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Impacts of Economic Integration on Energy Demand and CO_2 emissions in Western Europe

Abstract:
This paper provides an empirical study of likely impacts of future economic integration or lack of integration on energy demand and CO_2 emissions in Western Europe. We employ a multisector energy demand model of thirteen Western European countries to study two scenarios that differ with respect to the degree of economic integration in the next decades. The simulations show that energy demand and accompanying CO_2 emissions are likely to increase substantially more by the year 2020 in a situation with further economic integration, as scheduled in the Maastricht treaty, than in a situation with a more economically fragmented Western Europe. Our findings are interesting in light of the EU stabilisation target of CO_2 emissions at the 1990 level by the year 2000, and they give an indication of future emissions when no specific policy measures are undertaken. Thus, this study supports the view that an effective energy policy is called for in order to stabilise CO_2 emissions in Western Europe.

Keywords: Western Europe, economic integration, energy demand, CO_2 emissions.

JEL classification: FO2, Q41, Q43.

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1. Introduction

Economic integration has been on the agenda at the European Community level for a long time, and Western Europe has in the wake of the integration processes undergone major political, institutional and judicial changes. The Maastricht Treaty, which was signed by the member states in 1991, draws up guidelines and objectives for the further economic and political integration in Western Europe in the next decades. However, the current national interests and economic conditions prevailing in most of the member states makes it uncertain whether or not all parts of the treaty can be expected to be fulfilled. These conditions thus create considerable uncertainty about future economic developments and the functioning of markets in Western Europe. This paper analyses the future energy demand and accompanying emissions of CO_2 in Western Europe under the assumption of successful further economic integration and compares this to a situation where fragmentation and national interests dominate.

The strategy followed is first to describe how further economic integration or lack of integration may affect the economic development in Western Europe. This description is of a somewhat ad hoc nature and is treated as exogenous information in the analysis. Based on the alternative economic growth paths, we then employ a Sectoral European Energy Model (abbreviated SEEM) with inter-fuel substitution to forecast fossil fuel demand and CO_2 emissions[1]. SEEM is a model of the demand side of the energy markets in *each of* thirteen Western European countries. Together these countries covered approximately 90 per cent of the total energy consumption in OECD Europe in 1991. Hence, the model focuses on energy demand in, and emissions from, each of the countries which are important for Western European energy markets and emissions to air. Several models in the literature have treated Western Europe as one block when analysing energy and environmental issues similar to the present study. Examples of these global models are Global 2100 (Manne and Richels 1992), GREEN (Burniaux et al. 1992), and ECON-ENERGY (Haugland et al. 1992). Our model differs from these, since each country is individually modelled and simulated. Earlier studies employing the SEEM model include Birkelund et al. (1993, 1994) and Alfsen et al. (1995).

In order to study future energy demand and CO_2 emission within the framework outlined above, we consider *two economic scenarios*. In the first scenario the European integration process is assumed to continue according to the time schedule in the Maastricht Treaty. In fact this scenario assumes that all proposals mentioned in the Maastricht Treaty are fully implemented by the turn of the millennium, resulting in a moderate but positive overall effect on economic growth in the EU. As a part of a complete economic integration, this scenario further assumes that energy taxes are harmonised across the EU countries. By way of contrast, the second scenario assumes that national disagreements halt further EU unification, resulting in a more economically fragmented Western Europe in the next decades. Consequently, this scenario is based on the main assumption that average economic growth in the EU would be lower than in the integration scenario. Noticeably, no energy tax harmonisation takes place in the fragmentation scenario. The base year for the simulations is 1991, and the time horizon includes the final year 2020.

The rest of the paper is organised as follows: Section 2 briefly outlines the structure and the relations in the SEEM model. Section 3 then describes the two economic scenarios and summarises their basic underlying assumptions, while section 4 presents the simulation results. Finally, section 5 concludes the paper. The appendix contains detailed tables of simulated long term elasticities together with main simulation results.

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[1] The SEEM-model has been developed in a co-operation between Statistics Norway and the Netherlands Energy Research Foundation ECN (Energieonderzoeck Centrum Nederland).

2. The SEEM model

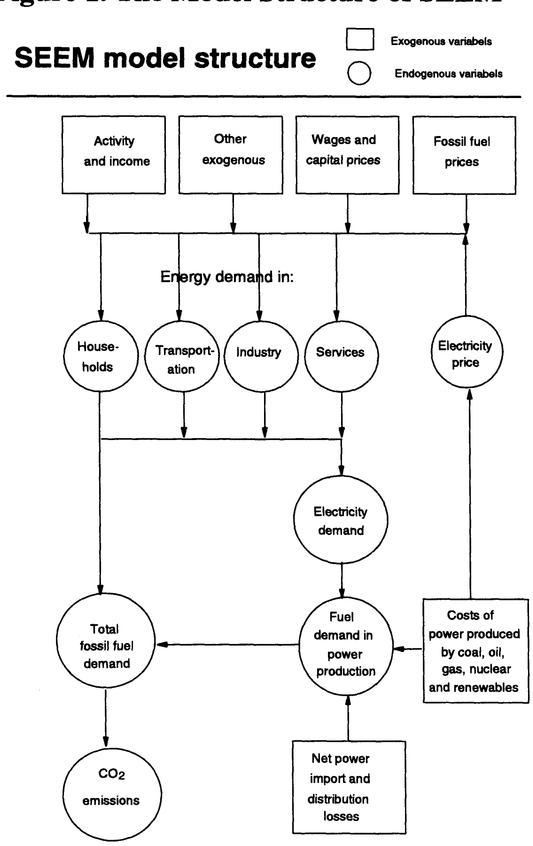
The presentation of the SEEM-model is restricted to a rather brief and descriptive outline. A more detailed documentation of the model can bee found in Brubakk et al. (1995), Boug (1995) and Kolsrud (1996).

2.1. The Model Structure

The complete SEEM-model comprises separate models for the following thirteen Western European countries: the four major energy consumers Germany, France, Italy and United Kingdom, the four largest Nordic countries Denmark, Sweden, Finland and Norway, and five other countries Spain, Austria, Belgium, the Netherlands and Switzerland. Each country is treated as a separate block, in which neither trade between countries nor supply of primary energy is modelled. The model is partial in the sense that import fuel prices and production activity in the economies are exogenously given. However, the supply of electric power is modelled, and prices and quantities of electricity are thus endogenously determined. In each country, five sectors are modelled: Power production, Manufacturing industries and Service industries (in the following denoted Industry and Services), Households and Transportation[2].

Figure 1 depicts the structure of each country model. In a first step the model determines the demand for coal, oil, natural gas, and electricity in the end user sectors (households, transportation, industry and services), based on exogenous information on technology, economic activity and income levels as well as prices on fossil fuels, labour, and capital.

Figure 1. The Model Structure of SEEM



The electricity generation sector then provides the required domestic production of power, given exogenous information on net power import and distribution losses. Electricity is produced by thermal power plants using coal, gas or oil as inputs, nuclear power plants or by plants using renewables. The different thermal power plant's share of the total electricity generation depends on their relative costs in producing the power. Based on the production costs of electricity, margins and taxes, the model calculates electricity end user prices in all sectors. Adding the use of fossil fuels in the end user sectors to fossil fuel inputs in thermal power production, total demand for each fossil fuel is derived by country. In a sub model emission coefficients for CO_2 are linked to the consumption of coal, oil and gas in all sectors in order to estimate CO_2 emission[3].

2.2. The Sector Models

Energy demand in all sectors are modelled according to variants of the fuel-share model. This representation draws upon the early work of Sato (1967), Brown and Heien (1972), and Berndt and Christensen (1973). For an elaborated description of the fuel-share approach, consult Longva and Olsen (1983). The starting point of the fuel-share model is a neo-classical macro production function of the form

[2] Energy demand from other activities, like agriculture and fisheries, is exogenous in the SEEM-model.

[3] Note that only anthropogenic emissions of CO_2 from fossil fuels are calculated. CO_2 emission from biomass/wood combustion is not included, assuming that there is zero net flux of CO_2 to the atmosphere from this activity in this part of the world because of sustainable yield. Additionally, emissions from industrial (non-combustion) processes have not been included.

(1) $$Y = F[K, L, E(c, o, g, el)],$$

where Y is production, K is capital, L is labour and E is an energy aggregate composed of coal (c), oil (o), gas (g) and electricity (el). The notion of the energy aggregate function E means that energy is produced by use of the energy inputs coal, oil, gas and electricity, and that the optimal combination of these is independent of the other inputs in the production function (weak separability). Besides, it is assumed that the fuel shares are independent of the level of production Y (homotheticity property). The assumptions of weak separability and homotheticity allow the optimisation problem to be carried out in two steps: First, at the lower level, a calculation of the cost-minimising combination of energy inputs for a given level of aggregate energy use E, and then, at the upper level, a calculation of the cost-minimising combination of the aggregates K, L, E for exogenous levels of production Y[4]. This stepwise optimisation is also utilised for sectors in which energy demand is derived from the consumer side of the economy, like in the household and the passenger transport sector. Equation (1) will then express a utility function rather than a production function, and the optimisation problem is solved by maximising this utility subject to the consumers budget constraint.

In general, we do not explicitly specify the objective function $F(\cdot)$[5], but instead postulate behavioural functional forms for the energy aggregate E resulting from cost minimising and utility maximising behaviour. In SEEM the energy aggregate is either specified as a Cobb-Douglas or a CES (Constant Elasticity of Substitution) function when deriving the energy demand functions for the sector at hand. Parameters representing the behaviour of the sectors are either estimated by Statistics Norway or adopted from the literature [Pindyck (1979), Abodunde et al. (1985) and Wavermann (1992)]. Estimations and calibrations of the energy use and prices to the base year of 1991 are based on data from the International Energy Agency (IEA 1993a, b).

2.2.1. Manufacturing

The industry sector is described by the two level fuel share model, as given in (1). At the upper level, the cost minimising combination of capital, labour and energy is derived. The lower level determines the cost minimising combination of the different fuels included in the energy aggregate, i.e., the optimal proportion (fuel shares) of coal, oil, gas and electricity based on relative fuel prices and substitution possibilities. At both levels the Cobb-Douglas specification has been used. To allow for sluggish adjustment of capital input to price changes, demand is lagged according to a partial adjustment hypothesis. Hicks neutral technical progress[6] is specified at the upper level.

2.2.2. Services

The service sector fuel share model is similar to that of the industry sector. A CES-function is postulated for the energy aggregate. This sector model allows for a nested model in *three* levels for countries with substantial use of all three fossil fuels, i.e., coal, oil, and gas. At the upper level, electricity and a fossil fuel aggregate consisting of oil, gas and coal are modelled as separate arguments in the production function in addition to capital and labour. This implies a hypothesis that the use of electricity contributes to production in a profoundly different way compared to fossil fuels. While the latter are used mainly for space heating, electricity is mostly used in appliances like computers and lighting for which energy substitution is impossible. Cost minimisation at the upper level is assumed to result in log-linear demand functions for electricity and the fossil fuel aggregate. At the lower level, the fossil fuel aggregate is specified as a two-level CES-function. This implies that the problem of finding the cost minimising fossil fuel mix can also be solved step-wise as previously described. Hence, at the first level (of the lower level), the fossil fuel aggregate is distributed on a subaggregate and a remaining fuel in proportions determined by substitution possibilities and relative prices. Demand for each of the two fuels, constituting the subaggregate, is determined in the same way at the second level (of the lower level)[7].

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[4] As will be clear later, the lower level in the household and services sector is further divided into two sub-levels. These two levels are referred to as the first and second level.

[5] Except for the industry sector, where the production function is assumed to be of the Cobb-Douglas form.

[6] That is, the marginal rate of substitution of the inputs in production is unaffected by the technological change.

[7] In countries where only two types of fossil fuels are used, this second level (of the lower level) is omitted.

2.2.3. Households
The energy demand model for this sector is identical to the service sector model, but with a few deviations. At the upper level, an aggregate of «all other goods» replaces the inputs capital and labour in the objective function which now represents level of utility instead of service production. Electricity and fossil fuel prices are variables which determine the households demand for electricity and the fossil fuel aggregate at the upper level. The modelling of the lower levels are similar to the service model.

2.2.4. Transport
The transport sector is divided into three main modes: *passenger transport, freight transport*, and *air transport*. Passenger transport is further subdivided into private and public transport. Furthermore, private transport consists of cars running on gasoline, gas, and diesel, while public transport is divided into rail transport produced by diesel and electricity, and bus transport produced by diesel. Within freight transport, we distinguish between transport on road, rail and inland waterways. Air transport is considered separately because most air transport is combined passenger and freight transport, and because of small substitution possibilities with other transport modes. Altogether the transport sector is thus divided into ten different transport categories (modes). Demand for passenger transport is coming from the consumers, while demand for all other types of transport is derived from the producing sectors. The modelling of the various transport modes are all based on Cobb-Douglas specifications. At the upper level of the *passenger transport* model, total demand for person kilometres is a function of consumers expenditures and a passenger transport price index. At the lower level the demand for passenger transport is split into the different modes in proportions depending on fuel prices and capital prices of the respective modes. This in turn determines demand for person kilometres by mode. Given figures for car occupancy and fuel efficiency, the corresponding fuel use are then computed. Note that the fuel efficiency is based on the assumption of linear penetration of new technologies. *Freight transport* is to some extent modelled similar to passenger transport. At the upper level the development of gross domestic product determines total demand for ton kilometres. Given exogenous assumptions on mode shares and fuel efficiency, the demand for the individual fuels are then calculated at the lower level. As opposed to fuel demand in passenger and freight transport, demand for air fuel (kerosene) in the *air transport* mode is simply modelled as a function of the price of kerosene and the gross domestic product.

