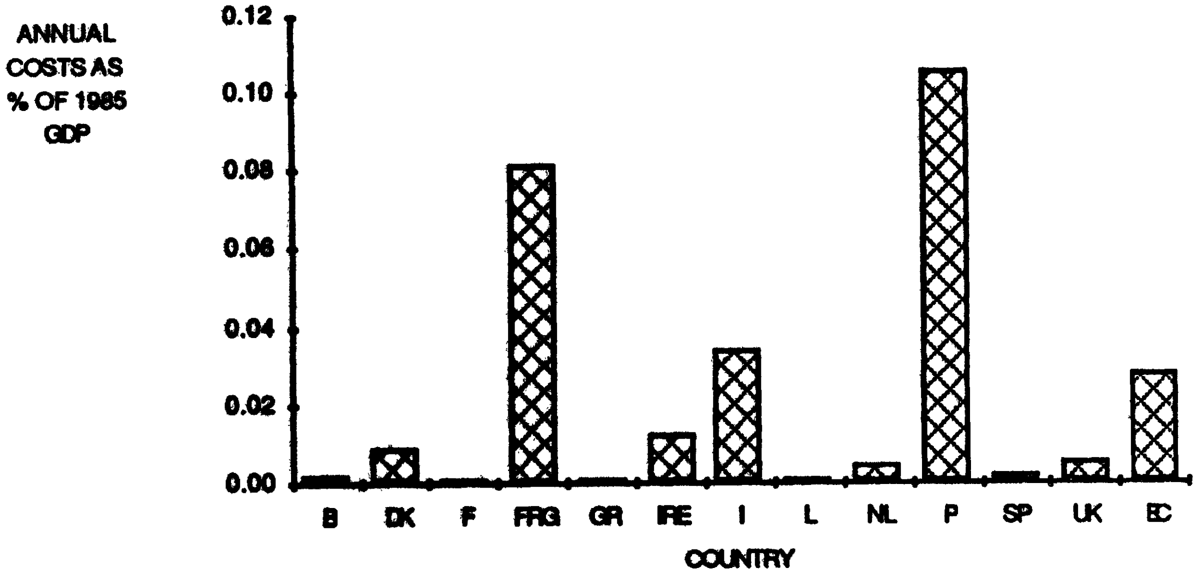

Figure 4. NO_X abatement costs in 1995 (in constant prices of 1985) as percentage of the 1985 gross domestic product(GDP).

5.3.4. Costs of abating SO_2 and NO_X emissions

Absolute level of costs and investments

Table 11 summarises the investments and costs of both SO_2 and NO_X emissions. In an absolute sense the costs and investments are very large in the Federal Republic of Germany due to their stringent national policy. The efforts of Italy and the United Kingdom in response to the Directive are also reasonably high. This is mainly the result of their SO_2 abatement costs and investments being high.

Table 11. Investments and costs of reducing SO_2 and NO_X emissions (in million ECU's in 1985 prices)

Country	EEC target reduction (% of 1980)		Investments (1985-1995)		Annual costs (1995)		Emission abated (kton)	
	SO_2	NO_X	SO_2	NO_X	SO_2	NO_X	SO_2	NO_X
Belgium	45	30	238	26	46	2	67	21
Denmark	45+	30	436	65	103	7	201	78
France	45	30	0	0	0	0	0	0
FRGermany	45+	30+	4769	1620	977	667	1716	727
Greece	0	0*	31	0	11	0	25	0
Ireland	0	0	168	22	40	3	64	20
Italy	45	30	2319	577	439	189	753	460
Luxembourg	0	0	0	0	0	0	0	0
Netherlands	45+	30	633	83	129	7	256	52
Portugal	0*	0	0	149	0	29	0	63
Spain	10	10	500	51	93	4	180	95
United Kingdom	45	30	3160	289	628	28	1344	339
EEC	45	30	12253	2882	2455	935	4606	1878

* granted an increase

\+ actual reduction exceeds the required EC target (a minimum reduction)

Costs as percentage of the gross domestic product.
In figure 5 costs as percentage of the 1985 gross domestic product are depicted.

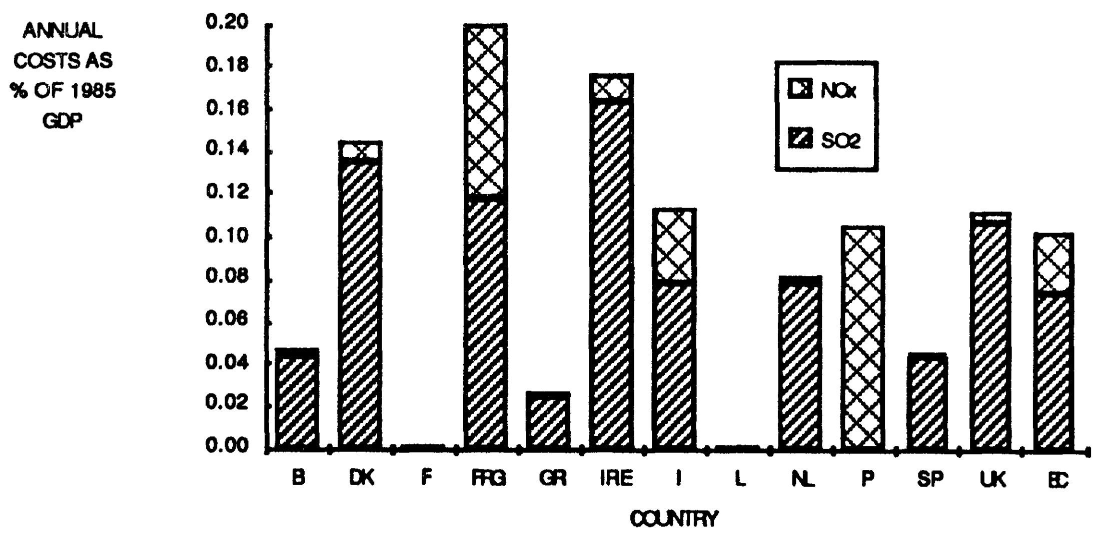

Figure 5. NO_X and SO_2 costs (in constant prices of 1985) as percentage of the 1985 gross domestic product(GDP).

Average annual abatement costs in the EC are not very high (0.10% of GDP in 1985). Costs are relatively high, compared to the EC average, in Germany, Denmark and Ireland. In Denmark as well as in Germany this is due to their own stringent policy. If measures effected in Germany before 1985 are taken into account costs are even higher (0.14% instead of 0.12% of GDP). Costs for Ireland are high since their GDP is low and SO_2 abatement costs are high with their increase in, coal-related, sulphur emissions. Costs in the United Kingdom and Italy are mainly the result of the required 45% SO_2 reduction. In Portugal costs are high since NO_x abatement costs are high compared to the gross domestic product.

Impact on electricity prices

Generally the impact on the electricity production costs (figure 6, next page) shows a comparable picture to that of the costs as % of GDP. Differences are due to differences in electricity intensity (electricity consumption/GDP) and the share of fossil fuels in electricity production. Figure 6 presents the increase in production costs in ECU/100 Kwh for the total domestic electricity consumption. Only costs for electricity generation are included; costs of industrial measures are excluded. For SO_2 the EC average is 0.12 ECU/100 Kwh. As a result of the Directive the industrial electricity price for large scale use, might rise for most countries between 1 and 3.5%. The impact on the electricity price for consumers is smaller since the average electricity price is higher. For several countries their impact is somewhat overestimated since costs were based on the assumption that only power plants would take abatement measures. These impacts occur only from 1995 onwards if all abatement measures are taken.

In Denmark the impacts of abating SO_2 emissions on electricity production costs are high due to its nearly fully (95%) coal based electricity production. In Germany costs are low since 40% of the electricy is produced in non-fossil installations although electricity consumption per unit of GDP is very low. If SO_2 abatement measures taken in Germany before 1985 are included, the impact on electricity price is comparable with that of Denmark (0.23 ECU/100 KWh). In Ireland the electricity intensity is quite high so the impact on electricity price is less striking as the costs as percentage of GDP. Still the impact in Ireland is rather high compared to the relatively minor impact in most countries.

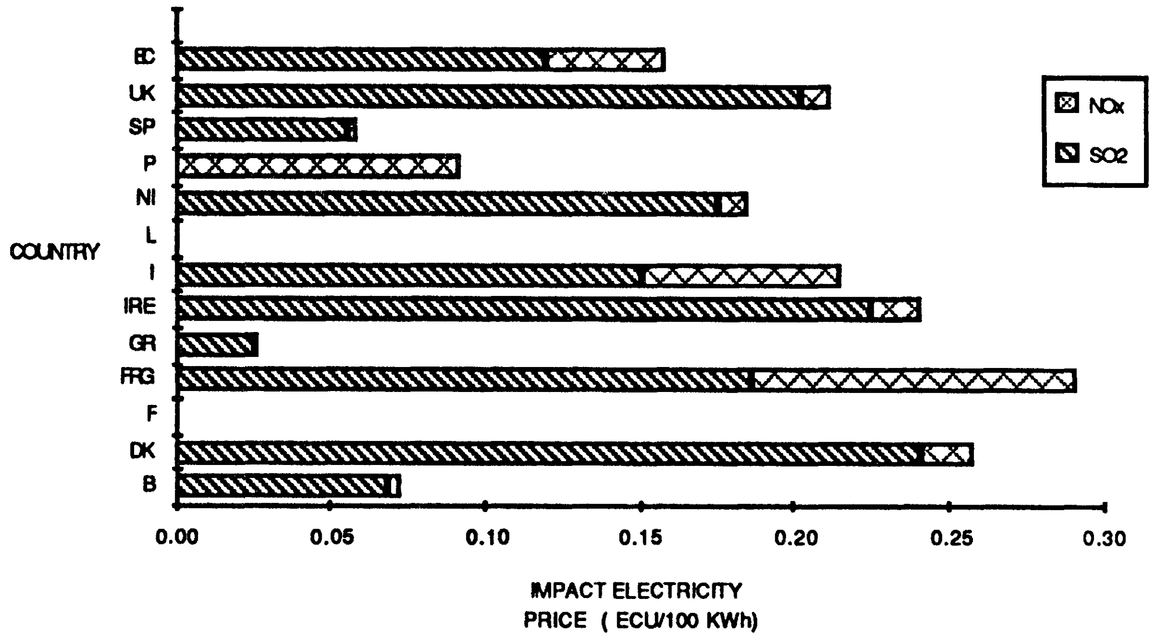

Figure 6. Impact of SO_2 and NO_X abatement on the average electricity production costs.

In general the impact for NO_X abatement does not exceed the level of 0.02 ECU/Kwh. The average EEC impact (0.04 ECU/100Kwh) is only one third of the impact for SO_2. The impacts for Portugal and Germany are comparable. The lower electricity intensity of the well developed German economy raises the costs per Kwh somewhat whereas in Portugal the high electriciy intensity decreases the cost per KWh. In both countries the share of non-fossil fuels (40%) is comparable although the composition is somewhat different. In Italy the electricity intensity equals that of Germany. The share of non fossil fuels is less prominent (20%) forcing costs/Kwh up somewhat.

The combined impact of both SO_2 and NO_X is not very striking either. The highest is in Germany (0.3 ECU/100 Kwh) which corresponds with an average increase of some 5% in the industrial electricity price. The impact in the Netherlands will be an increase of some 3%. The costs of SO_2 abatement are major component in the total costs, except for Portugal and Germany.

5.4. Discussion on sensitivity

Main discussion points

Several factors have a major impact on the results of the analysis on costs, investments and emission reduction:

- the amount of emissions to be abated to meet the bubble
- the assumption that costs are comparable per country for a specific abatement technique; unless the defined country specific factors vary.
- the assumptions made on the abatement strategy for each country e.g. the assumption that the abatement of emissions from all large plants would take place via abatement measures on new and, if necessary, existing power plants
- the fact that no (firm) estimate was possible of the emissions and costs of the emission standards for new industrial plants.

The amount of emissions to be abated

The amount of emissions to be abated depends on the contribution of large combustion plants to the total emissions. As stated there is uncertainty on the present amount of fuel burned especially in industrial plants above 50 MWth. In addition it should be noted that there is even more uncertainty on the future amount of fuel burned in such combustion installations.

The recent drop in the oil price is not likely to have a major impact on the emissions to be abated. For Spain and Portugal IEA figures used for fuel use in industry, compared to the "Energy 2000" used for other EC countries, show higher growth rates of energy demand. More uncertain seems to be the energy use for electricity generation especially in Italy. In addition NO_X emissions in 1980, as well as future emissions are less firm than those for SO_2.

The costs per ton abated

Differences in costs accross countries, due to generic factors, tend to be minimised due to existence of an international market for abatement technologies. National preferences to buy domestic equipment, even if this is more expensive, interfere to a certain extent with this principle. Practical experience in Denmark, Germany and the Netherlands suggest that such preferences do exists but did not lead to significant differences in costs. This might well be different for other EC-countries. For these countries however no practical experience exists. Moreover one might doubt if surplus costs caused by these national preferences can be attributed to pollution control or must be seen as support for the home industry. Still differences might occur be it only for differences in costs of production factors as labour. For SO_2, compared to other information on the costs per ton abated (ADL, 1984), estimates made here might somewhat underestimate the costs for Ireland, Spain and the United Kingdom. A thourough comparison however was impossible due to lack of insight in the underlying assumptions of the ADL study. For NO_x costs are more uncertain since less experience exists.

