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Taran Fæhn and Erling Holmøy

Trade Liberalisation and Effects on Pollutive Emissions and Waste
A General Equilibrium Assessment for Norway

Abstract:
This paper assesses effects of the last decade's multinational liberalisation of foreign trade, in terms of economic gains and in terms of pollution. By means of a disaggregated intertemporal CGE model for Norway two scenarios with and without the trade reforms are compared. Despite a slight decrease in GDP, emissions of several pollutants rise significantly. This is partly attributable to a modest increase in aggregate welfare, as polluting consumption rise significantly along with reduced labour effort. Further, the trade reforms, in combination with existing policy concessions, result in a long-run structural change in favour of heavy-polluting export industries. As these are large consumers of electricity, prices of clean hydropower rise and cause an economy-wide substitution towards more pollutive energy sources.

Keywords: Trade Reforms; Welfare; Environment; Intertemporal CGE Model

JEL classification: D58, D60, F13, Q25

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Address: Taran Fæhn, Statistics Norway, Research Department, P.O.B. 8131Dep., N-0033 Oslo, Norway. E-mail: taran.fahn@ssb.no

Erling Holmøy, Statistics Norway, Research Department, P.O.B. 8131Dep., N-0033 Oslo, Norway. E-mail: erling.holmoy@ssb.no

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1. Introduction

The last decade has witnessed a strong increase in the degree of regional and global economic integration. This has been motivated by the mutual national gains from stronger specialisation of the production structure according to comparative advantage and scale economies, stronger competition, and access to a richer menu of goods. Simultaneously, there has been a growing awareness of the potential environmental consequences of trade liberalisation. The scientific literature also reflects a revitalisation of these issues, starting in the early 90's, see e.g. Whalley (1991), Grossman and Krueger (1993), Perroni and Wigle (1994) and Copeland and Taylor (1994).

From a national point of view, the relationship between environmental pressure and growth from trade is ambiguous. First, direct effects on environmental pressure will come through scale and composition effects in domestic production and consumption. The numerous contributions to the Environmental Kuznets Curve (EKC) literature[1], connecting the development of environmental quality to growth, throw light on these effects. The EKC literature also emphasises that economic growth may stimulate environmental policies and technology innovations because the demand for environmental goods and regulatory policy is income elastic. In a world of freer trade, however, incentives may well pull in the other direction, e.g. through initialising a race to the bottom of environmental standards or by limiting the national scope of policy instruments. Clear and robust policy implications are even less likely in cases where environmental damage spills across borders. Multilateral arrangements are then required to ensure abatement policies. Several studies have pointed to the dominance of the WTO over environmental treaties when comes to enforcement and dispute settlement mechanisms (Fauchald (1997), Neumayer (2000)).

This study addresses both economic and environmental implications for Norway of three multinational trade agreements of the last decade: The European Economic Area Agreement (EEA) and the EFTA Resolution on Fisheries, both in force from 1994, and the WTO Agreement from 1995. The resulting reforms in tariffs, non-tariff barriers and governmental aid imply new domestic and world market conditions for Norwegian agents. Environmental effects considered in this study include changes in air emissions and deposits of solid waste, which are either locally harmful or affect the government's ability to fulfil international commitments on transboundary pollution.

We apply a dynamic and disaggregated CGE model for Norway. By comparing a simulated trade reform path with a business-as-usual reference scenario we isolate the effects of implementing the trade reforms. No simultaneous growth effects from technological or demographic changes are

[1] See Stagl (1999) for a survey on the Environmental Kuznets Curve literature.

considered. The model allows us to quantify changes in an aggregate welfare index and other macroeconomic aggregates, as well as detailed composition adjustments within production, factor input and consumption. As in most other comparable trade policy studies[2], the simulated macroeconomic effects are small; while GDP is slightly reduced in the long run, aggregate consumption increases by 1.0 per cent. Nevertheless, the increases in emissions of several gases are stronger, as can be explained by composition effects. A structural change in favour of manufacturing industries is the main reason why pollution of *Sulphur Dioxide* and *Suspended Particulates* increase by more than 1 per cent, while long-run increases also occur in emissions of *Carbon Monoxide* and Kyoto gases. In addition to being heavy polluters, the manufacturing industries that expand in the long run, are hydropower intensive. Thus, their expansion causes a rise in the relative price of electricity that brings about a more fuel-based composition of energy use throughout the economy. Some emissions fall, primarily those associated to agricultural production, which is reduced.