2.2.5. Electricity Generation
In the electricity generation model the domestic power production requirements are determined by adding end user electricity demand (i.e., total demand from industry, services, households and transportation), net power imports (exogenous) and distribution losses (exogenous). An important underlying assumption is that total supply of electricity equals net demand for electricity. Electricity can be produced by different technologies relying on different energy sources - coal, oil, gas, nuclear and renewables. The share of electricity produced by some specific fuel is determined by the relative costs of the different plants. The cost is a combination of fuel costs and technology related costs. This in turn determines demand for the different fuels, given fuel efficiency in different plants. As in the transport model the fuel efficiency is based on the assumption of linear penetration of new technologies.

2.2.6. Fossil Fuel Prices
The fuel price module in SEEM computes sectoral end user prices for the different fuels. The end user prices are divided into import prices, gross margins and taxes. For electricity, the «import price» corresponds to the electricity generation price calculated by the average unit costs of producing electricity domestically. Gross margins for all fuels include costs and profits in transformation, distribution, retailing etc. Taxes are divided into fuel specific taxes, carbon taxes and value added tax. The end user prices are hence calculated according to the following identity:

$$(2) \qquad P = (P^{CIF} + M + T^{E} + T^{C})(1 + T^{VAT}),$$

where P^{CIF} is the import price (CIF), M is the gross margin, T^{E} is the excise energy tax, T^{C} is a carbon tax, and T^{VAT} is the relevant rate of value added tax. Note in particular that the impact of the import price on the end user price is larger the greater the import price is initially relative to the other price components. Similarly, the impact of the excise tax is larger the smaller the import price, gross margin and the other taxes are, that is the smaller the end user price is initially.

2.2.7. Price and Income Elasticities

There is much variation across empirical studies of elasticities and hence it is difficult to come up with representative price and income elasticities [see, e.g., Dahl and Erdogan (1995)]. Table 1 shows average long term elasticities by fuel and sector applied in this study.

The average direct price elasticities in the industry sector are almost equal for all fossil fuels as opposed to the service and the household sectors, where the elasticities vary considerably. For example, the high direct price elasticity of coal in the service sector is due to high elasticities in Germany and the United Kingdom, whereas the elasticities of oil and gas are driven by high and low elasticities in France and Italy, respectively. As far as cross price elasticities in the service sector are concerned, note in particular the relatively high elasticities of coal with respect to oil and gas and the elasticity of gas with respect to oil. The former elasticities are driven by high cross price elasticities in Germany and the United Kingdom, respectively, while the latter is driven by high elasticity in France. The direct price elasticity of oil in the household sector is mainly due to high elasticity in United Kingdom, while the elasticity of gas and electricity are due to high elasticities in Italy. For coal, the direct price elasticities are more equal across the four major countries. The various price elasticities in the power sector are also relatively equal across the four major countries. On the other hand, the simulated long term direct elasticities in the transport sector indicate that energy demand for transport purposes on average is less elastic than energy demand in the other sectors. However, it should be noted that the elasticities in Italy are high compared to the average. Table 1 also shows that the average income elasticities are quite equal across the sectors, despite of high elasticities in the household sector in both Italy and France.

Table 1. Simulated Long Term Elasticities in SEEM. Average of the Four Major Countries[8]

Demand for		Price of						
Sector	Fuel	Coal	Oil	Gas	Electricity	Gasoline	Diesel	Activity
Industry[1)]	Coal	-0.98	0.02	0.03	0.10	.	.	0.80
	Oil	0.02	-0.97	0.03	0.10	.	.	0.80
	Gas	0.02	0.02	-0.97	0.10	.	.	0.80
	Electricity	0.02	0.02	0.03	-0.89	.	.	0.80
Services[1)]	Coal	-2.24	0.81	1.16	0.09	.	.	0.77
	Oil	0.10	-0.83	0.50	0.09	.	.	0.79
	Gas	0.25	0.81	-1.22	0.09	.	.	0.79
	Electricity	0.01	0.04	0.05	-0.26	.	.	1.01
Household[1)]	Coal	-0.62	0.21	0.10	0.08	.	.	0.89
	Oil	0.19	-0.59	0.02	0.09	.	.	1.03
	Gas	0.02	0.03	-0.46	0.09	.	.	1.03
	Electricity	0.00	0.02	0.05	-1.01	.	.	1.13
Power[2)]	Coal	-0.38	0.08	0.03	.	.	.	.
	Oil	0.11	-0.67	0.03	.	.	.	.
	Gas	0.11	0.08	-0.61	.	.	.	.
Transport[2)]	Gasoline	.	.	0.00	0.02	-0.26	0.06	0.96
	Diesel	.	.	0.00	0.02	0.14	-0.42	0.96
	Gas	.	.	-0.26	0.02	0.16	-0.22	1.09
	Electricity	.	.	0.00	-0.36	0.14	0.06	0.96

1) Source: Brubakk et al. (1995). 2) Simulated for the purpose of the present paper. Note: . denotes not applicable.

[8] Tables A1-A4 in the Appendix summarise the simulated elasticities for Germany, United Kingdom, Italy and France.

To sum up, it is the direct price elasticities and the income elasticities that dominate energy demand responses in this study, while the cross price elasticities are moderate. These moderate cross price elasticities can be attributed to the fact that they consist of two opposite working price effects which more or less offset each other; one positive price effect which increases demand for competing fuels as they become relatively cheaper than the fuel that faces the price increase, and one negative price effect which decreases energy demand as such as the fuel price increase itself makes energy relatively more expensive than other production factors and commodities in the economy. In comparison, all direct price elasticities are equal to -0.90 in OECD-regions, while the cross price elasticities are on average 0.10 in a study by Golombek and Bråten (1994). Berg et al. (1996) apply the same price elasticities and assume that the income elasticities in the OECD-regions are 0.50 on average.

3. Description of Economic Scenarios

As indicated in the introduction, we consider two economic scenarios in the present analysis. In this section we describe these scenarios together with a summary of their most important underlying assumptions.

3.1. The Integration Scenario

The integration scenario (henceforth referred to as IS) is based on the assumption that the ongoing European integration process will continue more or less according to the time schedule laid out in the Maastricht Treaty. In fact, the scenario assumes that all proposals mentioned in the Maastricht Treaty are fully implemented by the year 2000. Due to resulting positive economic perspectives the scenario further assumes that EU will be joined by the present EFTA countries around the turn of the century. Hence, the integration process concerns all thirteen Western European countries included in SEEM. Furthermore, the scenario assumes an association of all central European countries (the so called Visegrad countries) around year 2000, improving trade possibilities and access to foreign investments. The integration process will result in the completion of all objectives of the internal market, so free movement of all goods, persons and capital will be realised. It is expected that the completion of the internal market will have a moderate, but positive overall effect on economic productivity and income in EU. Presumably funds for structural improvements in the Southern European countries will contribute to a more homogenous economic development within the EU-area.

Yet another important assumption underlying the integration scenario is concerned with the energy tax structure on fossil fuels in the next decades. Energy taxes are important policy instruments, as they influence energy demand and thus CO_2 emissions. In SEEM such energy tax policies may be introduced as either direct energy taxes or CO_2-taxes (cf. equation 2). As part of a complete economic integration, the integration scenario assumes that a harmonisation of energy taxes takes place in order to avoid fiscal inequalities across the member states. More specifically, the excise tax for each fuel in each of the economic sectors in SEEM is harmonised towards the corresponding unweighted average tax levels in the four major energy consuming countries: Germany, France, United Kingdom and Italy. This harmonisation is based on the energy taxes as of 1991, and is assumed to take place gradually over the period from 2000 to 2010[9].

3.2. The Fragmentation Scenario

As opposed to the integration scenario, the fragmentation scenario (henceforth referred to as FS) is based on the assumption that the EU integration is halted from now on. National interests and economic conditions prevailing in the member states hinder further EU unification. As a result, the Maastricht Treaty will become a dead letter and not be implemented, and the completion process of

[9] Another energy policy could be the introduction of carbon taxes as proposed by the Commission of the European Communities (EC) in 1992 (cf. Europe Information Service 1992). However, the EC proposal has been greatly criticised, both in international fora and within the European Community itself. Given this criticism, it seems by now that the proposal is difficult or even impossible to implement. Hence, we do not consider introduction of carbon taxes in the integration scenario. Thus the CO_2-tax in the end user price equation above is set equal to zero in this study. We refer the reader to Alfsen et al. (1995) and Birkelund et al. (1993 and 1994) who assess the impact of the proposed carbon/energy tax on energy demand and CO_2 emission in the context of the SEEM model.

the internal market will not progress further. Instead national protectionism and stagnation in trade between the member states will dominate the economic situation, and EU will experience a more economically fragmented Western Europe in the next decades. The discontinued integration process is supposed to hamper overall economic growth performance in all Western European countries. Consequently, the fragmentation scenario assumes that average economic growth in Western Europe is lower than in the integration scenario, and also that country differences in growth are greater in FS than in IS. Due to the situation of a fragmented Western Europe, no energy tax harmonisation is assumed to take place in FS. Hence, permanent inequalities in the national taxation systems existing as of 1991 will prevail over the next decades in this scenario.

3.3. Basic Exogenous Assumptions

As described in section 2, demand for coal, oil, natural gas and electricity in the end user sectors is determined from exogenous information on economic activity, technology, and labour, capital and fossil fuel prices. The following exogenous assumptions adopted for the simulation period 1991-2020 are partly based on forecasts from studies made by the International Energy Agency (IEA) and partly based on considerations made by Statistics Norway.

3.3.1. Economic Growth

Table 2 shows the assumptions on economic growth that have been adopted for the two economic scenarios in the end user sectors. The annual growth of gross domestic product, production in industry and services, and consumer expenditure are averages over the scenario period 1991-2020 and are made up from different figures for each of the following three periods: 1991-2000, 2000-2010, and 2010-2020.

Table 2. Average Annual Growth in Economic Activity. 1991-2020. Per cent

	Gross domestic product[1)]		Industry production		Service production		Consumer expenditure[2)]	
Country	IS	FS	IS	FS	IS	FS	IS	FS
Austria	2.4	2.1	2.4	2.1	2.5	2.2	2.5	2.0
Belgium	2.3	1.9	2.3	1.9	2.4	2.0	2.4	1.8
Denmark	2.2	1.8	2.1	1.6	2.3	1.9	2.2	1.6
Finland	2.3	0.5	2.3	0.5	2.4	0.5	2.3	0.5
France	2.3	1.9	2.3	1.9	2.4	2.0	2.3	1.8
Germany	2.3	2.1	2.3	2.1	2.4	2.2	2.4	2.0
Italy	2.6	1.7	2.5	1.7	2.7	1.8	2.6	1.6
Netherlands	2.2	1.8	2.1	1.6	2.3	1.9	2.2	1.6
Norway	2.4	2.0	2.4	2.0	2.5	2.1	2.5	1.9
Spain	2.6	1.7	2.5	1.7	2.7	1.8	2.6	1.6
Sweden	2.3	1.6	2.3	1.6	2.4	1.5	2.4	1.4
Switzerland	2.3	2.1	2.3	2.1	2.4	2.2	2.4	2.0
United Kingdom	2.2	1.0	2.1	1.1	2.3	1.0	2.1	1.0
Average	2.3	1.7	2.3	1.7	2.4	1.8	2.4	1.6

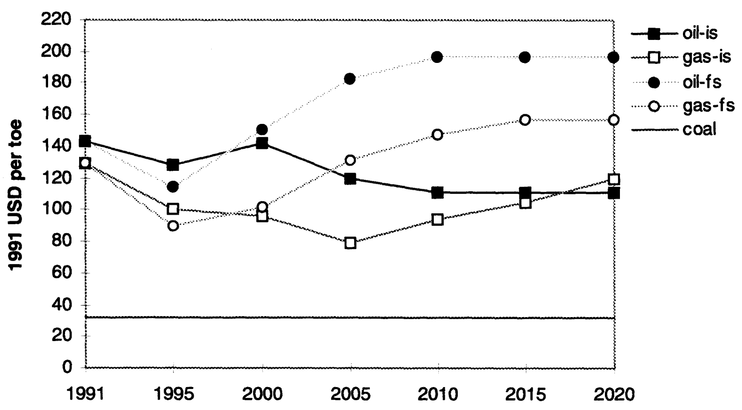
Sources: IEA (1994) and Statistics Norway. 1) The GDP growth rates apply to the freight and air transport sectors. 2) The growth rates for consumer expenditure apply to the household and passenger transport sectors.

3.3.2 Fossil Fuel Prices

Figure 2 shows developments in assumed SEEM average of fossil fuel import prices according to the two economic scenarios. In the integration scenario it is assumed that a successful transition in Russia will take place and that this will keep oil and gas prices low during the simulation period. Together with the structural developments in Western Europe this will lead to decreasing gas prices in the period from 1995 to 2005. The oil price is likewise expected to decrease gradually from the turn of the century. At about 2005 the gas price is expected to be uncoupled from the oil price. When translated into average annual growth rates, the oil and gas import prices in each SEEM-country are assumed to decrease by 0.87 and 0.26 per cent annually in the period from 1991 to 2020 in the IS scenario. Except for changes in the direct energy taxes as a result of harmonisation from 2000 to 2010, the other price components shown in equation (2) are set constant at 1991 levels throughout the simulation period in the integration scenario. Hence, the forecasted growth in the end user prices of oil and gas in IS is driven by the forecasted growth in the import prices and the direct taxes.