Abatement strategies per country

The costs of abating SO_2 for all countries except Germany, Denmark and the Netherlands were primarily based on the application of FGD on new and, if needed, existing plants. This leads to an overestimate of the costs since the application of cheaper abatement options, such as low sulphur coal and dry sorbent injection for existing power plants and new industrial plants, is not taken into consideration.
For the abatement of NO_x the potential of applying cheap abatement techniques to new industrial installations was not used. This again might lead to an overestimate of costs since relatively more expensive techniques, such as CM on existing plants and SCR on new plants, could have been avoided.
On the other hand for some countries, e.g. France and Luxembourg, it is an underestimate of the costs since for these countries complying with the emission standards for all new plants could be more demanding than the abatement required under the bubble concept. To explore the order of magnitude of the error introduced an estimate was made on the impact of the proposed emission standards for SO_2 for new industrial plants as a sensitivity analysis.

Sensitivity for emission standards on new industrial plants

The exclusion of abatement measures on new industrial combustion plants, needed to meet the emission standards, introduces some questions:

* Which abatement measures will be taken for new industrial combustion plants to meet the emission standards for SO_2 and NO_x in the flue gases?
* What amounts of SO_2 and NOx are abated in new industrial plants if these are to meet these emission standards?
* If these emission reductions are taken into account, to what extent will bubble emission levels be met, and what will it mean with regards to the retrofitting existing power plants?
* What are the associated costs? Will total investments and annual costs differ significantly if estimates for new industrial plants are included?

An effort has been made to answer these questions, for the abatement of SO_2. In the calculations a number of assumptions had to be made regarding:

- fuel characteristics
- size distribution of the new industrial plants (>300, 100-300, 50-100 and < 50 MWth)
- operating hours of plants

These resulted in data for future fuel combustion in large industrial plants by size category.
The next - plausible - assumption is that for plants with a power > 300 MWth flue gas desulphurisation is the most appropriate way to meet the emission standards, while for plants with capacities between 100 and 300 MWth, dry sorbent injection is the likely technique because of its relatively low costs. In case of oil combustion use of low sulphur fuel oil is an abatement option for small plants as well. Finally it was assumed that as a result of the abatement measures for new industrial plants, the most expensive measures on existing power plants were avoided[1]).
Conclusions from the sensitivity analysis are as follows.
For Ireland it seems that by the necessary abatement of emissions from new industrial plants expensive abatement (retrofit FGD) on power plants could be avoided. In Portugal, Spain, France and Greece the application of emission standards for new power as well as industrial plants demands more efforts than only the emission reduction under the bubble concept. Costs are thus underestimated; for the remaining countries differences are not significant.

5.5. Conclusions

With respect to the control of SO_2 emissions the EC as a whole is expected to invest 12.3 billion ECU up to 1995 (in constant prices of 1985) upon application of the draft Directive. Total annual costs are 2.5 billion ECU in 1995. To control NO_X emissions the EC has to invest some 3.3 billion ECU until 1995. Annual costs are 0.9 billion ECU.

In an absolute sense Germany, Italy and the United Kingdom bear most of the costs of controlling SO_2 emissions; in the case of NO_X the costs are mainly borne by Germany and to a lesser extent Italy.
Compared to the 1985 gross domestic product the efforts of Germany (reflecting their stringent national policy), Denmark (mainly national SO_2 policy) and Ireland (due to SO_2 reduction) are relatively high. Belgium, France, Greece, Luxembourg and Spain are below the EEC average (0.1% of GDP) especially since the amount of emissions to be abated is small. The need to apply selective catalytic reduction to control NO_X explains the high costs for Germany (own policy), Italy and Portugal. Generally costs to control NO_X are negligible.
The overall impact on the electricity production costs, as an EEC average, is some 0.16 ECU per 100 Kwh which corresponds to an increase in the electricity price for industries of 2.5 to 3.0%. For Italy and the Netherlands the impact is more severe due to a relatively high share of fossil fuels in electricity generation and the low electricity intensity (Kwh/GDP) of the economy. In Portugal the impact is lowered

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[1]) Details are to be found in technical document I.

due to the high electricity intensity, and the large share of non-fossil fuels in electricity generation.
The obtained results are probably most sensitive to the amount of emissions to be abated, the costs per ton abated, the assumed strategy of abating all large plants emissions via measures on power plants only, and the exclusion of explicit abatement measures related to the emission standards proposed for new industrial plants. A sensitivity analysis for SO_2 shows that if an estimate for the compliance with emission standards for new industrial plants is included costs, investments and emission reduction do not change very much. France, Greece, Protugal and Spain are exceptions - costs are probably higher - and also Ireland - costs lower.

6. RESULTS WITH INTERLINK

6.1. Introduction

The macroeconomic impact of the Directive on large combustion plants, as simulated with the adapted OECD INTERLINK model, is the subject of this chapter. Attention is focused on second and higher order effects on key indicators of national economic activity of pollution control investments and costs. This macroeconomic analysis deals with aggregate indicators which express broad totals and averages for the whole economy, such as: gross domestic product, employment, consumer prices, current balance, private consumption, business investments and government financial balances.

In this contribution only the most important variables, as calculated with INTERLINK, are presented:

- gross domestic product which represents the value of the total production, or output of goods and services, within a country. The indicator is important since it chiefly determines the real national income and, on the short term, influences employment;
- business fixed investment: the investments of the business sectors in capital goods such as (pollution control) equipment and machinery;
- employment;
- private consumption;
- current balance, or the balance of payments on the current account, includes all payments made because of current purchases of goods and services. The main item is the trade balance, the difference between the dollar value of exports and imports. The current balance indicates to what extent policy makers have freedom to pursue national economic targets;
- government financial balance is viewed as the difference between the revenues and expenditures of the government;
- consumer prices. Prevention of inflation is one of the targets of economic policy because a high price level may have a negative effect on the competitive position and production capacity of a country.

To simulate the macroeconomic impacts with INTERLINK it has been assumed that the investments in pollution control equipment, in order

to meet the Directive, take place in the period 1988 - 1993. The macroeconomic impact however was also simulated for the period 1994 - 1997, a period in which no such investments take place. This was deemed necessary since the influence of pollution control costs is fully reflected in the economy only in the longer term.
To simulate the impacts first a reference or baseline projection is made of the economic development without the pollution control programme. Next a projection is made which includes the pollution control measures. Differences in the resulting economic indicators (e.g. employment) between projections can be ascribed to the pollution control meausures. These differences are discussed in this section. They are generally presented as average annual percentage differences over the baseline projection for the specific period: 1988 - 1993 and 1994 - 1997. Only the influence on the current account is expressed as an annual difference in billion dollars.
The assumptions made for these calculations are described in section 6.2.(Input and assumptions). The results for the control of sulphur dioxide emissions are presented and explained in section 6.3. (Results for SO_2). Results for NO_X are the subject of section 6.4.. Section 6.5. shows the combined impact of reducing SO_2 and NO_X emissions. Section 6.6. compares the size of the impacts with past changes in economic indicators. Elements of uncertainty in the results are discussed in section 6.7. Finally the main conclusions of the analysis are displayed (section 6.8.).

6.2. Input and assumptions

As explained in Chapter 2 a number of key factors will influence the macroeconomic impact in each country:

* the absolute and relative size of the pollution control investments and costs;
* the capital and labour intensity, as well as the import coefficient of the pollution control measures;
* the mode of financing the investments (capital market, government subsidies, internal business financing);
* the monetary, exchange rate and budgetary (fiscal) policy of the country;
* the prevailing economic circumstances (e.g. unemployment, overcapacity;
* the transmission of:
  - pollution control costs into prices of final demand categories (e.g. consumer prices);
  - prices in wage changes (wage price indexation);
* dependence on international trade especially with other EC countries (the extent of intra-EC trade and its geographical source and destination).

The absolute and relative size of the costs and investments were dealt with in the preceding chapter. Furthermore it is assumed that the pollution control investments take place in the period 1988-1993.
With respect to the remaining key factors the following should be noted. The direct import coefficieny of the pollution control investments corresponds with that for total investments. This assumption is made since no data were available on the import coefficient for air pollution control equipment despite documentation on the environmental industry (Metra/CITEPA, 1984).
Pollution control investments are financed as traditional business fixed investments. Available data (ERL, 1984) on pollution control subsidies for industry did not allow a comprehensive and uniform inclusion of special subsidies for environmental investments for all EC countries.
No direct crowding-out (offsetting reduction) of traditional business fixed investments is expected to take place since the electricity generation sector takes the majority of the investments. Such a crowding-out might otherwise result from limited financial means for investment. The electricity generation sector usually is a publicly owned sector and postponement of investments in electricity generation due to financial constraints is not very likely. However, a more indirect negative impact on investments is included in the analysis: pollution control costs, via a decline in business profits, exert a negative influence on business investments.
As a technical assumption nominal interest rates are kept constant. In practice this assumption could hold, if monetary policies are fully accomodating. In such a case a possible upward pressure on the interest rate is compensated by a balancing change in money supply in such a way that nominal interest rates remain constant[1]). This assumption corresponds with a continuation of past policies (OECD, 1987).
In addition the volumes of government consumption and investments are constant in real terms; a change in the government financial balance will not affect the level of government consumption and investment. In the absence of information on the budgetary policy this seems plausible.
Furthermore, nominal exchange rates are fixed; the nominal exchange rates remain unchanged from a period shortly before the projection was made. This is a customary technical assumption made by the OECD (OECD, 1987).
In section 6.7 (Elements of uncertainty) the possible impact on the macroeconomic results of changes in these assumptions is investigated.

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1) A sensitivity analysis was carried out assuming non-accomodating monetary policy. In that case the additional demand for money to finance the environmental investments is reflected in a rising nominal interest rate (see section 6.7).

The extent of 'openness' of a country as well as the import share, prevailing economic conditions and the transmission of environmental costs into prices and into wages are discussed in the following sections.

6.3. Results for SO_2

6.3.1. Introduction

Although the macroeconomic impacts differ across countries, the results display the same basic pattern (see table 12). During the period in which the investments take place (1988-1993) indicators of real activity, such as gross domestic product, are positively influenced. After the investment period (1994-1997) however, the environmental costs induce a fall back. First this basic pattern is explained. Subsequently the differences in country results are adstructed.

6.3.2. Basic pattern

Investment period (1988-1993)

During the investment period the basic pattern for the main indicators can be explained as follows.

Gross domestic product is stimulated. Firstly since business fixed investment is influenced positively by the pollution control investments. To the extent that the environmental equipment is produced domestically, domestic demand for capital goods is raised and consequently output increases and income is generated. Imports of the investments, and of the materials and energy to exploit them, have a positive influence on the gross domestic product of other countries since their exports are raised. Due to the coordinated EC action the latter impact is important.

Business fixed investment levels are not only higher through environmental investments, but also due to the positive impact of the rise in gross domestic product (accelerator). During this period the positive impacts on business fixed investments are more important than the negative influence resulting from pollution control costs.

The increase in employment during the investment period is mainly caused by the increase in the general level of activity (as measured in the gross domestic product). Exploitation of the pollution control equipment generates little direct permanent employment.

Private consumption is only slightly positively or negatively influenced. This is the consequence of two opposing forces. On the one hand national income increases because of the higher level of final demand. On the other hand real consumer income is reduced since pollution control costs are raised. The changes in real income and real consumption are the result of changes in nominal income, current prices and wages; against a positive impact on the size in nominal income stands an increase in consumer prices. As a result real household disposable income as well as consumption is hardly affected.

Consumer prices are higher due to the pollution control costs which are passed on to consumers, partly directly and partly via price changes. In addition wage indexation and import of price increases, resulting from pollution control costs in foreign countries, influence prices as well.
In general the current balance deteriorates in the investment period. This is mainly the consequence of the additional direct and indirect import connected with the environmental investments and more generally with the higher level of gross domestic product. This additional import is only partly counterbalanced by an increase in the volume of exports which results from an increase in market growth. World trade volume rises as a result of the coordinated EC action. Export as well as import prices are both higher due to the environmental costs.
Government financial balances, the difference between revenues and expenditures, are positively influenced. The increase in national income leads to an increase in government tax revenues. In addition the social security payments are lower because employment is raised. These positive influences balance the negative impact of additional investment subsidies.