The rest of the paper is organised as follows. Section 2 presents a brief non-technical overview of the structure of the applied model. Section 3 describes the exogenous changes associated with the trade liberalisation. Section 4 explains the macroeconomic changes, while Section 5 sums up scale and composition effects on emissions to air and waste generation. Section 6 provides a sensitivity discussion on important assumptions. Section 7 concludes.

2. The Numerical Model[3]

2.1. General features

The applied CGE model of the Norwegian economy, MSG-6, is dynamic, based on rational agents with intertemporal behaviour and perfect foresight. The equilibrium of the economy moves towards a path dependent steady state along a saddle path. As in most models in the CGE tradition, all goods and services are perfectly mobile across industries within the economy, and supply equals demand in all markets in all periods. Since the Norwegian economy is small, and the exchange rate is normalised to unity, all agents face exogenous world prices and real interest rates. Tariff and tax rates, as well as governmental spending are exogenous. The public budget constraint is satisfied through endogenous lump-sum transfers. The model specifies 60 commodities and 40 industries (of which 8 are government sectors)[4], classified in order to make the model well suited for studies of industrial

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[2] See e.g. Haaland and Tollefsen (1994), Keuschnigg and Kohler (1996), Francois et al. (1996), and Krugman (1996).

[3] For more details on the MSG-6 (Multi-Sectoral Growth) model, confer Fæhn and Holmøy (2000) on the economic aspects, and Strøm (2000) on the recursive sub-model that calculates emissions and waste generation. More technical documentations of the model and the simulations are available from the authors on request.

[4] See Table A.1 in the Appendix for a list.

policies as well as environmental issues. Parameters are estimated or calibrated on the basis of the Norwegian National Accounts and relevant micro-econometric studies.

2.2. Household behaviour

Consumption, labour supply, and savings are derived from standard welfare-maximising behaviour over an infinite horizon of one representative, price-taking household. External effects, and in particular repercussions from environment to the utility of the household, are not modelled. Thus welfare changes in the model are related to aggregate efficiency in a strict economic sense. The *intra*temporal household decision can be solved by a stepwise budgeting procedure due to a nested CES structure of the utility function (see Appendix, Figure A.1), where the goods in each aggregate are imperfect substitutes[5]. At the top level, utility in a given year is a CES aggregate of leisure and consumption. The classification of consumption goods distinguishes between activities with different pollution profiles and reflects relevant substitution possibilities. Most of the emissions from households are due to heating and transport. In the heating process the “dirty” energy carriers fossil fuels and wood can be substituted by “clean” hydropower-based electricity. Own transport is based on polluting petrol and diesel. Four substitutable public alternatives are specified, transport by road, sea, air and rail/tramway, all with individual emission intensities. Consumption of most material goods generates waste for deposition, which in turn emits *Methane*.

2.3. Market Structure and Producer Behaviour

All firms in the private business sector are run by managers who maximise present after tax value of the cash flow to owners. Commodities produced by the primary industries are assumed to be homogenous and traded in perfectly competitive markets. For manufactures and services, constituting the main part of the specified industries, the model captures that output and input in an industry may change both because of changes at the firm level and as a result of entry or exit of firms. The model includes a rough description of productivity differentials between firms within the same industry causing firms to differ in size and profitability[6]. Producers of manufactures and tradable services allocate their output between two segregated markets, the domestic and the foreign, and it is assumed costly to reallocate deliveries between them. Whereas world prices of exports are exogenously determined in the world markets, the market structure in the domestic markets for manufactures and

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[5] Bye and Holmøy (1997) provides a description of the intertemporal allocation of consumption and the determination of labour supply. Holtsmark and Aasness (1995) documents the estimation of the demand system determining the intratemporal composition of consumption.