In the fragmentation scenario, the oil import price is assumed to increase by 1.14 per cent while the gas import price is assumed to increase by 0.68 per cent annually over the period from 1991 to 2020 in each SEEM-country due to lack of new investments and thus exports from Russia. Since gross margins and the different taxes are assumed constant at 1991 levels, the forecasted growth in the end user prices of oil and gas in the FS scenario is determined by the forecasted growth in the import prices alone.

Figure 2. Forecasts of Fossil Fuel Import Prices. Average of the SEEM-countries



Sources: IEA (1994) and Statistics Norway. The import prices are measured in 1991 US dollar per tonnes oil equivalents.

As opposed to oil and gas import prices, the coal import price for the SEEM countries is assumed to remain stable at the present price level in both scenarios. Forecasts for the other end user price components of coal are also set constant at 1991 levels in the FS scenario. Hence, the end user prices of coal in FS are assumed constant at the 1991 level throughout the simulation period. However, the forecasted growth in the end user prices of coal in the integration scenario is determined by forecasted growth in the direct energy taxes as a result of the tax harmonisation from 2000 to 2010.

3.3.3. Technical Progress

In general, efficiency improvements in IS are expected to be larger than in FS, because of higher economic growth and thus faster turnover and more competition in Western Europe. In addition, it is expected that the industry sector is more efficiency oriented, so that more improvement can be realised in this sector than in the service and the household sector. Furthermore, it is expected that the present technological situation in peripheral countries such as Spain and Italy lags behind the Western European average. As a consequence, the realised annual efficiency improvements are assumed to be higher in these countries, especially in industry. Table 3 shows the country averages of the autonomous efficiency improvements adopted in the simulations.

Table 3. Annual Improvement in Autonomous Efficiency. 1991-2020. Per cent

	IS	FS
Industry	0.6	0.3
Services	0.4	0.2
Households	0.4	0.2

Source: Statistics Norway.

3.3.4. Capital and Labour Costs

Finally, forecasts of annual growth rates in capital and labour costs were made. It is assumed an annual growth rate in capital and labour cost of 0.2 and 1.6 per cent for the entire simulation period in both scenarios.

4. Simulation Results

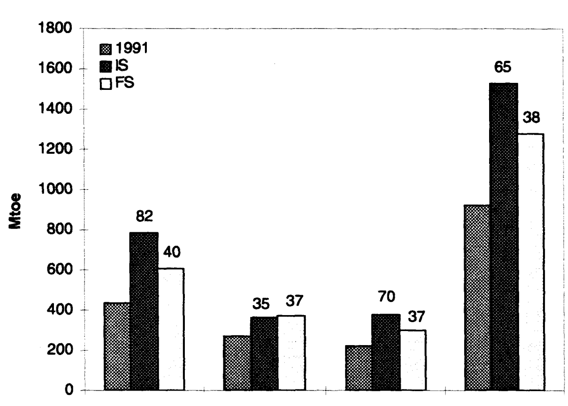
The purpose of the present section is to compare the two economic scenarios along two dimensions: their impact on energy demand and their environmental effects in terms of CO_2 emissions. A presentation of the energy demand analysis is given in sections 4.1-4.4, while the environmental implications of the scenarios are discussed in section 4.5. First, we present the analysis at the aggregate level, focusing on the overall simulation results for the thirteen SEEM countries in total. Then, we turn to the micro level in which separate results for the four major countries Germany, the United Kingdom, Italy and France are presented. Throughout the presentation, we concentrate on the endogenously determined fossil fuels oil, coal and natural gas. Although the simulation period is divided into sub-periods, we focus on the main results in the final year 2020 and compare them with the base year 1991.

Before turning to the simulation results, it is useful to point out some important model properties. The final impact on energy demand in each country of a change in an exogenous variable depends on the following major aspects: (i) the magnitude of the exogenous shift, (ii) price and income elasticities in each sector, (iii) fuel shares by sector in the base year and (iv) sector shares of total energy demand in the base year. Since a change in an exogenous variable works simultaneously through the model aspects (ii)-(iv), it is sometimes difficult to single out explanations of a particular impact. In the following discussion we will point to dominating factors whenever possible.

4.1. Aggregate Energy Demand by Fuel

Figure 3 shows aggregate energy demand for the entire SEEM area in the IS and FS scenario. The aggregate energy demand in the model area rises in both scenarios. In IS the energy demand grows by 65 per cent from 1991 to 2020, while the corresponding growth in FS is 38 per cent. As indicated in the figure, oil demand is expected to show the highest growth rate in the simulation period, closely followed by gas, in IS. Coal demand, on the other hand, shows only half the growth rate of the two other fossil fuels. When considering the impacts of economic integration, the growth rates of oil and gas in FS are approximately cut in half compared to IS, while the growth rate for coal actually increases slightly. The main explanation for the latter implication on coal demand is that under the adverse economic conditions in the fragmentation scenario, the coal price is competitive against the other fuels. Additionally, since electricity demand drops in FS relative to IS (not reported), less investments are made in thermal power supply and the introduction of gas fired power plants is postponed.

Figure 3. Aggregate Energy Demand by Fuel in 1991 and 2020



Note: *Total* is the sum of oil, coal and gas demand, and the figures above the bars represent the percentage growth in energy demand over the period from 1991 to 2020. Demand is measured in million tonnes oil equivalents (Mtoe).

In table 4 the increase in figure 3 are translated into average annual growth rates over the simulation period. Aggregate energy demand shows an average annual growth rate of 1.8 and 1.1 per cent in IS and FS, respectively. For comparison, we report the corresponding figures from the study «Energy for a New Century: the European Perspective» [Energy in Europe (1990)]. In that study a «high growth» scenario and a «business as usual» scenario are simulated for the period 1990-2010. The reported annual growth rates for aggregate energy demand are 1.4 and 0.9 per cent, respectively[10]. Another similar study includes IEA's «World Energy Outlook» (1994), in which projections for expected future development in energy demand and

[10] The «high growth» scenario and the «business as usual» scenario are comparable to the IS and FS scenario, respectively.

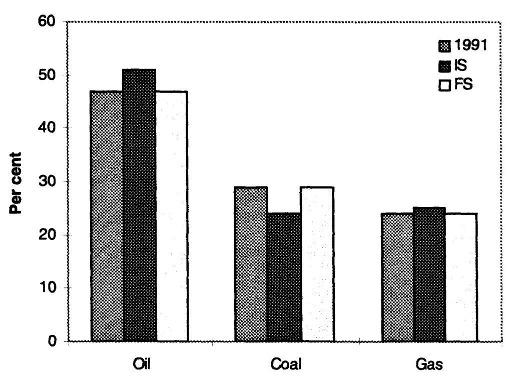
accompanying CO_2 emissions are presented. Based on moderate growth in economic activity and import prices on oil and gas, that study projects that aggregate fossil fuel demand in OECD-Europe is likely to increase from 1209 Mtoe in 1991 to 1521 Mtoe in 2010, averaging 1.2 percentage increase annually.

Table 4. Average Annual Growth in Aggregate Energy Demand. 1991-2020. Per cent

	Oil	Coal	Gas	Total
IS	2.1	1.0	1.9	1.8
FS	1.2	1.1	1.1	1.1

The growth rates of total fossil fuel demand, reported in table 4, correspond to economic growth rates of around 2.3 and 1.7 per cent, as shown in table 2. Thus, growth in aggregate energy demand is lower than economic growth in both scenarios, but energy use is reduced relatively more than economic activity in going from IS to FS.

Figure 4. Fossil Fuel Shares in 1991 and 2020



A comparison of the fossil fuel shares in 1991 with the simulated shares in 2020 shows that the gas share of total fossil fuel demand is almost constant equal to 25 per cent in both scenarios (see figure 4). Oil increases its share from somewhat below 50 per cent in 1991 to somewhat above 50 per cent in 2020 in the IS scenario. Coal reduces its share correspondingly from almost 30 per cent to almost 25 per cent. The change in shares among oil and coal is reversed when going from IS to FS, restoring the 1991-shares of 47 per cent for oil and 29 per cent for coal.

A more detailed explanation for the development in the aggregate energy demand in the two scenarios can be found by considering the relative importance of the main exogenous assumptions on economic activity, technological improvement, fuel import prices and fuel taxes. The relative impacts of these economic factors in going from the IS scenario to the FS scenario are shown in table 5.

Recall from section 3 that a higher economic activity growth is assumed in IS than in FS. As marked by «–» in the first row of the table, this economic factor alone tends to lower the demand for all fossil fuels in FS relative to IS. Oppositely working are the technology assumptions made in table 3. Higher autonomous energy savings assumed in the integration scenario implies, ceteris paribus, that the energy intensities become higher in FS compared to IS. This is marked by «+» in the second row of the table.

Table 5. Relative Impacts of Exogenous Factors on Aggregate Energy Demand

	Oil	Coal	Gas	Total
Economic growth	–	–	–	–
Technology	+	+	+	+
Fuel import prices	– –	+	–	– –
Fuel tax harmonisation	+	0	–	0
Total input	– –	+	– –	– –

Note: + denotes higher fuel demand in FS than in IS.

From figure 2 it is clear that the oil and gas import prices are assumed lower in the integration scenario than in the fragmentation scenario. Ceteris paribus, this economic factor leads to lower oil and gas demand in FS relative to IS. Noticeably, the oil demand difference is marked with a double «–» in the third row of the table. This is due to the fact that the discrepancy between the oil price evolutions in IS and FS are much greater than the discrepancy between the gas price evolutions, particularly after 2005. Hence, the price effects have time to work out completely on energy demand, despite lag effects in the SEEM model. Although the coal import price stays constant in both scenarios, it is more favourable compared to oil and gas prices in FS. Thus, the fuel price effect is that coal demand is higher in FS than in IS.

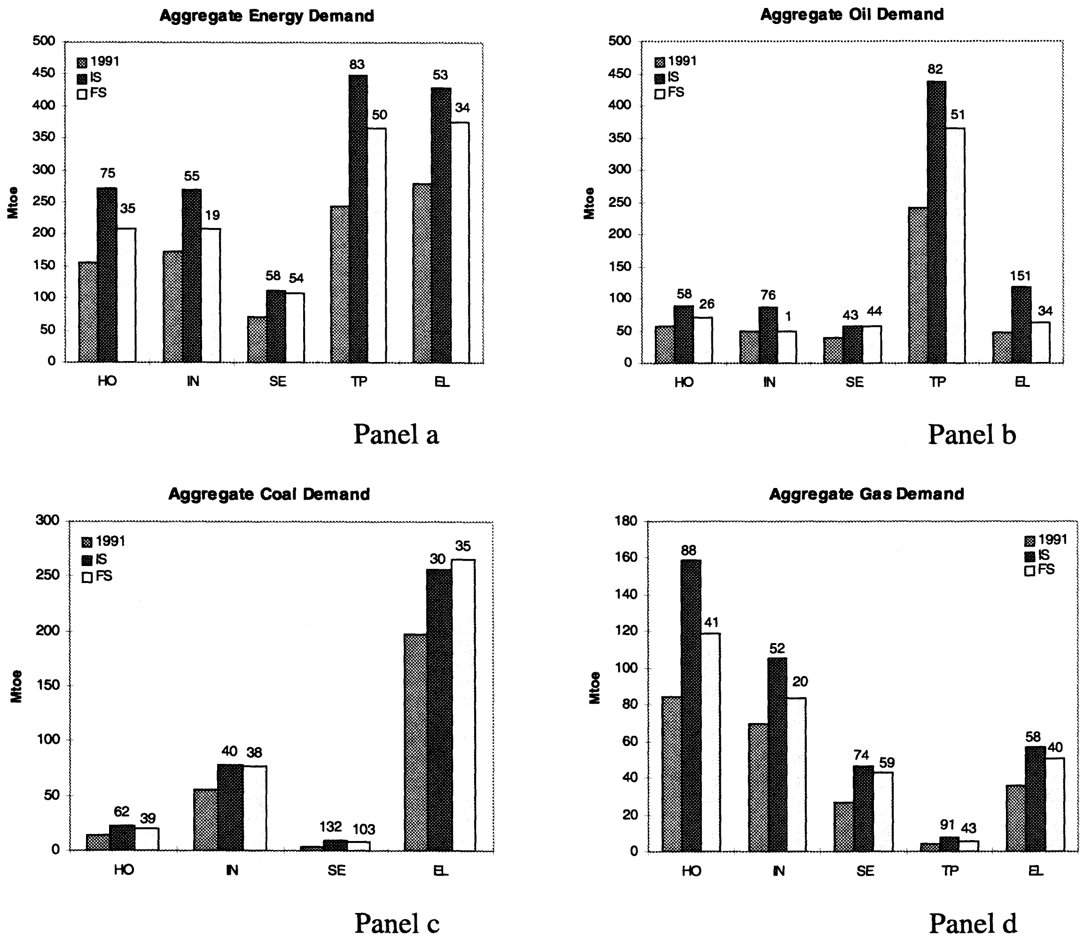
The fourth major difference in the input assumptions between the two scenarios is the tax harmonisation implemented in the IS scenario. Due to extremely high taxes on natural gas used in the household sector in Italy, removal of the tax harmonisation leads to reduced gas demand at the aggregate level. The effect of tax harmonisation on oil demand is opposite, though weak, mainly because some of the large oil consuming countries today have gasoline taxes slightly below the average of the gasoline taxes presently found in the four major countries in the SEEM area. Finally, there is no significant relative impact of tax harmonisation on coal demand, as marked by «0» in the fourth row of the table. This is explained by absence of taxes on coal used in all sectors in the four major countries and in most of the other countries covered by SEEM. Overall, the relative effect of the tax harmonisation on aggregate fossil fuel demand must be considered to be weak, ceteris paribus.