After the investment period (1994-1997)

In this period the indicators of real activity show an opposite movement in comparison to the first period in most countries. Price levels however generally remain on a structurally higher level. Gross domestic product and business fixed investment fall below reference levels.
One explanation is the fact that there are no pollution control investments taken in this period (neither in the home country nor abroad). Once gross domestic product falls the accelerator effect will add to the decrease in investments. Moreover business fixed investment levels are negatively influenced due to the erosion of business profits resulting from pollution control costs and wage claims. This impact is also of importance in the first period but floats to the surface after the investment period. Furthermore the increase in price levels result in a deterioration of the competitive position of the EC member states over non EC countries. As a consequence export volumes will reduce.
Employment levels are negatively influenced in this period although employment in some countries remains positive. The negative impact is mainly due to the drop in total expenditures: exports, consumption, as well as investments. A positive impact results from a relative improvement in competiveness in certain countries.
The current balance improves in this period with few exceptions. Import volumes are lower since the aggregate levels of expenditures are lower. Furthermore export volumes are negatively influenced due to the fall in world trade volume and the increase in relative export prices.
Consumption levels are below baseline levels and consumer prices are still higher in this period; consumers are confronted with the structural higher level of pollution control costs and the gross domestic pro-

TABLE 12 Macroeconomic impacts of reducing SO_2 emissions

	BLX	DEN	FR	GER	GRE	IRE	ITA	NET	POR	SPA	UKM
Gross domestic product											
1988 - 1993	0.12	0.17	0.04	0.13	0.06	0.12	0.08	0.12	0.08	0.09	0.06
1994 - 1997	-0.03	+0.00	0.03	-0.06	0.05	-0.21	0.03	-0.08	0.03	0.03	-0.05
Business fixed investment[1]											
1988 - 1993	0.60	1.30	..	1.11	0.16	1.15	1.12	0.79	..	0.38	1.09
1994 - 1997	-0.16	-0.20	..	-0.23	0.04	-0.62	0.16	-0.21	..	-0.02	-0.02
Private consumption											
1988 - 1993	0.02	0.01	..	-0.01	0.01	0.00	-0.03	0.01	..	0.03	-0.03
1994 - 1997	-0.08	-0.15	..	-0.06	+0.00	-0.29	-0.02	-0.03	..	-0.02	-0.11
Current balance[2]											
1988 - 1993	0.02	-0.06	0.10	-0.21	0.00	-0.05	-0.18	-0.03	-0.01	0.00	-0.22
1994 - 1997	0.03	-0.03	-0.11	-0.06	0.00	-0.09	-0.08	-0.09	-0.02	0.02	-0.13
Employment											
1988 - 1993	0.06	0.05	0.02	0.13	0.03	0.05	0.02	0.09	0.03	0.05	0.03
1994 - 1997	0.01	0.04	0.02	-0.11	0.02	-0.03	0.01	-0.04	0.01	0.02	-0.05
Consumer prices											
1988 - 1993	0.15	0.20	..	0.34	0.07	0.45	0.34	0.21	..	0.14	0.43
1994 - 1997	0.33	0.36	..	0.24	0.13	0.56	0.10	0.48	..	0.19	0.20
Government financial Bal.[3]											
1988 - 1993	0.06	0.10	..	0.13	0.01	0.01	0.10	0.09	..	0.03	0.08
1994 - 1997	0.04	0.06	..	0.06	0.00	-0.16	0.12	0.01	..	0.01	0.10

All changes expressed as average annual percentage changes from baseline levels
[1]) inclusive of pollution control investments
[2]) billion $
[3]) % of baseline gross domestic product
.. not available

duct in this period decreases. The costs of emission abatement are reflected in higher prices. A second factor causing a rise in domestic prices, such as the one for private consumption, is the increase in prices of imports from other EC countries. Moreover, wage indexation may enforce these prices increases. Eventually prices will increase more than the money wage. This causes a decline in real household disposable income to the detriment of real consumption.
Government financial balances, as percentage of baseline gross domestic product are less positively influenced than in the first period. Tax revenues decline compared to the first period since national income is on a lower level. On the other hand investments subsidies decline as well.

6.3.3. Country results for SO_2

Despite the observed similarities in results there are also differences between countries. Differences which can be explained by differences in the size of the pollution control programme, the multiplier values and the direct import coefficient of investment goods, the extent of wage indexation and the dependence on intra EC trade. Although there are differences, (see figure 7 and table 12) results for several countries are more or less comparable:

- France and Portugal,
- Greece and Spain,
- Ireland,
- The Netherlands, Belgium and Denmark,
- Germany, the United Kingdom and Italy.

France and Portugal
The macroeconomic impacts for France and Portugal are included in table 12 for only a few indicators since these countries have no abatement investments and costs. Table 12 shows that both countries benefit from the improvement in competitive position. In both countries gross domestic product is raised due to the increase in exports and consequently employment increases too.

Greece and Spain
For Greece and Spain the control of SO_2 emissions has a more favourable impact than for other countries, with the exception of France and Portugal. Although the impact on gross domestic product is not that high it remains positive during both periods: the investment period and the second period (1994-1997). Consequently in the second period business fixed investment as well as employment remain positive or become only very slightly negative. The current balance as well as private consumption and the government financial balance are hardly influenced. Consumer prices are increasing but only very modestly. The relatively low level of pollution control investments and costs is the main explanation for the small extent of the impact. The rise in prices is rela-

tively modest since the pollution control costs are low. Consequently the relative export price of both countries falls. As a result exports from Greece and Spain increase. This export impulse accounts for the increase in gross domestic product and employment during the full period 1988-1997. Since pollution control costs are low the increase in consumer prices is initially very low but the rise of import prices greatly reinforces the rise in consumer prices.

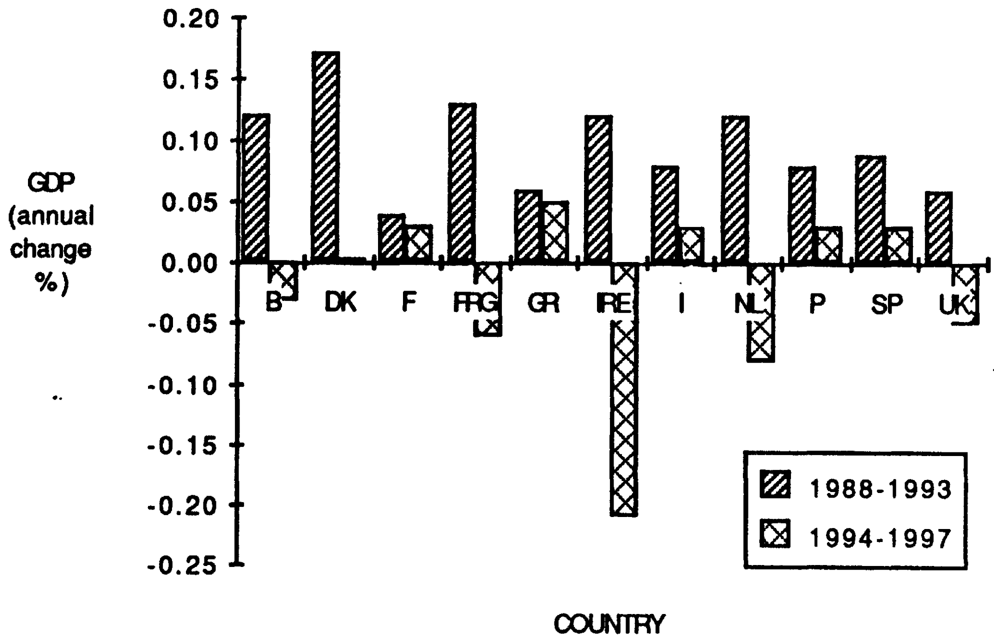

Figure 7. Impact of controlling SO_2 emissions on the gross domestic product

Ireland

The macroeconomic impact for Ireland is more negative than the basic pattern. Gross domestic product , business fixed investment and employment are still positive in the first period but rapidly become negative in the second period. Private consumption from 1994-1997 is declining more pronouncedly than in other EC-countries. The current balance and even the government financial balance, which is exceptional, deteriorate in the second period.

The relatively high level of pollution control costs is the main cause of this negative outcome. These costs cause a rise in prices, including export prices, and consequently exports decrease. This decrease in exports is the main cause of the relatively large dump in gross domestic product during the period 1993-1997; the domestic pollution control investments having raised gross domestic product during the period 1988-1993. These negative impacts are reinforced by the relatively strong dependence of the Irish economy on imports from the EC. Rising prices in other EC countries, especially the United Kingdom, have a considerable impact on the price level in Ireland. This is due to the large propensity to import and the fact that imports, originate from those EC countries, e.g. the United Kingdom, that have large domestic increases in price levels[2]). In addition the price rise is reinforced since money wages, raised in response to the increase in consumer prices, add to the initial increase in production costs. The fall in gross domestic product and the rise in prices account for the decline of consumption and employment in the period 1994-1997. The rise in prices however is a temporary phenomenon in Ireland and gradually becomes weaker at the end of the second period (1993-1997).

The Netherlands and Belgium

For the Netherlands and Belgium results are more or less comparable: impacts closely resemble the basic pattern although the overall economic impact on the Belgian economy is slightly better. Both countries are relatively open economies: export and import values amount to nearly 50% (Netherlands), and 70% (Belgium) of gross domestic product. Gross domestic product, business investments as well as employment and government financial balances are positively affected in the first period and fall slightly back in the second period. As consumer prices keep rising in the second period consumption becomes negative. The current balance reveals a difference: the Dutch balance is already negative in the first period and deteriorates further in the second period whereas the Belgian balance improves in both periods.

In both countries the import leakage is quite high, and dependency on EC trade is large. Consequently both countries are affected by the international character of the proposed EC air pollution control policy. The level of costs and investments however is twice as high in the Netherlands as in Belgium, which accounts for a large part of the differences.

Export prices rise more in the Netherlands than in Belgium due to the higher pollution control costs. Consequently exports are lower and gross domestic product and employment are more negatively influenced in the Netherlands than in Belgium. Consumption declines less in the Netherlands than in Belgium: this can be explained by the fact that in the Netherlands money wages are less negatively influenced by price increases than in Belgium. As a result the current balance and connected employment are still positive in Belgium from 1994-1997 whereas employment and current balance in the Netherlands become negative.

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[2] The propensity to import is the increase in imports which results from an increase in the national income or the gross domestic product.

Denmark

The picture for Denmark differs somewhat from Belgium and the Netherlands. Gross domestic product and business fixed investment initially rise more sharply since the environmental investments are higher. For the same reason the current balance is negatively influenced in the first period. The other indicators show the more general picture: a modest increase in employment, consumption, consumer prices and government financial balance. In the second period the divergence from the developments in Belgium and the Netherlands is remarkable. Gross domestic product and employment are more positive whereas consumption is more negative compared to Belgium or the Netherlands.

A major factor which accounts for these differences is the lower response of money wages, via price-wage indexation, to price changes in Denmark compared with Belgium and the Netherlands. The decline in private consumption is relatively large due to the shrinkage in real wages. Thus rising wages do not add very much to the initial price increases caused by the pollution control costs. In addition the import coefficient for Denmark is smaller than those for Belgium and the Netherlands, and Danish imports are less originating from EC countries. As a result rising import prices affect the price level of consumption to a lesser degree and the increase in export prices is relatively more modest. In spite of the fact that SO_2 abatement costs in Denmark are twice as high than in the Netherlands the impact on gross domestic product, employment, and current balance is more positive in Denmark than in their Dutch counterparts. It is the better export performance in Denmark that explains differences between both countries in the second period.

Federal Republic of Germany

The impacts for Germany do not differ very much from the basic pattern: a positive impact during the investment period due to pollution control expenditures, and a later negative impact due to the pollution control costs.

The pollution control costs and investments are relatively high which rxplains the relatively strong impact. The rise in consumer prices, as well as other prices is modest in relation to the pollution control costs. The major reason for this is that the impact of imported prices increases is less important in Germany in comparison to other large countries such as the United Kingdom and Italy. This is due to the relatively smaller import coefficient of Germany. As a result the competitive position in Germany, in spite of the higher abatement costs, deteriorates less. Over both periods the picture remains satisfactory although consumption is negatively affected by the costs of pollution control.

Italy

Results for Italy are more positive than for Germany. Although the re-

sults display the same basic pattern, there are some differences. Employment, though hardly affected, remains positive whereas consumer prices, especially in the second period, increase mere slowly in Italy.
The size of the abatement programme in Italy is about two-thirds of that of the German effort, so the initial impact is proportionally lower. In Italy however the competitive position deteriorates less than in Germany and, more significantly, improves in the second period. Next to the lower level of abatement costs this can be explained by the composition of the Italian exports; a relative large share of the Italian exports is geared towards countries with higher price increases, notably Germany, but also the United Kingdom, Belgium and the Netherlands. As a result relative export prices even improve. Consequently Italian exports perform somewhat better than in Germany. Consumption expenditure declines only slightly in the second period since pollution control costs are relatively low compared to Germany. The decrease in gross domestic product in the period 1994-1997 is only small since exports and consumption decrease only slightly. Business financial balances, business investments and employment still remain positive, although only slightly.

United Kingdom
The impact of abating SO_2 emissions în the United Kingdom is somewhat more negative than in Germany, especially in the first period (1988-1993). The increase in gross domestic product in the first period is smaller, private consumption declines more and the current balance is more negatively affected.
This is so despite the fact that the pollution control investments and costs, in comparison to the gross domestic product, are (only slightly) smaller in the United Kingdom. One possible cause of this more unfavourable impact is the higher import coefficient in the United Kingdom. As a consequence the initial impact on the gross domestic product is smaller and imports increase relatively faster. In addition pollution control costs seem te be more fully reflected in rising prices, i.e. export prices. Probably money wages respond quicker and to a larger extent to price changes. This adds to the increase in the domestic price level caused by the increase in pollution control costs. As a result prices, including export prices, increase more in the United Kingdom. Consequently the relative competitive position is more negatively affected in the United Kingdom and exports thus decrease more than in Germany. This decrease in exports accounts for the less favourable impact on gross domestic product, employment and current balance in the period 1994-1997. In this period the impact on employment is more negative in Germany than in the United Kingdom whereas in the United Kingdom the level of consumption decreases more. Towards the end of this period the differences between both countries appear to be less pronounced than in the first period[3]).