[6] Klette (1994) and Klette and Mathiassen (1995, 1996) document that such differentials are substantial and persistent in Norwegian industries. Holmøy and Hægeland (1997) provides a detailed exposition of this model of aggregate industry behaviour, which is characterised by asymmetric monopolistic competition.

services is described by monopolistic competition among domestic firms[7]. Decreasing returns to scale characterise the production structure in all private industries, most notably in resource-based industries such as *Agriculture* and *Production of Electricity*.

In all industries the demand for input factors is derived from a nested structure of linearly homogeneous CES-functions[8] (see Appendix, Figure A.2). As for households, the model captures that the composition of energy use for stationary purposes is dependent on the relative prices of the sources fuel and electricity, respectively. Transport services are partly provided internally, with associated emissions from use of petrol and diesel, and partly outsourced. Industries differ significantly with respect to the extent to which transport services can be profitably purchased from one of the commercial transport sectors. As for consumption, use of several input factors involves waste generation.

2.4. The energy market

The energy market is especially important in studies of the links between economic and environmental effects. It has therefore been given a relatively detailed treatment in the model. On the demand side particularly large amounts of energy are needed to generate power on oil platforms, because the efficiency of this process is very low. *Extraction and Transport of Crude Oil and Gas* is a large and heavily regulated sector in the Norwegian economy, and its activity is exogenous in the model. The exposition above has clarified how households and firms may change their demand for electricity and fuels as a response to changes in relative prices and real income to households.

On the macro level, changes in the industry structure may contribute significantly to the price sensitivity of the energy demand. By its disaggregated structure, the model captures many interesting composition effects. The separation of transport and communication into six sectors, *Post and Telecommunications*, *Railway and Tramway Transport*, *Air Transport*, *Road Transport*, *Coastal and Inland Water Transport,* and *Ocean Transport*, is one example in this respect. Another is the specification of the three extremely electricity-intensive industries *Manufacture of Metals*, *Manufacture of Industrial Chemicals* and *Manufacture of Pulp and Paper*. According to existing contracts with the government, these industries have access to about 50 per cent price subsidisation of hydropower deliveries limited up to 30 TWh, which accounts for about one quarter of the total Norwegian electricity consumption in 1992. These power contracts are explicitly taken into account in

[7] Based on Norwegian data, Aukrust (1970) and Bowitz and Cappelen (1994) find empirical evidence of less competitive behaviour in the domestic markets than in the export markets.

[8] Elasticities of substitution between inputs have been set in accordance with estimates presented in Alfsen, Bye and Holmøy (1996, Ch. 3).

our analysis. Reallocation of resources into these industries will contribute to a significant increase in the aggregate electricity demand.

On the supply side the model specifies three potential sources of electricity supply. First, hydropower is produced domestically with virtually no emissions to air. This sector is characterised by large irreversible investments, and capacity expansion is limited by sharply decreasing returns to scale. Second, domestic supply of hydropower is supplemented by imports from the Nordic market. In 1998 3 per cent of the total Norwegian electricity consumption was covered by net imports. As a potential third source, the model specifies the technology of gas combustion for electricity production, which would involve national emissions to air of several gases (see Section 2.6). The production of gas power is determined in the model according to standard investment behaviour. In this study the capacity of the Norwegian hydropower system is assumed to be constant, in accordance with recent practice and intentions expressed by the government. Also net imports of electricity has been fixed exogenously, so that gas power represents the marginal source of electricity supply. This assumption is a simplification that describes the first part of the reform period better than the present and future situation. However, a more satisfactory modelling of the recent development of the Nordic electricity market has so far been beyond the scope of the project described in this paper. Assuming gas power to be the marginal source of electricity supply probably implies an overestimation of the slope of the supply curve for electricity compared to a more realistic representation of the possibilities for electricity import from the other Nordic countries[9]. In Section 6 we discuss the sensitivity of our results with respect to our choice of assumptions at this point.