Summing up the separate effects, as shown by the bottom line of the table, the net relative effect of the different scenario inputs is that the demand for oil and gas and thus total fossil fuel demand is higher in IS than in FS. Coal demand is, however, slightly higher in FS than in IS, as previously recognised from figure 3.

4.2. Aggregate Energy Demand by Sector

These scenario differences in fossil fuel types can be analysed further by decomposing the simulated demand into sectoral demand. The sectoral demand for fossil fuels shown in figure 5a indicates that the growth rates are somewhat more equal across sectors than across fossil fuel types during the simulation period in both scenarios. However, the simulation results suggest that fossil fuel demand in the transport and the household sector increases somewhat more than demand from the other sectors in the IS scenario with growth rates of 83 and 75 per cent from 1991 to 2020, respectively. These figures correspond to annual average growth rates of 2.1 per cent in the transportation sector and 1.9 per cent in the household sector. In comparison, the fossil fuel demand in the power generating sector increases by 53 per cent from 1991 to 2020, averaging 1.5 per cent per year. According to figure 5a, the most significant difference in the fragmentation scenario is that the service sector faces the highest growth rate in fossil fuel demand of 54 per cent, while the industry sector faces a growth rate of 19 per cent only, averaging 0.6 per cent per year.

Figure 5. Aggregate Energy Demand by Sector in 1991 and 2020



Note: HO, IN, SE, TP and EL denote the household, the industry, the service, the transport and the power generating sector, respectively. The figures above the bars represent the percentage growth in energy demand over the period from 1991 to 2020. Demand is measured in million tonnes oil equivalents (Mtoe).

In figures 5b-d these patterns of aggregate fossil fuel use are decomposed into sector-wise consumption of oil, coal and gas. Figure 5b shows that the transport sector, with a share of 56 per cent, is by far the most oil consuming sector in the base year. The other sectors follow with shares of around 10 per cent. The transport sector faces a 82 and 51 per cent increase in oil demand over the simulation period, and thus contributes to the aggregate oil demand growth by 56 per cent and 71 per cent in the IS and FS scenario, respectively. Even though the power generating sector shows the highest growth by as much as 151 per cent in the IS scenario from 1991 to 2020, it is only ranked as the second largest contributor to the aggregate oil demand growth. The largest scenario differences in the simulated oil demand growth are found in the power generating sector, viz. 117 percentage points larger growth in IS than in FS. This is mainly explained by very low energy taxes in most of the countries in the model area in 1991, and thus by heavily decreasing oil end user prices in the electricity sector in the IS scenario due to a large negative impact from falling import prices[11]. In the industry sector, the gap in the growth rates between IS and FS over the simulation period is also rather large for oil demand (75 percentage points). Again, this can be explained by low energy taxes combined with relatively high direct price elasticities and low cross price elasticities in this sector compared to the household and the service sector (cf. table 1).

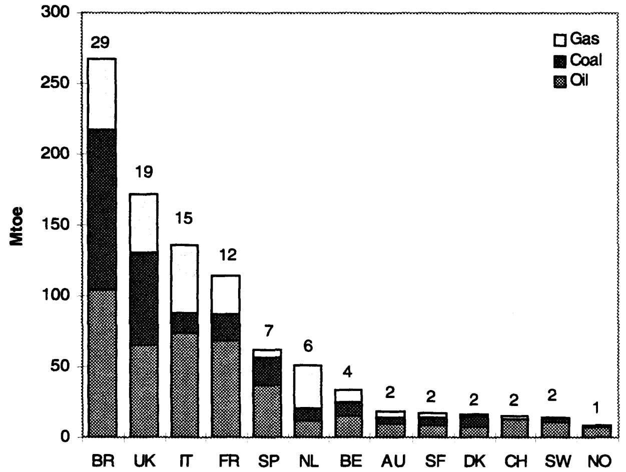
As figure 5c demonstrates, the power generating sector is by far the most coal consuming sector with a share of 73 per cent in 1991, followed by shares ranging from 21 per cent in the industry sector down to 1 per cent in the service sector. No coal is used in the transport sector in any of the countries

[11] The impacts of changes in import prices and taxes on end user prices will be persued later in section 4.4 in connection with the sectoral energy demand analysis in the four major countries.

in the model area. Despite the fact that the power generating sector faces the lowest coal demand growth in both scenarios, it contributes to the aggregate coal demand growth with 61 and 69 per cent in the IS and the FS scenario, respectively. Although significant growth rates in both scenarios, the very low consumption share in 1991 still makes the service sector a negligible coal consuming sector in 2020. Absence of coal taxes in most of the SEEM countries in addition to constant coal import prices, and thus constant end user prices of coal through the simulation period in both scenarios, explain the small scenario differences in coal demand growth. Noticeably, coal demand in the power generating sector increases slightly in going from the IS scenario to the FS scenario. Thus, the source of the higher aggregate coal demand growth in FS than in IS (cf. figure 3) can be found in the scenario differences in the power generating sector alone. The main reason for this is that the relative coal end user price (i.e., relative to oil and gas prices) decreases in the fragmentation scenario due to increasing import prices on oil and gas. This favourable development of the end user coal prices is most significant in the power generating sector where energy taxes are a negligible part of the end user prices.

As opposed to the oil and coal demand pictures, figure 5d shows that the aggregate gas demand growth is more evenly spread on all sectors in both scenarios. The household sector with a share of 38 per cent in 1991 is the dominant gas consuming sector, closely followed by the industry sector with a share of 31 per cent. The figure indicates that the household sector, facing 88 and 41 percentage increase in the IS and FS scenario, respectively, contributes the most to the growth in aggregate gas demand by around 45 per cent in both scenarios. In contrast, the transport sector is a negligible contributor to the aggregate gas demand growth, despite relatively high growth rates in both scenarios. For sectoral gas demand, the service sector shows only a small scenario difference in the growth rates. This is mainly due to a high energy tax in Italy which dampens the impact of scenario differences in import prices on gas end user prices, and thus gas demand for all countries, except Italy. In the household sector, the energy tax in Italy is also relatively high compared to the other countries. However, since the income elasticities are much larger in this sector than in the service sector, reaction on gas demand is much larger. This can be seen by the 47 percentage points higher gas demand growth in the IS scenario than in the FS scenario.

Figure 6. Energy Demand by Fuel in the SEEM Countries in 1991



Note the following country abbreviations: BR (Germany), UK (United Kingdom), IT (Italy), FR (France), SP (Spain), NL (Netherlands), BE (Belgium), AU (Austria), SF (Finland), DK (Denmark), CH (Switzerland), and NO (Norway). The figures above the bars represent the percentage proportion of total fossil fuel demand in the SEEM area. Demand is measured in million tonnes oil equivalents (Mtoe).

4.3. Energy Demand by Fuel in the Four Major Countries

As shown in figure 6, the consumption of fossil fuels in Germany, United Kingdom, Italy and France represented about 75 per cent of total fossil fuel use in Western Europe in 1991. Oil demand is dominated by all four countries with demand shares varying from 24 per cent in Germany to around 15 per cent in the other three major countries. Gas demand is also dominated by the four major countries with demand shares ranging from about 20 per cent in Germany, United Kingdom and Italy to 12 per cent in France. Coal demand is, however, dominated by Germany and United Kingdom only, with demand shares of 42 and 24 per cent, respectively. Hence, the main contributors to the aggregate energy demand pattern discussed above can be analysed by looking at the energy developments in these four major countries. First, we look at energy demand across fuels in the present section. Then, we continue with a study of the energy demand development across sectors in section 4.4.

Figures 7a-c compare the simulated demand of fossil fuels in each of the four major countries in 2020 with their respective demand in the base year 1991[12]. Driven by economic growth and fossil fuel price changes, the figure demonstrates that the end user demand for all fossil fuel types in all four countries increases in both scenarios, with the highest growth in Italy and France. Italy as the main example is also the country which shows the biggest differences in the growth rates between the scenarios. The growth in oil demand in Italy is reduced from 171 per cent to 55 per cent in going from the IS scenario to the FS scenario. Demand for oil and gas in all of the major countries grow significantly more in IS than in FS. The opposite picture can be seen for coal demand, except for the United Kingdom.

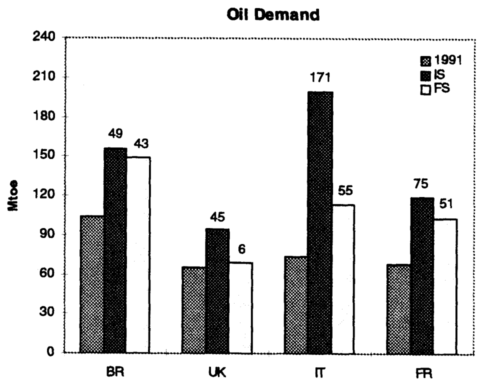
In the IS scenario Italy is the only country expected to show a growth in oil demand well above the average of 82 per cent for the entire SEEM area (cf. figure 3). France has a growth rate just below the average, while Germany and United Kingdom have growth rates well below the average. Turning to the fragmentation scenario, the figure shows that oil demand in Germany and France are relatively little affected, giving them growth rates above the SEEM average of 40 per cent. Although oil demand in Italy is reduced considerably from the level in the IS scenario, the growth of 55 per cent is still above the average. In contrast, oil demand in the United Kingdom is reduced to a very small growth of only 6 per cent over the simulation period.

With respect to coal demand in the IS scenario, both Italy and France show growth well above the SEEM average of 35 per cent, while Germany and the United Kingdom show growth just below the average. The same pattern is also found in the fragmentation scenario, except from the fact that the growth of 37 per cent in Germany is identical to the SEEM average. Additionally, the spread in growth rates in going from the integration to the fragmentation scenario are not as apparent as for oil demand.

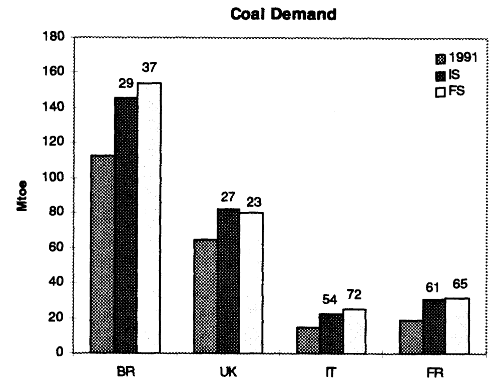
Figure 7 shows further that the growth pattern for gas demand is almost identical to the pattern found for oil demand. Both Italy and France are now the countries with growth well above the SEEM average of 70 per cent when it comes to gas demand in the IS scenario. Germany and United Kingdom, on the other hand, have growth rates well below the average. Even though the gas demand in Italy drops significantly in the FS scenario relative to the IS scenario, the growth remains above the SEEM average of 37 per cent. The growth rate in France also stays above the average in the fragmentation scenario. United Kingdom next after Italy is the country which is hardest hit by fragmentation. Gas demand in United Kingdom is reduced to a very small growth of 14 per cent, and thus stays far below the SEEM average. For Germany the growth of 33 per cent is now just below the average.

[12] Table A5 in the Appendix summarises the simulated demand of fossil fuels in terms of average annual growth rates over the simulation period for all countries comprised by SEEM.

Figure 7. Energy Demand by Fuel in the Four Major Countries in 1991 and 2020



Panel a



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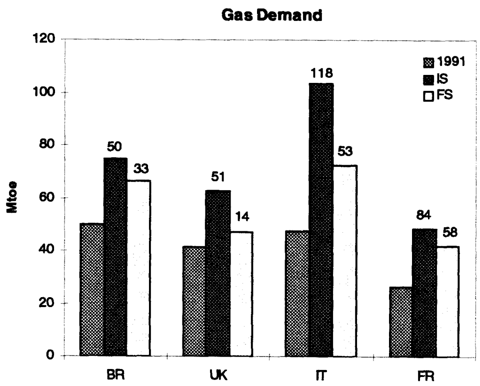
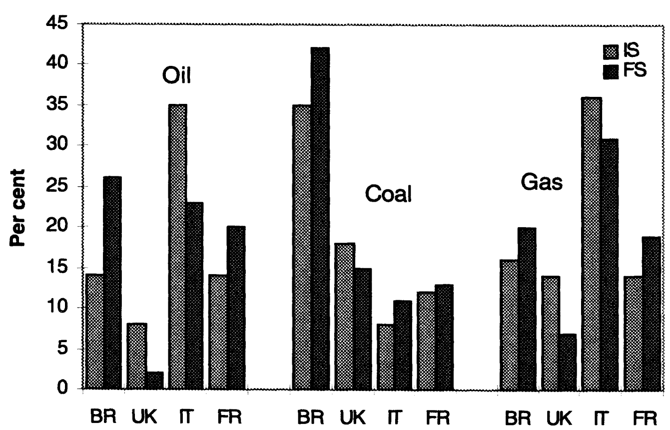


Panel c

Note: BR, UK, IT and FR denote Germany, United Kingdom, Italy and France, respectively. The figures above the bars represent the percentage growth in energy demand over the period from 1991 to 2020. Demand is measured in million tonnes oil equivalents (Mtoe).