6.4. Results for NO_x

6.4.1. Introduction

This section briefly presents and explains the macroeconomic impacts of reducing NO_x emissions. The main results are summarised in table 13.

6.4.2. Basic pattern

The basic pattern for SO_2 has been explained in detail in the previous section. For NO_x therefore only the most salient differences are discussed. Taking a look at the figures in table 13 (next page) it is possible to recognise the same basic pattern. In the first period (1988-1993) the results are positive for all countries; gross domestic product, business investments as well as employment rise due to the additional expenditures on environmental investments. These investments induce an increase in other expenditures and cause imports to rise so current balances are affected negatively. Consumer prices rise slightly, consumption stabilises and government financial balances improve. In the second period the trend corresponds with that of SO_2. Gross domestic product, investments and employment as well as consumption fall down. Consumer prices remain on a higher level whereas the current balance generally improves.
The most important difference between SO_2 and NO_x is the size of the investment program. In the case of NO_x the environmental costs and investments for most countries are far below the costs and investments of SO_2 control, explaining the smaller macroeconomic impact for most countries.

6.4.3. Country results for NO_x

There are only a few exceptions to the conclusion that the impact of controlling NO_x emissions is small namely: the Federal Republic of Germany, Portugal and to a lesser extent Italy. For remaining countries impacts are marginal (see figure 8 and table 13).

France and Greece

France and Greece have no pollution control costs at all and benefit from pollution control investments elsewhere in the EC.
Gross domestic product and employment rise. The impact is due to the increase in world trade volume and the relative improvement in competiveness in both countries.

Germany and Portugal

For Germany and Portugal the impact is greater than for the other countries. Gross domestic product, business investments and employment are

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[3]) This is probably due to the fact that money wages respond quite strongly to short term changes. So price increases are quite rapidly passed on in wage changes but are also even rapidly fading out.

TABLE 13 — Macroeconomic impacts of controlling NO_x emissions

	BLX	DEN	FR	GER	GR	IRE	ITA	NET	POR	SPA	UKM
Gross domestic product											
1988 - 1993	0.03	0.02	0.01	0.06	0.01	0.02	0.03	0.03	0.08	0.02	0.01
1994 - 1997	0.00	-0.01	0.01	0.00	0.01	-0.03	0.02	-0.01	0.02	0.01	-0.01
Business fixed investment[1]											
1988 - 1993	0.10	0.18	..	0.43	..	0.15	0.30	0.12	0.49	0.05	0.10
1994 - 1997	-0.02	-0.05	..	-0.05	..	-0.09	0.05	-0.04	-0.02	0.00	0.01
Private consumption											
1988 - 1993	0.00	0.00	..	0.00	..	0.00	-0.01	0.00	0.03	0.01	0.00
1994 - 1997	-0.02	-0.03	..	-0.02	..	-0.04	0.00	-0.01	-0.02	0.00	-0.02
Current balance[2]											
1988 - 1993	0.01	-0.01	0.02	-0.15	0.00	-0.01	-0.05	0.01	-0.01	0.01	0.00
1994 - 1997	0.02	0.00	-0.03	-0.21	0.00	-0.01	-0.03	0.00	-0.02	0.02	0.02
Employment											
1988 - 1993	0.01	0.00	0.00	0.05	0.00	0.01	0.01	0.02	0.03	0.01	0.01
1994 - 1997	0.00	0.00	0.01	-0.03	0.01	-0.01	0.01	-0.01	0.01	0.00	-0.01
Consumer prices											
1988 - 1993	0.03	0.03	..	0.15	..	0.06	0.09	0.04	0.08	0.03	0.06
1994 - 1997	0.08	0.06	..	0.12	..	0.10	0.04	0.10	0.13	0.05	0.06
Government financial Bal.[3]											
1988 - 1993	0.01	0.01	..	0.06	..	0.00	0.03	0.02	0.02	0.00	0.01
1994 - 1997	0.01	0.00	..	0.04	..	-0.02	0.04	0.00	0.00	0.00	0.01

Figures expressed as annual average percentage changes over the baseline levels
[1]) inclusive of environmental investment
[2]) billion $
[3]) % of baseline gross domestic product
.. not available

more positively affected in the first period. Consumer prices increase in the first (1988-1993) as well as in the second period (1994-1997). The main explanation is the higher level of environmental investments and costs in both countries. The higher domestic environmental investments strongly influence the impact on gross domestic product and business fixed investments; the higher level of abatement costs strongly influence consumer prices, current balance and consumption level.

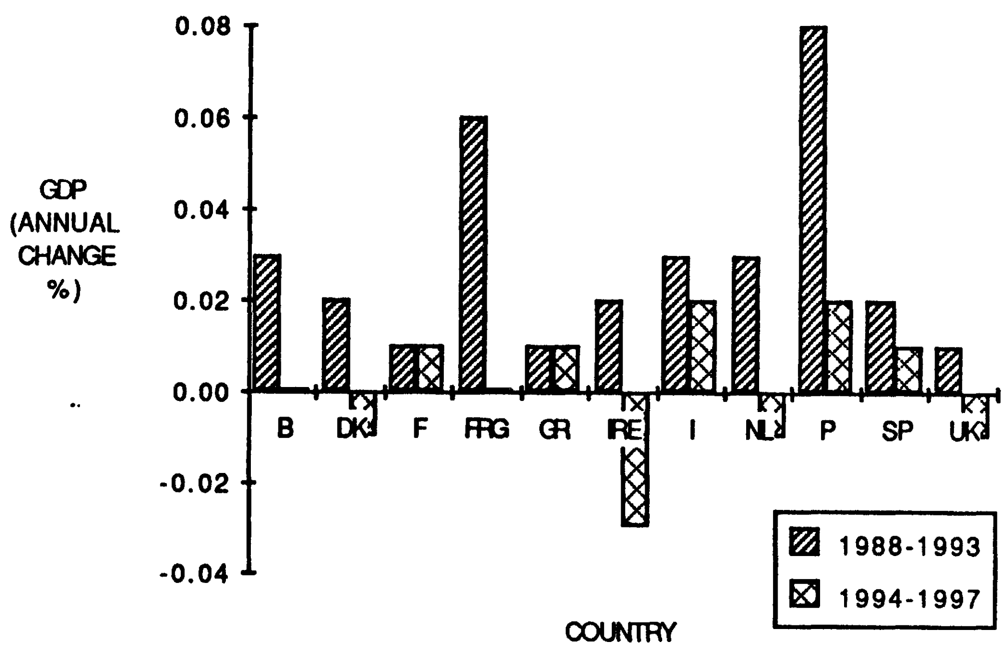

Figure 8. Impact of controlling NO_x emissions on the gross domestic product.

There are also differences between Portugal and Germany; gross domestic product as well as employment are negatively influenced in Germany in the second period. In Portugal however both indicators remain positive but decline. The German economy is less sensitive to coordinated action due to its relatively large size. In addition Germany takes the majority (60%) of the investments in NO_x control while the Portuguese contribution in an absolute sense is very small (less than 10%). Consequently the potential market growth is very high for Portugal and small for Germany.

In both countries competitiveness deteriorates but less so for Portugal. This is due to the fact that Portugal is able to improve its relative export price over Germany. As a result, and especially during the investment period (1988-1993), German exports decline whereas the volume of the Portuguese exports increases. In Portugal however import prices increase more. On balance the impact on the current balance in the first period, in relation to the size of the initial pollution control investments, is more or less comparable for both countries, although different in billion dollars. Due to the fact that the initial impulse in Portugal is greater, in relation to the size of its economy, it exerts a more positive, but shrinking impact in the longer term.

Italy

The overall impact is quite positive for Italy. Gross domestic product, business investments and employment remain positive in the second period. Although the current balance is negatively influenced in the second period (1994-1997) it deteriorates less than in Germany.
The impact is not as large as in Portugal or Germany due to the smaller size of the environmental investments and costs. In the first period Italy derives some benefits since its export markets, especially in Germany, increase. Moreover competitiveness deteriorates less. As a result the volume of export grows in the first period. In the second period Italy improves its relative competitiveness over Germany: the relative export price for manufacturers even improves. As a result exports fall less and investments, gross domestic product and employment remain positive.

Belgium, Denmark, Ireland, the Netherlands, Spain and the United Kingdom

For Belgium, Denmark, Ireland, the Netherlands, Spain and the United Kingdom the proposed NO_x control programme has only a small impact; however, the eventual impact is somewhat more positive for Spain and Belgium and somewhat more negative for Ireland. In all these countries the pollution control costs and investments are very small compared to the size of the economy, and this explains the small impact.
Spain and Belgium benefit more from coordinated action since their abatement costs are very low and they are able to improve their competitive position. In addition the volume of exports from Belgium increases more since the relevant export markets, especially in Germany, grow more.
Ireland however, is hardly able to benefit from the coordinated impulse. Firstly the environmental costs are somewhat higher than in Belgium and Spain and, due to Ireland's bigger import leakage and import of price increases, the competitive position deteriorates more. The export volumes increase in the first period because the international market grows. The volume of imports however also rises and, as a result, the current balance deteriorates. The final impact remains very small.

In Denmark, the Netherlands and the United Kingdom pollution control costs are small. As a result the relative export prices of manufactures are hardly affected over both periods. There are only marginal differences between these countries which are related to the geographical distribution of exports and the origin of the imports. The Netherlands is influenced somewhat more due to the more open character of its economy. During the investment period the expenditures are increased somewhat. On the other hand in the second period the rise of import prices is of importance and the competitive position is slightly deteriorating.

6.5. Results for the sum of SO_2 and NO_X

6.5.1. Introduction

Table 14 (next page) contains the results of the combined impact of controlling SO_2 and NO_X emissions. Effects are only briefly discussed and reference is made to the preceding sections on SO_2 and NO_X for details. First the basic pattern is summarised and subsequently the main differences between countries are discussed.

6.5.2. Basic pattern for SO_2 plus NO_X

During the period in which the environmental investments take place (1988-1993) gross domestic product, business investments, employment as well as government financial balances are influenced positively and the current balance negatively. Despite the increase in nominal income consumption is hardly affected since consumer prices also rise. In the second period (1994-1997) gross domestic product, investments and employment fall, the current balance becomes less negative and the government financial balance is less positive. The consumer prices increase to a larger extent than nominal income, which results in lower levels of consumption. Summarised over both periods the impact is positive for indicators of macroeconomic activity: gross domestic product, employment and business fixed investment. Only consumption is at a lower level. Consumer prices are also at a higher level and the current balance is negatively affected.

6.5.3. Differences between countries

Results for SO_2 and NO_X combined are quite similar to those for SO_2 alone, except for countries where investments in NO_X control are high: Germany, Portugal and to a lesser extent Italy. Table 14 shows that combined control of SO_2 and NO_X has a net negative impact for Ireland and a very positive impact for Spain, Portugal, Greece and, in a sense also for Italy. The impact on the remaining countries is generally positive; this impact is somewhat less for Germany, the United Kingdom and the Netherlands and somewhat more for Belgium and Denmark. The impacts for France, which has no abatement costs, are positive as well.

TABLE 14 The macroeconomic impacts of controlling SO_2 and NO_X emissions

	BLX	DEN	FR	GER	GRE	IRE	ITA	NET	POR	SPA	UKM
Gross domestic product											
1988 - 1993	0.15	0.19	0.06	0.19	0.07	0.13	0.11	0.15	0.12	0.10	0.07
1994 - 1997	-0.03	-0.01	0.03	-0.06	0.07	-0.24	0.05	-0.10	0.00	0.04	-0.06
Business fixed investment[1])					[4])				[5])		
1988 - 1993	0.69	1.48	..	1.54	0.16	1.30	1.44	0.90	0.49	0.43	1.19
1994 - 1997	-0.19	-0.25	..	-0.28	0.04	-0.41	0.21	-0.25	-0.02	-0.02	-0.01
Private consumption					[4])				[5])		
1988 - 1993	0.02	0.00	..	-0.01	0.01	0.00	-0.03	0.01	0.03	0.04	-0.03
1994 - 1997	-0.09	-0.18	..	-0.07	0.00	-0.33	-0.02	-0.03	-0.02	-0.02	-0.14
Current balance[2])											
1988 - 1993	0.02	-0.07	0.12	-0.36	0.00	-0.06	-0.22	-0.02	-0.02	0.01	-0.22
1994 - 1997	0.05	-0.03	-0.15	-0.27	0.00	-0.09	-0.12	-0.09	-0.04	0.04	-0.11
Employment											
1988 - 1993	0.07	0.05	0.02	0.18	0.03	0.06	0.03	0.10	0.06	0.05	0.04
1994 - 1997	0.01	0.04	0.03	-0.14	0.03	-0.05	0.01	-0.06	0.00	0.02	-0.07
Consumer prices			[6])								
1988 - 1993	0.18	0.23	0.08	0.49	0.09	0.51	0.42	0.24	0.18	0.17	0.48
1994 - 1997	0.40	0.42	0.27	0.36	0.16	0.66	0.14	0.58	0.31	0.24	0.27
Government financial Bal.[3])					[4])				[5])		
1988 - 1993	0.08	0.12	..	0.19	0.01	0.01	0.13	0.10	0.02	0.03	0.09
1994 - 1997	0.05	0.07	..	0.09	0.00	-0.18	0.16	0.01	0.00	0.01	0.10

Figures expressed as average annual percentage changes from baseline levels

[1]) inclusive of environmental investment

[2]) billion $

[3]) % of baseline gross domestic product

[4]) impact of abatement NO_X emissions not available

[5]) impact of abatement SO_2 emissions not available

[6]) deflator for GDP

.. not available

Ireland

In Ireland results are more negative due to the relatively high pollution control costs, especially for SO_2 which leads to a deterioration of its international competitiveness. Moreover the import coefficient is high. This raises import prices and adds to the deterioration in competiveness. As a result gross domestic product, consumption current balance as well as government financial balance over both periods (1988-1997) are negatively influenced, although employment is hardly affected. The rise in consumer prices is considerable but one should note that towards the end of the second period the price increases become less prominent. In comparison to other countries the price rises are a more temporary phenomenon in Ireland.