2.5. Import and trade policies

In case of services and manufactured goods, imported products are considered as close, but imperfect substitutes for the corresponding differentiated products supplied domestically[10]. It is assumed that both Norwegian and foreign consumers consider *Electricity*, *Crude Oil and Natural Gas*, as well as commodities produced by the primary industries *Agriculture*, *Forestry* and *Fisheries*, as homogenous. The domestic prices of these commodities are equal to the corresponding import prices, and the model determines net imports as the residual between domestic production and domestic demand. However, there are exemptions from this rule. As explained above net imports of *Electricity* has been fixed exogenously. The same assumption holds for net imports of *Agricultural Products*, due to heavy regulations of foreign trade.

[9] Johnsen (1998) provides a description of a detailed model of the Nordic energy market.

[10] The elasticities of substitution between Norwegian and imported varieties have been set in accordance with the stationary time series estimates reported in Naug (1994).

Barriers to import of a particular good *i* are quantified by the generated gap between the price of the imported good (net of indirect taxes), and a reference price, defined as the lowest possible import price inclusive of insurance and freight costs (c.i.f.). This gap is made up of the *Tariff rate* (*T*) and the *Non-Tariff Protection rate* (*NTP*). The *NTP* captures exogenous increases in the costs of penetrating the domestic border on top of the tariffs and also, in case of import quotas or prohibitive import barriers, the shadow price of such restraints, which depends endogenously on the market conditions and the exogenous import volumes. The import price of commodity *i*, P_i^I, is then determined as $P_i^I = P_i^W(1+T_i)(1+NTP_i)$, where P_i^W is the exogenous world price.

Table 1: Air pollutants and important sources in MSG-6

Pollutant	Important sources MSG-6 sector in parenthesis
Kyoto gases:	
Carbon Dioxide (CO_2)	Combustion of fossil fuels (Several), reducing agents (Manufacture of Metals)
Methane (CH_4)	Livestock, manure management (Agriculture), landfills, production and use of fossil fuels and fuel wood (Several)
Nitrous Oxide (N_2O)	Fertilising (Agriculture), fertiliser production (Manufacture of Industrial chemicals), road traffic (Road Transport)
Perflourocarbons (PFKs)	Aluminium production (Manufacture of Metals)
Sulphur Hexafluoroides (SF_6)	Magnesium production (Manufacture of Metals)
Hydrofluorocarbons (HFKs)	Cooling fluids (Several)
Other pollutants:	
Ammonia (NH_3)	(Agriculture)
Sulphur Dioxide (SO_2)	Combustion (Several), process emissions (Manufacture of Metals)
Nitrogen Oxides (NO_x)	Combustion (Several)
Carbon Monoxide (CO)	Combustion (Several)
Non-Methane Volatile Organic Compounds (NMVOCs)	Oil and gas-related activities, road traffic, solvents (Oil Refining, Road Transport, Households)
Suspended Particulates ($PM_{2,5}$ and PM_{10})	Road traffic (Households, Agriculture, Road Transport), fuel wood (Households)

Source: Statistics Norway (1999, Box 4.1).

2.6. The modelling of emissions

The model calculates emissions of 12 air pollutants. Table 1 provides an overview of the specified air pollutants and their sources. The calculations of emissions are based on exogenous coefficients for each source in each sector[11]. The coefficients are generally linked to economic variables in the model. For example, stationary emission from combustion in an industry is linked to the input of fuel, whereas mobile emission from road transport is linked to the input of petrol and diesel. Several process emissions are linked to the input of intermediates. Solid waste generation is calculated by the same methodology as emissions of air pollutants.

[11] Accounts of emissions of air pollutants and waste generation are given in Statistics Norway (1999).