When identifying the relative contribution of each country to the growth in aggregate energy demand in Western Europe, the demand shares in figure 6 and the growth rates shown in figure 7 have to be assessed together. Figure 8 summarises the results. Italy, with 35 per cent, is the main contributor to the growth in aggregate oil demand in the IS scenario, while Germany with 26 per cent is the main contributor in the FS scenario, closely followed by Italy and France. United Kingdom is the smallest contributor in both scenarios. With respect to growth in aggregate coal demand, Germany is the main contributor and Italy is the smallest contributor in both scenarios. Finally, Italy with 36 and 31 per cent is the main contributor behind the growth in aggregate gas demand in both scenarios, while United Kingdom again is the smallest contributor with 14 and 7 per cent.

Figure 8. Contribution by the Four Major Countries to Aggregate Energy Demand Growth



Note: BR, UK, IT and FR denote Germany, United Kingdom, Italy and France, respectively.

4.4. Energy Demand by Sector in the Four Major Countries

This final section of the demand analysis explains the driving forces behind the energy use pattern in the four major countries by looking at the energy developments in each economic sector separately. At such a disaggregated level of the analysis, it is possible to take the sectoral price and income elasticities in each of the four major countries explicitly into account when explaining the simulation results. Before turning to the simulation results, let us first examine the existing price and tax structure.

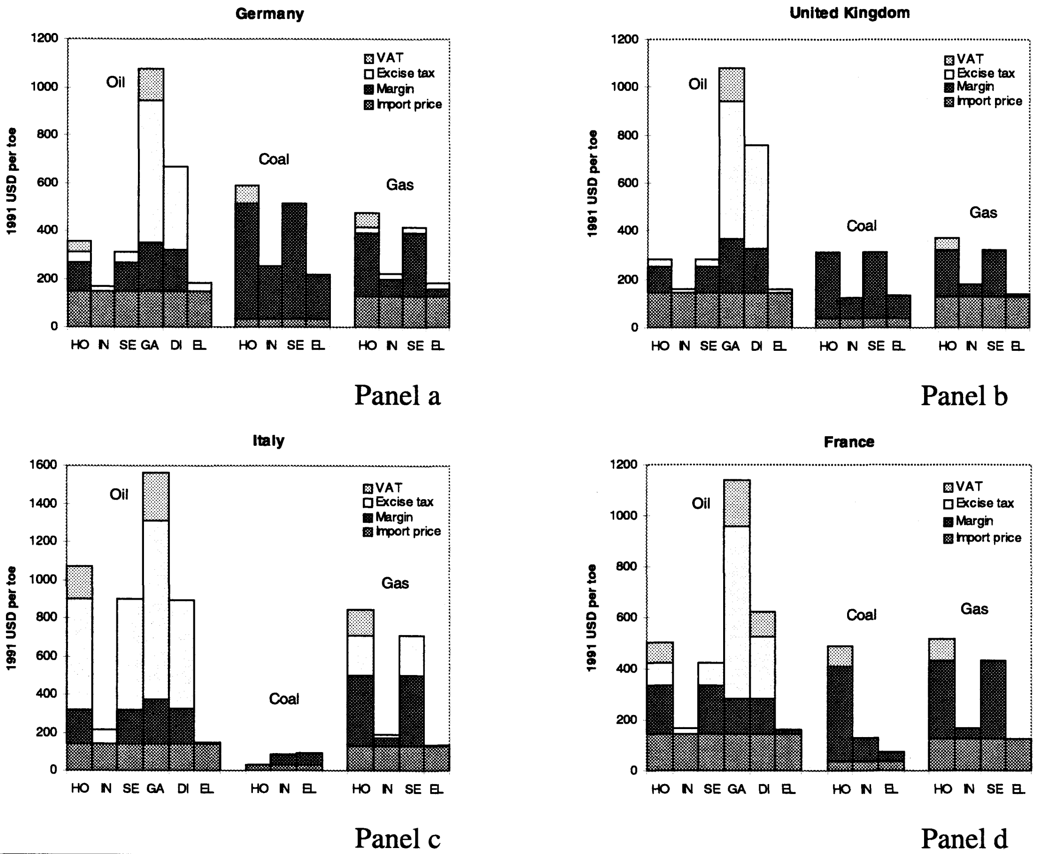
Recall from equation 2 in section 2.2.6 that the impact of an annual percentage change in the import price on the end user price, and consequently energy demand, is larger the greater the import price relative to the other price components is. However, it is not the taxation shares alone that matter when anticipating the effects of the tax harmonisation, but also the absolute discrepancy between the tax and the tax average found in the four major countries. Thus, it is important to study the end user price structure prevalent in 1991 as a starting point for the sectoral demand analysis in the four major countries. Figure 9 gives an overview of the sectoral end user price structure in 1991 in the four major countries[13]. While the sectoral import prices on the various fuel types are roughly at the same level in the four major countries in the base year, the gross margin, energy excise taxes and value added taxes vary considerably. This is the main reason for the discrepancy in end user prices, and hence the import price shares, between the countries at the sectoral level. Obviously, the effects on end user prices due to relative changes in the import prices vary between sectors and countries.

Figure 9a demonstrates that the shares of oil import prices in Germany vary from about 85 per cent in the industry and power generating sector to around 15 per cent in the transport sector. The oil import price shares in the household and service sector represent about 45 per cent of the end user prices. The same picture of oil import price shares is roughly also the case in the United Kingdom and France, as shown in figure 9b and 9d. Hence, except for the transport sector, the effects of changes in import prices are large on the oil end user prices in Germany, the United Kingdom and France. By way of contrast, Italy faces much lower effects as far as the household and service sectors are concerned. Figure 9c shows that the import shares of oil end user prices in Italy in these sectors are around 15 per cent compared to 45 per cent in the other three countries. For the industry, transport and power generating sector in Italy the oil import price shares roughly match those in Germany, the United Kingdom and France.

Figure 9 further shows that the effects of changes in import prices on end user prices of gas are relatively high in most of the sectors in each country, though somewhat less than in the case of oil. In Germany, the gas import price shares range from around 30 per cent in the household sector to nearly 70 per cent in the power generating sector, while the corresponding shares in the United kingdom range from 35 per cent to somewhat above 90 per cent, respectively. Roughly speaking, the same figures can also be recognised for France. Again, the household and the service sectors in Italy are the major exceptions to the relatively high import price shares found in the other countries. In these sectors in Italy, the import prices represent about 15 per cent of the end user prices of gas. However, the import price shares of around 70 and 95 per cent in the industry and power generating sector, are almost identical to the figures found in the United kingdom. Hence, the effects of changes in the import prices on gas end user prices are large in these sectors in Italy.

[13] Note that figure 9 considers the gasoline price and the diesel price in the transport sector, as the gasoline and diesel demand together represent about 90 per cent of total oil demand in the transport sector in all four countries. Likewise, the end user price of gas in the transport sector is not shown in the figure since gas consumption in this sector is negligible in all four countries. Since no coal is used in the transport sector in either of the countries, no end user price of coal is reported in the figure. This is also the case for the service sector in Italy and France.

Figure 9. Sectoral End User Prices in the Four Major Countries in 1991

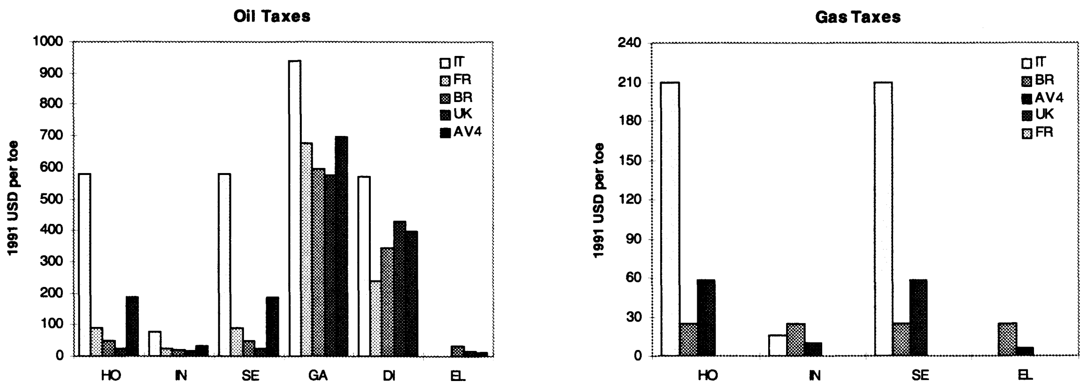


Note the following abbreviations: HO, IN, SE, GA, DI and EL denote the household, the industry, the service, gasoline and diesel in the transport, and the power generating sector, respectively. The unit is 1991 USD per tonnes oil equivalents.

Moreover, figure 9 indicates that the import shares of coal end user prices are relatively small in most of the sectors in all countries compared to the import shares of oil and gas. Except from the household sector in Italy where the coal import shares is almost 100 per cent, the coal import shares range from around 5 per cent to somewhat above 30 per cent in all sectors in each of the four major countries. Thus, the effects of changes in coal import prices are more moderate than the effects of changes in oil and gas import prices.

When considering the energy excise taxation, figure 9 demonstrates that the transport sector is by far the most heavily oil taxed sector in Germany, United Kingdom and France. The taxation share of oil end user prices amounts to around 50 per cent in these countries. The corresponding taxation share in Italy is even larger, viz. around 60 per cent. Italy is also the country with relatively high oil taxation in the other sectors. Except for the power generating sector where there are no taxes, the taxation shares range from 35 per cent in the industry sector to 65 per cent in the service sector in Italy. In the other three countries these shares range from about 10 per cent to 15 per cent. With respect to gas taxation, there is absence of any taxes in all sectors in both the United Kingdom and France. The gas taxation in Germany is relatively small with shares ranging from 5 per cent in the household sector to nearly 15 per cent in the power generating sector. The most significant gas taxation can be seen in the household and service sectors in Italy. Noticeably, there is absence of coal excise taxes in all sectors in all four countries. This structure of energy excise taxation in the base year is the starting point for the tax harmonisation assumed in the integration scenario. In order to have a closer look at the effects of the tax harmonisation on end user prices, figure 10 compares the discrepancy between each sectoral fuel tax in each country with the average tax level found in the four major countries.

Figure 10. Sectoral Excise Taxes in the Four Major Countries in 1991



Panel a Panel b

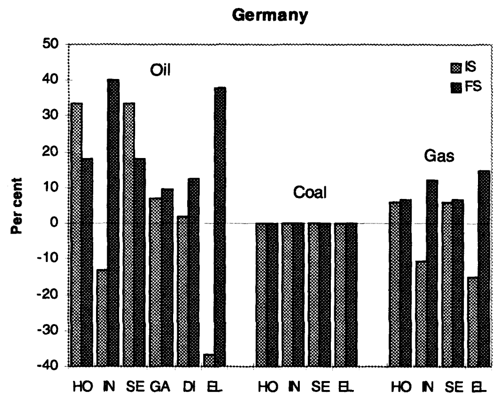
Note the following abbreviations: BR, UK, IT, FR, and AV4 denote Germany, United Kingdom, Italy, France and the average tax level in the four major countries respectively. HO, IN, SE, GA, DI and EL denote the household, the industry, the service, gasoline and diesel in the transport, and the power generating sector, respectively. The unit is 1991 USD per tonnes oil equivalents.

The most apparent feature of figure 10a is that the oil taxes in the household, industry, service and transport sector in Italy are far above the average tax level. Hence, the effects of tax harmonisation on oil end user prices are particularly high in these sectors in Italy. The zero oil tax level in the power generating sector is, however, slightly below the average tax level, and the effect of tax harmonisation on oil end user price in this sector in Italy is thus moderate. From figure 10a it is further clear that the oil taxes in Germany are all below average, except for the power generating sector, which has a tax slightly above the average. The oil taxes in United Kingdom are all below the average, except for the power generating sector and the diesel tax in the transport sector. The most significant effects of tax harmonisation in these countries exist in the household and service sector, because the discrepancy from the average tax level are largest in these sectors. In France, the oil tax is below the average in all sectors. However, the most apparent effects of tax harmonisation are expected in the household, service and transport sector when it comes to diesel.

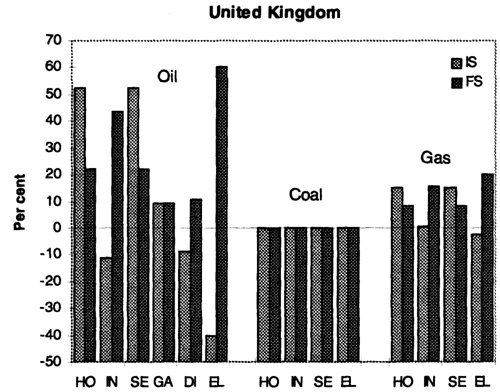
A key characteristic of figure 10b is that the gas taxes in the household and service sector in Italy are far above the average tax level found in the four major countries, and the effects of tax harmonisation on gas end user prices are expected to be high in both sectors. On the contrary, the gas taxes in the industry and power generating sector (zero tax in the latter) in Italy are only slightly above and below the average, and the tax harmonisation effect on end user prices are thus excepted to be moderate in these sectors. Figure 10b shows further that the gas taxes levied in the household and service sector in Germany are somewhat below the average and the gas taxes levied in the industry and power generating sector are somewhat above the average tax level. Hence, the tax harmonisation effect on gas end user prices are moderate in all sectors in Germany. As previously mentioned, no gas taxes are levied in any sectors in the United Kingdom and France. However, the discrepancy between a zero tax and the average tax level is most visible in the household and service sector, and the effects of tax harmonisation are thus largest in these sectors.