Spain, Portugal, Greece and Italy

The impact on Spain, Greece and, to a lesser extent, on Portugal and Italy is clearly positive. Gross domestic product, employment and government financial balance are affected positively during both periods. Consumption and current balance are hardly affected.

For Spain and Greece this is due to their relatively low level of pollution control costs which leads to an improvement in their competitiveness. The increase in prices of imports from EC countries with high pollution control costs counterbalances the strengthening of the competitive position. This rise in import prices adds to price increases caused by domestic pollution control.

In Italy pollution control costs are higher than in Spain or Greece. Although relative export prices go up in Italy the country is still able to increase the export volume in the first period due to the growth in relevant export markets. In the second period Italy improves competitiveness; its main competitors (e.g. Germany, United Kingdom, Netherlands) are confronted with higher increases in export prices during the period 1988-1993.

In Portugal environmental investments and costs are twice as high as in Spain and Greece. Despite this high level of pollution control costs the competitive position of Portugal does not deteriorate substantially, and exports and current balance are not affected too adversely. However, results are less positive than for Spain or Greece, especially for the current balance. Due to the large size of the impulse gross domestic product and employment remain positive in Portugal, although declining, during the full period 1988-1997.

Germany and the United Kingdom

Macroeconomic results for Germany and the United Kingdom more or less resemble the basic pattern. However, the eventual impact for Germany is more prominent since the abatement program is larger. The German results are more positive during the investment period and more negative afterwards. The lower impulse in the United Kingdom compared to Germany induces a less prominent impact on gross domestic product, business investments and employment. Compared to Germany the United Kingdom has a larger import coefficient and imports originate from countries with a high price increase. These factors explain the relatively larger volume of imports, larger price increases, deteriorating competitiveness, and consequently decreasing exports in the United Kingdom. These have a negative influence on the gross domestic product which decreases as much as the German gross domestic product in the period 1994-1997. This despite the fact that costs to control SO_2 and NO_X emissions in the United Kingdom are only seven-tenths of those in Germany.

The Netherlands

Foreign emission control policies influence the economy of the Netherlands more strongly, compared to Germany or the United Kingdom, due to the greater dependence on international trade. In the first period the Netherlands is able to benefit from the EC abatement policy: the Dutch exports increase as a result of the rise in foreign expenditures and income in all EC countries. In the second period, however, the rise in import prices affects the domestic price level, among them the export price, rather strongly. (The importcoefficient of the Netherlands, being twice as high as the ones for the United Kingdom, respectively Germany). As a result the impact in the second period is somewhat more negative.

Belgium and Denmark

The impact on the Belgian and the Danish economy is more positive than for the Netherlands although for different reasons. In both countries employment remains positive after the investment period and gross domestic product does not fall substantially in the second period. The Belgian current balance even improves in the second period whereas the Danish balance deteriorates less than the Dutch current balance. In both Belgium and Denmark the rise in consumer prices and the drop in consumption is relatively high.

The positive impact on Denmark corresponds to the large size of the pollution control investments. The Belgium pollution control impulse is far smaller but Belgium benefits more from the EC-wide rise in expenditures. Belgium is more export-orientated than Denmark; the rise in specific EC expenditures as described here has a favourable impact on the exports. Also exports increase since the competitive position of Belgium improves as a result of the relatively small pollution control costs. However, this open character of the Belgium economy also facilitates the import of price increases. Moreover, the responsiveness of money wages to price increases in Belgium is somewhat higher in Belgium than in Denmark. Thus the improvement in the relative export price of manufacturers, observed in the first period, is not maintained in the second period. The drop in exports is the main cause of the slightly negative economic performance in Belgium in the period 1994-1997.

Denmark improves competitiveness in the first period. The rise in prices is relatively modest compared with the rather high level of pollution control costs. In Denmark the impact of rising import prices, relative to Belgium, is smaller; the import coefficient in Denmark is lower and imports tend to originate from non-EC countries. Domestic pollution control costs however are far higher in Denmark than in Belgium and the eventual impact on consumer prices is comparable in both countries. The higher pollution control costs in Denmark, in combination with the lower responsiveness for money wages for price changes, explain the negative impact on consumption. The higher initial investments, and the smaller drop in nominal income, result in a more positive impact on government financial balance and on employment relative to Belgium.

6.6. The relative size of the impacts

A main conclusion of the analysis is that the macroeconomic impacts of the proposed Directive on large combustion plants are very small. Table 15 shows the changes in some of the macroeconomic variables over the past seven years to illustrate this.

Tabel 15. Economic indicators in the recent past

Indicator Country	Gross domestic product (%)	Private consumption prices (%)	 level (%)	Total employment (%)	Current balance in 1985 billion $
Belgium	1.2	6.7	0.6	-0.6	0.7[4])
Denmark	1.9	8.5	0.9	0.5	-2.7
France	1.1	9.9	1.8	-0.3	-0.2
Germany	1.3	4.1	0.7	-0.3	13.2
Greece	1.1	20.1	1.5	1.3	-3.3
Ireland	2.0	12.5	-1.1	-1.1	-0.6
Italy	1.4	15.3	1.6	0.4	-4.2
Netherlands	0.7	4.4	-0.3	0.9	5.2
Portugal	1.6	22.6	0.4	0.3	0.4
Spain	1.4	11.6	0.4	-1.6	2.7
United Kingdom	1.2	8.5	1.7	-0.7	3.8

All percentages are average annual changes for the period 1979-1985.
Sources: Eurostat (1987), OECD (1987a), OECD (1987b).

From a comparison of table 15 with table 14 (the combined impact of controlling SO_2 and NO_X emissions) it can be seen that the impact of the pollution control program on the gross domestic product is generally smaller than 10% (period 1988-1993) to 5% (period 1994-1997) of the

[4]) For the jointly modelled Belgium-Luxembourg economy.
[5]) Although the direction of the change might be opposite to past changes as the preceding section showed.

general changes over the past period 1979-1985.[5]) Only in Ireland and the Netherlands is the impact higher. The impact on consumer prices resulting from the pollution programme for most countries (including Ireland), is only around 5% of the observed changes in the past (1979-1985). For Germany and the Netherlands the impact is some one-tenth of past changes.
The impact of the Directive on the level of private consumption, during the investment period (1988-1993) is not larger than 5% of the average annual change in the past seven years.
In the second period (1994-1997) the impact of the Directive is more prominent: 5 to 25% of past changes. This is especially so in Denmark and Ireland.
With regards to employment the average annual change caused by the pollution control programme would remain below or around one-tenth of historical changes described in table 15. Only in Germany would the impact be half of the (minor) annual change in the past.
Compared to the position of the current balance in 1985 (expressed in billion US dollars) one might see that the impact of the Directive is only a small percentage of the 1985 balance deficit/surplus. Exceptions are France, Ireland and Portugal where the impact is more significant.
Even taking into account the restricted number of key indicators and the limited time period observed, the conclusion is warranted that the macroeconomic impacts of the proposed Directive are very small compared to past changes in macroeconomic indicators.

6.7. Elements of uncertainty

The main factors that influence the results are:
* the level of abatement investments and costs;
* the assumed constant nominal interest rate;
* the fact that exchange rates are fixed;
* no direct 'crowding out' of traditional investments is taking place;
* the direct import share of investments in pollution control corresponds with the import share of total fixed investments;
* the exclusion of reductions in environmental damage.

Level of abatement costs and investments
A sensitivity analysis for the abatement of SO_2 emissions (chapter 5) revealed that costs and investments do not change substantially if an estimate of the impact of emission standards for new industrial plants is included; exceptions include France, Greece, Portugal and Spain where costs would probably be higher. For Ireland however, costs could be lower. If countries have a strong preference to buy domestic pollution control equipment, even if this is more expensive, costs for the abatement of SO_2 emissions could be higher, especially for Ireland, Spain and the United Kingdom. Costs for the abatement of SO_2 as well as NO_X could be lower if other abatement strategies are included such as ener-

gy conservation, fuel substitution, use of low sulphur coal and combustion modifications on new industrial plants instead of catalytic reduction on power plants.

Generally costs for abating NO_x emissions are more uncertain than the costs for controlling SO_2 emissions.

If abatement costs and investments are higher the positive macroeconomic impact during the investment period will be reinforced but the negative impact, observed after the investment period, will also be strengthened. The result also depends on the ratio between investments and costs; a higher ratio induces a more favourable impact due to the increase in (investment) expenditures and the decrease in cost-related negative impacts. If countries rely more on home-made pollution control equipment, costs could be higher and the negative impact in the second period could be more pronounced. Over against that the importcoefficient would be smaller, investments would be higher, and consequently the positive impact during the investment period would be reinforced.

A flexible interest rate

In this study the nominal interest rate was kept constant. This assumes a continuation of present, accomodating monetary policies in the EC member states. A sensitivity analysis with INTERLINK revealed that, by keeping the money supply constant, the short term interest rate would rise by as much as 0.2 to 0.5% in the period 1988-1997[6]). In the same period the long term interest rate would rise by 0.1 to 0.25%. As a result the pollution control programmes would have a predominantly negative impact on employment, the gross domestic product, and the government financial balance due to the increased interest rate. The consumer prices would be slightly lower (about 0.1% in the period 1994-1997) compared to the increase observed with a fixed nominal interest rate.

Flexible exchange rates

Furthermore a fixed exchange rate was assumed. Most EC countries, except Greece, Portugal, Spain and the United Kingdom, take part in the EMS (European Monetary System) which explicitly aims at fixed exchange rates. In addition the assumption of a fixed rate is commonly used by the OECD in its 'Economic outlook'. However, a flexible exchange rate exists in relation to important trade partners (e.g. Japan, USA). Although no sensitivity analysis was carried out, the introduction of a flexible exchange rate would affect the macroeconomic indicators in a positive direction: exports would decrease less, imports would increase less, current balance deficits would be smaller or surpluses would enlarge. As a result gross domestic product and employment would perform somewhat better but prices would be higher since the prices of

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[6]) The analysis was carried out for the combined impact of controlling SO_2 and NO_x emissions. Detailed results of this analysis are displayed in technical document II: INTERLINK: modifications and detailed results.

imports from Japan and the USA would increase slightly. In quite the same manner the existence of a flexible exchange rate in Greece, Portugal, Spain and the United Kingdom might improve the macroeconomic impacts of these countries relative to other EC countries.

Direct crowding-out
It was assumed that investments in pollution control equipment do not directly lead to a 'crowding-out', or offsetting reduction, of other investments. Since the majority of the pollution control investments take place in publicly-owned, power plants this is a plausible assumption: a postponement of investments in electricity generation due to financial constraints is not likely. One should remember that the indirect decrease in business fixed investment as a result of the increased pollution control costs, and thus decreased profitability, is included in the INTERLINK model. If more investments were to be made by the industrial sector direct 'crowding-out' would become more relevant and the macroeconomic impact could be more negative.

Direct import share of pollution control investments
The assumption that the direct import share of investments in pollution control corresponds with the import share of total fixed investments, means that countries with a strong position on the market of investment goods also have a strong position in air pollution control equipment. Given the fact that Germany is well ahead with the implementation of its national pollution control policy, and seems to have established a well developed environmental industry, the negative impact for Germany could be somewhat overestimated. Conversely the impact for other countries might be somewhat more negative.

Impact of damage reduction
In this study it was impossible to include the macroeconomic impact of reductions in damage that result from the proposed Directive. Although the extent of the damage reduction resulting from implementation of the Directive is uncertain, the positive macroeconomic impact of this Directive is probably underestimated since the positive impacts of damage reduction, increased productivity and other so called 'utility-increasing' benefits (see chapter 2, section 2.3 and appendix A) are excluded.

Finally
One possible misunderstanding should be removed. One might think that the above pollution control programme is subject to a higher margin of error since the impacts are only marginal. There are no logical arguments however for the viewpoint that the margins of error would increase, and even exceed the initial impacts because the latter impacts are smaller. The macroeconomic impacts are small simply because the costs and investments of the Directive, related to the size of the national

economy, are very small. Of course it is so that, due to rounding, differences calculated accurately with the model become smaller in the final presentation[7]).
Next to these uncertainties one should note that, despite the experience gained with the INTERLINK model, it is still difficult to model reality. For example the modelling of behavioural relations, such as investment behaviour, is one of the most difficult and controversial tasks in macroeconomic modelling. Results therefore should not be looked upon in a deterministic manner. The model should be seen as a useful tool to understand possible changes in complex economic reality, given various assumptions, of an exogenously determined change, such as the Directive on large combustion plants.
Despite the elements of uncertainty the major conclusion of this study would not be affected: the Directive only has a small, positive macroeconomic impact during the investment period and a small, negative impact in the subsequent period. Of course the distribution of positive and negative macroeconomic impacts over the various EC countries could differ: a definite answer on the changes amongst countries however is not possible without a renewed analysis with INTERLINK.