3. Interpreting the trade agreements

3.1. Reductions of the Norwegian import protection

According to the WTO Agreement, tariffs on manufactured goods are to be reduced by nearly 40 per cent within 2005. Since tariffs were already eliminated on imports from a number of countries, including the EU and EFTA countries, this affects less than 20 per cent of Norwegian imports. The initial rates were already low (unweighted average of 3.6 per cent). Only the unconcessional tariffs on *Textiles and Clothing*, where initial rates averaged 17 per cent, become notably affected.

The new trade agreements go a long way in specifying the prohibitions of Non-Tariff Barriers (NTBs) and pave the way for enforcing the rules. NTBs contribute to raise import prices either through higher import costs or margins, or indirectly by limiting import volumes. NTBs are difficult to document, and quantitative estimates of their price effect in terms of *NTP*s are necessarily uncertain. Fæhn (1997) describes our methods. In Table 2, NTBs are quantified by *NTP*s before and after liberalisation. In the model-based calculations, we have taken into account that the agreements are implemented over time. The table shows the rates in the pre-reform and post-reform long-run equilibria.

A common type of NTB is national product and packaging standards, which imply additional costs of marketing the products in Norway. With the EEA and WTO Agreements these standards have generally been harmonised between countries. Their previous protection effect is thus eliminated for pharmaceutical products (in the commodity group *Chemical and Mineral Products* in MSG-6), fertiliser (in *Industrial Chemicals*), as well as machinery and electrical equipment (in *Hardware and Machinery*). Technical trade barriers still remain to some extent for food (in *Agricultural Products*, *Dairy and Meat Products* and *Other Processed Food*) and *Beverages and Tobacco*.

Table 2: Pre- and post-reform Long-run Non-Tariff Protection rates, measured as the percentage increase in import prices

MSG-6 Commodity	Pre-Reform	Post-Reform
Agricultural Products	40	36
Dairy and Meat Products	66	54
Other Processed Food	33	34
Beverages and Tobacco	42	26
Textiles and Clothing	1	0
Chemical and Mineral Products	7	0
Industrial Chemicals	3	0
Hardware and Machinery	4	0
Oil Platforms	3	0

NTBs in the form of trade quotas are prohibited by the WTO Agreement. The prohibition affects export quota agreements, which previously protected producers of textile items against imports from low-cost countries. The shadow prices associated with some of the quotas are estimated to be on *a par* with the tariffs prevailing before the Uruguay Round, and come in addition to these (see Melchior (1993)). For the aggregate *Textiles and Clothing* as a whole, however, *NTP* was small. The prohibition of quantitative trade restrictions also affects food production. Quota-type arrangements for imports largely applied within the aggregates *Agricultural Products* and *Dairy and Meat Products*. The Previous *NTP*s are derived from the size of the quotas, and vary endogenously over time depending on supply and demand conditions. With the WTO prohibition, quota arrangements have been replaced by tariffs. However, for all significant Norwegian products tariff rates are set above prohibitive levels, implying that the new regime works much like quantitative restrictions. The reform imposes certain minimum import requirements that increase imported amounts and reduce *NTP*s for *Agricultural Products* and *Dairy and Meat Products*. Minimum import amounts are achieved in part by setting lower tariffs on minor products in the Norwegian production and in part through lower tariffs on imports from the poorest developing countries.

The WTO Agreement also prohibits variable import levies, an NTB instrument that previously protected many products included in the model aggregate *Other Processed Food*. Variable import levies were imposed on imported goods to the extent that they contained intermediate goods that competed with Norwegian agricultural products. These levies are now replaced by fixed tariffs, and the EEA Agreement on tariff reductions has reduced the level of protection for many processed food products. Nevertheless, *NTP* for *Other Processed Food* increases marginally as a result of increased protection of flour. In accordance with the WTO tariffication, formerly quantitative barriers on grains have been replaced by tariff rates of more than 300 per cent. This implies a substantial increase in the costs and prices of sheltered flour production.