With this price and energy tax structure in the base year in mind, we now turn to the projected end user prices in the integration and fragmentation scenario in the four major countries. Generally speaking, if a particular excise tax is above the average tax level, then the effect of tax harmonisation in the integration scenario implies a reduced excise tax and thus a reduced end user price. Obviously, the opposite effect emerges if the excise tax initially is below the average tax level. Similarly, import price assumptions in the IS scenario decrease the end user price of oil and gas in all sectors, while they increase the end user prices in the FS scenario. The coal end user prices, on the other hand, stay constant in all sectors in all four countries in both scenarios due to absence of taxes in addition to constant import prices. This pattern of directions of effect is depicted in figure 11, showing the growth rates in the sectoral end user prices in the two scenarios over the period 1991 to 2020 in the four major countries.

Figure 11. Growth in Sectoral End User Prices in the Four Major Countries. 1991-2020



Panel a



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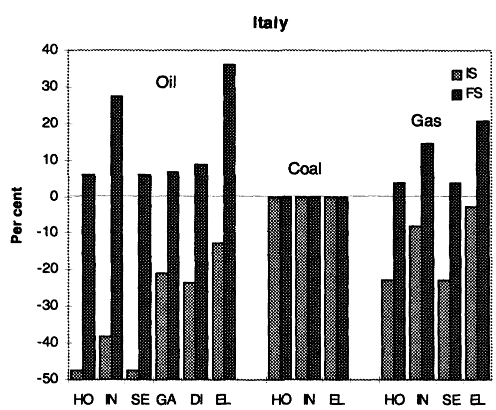

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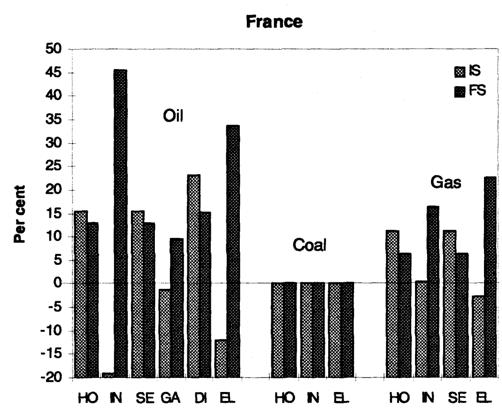
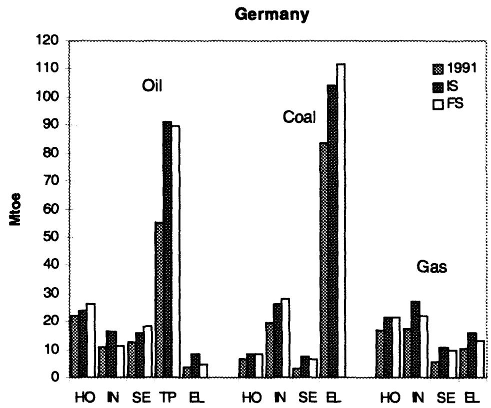


Panel d

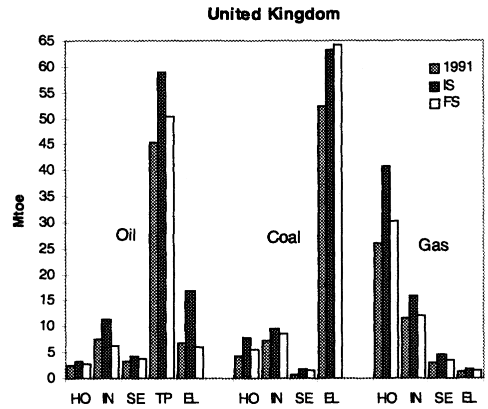
Note the following abbreviations: HO, IN, SE, GA, DI and EL denote the household, the industry, the service, gasoline and diesel in the transport, and the power generating sector, respectively.

In accordance with the price effects discussed above, the figure exhibits large oil and gas end user price changes in most of the sectors in all four countries. As a result, the relative prices of the various fuels also change somewhat. Hence, the direct price effects and the cross price effects, together with the income effects may be significant on sectoral fossil fuel demand in the four major countries. Figure 12 reports the simulated sectoral fossil fuel demand in the integration and fragmentation scenario in the four major countries.

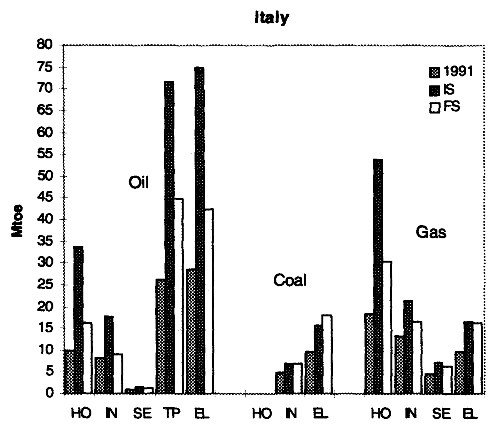
Figure 12. Sectoral Fossil Fuel Demand in the Four Major Countries in 1991 and 2020[14]



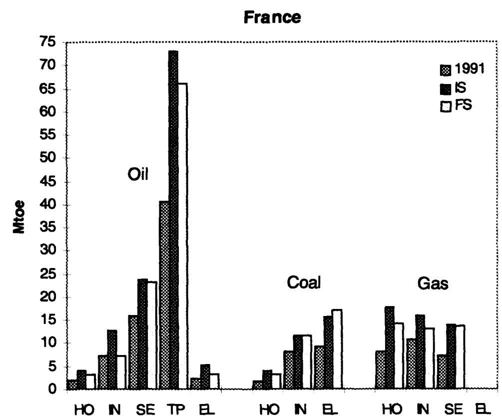
Panel a



Panel b



Panel c



Panel d

Note: HO, IN, SE, TP and EL denote the household, the industry, the service, the transport and the power generating sector, respectively. Demand is measured in million tonnes oil equivalents (Mtoe).

Figure 12a indicates that the electricity generating sector in Germany faces the highest oil demand growth in the IS scenario. The average annual growth of somewhat below 3 per cent is largely due to the huge drop in the oil end user price since the direct long term price elasticity is -0.76 (cf. table A1). This oil demand increase is considerably enhanced by increased electricity demand in the end user sectors, which is partly driven by the activity growth and partly by the direct price effect of reduced electricity prices. The reduction in the electricity prices are caused by the tax harmonisation. The scenario differences is also largest in the electricity generating sector in Germany, as the growth in oil demand drops to somewhat below 1 per cent a year in the FS scenario, mainly due to the significant increase in the end user price of oil. In comparison, the transport sector as the major oil consuming sector in Germany faces oil demand growth of around 1.7 per cent annually in both scenarios. Due to small end user price changes of gasoline and diesel in combination with small price elasticities, these figures are driven by the activity growth. Another interesting aspect of figure 12a is that oil demand increases more in FS than in IS in both the household and service sectors. This is mainly caused by relatively higher oil end user prices in IS due to the adverse effect of the tax harmonisation that dominates the import price effect. It is also evident that the oil demand growth in the industry sector in the fragmentation scenario is practically zero as the income effect and the direct price effect together with the energy saving effect nearly offset each other. With regards to coal demand in Germany, figure 12a shows that the service sector faces the highest growth of about 3 per cent and 2.7 per cent in IS and FS, respectively. These growth rates are attributed to the high income elasticity in addition to huge impacts from high cross price elasticities of oil and gas prices on coal demand as the

[14] Table A6 in the Appendix summarises sectoral fossil fuel demand in the four major countries in terms of average annual growth rates over the simulation period in both scenarios.

coal price is competitive against the other fuel prices (cf. figure 11a). On the other hand, the electricity generating sector, as the dominant coal consumer, is likely to face more moderate annual coal demand growth of around 1 per cent in both scenarios because the relevant cross price elasticities are practically zero in this sector. The service sector in Germany faces the highest growth in both scenarios (2.2 per cent and 1.9 per cent yearly in IS and FS, respectively) when it comes to gas demand. The dominating factors behind these figures are reflected in the high income elasticity together with the relatively high cross price elasticity between oil and gas (0.73). Even though the direct price elasticity is as high as -1.23, the change in the end user price of gas is quite small, making the direct price effect moderate in both scenarios. Finally, the household sector with a gas share of around 35 per cent in the base year is expected to experience a gas demand growth of somewhat less than 1 per cent annually in both scenarios due to smaller price and income elasticities compared to the service sector.

Turning to the simulated growth rates in the United Kingdom, figure 12b demonstrates that oil demand in the electricity generating sector is likely to show the highest annual growth of 3.2 per cent during the next decades in the integration scenario. The same driving forces that were identified for the electricity generating sector in Germany also apply for the United Kingdom in both scenarios (cf. the reported elasticities for United Kingdom in table A2). However, it should be emphasised that the growth rate in the fragmentation scenario virtually is negative. This is explained by the fact that the negative direct price effect dominates the positive income effect, which in turn reflects the assumption of particular moderate growth rates in economic activity in the end user sectors (cf. table 2). These explanations also apply to the negative growth rate of –0.6 in the industry sector in the fragmentation scenario. It is, however, more interesting to have a look at the simulated growth rates in the transport sector as this sector accounts for about 70 per cent of total oil demand in the United Kingdom. Simulations show that this sector faces an average annual oil demand growth of 0.9 and 0.4 per cent in the integration and fragmentation scenario, respectively. These figures are mainly driven by the activity effect, since the income elasticity is 0.55 and the gross domestic product and private consumption are assumed to increase annually by around 2 per cent in IS and by 1 per cent in FS. Figure 12b shows further that coal demand is likely to increase the most in the service sector in both scenarios (2.7 and 1.8 per cent average annual growth in IS and FS, respectively) partly caused by the income effect, and partly by the substitution effect from gas to coal as the cross price elasticity of gas on coal demand is as high as 1.57. The electricity generating sector, as the major coal consumer in the United Kingdom, faces far more moderate growth of around 0.7 per cent per year in both scenarios. Even though the relative price of coal and oil change considerably in favour of increased coal demand in this sector, the corresponding cross price elasticity is too low to permit any significant substitution effect. Finally, the household sector, as the dominant gas consumer in the United Kingdom, is expected to show an annual average growth of around 1.6 and 0.6 per cent in IS and FS, respectively. The major driving force behind these growth rates is found in the activity effect as the income elasticity is 0.9, whereas the price effects are relatively small.

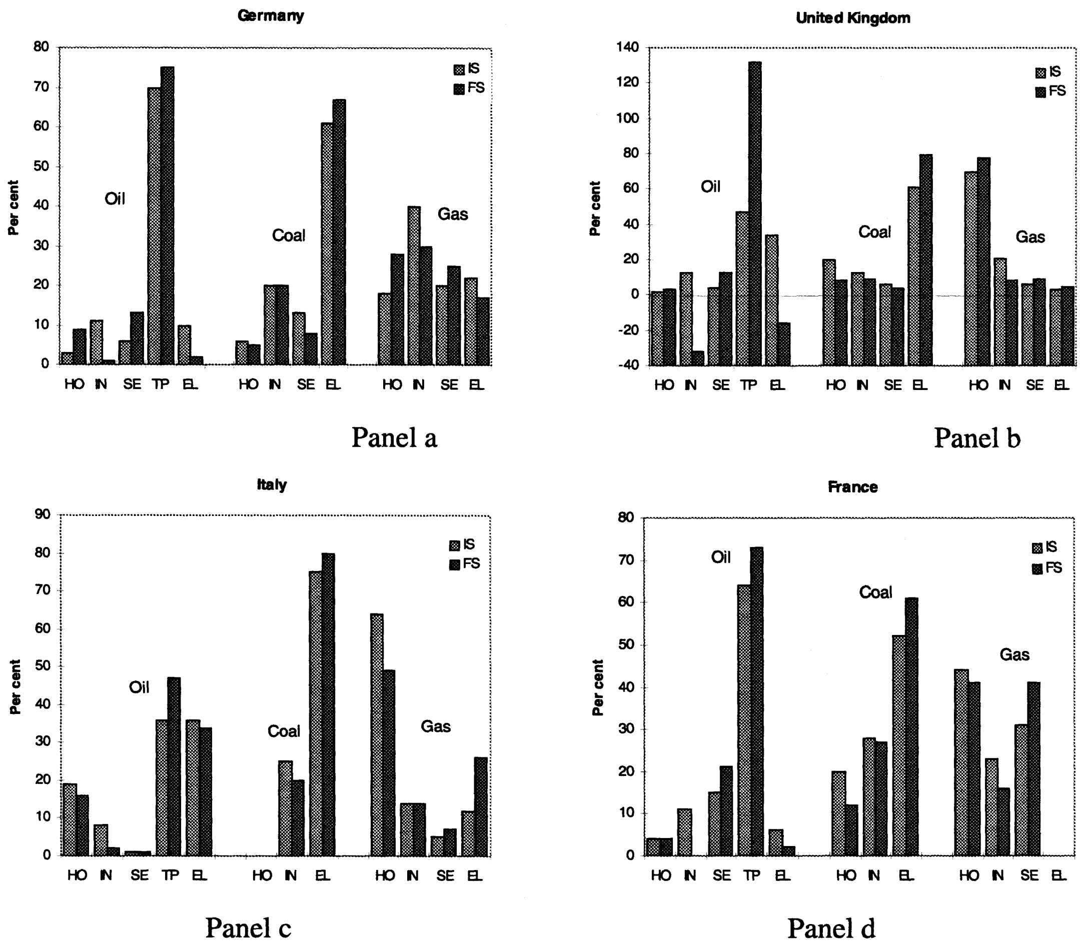
As discussed above, due to the existing price and tax structure, Italy is expected to experience the largest changes in the end user prices of oil and gas among the major countries, especially in the integration scenario (cf. figure 11). Hence, the impacts of economic integration on sectoral fossil fuel demand are potentially larger in Italy than in the other countries. This is also reflected in the growth rates implied by figure 12c. For instance, the household sector in Italy faces an annual growth in oil demand as high as 4.4 per cent in the IS scenario, whereas the annual growth rate in the FS scenario is simulated to be 1.8 per cent. In comparison, the corresponding figures for Germany and the United Kingdom are all well below unity. Both the direct price effect from the heavily reduced oil end user price and the activity effect from the high income elasticity of 1.42 explain the growth rate in the integration scenario in Italy (cf. table A3 in the Appendix). The growth rate in the fragmentation scenario, on the other hand, is mainly explained by the income effect alone, as the change in the end user prices in this scenario are moderate. The activity effect as a major explanatory factor is also applicable to the simulated growth rates of oil demand in the transport sector, which together with the power sector is the major oil consumer in Italy. Turning to coal demand, simulations show that highest growth is expected in the electricity generating sector in both scenarios. The average annual growth of 1.7 and 2.2 per cent annually in IS and FS, respectively, is due to the increased electricity demand in the end user sectors. Note that even though the price changes of the other fuels make coal less competitive in IS and relatively more competitive in FS, the cross price elasticities in the power sector are too small to permit any significant substitution effects. Finally, figure 12c shows that the household sector, as the major gas consumer in Italy, is likely to be responsible for the highest growth in gas demand in both scenarios (3.8 and 1.8 per cent per year on average in IS and FS, respectively). The main explanation is the growth in private consumption combined with a high income elasticity in the household sector, as previously noted. Besides, the direct price effect is evident in the integration scenario, while negligible in the fragmentation scenario because of a very small change in the end user price of gas in this scenario.