6.8. Conclusions

A main conclusion of the analysis is that the macroeconomic impacts of the proposed Directive on large combustion plants are very small. Compared to changes in economic indicators, observed in the recent past, changes induced by the Directive generally are not greater than 5 to 10%. The impacts on macroeconomic indicators are very small since the size of the costs and investments of controling SO_2 and NO_X emissions, compared to the size of the national economy, is very small. The macroeconomic impact for the control of NO_X emissions is even smaller than that for SO_2.
For most countries gross domestic product, employment, business fixed investments and government financial balances are positively influenced during the period in which the investments take place, (1988-1993). After the investment period (1994-1997) the pollution control costs induce a drop in these indicators. Over both periods consumer prices are at a higher level, consumption as well as current balance are negatively affected but the remaining indicators such as employment and gross domestic product are positively influenced.
The control of SO_2 emissions has a rather negative but still small impact for Ireland and a positive impact for France, Greece, Portugal and Spain. The control of NO_X emissions for most countries has a negligible impact. For the Federal Republic of Germany the impact is more

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[7]) Due to rounding the difference between e.g. 0.01 and 0.00 is only marginal.

negative; for Italy, Portugal as well as France and Greece the macroeconomic impacts are notably and predominantly positive.
The combined control of SO_2 and NO_X emissions is negative for Ireland, extremely positive for France, Greece, Portugal and Spain. The eventual impacts for the remaining countries are less prominent but positive for Italy, Belgium and Denmark. For Germany, the Netherlands and the United Kingdom the impacts are more or less neutral.
Assumptions and data on the following factors are believed to have a major impact on the results: the pollution control investments and costs, the interest rate, the exchange rates, direct 'crowding-out' of traditional investments, the import share of investments in pollution control and the exclusion of the reduction in environmental damage. Changes in underlying assumptions could either have a positive or a negative effect on the simulated impacts. Although the distribution of (small) positive and negative impacts amongst different countries could be affected, changes in the above factors are not believed to alter the conclusion that the macroeconomic impacts of the proposed Directive are small.

7. CONCLUSIONS

Abatement strategies to meet the Directive

Regarding the control of SO_2 emissions Denmark, the Federal Republic of Germany as well as the Netherlands will carry out their own policy and do more then meet the Directive. France, Portugal as well as Luxembourg do not take measures. The other countries comply with the emission standards for large plants and if necessary apply additional flue gas desulphurization on existing plants as well to meet the bubble.
For the control of NO_X emissions the Federal Republic of Germany continues it's present national policy. The Netherlands does the same but has to take additional measures. France, Greece nor Luxembourg take abatement measures. Remaining countries apply combustion modification to meet the emissions standards for their new plants. If this proves insuffient to meet the bubble additional measures are taken in the most cost effective manner.

Costs, investments and the impact on electricity production costs

Up to 1995 the EC would invest 12.3 billion ECU (constant prices of 1985) to reduce SO_2 emissions of large combustion plants with some 45% over the 1980 level if the EC Directive were to be accepted. Annual costs of this policy are 2.5 billion ECU in 1955. In an absolute sense Germany, the United Kingdom as well as Italy carry most of these costs (more then 80% of the EC total). But compared to the gross domestic product costs are relatively high in Ireland, Denmark, Germany and the United Kingdom.
To control NO_X emissions of large plants investments would amount up to 2.9 billion ECU, annual costs are some 0.9 billion ECU. The eventual reduction reached in total EC large plants emissions is 45%. The Federal Republic of Germany is mainly responsable for these efforts (70% of total EC costs) but the contribution of Italy (20%) is worth mentioning. Efforts of other countries are small. Compared to the gross domestic product the costs are high in Portugal and Germany and to a lesser extent in Italy.
The impact of SO_2 abatement on the electricityprice for large scale industrial use is an increase which is generally between 1 to 3.5%. The impact of NO_X abatement is negligible.

The macroeconomic impacts

With respect to the second and higher order macroeconomic impacts the following can be concluded.

A more general conclusion is that the macroeconomic impact is positive during the period in which the investments take place (1988-1993) due to the expenditure impulse. After this period (1994-1997) there is slight deterioration as a result of the increasing pollution control costs.

During the period in which the investments take place in all countries indicators of real activity, such as gross domestic product, business investments as well as employment rise due to the additional expenditures on environmental investments. The investments cause imports to rise so current balances show a deficit. Consumer prices rise slightly, consumption stabilises and the government financial balances improve. After the investment period however the environmental costs induce a fall back. Gross domestic product, investments and employment as well as consumption fall down. Consumer prices remain on higher level whereas the current balance generally improves.

Over both periods the impacts are generally positive for gross domestic product, employment, business fixed investment and the government financial balances. Private consumption, however, is negatively influenced and consumer prices are on a higher level.

As well as for the seperate control of SO_2 and NO_X emissions as for the simultaneous control of both pollutants the macroeconomic impacts are very small. The percentage changes in economic indicators, induced by the pollution control programma, for most countries, are not larger than 5 to 10% of annual changes observed in the recent past (1979-1985). Only for some countries, for some specific indicators, the impact is somewhat more significant but still very small.

Within the frame of this more general conclusion it is also clear that the proposed Directive, with respect to SO_2 emission control, has a rather negative influence on the Irish economy whereas the impacts are more positive for France and Portugal, which have no pollution control costs, as well as for Greece and Spain. The proposed Directive on large combustion plants, with respect to the control of NO_X emissions has a hardly noticeable impact on the economies of most EC countries. The impact on the Federal Republic of Germany is more significant due to the countrie's own stringent abatement policy. The macroeconomic impacts for Italy, Portugal, France and Greece are small, but notably positive.

The simultaneous control of SO_2 and NO_X emissions has negative consequences for the main macroeconomic indicators in Ireland. For Germany, the Netherlands and the United Kingdom the positive impacts more or less equal the negative impacts. For France, Greece, Portugal and Spain the macroeconomic effects are positive. For the Italian, the Belgian and the Danish economy results are positive as well although to a smaller extent.

Despite these differences among countries, and despite several elements of uncertainty, it can generally be concluded that the proposed Directive on large combustion plants is likely to have only small macroeconomic impacts for the EC countries.

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APPENDIX A. DAMAGE AND BENEFITS

1. Introduction

The aim of this appendix is to supply insight on the:

* information that can be made available on the present monetary damage caused by "acid rain" in Europe, especially in the European Community (E.C.), and the possibilities to express the damage in monetary terms (monetary damage);
* extent to which it would be possible to estimate the benefits (i.e. avoided damage) of "acid rain" control strategies in the E.C.

Generally the term "acid rain" is used as a collective noun for different types of air pollution. Acidification usually pertains to the dry and wet deposition from the atmosphere of pollutants which have been transformed into acids. However, "acid rain" also incorporates photochemical oxidants (ozone) and those pollutants (e.g. hydrocarbons) which play a part in the formation of acids or photochemical oxidants. Apart from SO_2, NO_X and to a lesser extent NH_3, hydrocarbons and ozone are important. Generally it is impossible to distinguish between a direct impact of these pollutants and their indirect impact through acidification or photochemical smog. Most of the time a cocktail of different pollutants in combination with other stress-factors (drought, frost, diseases etc.) is likely to cause negative effects on the environment. In this appendix the term "acid rain" will be used as a synonym for acidification, ozone and their precursors.

"Acid rain" has effects on practically all levels of ecosystems. The vitality and life expectancy of vegetation, especially forests is reduced. Various species of flora and fauna disappear or suffer from reduced growth. Also an increase in the vulnerability for fungi and "virus" infections is possible. Sensitive soils and surface waters are altered, sometimes irreversibly. Materials like steel and zinc, and the cultural heritage (buildings, stained glass) are deteriorating. "Acid rain" may also constitute a threat to human health due to the increased intake of heavy metals resulting from bio-accumulation or corrosion of water-works. Direct effects on human morbidity and mortality are also possible although there is no general agreement on this subject and the impact is not due to acidification in the sense described above. Table A.1 gives a preliminary overview of damage categories and acidifying emissions and photochemical oxydants that are likely to (partly) cause damage.

Table A.1. Damage categories and "acid rain"

"acid rain" components / damage category	SO_2	NO_X	Hydro-carbons	NH_3	Ozone
1 Forests and vegetation (crops i.e.)	X	X		X	X
2 Other terrestrial and aquatic ecosystems	X	X		X	
3 Buildings and materials	X	X			X
4 Recreation	not available				
5 Human health	X	X			?
6 Non-user benefits	X?	X?			X?

To fulfil the aim of this appendix, data would be necessary on each of the steps in the relation acidifying and photochemical emissions and damage expressed in monetary terms (see figure A.1).

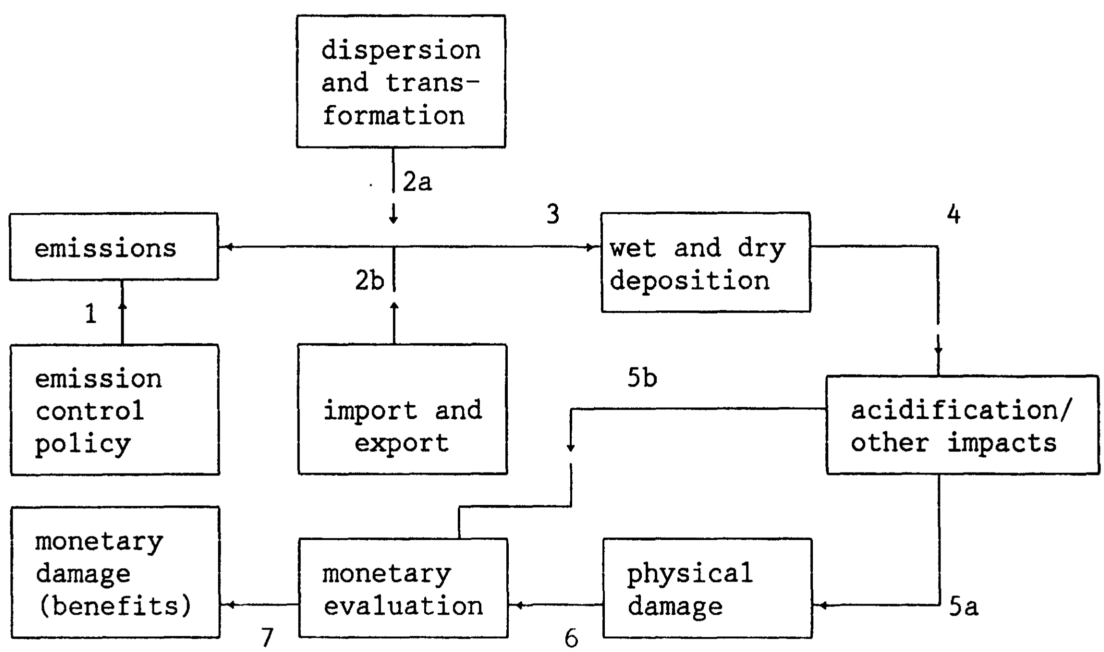

Figure A.1. Emissions-monetary damage chain

Step 5a (acidification/other impacts and physical damage) involves the construction of physical damage functions: relations between levels of exposure and the quantative expression of the effects of this exposure on receptors (materials, flora, fauna, men). This physical damage for example may be expressed in terms of reduced crops, square metres of zinc corroded, percentages of death, hectares of forest suffering from growth reduction if the dose-response function is known. If the effect is expressed directly in monetary units (step 5b, figure A.1) the relation between exposure and effect is called a monetary damage function (James et al., 1978). The benefits of European policies to control acidifying and photochemical emissions can at first hand be seen as the avoided monetary damage as a consequence of that policy compared to a reference case (i.e. no policy changes after 1980 or business-as-usual). At second hand the benefits might also, in a broader sense, be grasped as the willingness of people to pay for the improvement in the environment resulting from the proposed pollution-control policy. Or moreover the benefits could be seen as the compensation that would be necessary if such reduction in emissions and effects would not take place (Kneese, 1984).

As can be seen in figure A.1. two approaches are possible for relating acidification effects of ozone and direct impacts of their precursors to monetary damage: the indirect method (step 5a/6) and the direct method (step 5b). In the first case by using dose response functions first a physical damage function is constructed which then is transformed into a monetary damage function. In the latter method the monetary value is estimated directly (i.e. by measuring willingness to pay). Table A.2 shows the different techniques, within both methods, and their (possible) application to damage categories.

Using these theoretical concepts as a tool this appendix starts with a description of studies on monetary damage due to "acid rain" in the Netherlands. Subsequently, Europe-wide studies on the same subject are reviewed although a thorough examination of underlying concepts was not yet possible. Both sections, insofar as possible, describe the included physical effects, the calculated damage (monetary units) and evaluate the strength of the observed relation between emissions and monetary damage. The possibilities to estimate the benefits of control policies in the E.C. are then examined. This section compares an "heroic" attempt to assess these benefits (OECD) and tries to yield some insight in recent developments in model building on the relations emissions-physical damage (Phoxa and IIASA). In addition the potential to reduce sulphur deposition in the EC of an EC policy, is presented with the help of data on, the sources of deposition in the EC, and of the receptors of emissions caused by EC countries. Conclusions and recommendations are presented in the fifth section.

Table A.2. Techniques to estimate benefits in monetary terms and their application to damage, caused by "acid rain".