There is reason to argue that producers of cement (in *Chemical and Mineral Products*) and fertiliser (in *Industrial Chemicals*) were previously sheltered against competition in the Norwegian market, as firms' practice of collusive market sharing was not effectively prevented. According to the EEA Agreement, the EU's competition rules apply to Norwegian firms and represent an effective prohibition of collusion and mergers that hamper international competition[12]. The EEA Agreement also prohibits state-owned import monopolies. This reduces the level of protection of alcoholic beverages (in *Beverages and Tobacco*) and pharmaceutical products (in *Industrial Chemicals*). Prohibition has also eliminated public procurement schemes that favoured domestic enterprises, with

[12] This was for instance demonstrated in 1995 when the EU Commission/EFTA's Surveillance Authority imposed substantial fines for the tacit collusion of European cement producers, including the Norwegian company Aker Norcem.

consequences for deliveries of engineering products (within *Hardware and Machinery*) to government agencies (such as the Norwegian State Railways, power stations, TELENOR and the Directorate of Public Roads), and of *Oil Platforms* to the large oil companies.

3.2. Subsidy reductions

The distorting role of subsidies in international competition has been in focus in recent years' trade negotiations, with the result that several types have been prohibited. The WTO Agreement includes detailed rules on subsidies to *Agriculture*, with many prohibitions. However, according to Skjeflo et al. (1994), many exemptions make it possible, to maintain the Norwegian subsidy level by rechannelling and redefining the support. We thus keep the subsidy rate of 26.4 per cent from 1992 unchanged[13]. About 40 per cent of the subsidies to *Fisheries* in 1992 stemmed from arrangements that have been prohibited according to the EFTA Resolution on Fisheries. We have reduced the subsidy rate, which was 7.2 per cent in 1992, by the same proportion. Finally, subsidies for ordering new ships will be removed with effect from the year 2001. The subsidy rate for *Shipbuilding* was 6.2 per cent in 1992. We have not found that other regulations in the EEA or WTO Agreements will limit the Norwegian subsidy policy.

3.3. Changes in world prices

The EEA Agreement has reduced EU's protection rates on Norwegian fish by about two percentage points, thus raising Norwegian export prices[14]. Other effects on the price levels of Norway's European trading partners, of incorporating the small EFTA countries in the inner European market, are assessed to be insignificant. On the other hand, implementation of the WTO Agreement in all member states has a potential for changing price levels in significant areas for Norwegian trade. We have based our estimates on the study by Haaland and Tollefsen (1994), where the effects of the Uruguay Round are simulated on a global model. In most markets they find that consumer prices fall less than the trade barrier reductions, implying that production costs abroad, and thus the exogenous import and export prices of Norway, rise by between a half and one per cent. For the import prices this is, however, only part of the story. Norway's own removal of many types of NTBs reduces the import price before the good reaches the Norwegian border. For instance, technical barriers that require adaptation of products to special Norwegian standards, entail real costs in the exporting countries. Quota arrangements often imply that part of the quota rent accrues to agents in the exporting country. The average effect on import prices at the border is a reduction of about one per cent.

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[13]The subsidy rate is calculated as subsidies per gross value of production, in percentage terms.

[14] In periods the EU has introduced minimum prices for Norwegian fish. Anti-dumping rules that applied prior to the EEA Agreement also permitted this, and we do not consider the practice of recent years to be a consequence of EEA rules.

As a result of the EFTA Resolution, subsidy reductions increase marginal costs in all participating countries to approximately the same extent. This does not generate any impetus to Norwegian exports. Similarly, it is assumed that the removal of shipbuilding subsidies within the EEA will not result in changes in Norwegian prices relative to world market prices in the long run. On the basis of Hellesjø et al. (1994), we assume that the long-run world market price will be determined by Japan's cost level, independent of subsidy changes within the EEA countries.