As identified in section 4.3, France, together with Italy, is expected to show higher growth rates in the aggregate demand of each fossil fuel in both scenarios than Germany and the United Kingdom. To gain more insight into the reasons behind this, it is useful to study the simulated sectoral demand in France, as shown in figure 12d. Overall, the growth rates for all three fossil fuels in France are simulated to be higher in most of the sectors compared to the corresponding figures for Germany and the United Kingdom, mainly due to higher income elasticities. The simulation results related to the household and the transport sector, in which the respective income elasticities are 1.25 and 1.22, illustrate this point (cf. table A4 in the Appendix). Roughly speaking, the sectoral price effects in France match more or less the price effects in Germany and the United Kingdom. As an example, consider the price effects in the industry sector. First, the direct price elasticities in all three countries in this sector are around unity in absolute value. Second, the direction and magnitude of the change in the end user price of oil and gas are also quite similar in all three countries (cf. figure 11). These two aspects together make the direct price effects in the industry sector in Germany, United Kingdom and France similar. Furthermore, the industrial cross price elasticities are nearly zero in all three countries. Hence, no significant substitution effects are found in this sector in any of the countries, despite visible changes in the relative prices. This line of reasoning also apply to the price effects in the other sectors.

We end this section by studying the sectoral contribution to the growth in aggregate fossil fuel demand in the four major countries, analysed in section 4.3. Figure 13 summarises the sectoral contribution by combining the simulated growth rate pattern discussed above with the sectoral fossil fuel demand structure in the base year in each of the four major countries. In the case of oil, figure 13a and d show that the transport sector is by far the largest contributor to aggregate oil demand in Germany and France in both scenarios. The contributions from the transport and the electricity generating sector to aggregate oil demand in Italy are also rather large, viz. around 40 per cent in both scenarios. A contribution of 40 per cent is also recognised from the transport sector in the United Kingdom as far as the integration scenario is concerned. However, the corresponding percentage contribution in the fragmentation scenario is as high as 130 per cent[15]. Turning to coal, the electricity generating sector turns out to be the largest contributor to aggregate coal demand in all four countries. In general, the percentage contributions range from approximately 60 per cent to around 80 per cent. Finally, figure 13 illustrates that the household sector is the largest contributor to aggregate gas demand in the United Kingdom, Italy and France. The respective percentage figures range from around 70 per cent in the United Kingdom to 40 per cent in France. In Germany, however, the contributions are more equal across the sectors.

[15] Note that a sectoral contribution of more than 100 per cent is possible in this case since the industry and the power generating sectors contribute negatively to the aggregate oil demand in the United Kingdom.

Figure 13. Sectoral Contribution to the Fossil Fuel Growth in the Four Major Countries



Note: HO, IN, SE, TP and EL denote the household, the industry, the service, the transport and the power generating sector, respectively.

4.5. CO_2 emissions in Western Europe

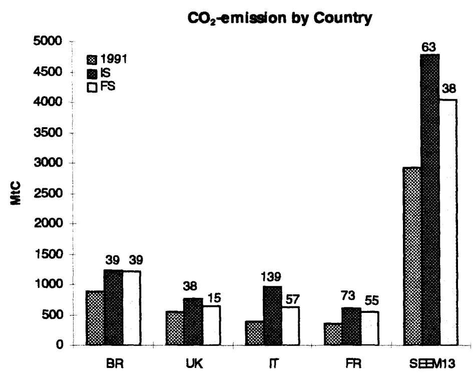
Given the concern about the environmental impacts of energy consumption, and more specifically, the possible threath of global climate change, many governments, including a majority of the EU member countries, have announced their intention to return greenhouse gas emissions to 1990 levels by the year 2000. In light of this environmental awareness, this final section examines the environmental implications of the energy demand projections associated with the integration scenario and the fragmentation scenario. Since emissions of CO_2 are proportional to consumption of the different fossil fuels, CO_2 emissions follow closely the energy demand pattern presented in sections 4.1-4.4. The emission factors employed in this study in terms of million metric tonnes CO_2 per million tonnes oil equivalents of energy inputs are 2.4 for natural gas, 3.1 for oil and 3.9 for coal [SFT (1990) and Calander et al. (1988)][16]. The presentation of the simulation results is restricted to the aggregate level. Figures 14a-c depict total emission levels in 1991 and in year 2020 in the two scenarios by country, fuel and sector, respectively.

As indicated in figure 14a, the CO_2 emissions in the model area rise by 63 per cent in the IS scenario and by 38 per cent in the FS scenario over the simulation period. This amounts to average annual growth rates of 1.7 and 1.1 per cent, respectively. Hence, total CO_2 emissions grow somewhat less than total demand for fossil fuels in IS (cf. figure 3 and table 4), since both oil and gas demand have higher growth (with relatively low emission coefficients) than demand for coal (with a relatively high emission coefficient). The corresponding figures of CO_2 emissions for the «high growth» and

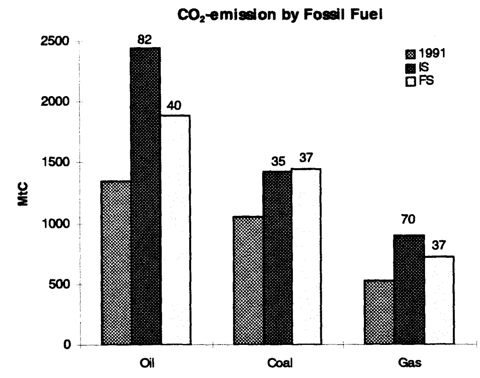
[16] There is no variation in factors between the sectors, because it is the carbon content of each fuel, and not the combustion technology, that determines the emissions.

«business as usual» scenarios in Energy in Europe (1990) are 25 per cent and 14 per cent, respectively, averaging 1.1 and 0.7 per cent growth annually. Note that the simulation period in that study is 1990-2010. IEA's (1994) projections likewise show that CO_2 emissions in OECD-Europe are expected to increase from 3580 MtC in 1991 to 4549 MtC in 2010. This increase means an annual average growth of around 1.3 per cent, a growth rate that is close to be in the middle of what we find in the two scenarios in our study.

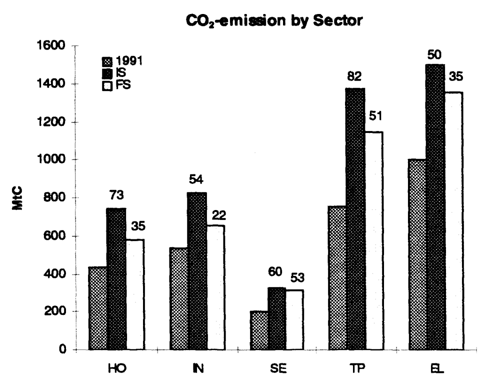
Figure 14. Aggregate CO_2 emission in Western Europe in 1991 and 2020



Panel a



Panel b



Panel c

Note: In panel a BR, UK, IT, FR and SEEM13 denote Germany, United Kingdom, Italy, France and all thirteen countries in SEEM, respectively. In panel c HO, IN, SE, TP and EL denote the household, the industry, the service, the transport and the power generating sector, respectively. The figures above the bars represent the percentage growth in CO_2 emission over the period from 1991 to 2020. CO_2 emissions are measured in million metric tonnes CO_2 (MtC).

Figure 14a shows further that Italy faces the highest growth rates in both scenarios, while United Kingdom faces the lowest growth rates in both scenarios[17]. This emission pattern corresponds to the energy pattern in the four major countries, shown in figure 7 above. The main contributor to the total fossil fuel CO_2 emissions in 1991 within the SEEM area is Germany with a share of 40 per cent, followed by United Kingdom, Italy and France with shares ranging from 19 per cent to 12 per cent. In the IS scenario, Germany and United Kingdom reduce their shares of emissions by 4 per cent and 3 per cent, respectively, while Italy increases its share by 6 per cent. The share of France remains stable in IS. In the fragmentation scenario the 1991-shares are more or less restored for all countries, except for United Kingdom which reduces its share from 19 per cent to 16 per cent.

[17] Simulations also show that CO_2 emissions are likely to increase by 39 per cent under both scenarios in Germany. This seems to contradict the fact that Germany has reduced their emissions by approximately 16 per cent from 1987 to 1994 due to restructuring of the economy and thereby attainment of significant energy efficiency improvements in the former Eastern Germany [Norwegian Ministry of the Environment (1994-95)]. However, our estimates of autonomous energy saving are averages for the entire simulation period, and they thus reflect the assumption of more moderate efficiency improvements in the former Eastern Germany in the future that are in line with the trend in the rest of Germany.

It is interesting to note that even in the FS scenario, the total CO_2 emission level in 2020 is far above the EU stabilisation target at the 1990 level of 3141 million metric tonnes CO_2 by the turn of the millennium [cf. Norwegian Ministry of the Environment (1994-95)]. The simulations also illustrate that none of the four major countries are able to meet their national CO_2-targets without CO_2 taxes.

With respect to type of fuel, figure 14b demonstrates that oil is the main contributor to CO_2 emissions in 1991, with a share of 46 per cent. Coal is not far behind with a share of 36 per cent, leaving the remaining share of 18 per cent for gas. The shares of oil and coal related emissions in 2020 in the IS scenario increases and decreases by 7 and 6 per cent, respectively, while the share of gas related emissions increases slightly by 1 per cent. The base year shares are restored in the fragmentation scenario for all three fossil fuels. We refer to the discussion related to figure 3 above when it comes to the story behind the growth rates in CO_2 emissions from oil, coal and gas in both scenarios.

Finally, figure 14c shows that the transport and power generating sectors are the dominating ones with respect to CO_2 emissions. Since the emission from transport activities shows the highest growth of 82 per cent during the simulation period in the integration scenario, its share increases from 26 per cent in 1991 to 29 per cent in 2020. Next after the service sector, the emission from the transport sector shows the highest growth in the fragmentation scenario and the emission share increases to 28 per cent. The opposite picture is true for the power generating sector which shows the lowest growth rates in emissions in both scenarios, except for the industry sector in the fragmentation scenario. As a result, the power generating sector reduces its share from 34 per cent in 1991 to 31 and 33 per cent in year 2020 in the two scenarios. Finally, the 1991-shares of 15, 18 and 7 per cent for the household, the industry and the service sector, respectively, all remain almost unchanged in both scenarios. This sectoral emission pattern corresponds closely to the sectoral energy pattern at the aggregate level, shown in figure 5 above.

5. Conclusions

In this paper, we have studied future energy demand and CO_2 emissions under two different sets of assumptions concerning likely degree of economic integration within the EU in the next decades. These sets of assumptions are summarised in an integration scenario (IS) and a fragmentation scenario (FS). The IS scenario is characterised by more optimistic estimates on economic growth and technology improvement than is the case in the FS scenario. In addition, fuel import prices of oil and gas are assumed to decrease slightly in the integration scenario and increase slightly in the fragmentation scenario, while the coal import price is assumed constant in both scenarios. Not surprisingly, simulations with the SEEM model illustrate that aggregate fossil fuel demand increases substantially more in the IS scenario than in the FS scenario, with annual growth of 1.8 and 1.1 per cent over the period 1991-2020, respectively. Roughly speaking, these results are in line with the studies «Energy for a New Century: the European Perspective» [Energy in Europe (1990)] and «World Energy Outlook» [IEA (1994)]. Our simulations indicate further that oil increases its share relative to gas and coal in both scenarios, although the difference is small in the FS scenario. Italy contributes the most to the growth in aggregate oil demand in the integration scenario, while Germany is the main contributor in the fragmentation scenario. It is interesting to observe that economic growth and fossil fuel price differences seem to play an important role in explaining the energy demand differences between the two scenarios. We also emphasise that the existing energy demand and price structure is very heterogeneous across the SEEM countries, and that this fact strongly affects the impacts in the model.