Method	Technique	Damage category (benefits)					
		Forest and vegetation (+crops)	Other terrestrial and aquatic flora and fauna	Buildings and materials	Recreation	Human health	Non user benefits
INDIRECT	"Human capital"					X	
	"Risk evaluation"					X	
	"Surveys"	X	X	X	X?		
	Market price (changes)	X	X	X			
DIRECT	Hedonic price differences	not to	be specified				
	Surveys (contingent valuation, willingness to pay)	various	categories	(i.e. health, forests, non user benefits)			

Source (Ministry of Housing, 1985; Oosterhuis, 1984; Ministry of Housing, 1984)

2. Damage and benefits in the Netherlands

Recent studies in the Netherlands on physical damage, caused by acidification, ozone and their precursors, considered effects on soil, groundwater, vegetation, surface water and animals that form part of aquatic and terrestrial ecosystems (MHPE, 1984). In earlier stages damage to buildings, materials, crops and health has been assessed. Table A.3 summarises the results.

Effects on vegetation and forests are probably due to air pollution although the exact processes are not completely known. Damage to surface waters and soil can largely be attributed to acidification by SO_2, NO_X and NH_3. Damage to buildings and materials is largely caused by SO_2 and to a certain extent by NO_X and its derivatives. Ozone can play a role in deterioration of certain materials (paper, rubber, leather, textiles). At present levels of air pollution, the occurrence of adverse health effects is highly uncertain. Epidemiological studies do affirm a relation between morbidity and air pollution (Nentjes, 1986), but on the other hand present SO_2 concentrations do not exceed the advised threshold concentrations advised by the Dutch Health Council; however, present levels of NO_X and ozone probably do have adverse effects on vegetation and health (ERL, 1986). For the latter effects no estimate is available on the related monetary damage.

Table A.3. Effects and "acid rain" in the Netherlands

"acid rain" pollutants damage categorie	SO_2	NO_X	Hydro- carbons	NH_3	Ozone	Remarks
1. Forests and vegetation (crops i.e.)	X	X		X	X	In combination with stress factors
2. Other terrestrial and aquatic ecosystems	X	X		X		
3. Buildings and materials	X	X			X	Especially SO_2
4. Recreation						
5. Human health	X	X			X	SO_2 in combination with particulate matter
6. Non-user benefits						

Source: (Ministry of Housing, 1986; Tweede Kamer, 1984; Oosterhuis, 1984; MPE, 1984)

Table A.4 shows the available data on monetary damage, caused by acidification, ozone and their precursors, in the Netherlands. The presented figures are an underestimate of the real damage:

- loss of capital in the case of forests, valued at 3-10 billion guilders and accumulated damage to natural ecosystems (200-300 million guilders) are not taken into account.
- certain categories of damage, i.e. the disappearance of unique ecosystems, cultural heritage, are not valued.
- because part of the damage is estimated on the basis of costs of the present (not repaired) damage this is an underestimate. Willingness to pay or compensation-costs-methods probably would yield higher values especially because non-user benefits (existence value, option value etc.) would be taken into account. Recent studies in Germany (Schultz, 1985) and in the Netherlands (Oosterhuis and Van der Linden, 1987) using contingent valuation for improvement in forests affirm this.

- no estimate is included for the monetary damage to human health. The expected damage may constitute a significant part of the total damage.

Table A.4. Damage due to "acid rain" in the Netherlands

Damage category	Damage[3] (million DFL)		Method (techniques) used to estimate damage
	Present	Future[2]	
1. forests and crops (agriculture)	565-655	735-1205	market prices (costs of compensation and market price changes (= not repaired damages)
2. other terrestrial and aquatic ecosystems	5- 30	15- 55	market prices (costs of compensating measures and not repaired damage)
3. buildings and materials	95-140	115- 190	as 1 and 2
4. recreation	pm	pm	
5. health [4])			no recent reliable estimate available
TOTAL	665-825	865-1450	

General notes:

[1]) Source (Ministry of Housing, 1986; MHPE, 1984; Tweede Kamer, 1984).

[2]) Damage if level of deposition is maintained.

[3]) Damage is calculated in guilders for different years mostly after 1980. No indexation is used.

[4]) Using an outdated (1974) study and a safety margin of +40% and -30%, damage of 700-1400 million guilders has been calculated, a not very useful indicator (Opschoor, 1987).

At this moment little information is available to estimate the benefits of a reduction of emissions. Damage to crops is probably reduced proportionally with deposition. Forest damage will only decline significantly (if this is even possible!) if deposition is reduced to 80% of the present level. Surface water and soils are sometimes irreversibly damaged and in some cases recovery will be possible. On the link between emission and health, no reliable answer is available. The physical damage function of buildings and materials seems to be a S-shaped curve in relation to SO_2-concentrations. Additional research is being carried out ("additioneel programma verzuring") on the relation between acidification and physical damage. If results are made available these can be used to update the above table. Figure A.2 depicts the results.

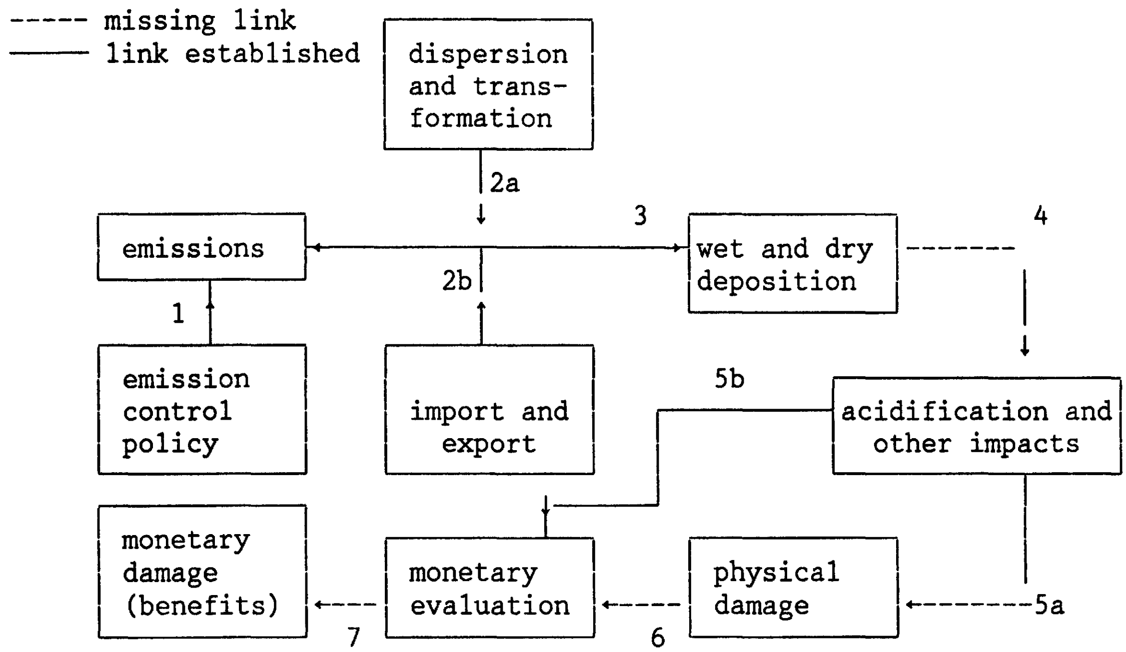

Figure A.2. Missing links in the Dutch "acidifying and photochemical emissions-monetary damage.

Concluding it can be stated that:

- it's very likely that "acid rain" is the major cause of damage to forests, crops, other terrestrial and aquatic ecosystems, buildings and materials. Not only acid deposition plays a role, but also ozone and other stress-factors;
- no agreement exists on the extent to which human health is being adversely affected by "acid rain";
- present damage due to "acid rain" is estimated at Dfl 700-800 million; future damage will rise to Dfl 900-1500 million per year if the deposition level is maintained;
- the above figures are underestimates because certain damage categories are not monetarily valued and others are not included, especially non-user benefits;
- though some information on the shape of the physical damage functions exist, especially for crops, certain materials and buildings, there is insufficient information at this moment to supply a comprehensive and reliable estimate of the benefits of emission reductions.

3. European damage studies

Relying for the moment on a few international studies that are more or less extensive, table A.5 shows the observed relations between damage categories and "acid rain".

Table A.5. Damage categories and "acid rain" in Europe

"acid rain" pollutants damagecategory	SO_2	NOx	Hydro- carbons	NH_3	Ozone	Remarks
1. Forests and vegetation (crops i.e.)	X	X			X	In combination with factors such as soil, climate, geography and forest management
2. Other terrestrial and aquatic ecosystems	X	X			?	
3. Buildings and materials[3]	X					Little data on NO_x in combination with particles (TSP)
4. Recreation						
5. Human health	X	?			X	acidification→ metal→health weakly
6. Non-user benefits		n.a.				

General remarks:
Source: (ERL, 1983; OECD, 1984; OECD, 1981)
1) at this stage results are tentative.
2) ? = results uncertain X = significant positive relation observed.
□ = no relation observed available
3) Other observed categories: visibility, soiling and cleaning included in category 4. Recreational benefits are related to surface water pollution. No clear relation between "acid rain" and this damage could be established from the literature.

Analogous to the approach in table A.2, table A.6 might be completed and reviewed. This could partly be done through the examination of inventories made by the OECD (1981), ERL (1983) and Bergmann (1985) and the underlying national studies. Information from recent national studies (e.g. from Germany and the Netherlands) would be necessary to fulfill this task.

Table A.6. Monetary damage in Europe due to "acid rain" decomposed by method and damage categories (milliard ECU of 1983).

Method	Technique	Damage category (benefits)						
		Forest and vegetation (+ crops)	Other terrestrial and aquatic flora and fauna	Buildings and materials	Recreation	Human health	Non user benefits	Total
INDIRECT	"Human capital"							
	"Risk evaluation"							
	"Surveys"							
	Market price (changes)	1.2	0.03	0.5-2.7				1.7-3.9
DIRECT	Hedonic price difference							
	Surveys (contingent valuation, willingness to pay)							
		1.2 +pm	0.03 +pm	0.5-2.7	pm	pm	pm	1.7-3.9

General remarks:
Source: (ERL, 1983)
1) Figures have to be completed!
2) 1 \$ ≈ 1 ECU.

Some of the results reached by Bergmann (1985) are presented in table A.7. At this moment no data are available to break down the calculated monetary damage over the different techniques that have been used to establish the estimates. The results in table A.7 should be looked at with scepticism because:

- estimates of Bergmann are insufficiently based on data on the "stocks at risk",
- some of the national studies used as a reference are outdated; for others the actual value may be questioned,
- an assumed share of the damage reported is arbitrary ascribed to sulphur deposition alone.
- damage based on studies of various years is expressed in tons of sulphur deposited in 1980 only.

Table A.7 Summary of damage due to "acid rain" (ECU/ton S deposited)

Damages of:		countries									
		USA	OECD	EEC	FRG	F	UK	I	NL	S	N
1. Recent buildings	A[1]	-[3]	-	300	370	-	283	237	-	78	-
	B[2]	200	300			137			296		
2. Metallic structures	A	260	291	-	272	-	333	334	267	-	-
	B			300		109					
3. Water supply systems	A	-	2	-	-	-	-	-	-	-	-
	B	2		2	2	2	2	2	2		
4. Historical monuments	A	-	-	-	-	-	-	395	72	-	-
	B		200	200	275	110	160				
5. Agriculture	A	112	60	61	-	-	/266_/	/29 /	-		
	B				50	44	46	142	138		
6. Forestry	A	33	-	-	/156_/	-	-	/88 /	-		
	B		10	10	100						
7. Aquatic life	A	-	-	-	-	-	/5_/	-	-	129	270
	B	5		5	10		50	5			
8. Human health	A	3,150	2,689	-	-	/1,029_/	2,509	/217 /	2,306	-	-
	B			1,970	2,450	1,293		1,333			
9. General estimates	A	1,657	3,203	-	-	1,010	-	1,032	3,997	According to bibliography of (12)	
Total A + B (without 9.)		3,762	3,552	2,848	3,529	1,695	3,383	2,448	3,084	Sum of detailed calcul. as above	
Values without human health (1 - 7)		612	863	878	1,079	402	874	1,115	778		

Source: Bergmann (12)
1) According to bibliography of Bergmann
2) Own estimates of Bergmann
3) - = no indication in the bibliography consulted by Bergmann
/ _/ Unreliable figures according to Bergmann

Notwithstanding this critisism the study by Bergmann supplies a useful overview of damage studies in Europe.
Using the above information and the completed table A.6 a picture could be given of the monetary damage categories that have been explored and the physical damage likely to occur (using table A.5) but not yet evaluated monetary. The distribution over different methods will, to a certain extent, permit conclusions to be drawn on the uncertainty in the estimates and the damage categories where new techniques could be applied and could result in extensive damage estimates (e.g. health or willingness to pay for forests and cultural heritage). Additional information on more recent (inter)national studies on physical and monetary damage, however, is indispensable for this aim.

4. Assessing benefits

This section first describes a study of the OECD on the benefits of controlling sulphur emissions. This is followed by an overview of the available information on the (acidifying and photochemical) emissions -monetary-damage chain. Finally the sources of sulphur deposition in the EC and the receptors of sulphur emitted by the EC are presented.