Furthermore, simulations show that the aggregate CO_2 emissions increase by 63 per cent in the IS scenario and by 38 per cent in the FS scenario over the period 1991-2020, averaging 1.7 and 1.1 per cent growth per year, respectively. The power generating sector and the transport sector are the two most important contributors to these growth rates with an emission share of around 30 per cent each in the year 2020. The study in Energy in Europe (1990) also found that the largest increments of CO_2 emissions take place in the power sector and in the transport sector. IEA's (1994) projections show that CO_2 emissions in OECD-Europe are expected to increase from 3580 MtC in 1991 to 4549 MtC in

2010. This increase implies an annual average growth of around 1.3 per cent, a growth rate that is close to be in the middle of what we find in the two scenarios in our study.

Our findings are interesting in light of the EU stabilisation target of CO_2 emissions at the 1990 level by the year 2000, and they give an indication of future emissions when no specific policy measures are undertaken. Thus, this study supports the view that an effective energy policy is called for in order to stabilise CO_2 emissions in Western Europe. It is beyond the scope of this paper to elaborate on this, but a natural next step for further research would be to investigate possible implications of such policies on future energy demand and accompanying CO_2 emissions, making use of the SEEM model and the two economic scenarios for the EU.

With respect to further work, we would also like to point out the following: The data used for estimating and calibrating parameters in the model can always be improved. Furthermore, the model's treatment of energy trade is simplistic. Finally, being a partial energy model, SEEM lacks explicit modelling of the linkages to the macro economy. Further work in all of these areas could improve the ability of the model apparatus to address the many future challenges facing the EU and neighbouring countries in Europe in the years ahead.

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Appendix

Table A1. Simulated Long Term Elasticities in Germany

Demand for		Price of						
Sector	Fuel	Coal	Oil	Gas	Electricity	Gasoline	Diesel	Activity
Industry[1)]	Coal	-0.97	0.01	0.02	0.10	.	.	0.76
	Oil	0.02	-0.98	0.02	0.10	.	.	0.76
	Gas	0.02	0.01	-0.97	0.10	.	.	0.76
	Electricity	0.02	0.01	0.02	-0.89	.	.	0.76
Services[1)]	Coal	-2.65	1.63	0.74	0.08	.	.	0.83
	Oil	0.17	-0.88	0.38	0.08	.	.	0.83
	Gas	0.17	0.73	-1.23	0.08	.	.	0.83
	Electricity	0.00	0.05	0.02	-0.15	.	.	1.23
Household[1)]	Coal	-0.63	0.22	0.25	0.16	.	.	0.53[3)]
	Oil	0.02	-0.42	0.25	0.16	.	.	0.53[3)]
	Gas	0.06	0.24	-0.45	0.16	.	.	0.53[3)]
	Electricity	0.00	0.04	0.04	-0.53	.	.	0.46
Power[2)]	Coal	-0.43	0.01	0.04	.	.	.	.
	Oil	0.21	-0.76	0.04	.	.	.	.
	Gas	0.21	0.01	-0.66	.	.	.	.
Transport[2)]	Gasoline	.	.	0.00	0.02	-0.12	0.09	1.00
	Diesel	.	.	0.00	0.02	0.24	-0.35	1.00
	Gas	.	.	-0.19	0.02	0.24	-0.08	1.00
	Electricity	.	.	0.00	-0.31	0.24	0.09	1.00

1) Source: Brubakk et al. (1995). 2) Simulated for the purpose of the present paper. 3) There is a type error in Brubakk et al. (1995). Note: . denotes not applicable.

Table A2. Simulated Long Term Elasticities in the United Kingdom

Demand for		Price of						
Sector	Fuel	Coal	Oil	Gas	Electricity	Gasoline	Diesel	Activity
Industry[1)]	Coal	-0.98	0.02	0.03	0.10	.	.	0.78
	Oil	0.01	-0.97	0.03	0.10	.	.	0.78
	Gas	0.01	0.02	-0.96	0.10	.	.	0.78
	Electricity	0.01	0.02	0.03	-0.89	.	.	0.78
Services[1)]	Coal	-1.83	-0.02	1.57	0.10	.	.	0.70
	Oil	0.03	-0.51	0.18	0.10	.	.	0.70
	Gas	0.33	-0.02	-0.62	0.10	.	.	0.70
	Electricity	0.01	0.01	0.06	-0.17	.	.	1.00
Household[1)]	Coal	-0.65	0.12	0.13	0.06	.	.	0.90
	Oil	0.25	-0.78	0.13	0.06	.	.	0.90
	Gas	0.00	0.00	-0.40	0.06	.	.	0.90
	Electricity	0.00	0.00	0.06	-1.01	.	.	1.02
Power[2)]	Coal	-0.34	0.04	0.01	.	.	.	.
	Oil	0.17	-0.63	0.01	.	.	.	.
	Gas	0.17	0.04	-0.63	.	.	.	.
Transport[2)]	Gasoline	.	.	.	0.00	-0.24	0.03	0.55
	Diesel	.	.	.	0.00	0.07	-0.33	0.55
	Gas	.	.	.	.	.	.	.
	Electricity	.	.	.	-0.14	0.07	0.03	0.55

1) Source: Brubakk et al. (1995). 2) Simulated for the purpose of the present paper. Note: . denotes not applicable.

Table A3: Simulated Long Term Elasticities in Italy

Demand for		Price of						
Sector	Fuel	Coal	Oil	Gas	Electricity	Gasoline	Diesel	Activity
Industry[1)]	Coal	-0.98	0.01	0.02	0.11	.	.	0.88
	Oil	0.01	-0.98	0.02	0.11	.	.	0.88
	Gas	0.01	0.01	-0.97	0.11	.	.	0.88
	Electricity	0.01	0.01	0.02	-0.88	.	.	0.88
Services[1)]	Coal	.	.	.	.	.	.	.
	Oil	.	-0.13	-0.07	0.10	.	.	0.70
	Gas	.	0.20	-0.40	0.10	.	.	0.70
	Electricity	.	0.06	0.04	-0.20	.	.	1.10
Household[1)]	Coal	.	.	.	.	.	.	.
	Oil	.	-0.54	-0.21	0.12	.	.	1.42
	Gas	.	-0.14	-0.60	0.12	.	.	1.42
	Electricity	.	0.04	0.08	-1.85	.	.	1.55
Power[2)]	Coal	-0.39	0.25	0.05	.	.	.	.
	Oil	0.03	-0.52	0.05	.	.	.	.
	Gas	0.03	0.25	-0.53	.	.	.	.
Transport[2)]	Gasoline	.	.	0.00	0.03	-0.48	0.03	1.06
	Diesel	.	.	0.00	0.03	-0.02	-0.63	1.06
	Gas	.	.	-0.40	0.03	-0.02	-0.48	1.06
	Electricity	.	.	0.00	-0.87	-0.02	0.03	1.06

1) Source: Brubakk et al. (1995). 2) Simulated for the purpose of the present paper. Note: . denotes not applicable.

Table A4: Simulated Long Term Elasticities in France

Demand for		Price of						
Sector	Fuel	Coal	Oil	Gas	Electricity	Gasoline	Diesel	Activity
Industry[1)]	Coal	-0.97	0.02	0.03	0.10	.	.	0.78
	Oil	0.02	-0.97	0.03	0.10	.	.	0.78
	Gas	0.02	0.02	-0.96	0.10	.	.	0.78
	Electricity	0.02	0.02	0.03	-0.89	.	.	0.78
Services[1)]	Coal	.	.	.	.	.	.	.
	Oil	.	-0.88	1.49	0.08	.	.	0.92
	Gas	.	0.73	-2.61	0.08	.	.	0.92
	Electricity	.	0.05	0.09	-0.50	.	.	0.71
Household[1)]	Coal	-0.59	0.22	-0.09	0.03	.	.	1.25
	Oil	0.31	-0.42	-0.09	0.03	.	.	1.25
	Gas	0.00	0.24	-0.37	0.03	.	.	1.25
	Electricity	0.00	0.04	0.03	-0.66	.	.	1.50
Power[2)]	Coal	-0.34	0.02	0.00	.	.	.	.
	Oil	0.03	-0.76	0.00	.	.	.	.
	Gas	0.03	0.02	-0.61	.	.	.	.
Transport[2)]	Gasoline	.	.	0.00	0.01	-0.20	0.09	1.22
	Diesel	.	.	0.00	0.01	0.26	-0.36	1.22
	Gas	.	.	-0.18	0.01	0.26	-0.11	1.22
	Electricity	.	.	0.00	-0.13	0.26	0.09	1.22

1) Source: Brubakk et al. (1995). 2) Simulated for the purpose of the present paper. Note: . denotes not applicable.

Table A5. Demand for Fossil Fuels in 1991 and Average Annual Growth in the IS and FS Scenarios over the Period 1991-2020

	Oil			Coal			Gas		
	1991	IS	FS	1991	IS	FS	1991	IS	FS
Country	Ktoe	%	%	Ktoe	%	%	Ktoe	%	%
Austria	9545	2.14	1.84	4299	1.60	1.81	5096	2.07	1.55
Belgium	15188	0.69	0.58	9584	0.99	1.22	8430	1.42	0.84
Denmark	7340	1.81	0.85	7687	1.51	0.98	1512	1.01	0.44
Finland	8600	0.87	-0.11	5983	1.06	0.21	2352	1.37	-0.20
France	68025	1.94	1.44	19286	1.66	1.74	26396	2.12	1.59
Germany	104365	1.39	1.25	112695	0.89	1.09	49959	1.40	0.98
Italy	73505	3.50	1.52	14654	1.51	1.88	47352	2.73	1.47
Netherlands	12433	1.38	0.89	8370	0.74	1.01	30248	1.55	1.09
Norway	8060	1.79	1.27	854	1.29	1.49	0	-	-
Spain	37456	2.87	1.40	19144	1.18	0.78	4833	1.24	0.62
Sweden	10962	2.54	1.04	2745	2.14	0.88	507	1.16	0.57
Switzerland	12628	1.65	1.64	722	0.95	1.20	2038	1.51	1.38
United Kingdom	65458	1.29	0.20	64834	0.83	0.72	41615	1.43	0.44
Total	433566	2.08	1.16	270856	1.04	1.08	220338	1.85	1.08

Table A6. Sectoral Demand for Fossil Fuels in 1991 and Average Annual Growth in the IS and FS scenarios over the Period 1991-2020. The Four Major Countries

		Oil				Coal				Gas			
Cou	Sec-	1991	1991	IS	FS	1991	1991	IS	FS	1991	1991	IS	FS
ntry	tor	Ktoe	%	%	%	Ktoe	%	%	%	Ktoe	%	%	%
BR	HO	22103	21	0.26	0.60	6353	6	0.90	0.97	16960	34	0.81	0.82
	IN	10769	10	1.48	0.09	19513	17	1.01	1.23	17121	34	1.57	0.87
	SE	12530	12	0.82	1.31	3038	3	3.05	2.68	5719	12	2.19	1.90
	TP	55244	53	1.74	1.68	0	-	-	-	48	0	2.17	1.74
	EL	3719	4	2.94	0.77	83790	74	0.75	0.99	10110	20	1.52	0.83
	TOT	104365	100	1.39	1.26	112694	100	0.89	1.09	49958	100	1.40	0.98
UK	HO	2595	4	0.71	0.18	4320	7	2.05	0.82	25835	62	1.58	0.55
	IN	7611	12	1.40	-0.61	7280	11	0.97	0.61	11552	28	1.12	0.14
	SE	3150	5	1.03	0.52	845	1	2.70	1.81	3088	7	1.29	0.52
	TP	45287	69	0.92	0.37	0	-	-	-	0	-	-	-
	EL	6814	10	3.20	-0.34	52389	81	0.65	0.71	1141	3	1.43	0.75
	TOT	65457	100	1.29	0.19	64834	100	0.83	0.72	41616	100	1.43	0.44
IT	HO	9805	13	4.36	1.75	107	1	0	0	18202	38	3.82	1.78
	IN	8010	11	2.79	0.40	4932	34	1.16	1.22	13140	28	1.67	0.80
	SE	911	1	1.99	1.18	0	-	-	-	4550	10	1.61	1.21
	TP	26175	36	3.53	1.88	0	-	-	-	1762	4	3.14	1.55
	EL	28605	39	3.37	1.37	9615	65	1.69	2.19	9697	20	1.86	1.78
	TOT	73506	100	3.50	1.52	14654	100	1.51	1.88	47351	100	2.73	1.47
FR	HO	1901	3	2.55	1.81	1767	9	2.93	2.14	7995	30	2.76	2.02
	IN	7343	11	1.90	-0.07	8208	43	1.17	1.19	10619	40	1.38	0.72
	SE	15968	23	1.39	1.31	0	-	-	-	7221	28	2.32	2.19
	TP	40485	60	2.05	1.70	0	-	-	-	527	2	1.96	1.43
	EL	2329	3	2.91	1.05	9311	48	1.78	2.10	33	0	2.18	0.99
	TOT	68026	100	1.94	1.44	19286	100	1.66	1.74	26395	100	2.12	1.59

Note: BR, UK, IT and FR denote Germany, United Kingdom, Italy and France, respectively. HO, IN, SE, TP and EL denote the household, the industry, the service, the transport and the power generating sector, respectively.

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