An early OECD study
An attempt has been made by OECD to estimate the benefits of controlling acidifying emissions (the study was limited to sulphur dioxide) (OECD, 1983). The report considered three types of scenarios:

Case I - a reference level including control technologies likely to be installed in 1985 (SO_2 emissions in 1985 21% higher than (1974);

Case II - in which 0.05% of Gross Domestic Product is spent annually on emission control (1985 SO_2 emissions 3% lower than 1974);

Case III - in which the best available technology is applied resulting in a 37% reduction of SO_2 emissions in 1985 over the 1974 level.

Using long range transport and urban dispersion models ambient air quality and deposition were estimated. On the basis of these atmospheric concentrations the physical impact was defined and translated in terms of avoided damage. Results are shown in table A.8.
The OECD in its study remarks that more understanding is needed about the stock at risk with respect to materials and effects on modern coatings, historical monuments and building materials. Also more research is necessary on direct and indirect effects on crops and forests. The OECD concludes that effects on health are highly uncertain though possibly representing the greatest benefit. Damage on aquatic ecosystems is important in Sweden and Norway though more studies are needed. Critics of the OECD study (Barnes, 1983) have made the following general

comment regarding the estimate of benefits:

1. the study relies on the implicit assumption that damage attributed to sulphur compounds collectively declines pro rato if SO_2 emissions decrease, thus ignoring atmospheric chemistry (in particular sulphates),
2. meteorology and climatology of the three base years 1974, 1975 and 1976 may be similar but are not likely to be typical for the rest of the 20th century, and so related dispersion patterns are doubtful.

Table A.8. Avoided damage accruing from a shift from case I to case III in SO_2 emissions in West-Europe (in million $)

Method	Technique	Damage category (benefits)						
		Forest and vegetation (+crops)	Other terrestrial and aquatic flora and fauna	Buildings and materials	Recreation	Human health	Non user benefits	TOTAL
INDIRECT	"Human capital"					170-4140		170-4140
	"Risk evaluation"							
	"Surveys"							
	Marketprice (changes)	214[1]	33[2]	963[3]	no reliable estimate	410-10260		1620-11470
DIRECT	Hedonic price difference							
	Surveys (contingent valuation willingness to pay							
TOTAL						580-14400		1790-15610

Source: OECD (1983).

1) Effect on forests not calculated. On crops for 11 countries.
2) Only for aquatic ecosystems in Scandinavia.
3) Only for certain materials i.e. steel.
4) Figures refer to morbidity only. Mortality expressed in increased life-expectancy.

The emissions-(monetary)damage chain

The above case study already shows that knowledge at this moment is too incomplete to make even an educated guess of the benefits of an European emission control strategy. The case study also indicates that several techniques for evaluating the damage are under exploited. Although some promising research has been and is being established figure A.3 shows that still some important links are partly missing.

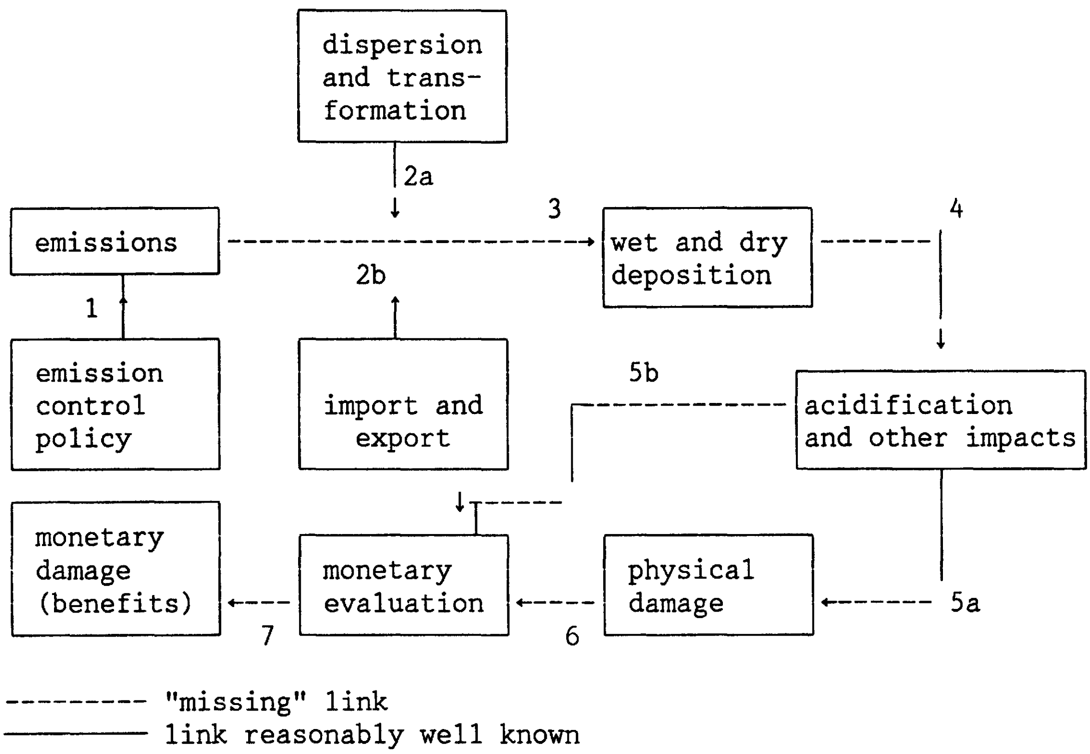

Figure A.3. Missing links in the European "acid rain" emission-monetary damage chain

Information based on table A.8, Phoxa and IIASA studies (Alcamo, Builtjes) shows that:

- dispersion and transformation models as well as imports and exports of pollutants other than SO_2 have not been established yet, although IIASA is investigating NO_X, and Phoxa NO_X, NH_3 and hydrocarbons (step 2a/b, 3, 4);
- there is not yet a reliable and politicaly established database for non-SO_2 emissions (step 1/3).

A preliminary assessment of available damage studies shows that (Perry et. al.; 1987):

- there is no accepted view on the exact relation between acidification, ozone and direct effects of their precursors and the impact of stress factors on physical damage (step 5a) for all damage categories, notably forests.
- methods and techniques to measure monetary benefits directly (step 5b) still suffer from growing pains and have not been widely ap-

plied. Although theoretically different types of biases could be avoided, in practice this seems to be more difficult (see also Opschoor, 1987);

- methods to measure benefits directly (step 5A) are lacking available data on the stock at risk, and do not always take into account changes in demand and supply, as a response of consumers and producers, and the impact on market prices.

The potential of an EC policy to reduce (sulphur)deposition in the EC

Part of the emission reduction reached by an EC control policy will accrue to non-EC countries. On the other hand part of the acid deposited within the EC is received from non-EC member states.

These aspects limit the possibilities of an EC policy to control deposition on the EC and in addition mean that part of the benefits of such an EC control policy will accrue to non-EC countries. On the other hand it should not be forgotten that in the present situation the damage, including welfare losses, in non-EC countries is partly caused by the EC.

Currently source receptor matrices, based on EMEP (European Monitoring and Evaluation Programme of long range transmission of air pollutants), are available for the emission and deposition of sulphur (ECE, 1986). The figures are having a 50% margin of uncertainty. From figure A.4. it can be seen that some 25% of the sulphur deposited in the EC comes from non-EC countries. About 60% is caused by the larger EC member states (FR, FRG, IT, SP and the UK). To some extent the EC thus is able to control the sulphur deposited on its own surface.

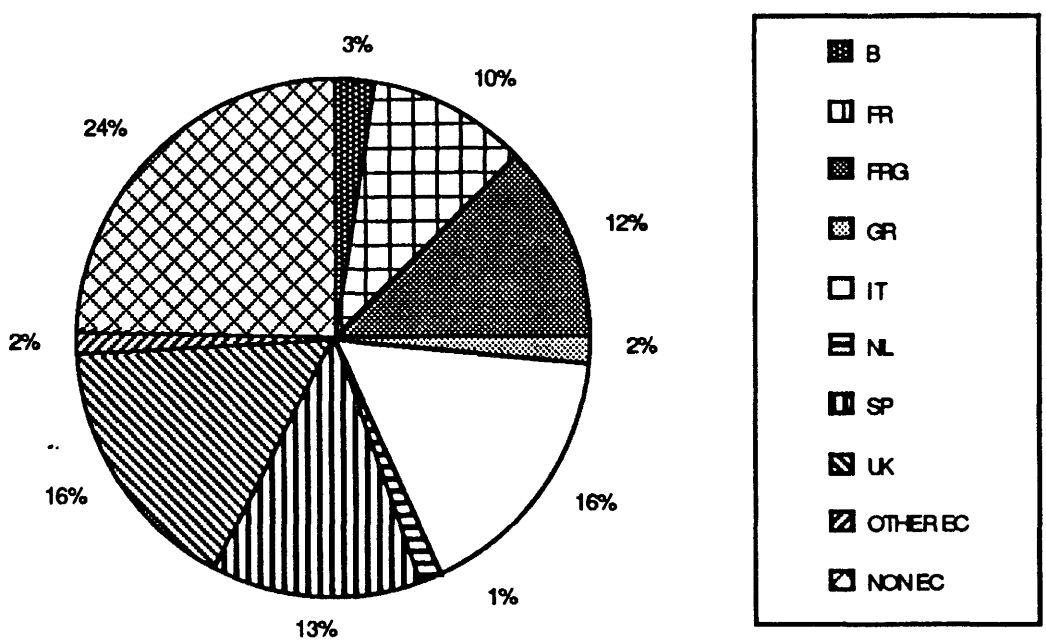

Figure A.4. Sulphur deposited in the EC and its sources in 1984.

Part of the emission reduction reached by the EC, however, will flow over to non-EEC member states as figure A.5. shows.

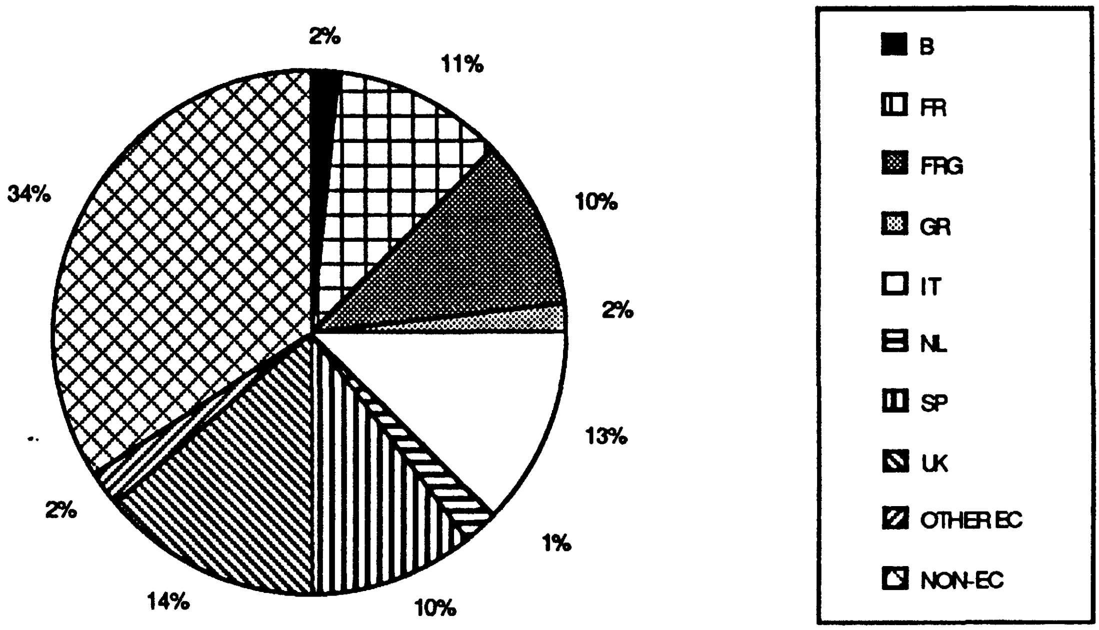

Figure A.5. Sulphur emitted by the EC and its receptors in 1984.

However, the actual impact also depends on the distribution of control measures over the EC member states since some member states deposit more sulphur within the EC than other member states. On the other hand several member states (e.g. Greece, Italy, Spain) hardly receive sulphur from other EC countries.
Ofcourse the distribution of "benefits" will also depend on the type of emissions controlled: high stack emissions, emissions with a more local dispersation pattern, etc. One might conclude that to a certain extent an EC control policy is an effective means of controlling (sulphur)acid deposition on the EC surface. However, part of the benefits (in the sense of reduced damage) will accrue to non EEC countries and the distribution of benefits over the EC member states might vary considerably.

5. Conclusions

Some attempts (OECD, ERL, Bergmann) have been made to assess the damage of "acid rain" (i.e. sulphur emissions) in Europe. In those studies not all damage categories, or pollutants have been assessed nor have al the available techniques to assess damage been applied.
Hence there exists no updated and comprehensive review of the present damage due to "acid rain" in Europe or in the EC. Therefore it seems to make sense, before trying to grasp the "benefits" of pollution control policies at the EC level, first to inventorise recent damage studies covering parts of Europe and the European Community. In doing so the

applied methods, observed damage categories and pollutants may be taken into account in order to perceive gaps and possibilities for promising research. At the same time an inventory of research efforts on the relation emissions-deposition-physical damage is needed in order to determine which pollutants, which atmospheric and deposition processes and physical damage categories could be included in a study and which probably not.

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