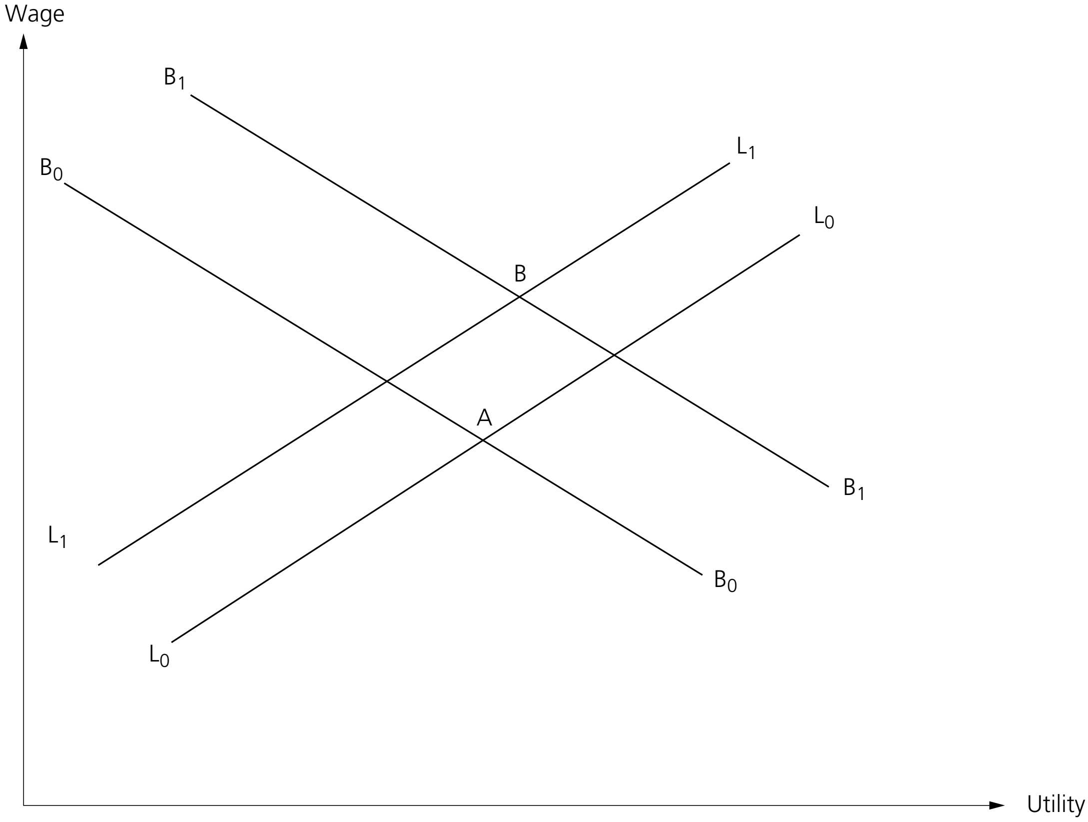
4. Effects on welfare and macroeconomic aggregates

In principle, the equation system that determines the steady state equilibrium of MSG-6 can be reduced to a system of two equilibrium conditions, which determines the steady-state wage rate and utility level. These conditions are depicted by the two curves LL and BB drawn in the wage-utility diagram in Figure 1. The LL- and BB-loci describe the wage and utility combinations that are consistent with, respectively, labour market equilibrium and the intertemporal budget constraint preventing the present value of the net foreign debt to explode. The budget constraint for the total economy follows from the budget constraints of the government and the representative household. The point where the two loci intersect represents the steady-state general equilibrium.

The LL-locus is upward sloping because a partial increase in the utility level causes households to decrease labour supply and increase consumption of goods, both contributing to excess demand for labour. To restore the labour market equilibrium, the wage rate must increase. The BB-locus is downward sloping because a partial increase in the utility level implies that households increase their consumption, including imported goods, so that the current account surplus falls. A fall in the wage rate restores the equilibrium surplus through export expansion, substitution of domestic deliveries for imports, and substitution of consumption for leisure.

In Figure 1, the loci with subscript "0" and "1" denote, respectively, the pre- and post-reform situations. The trade reform causes an upward shift in the BB-locus for two reasons: Firstly, the reduction of import prices and the increase in export prices improve terms of trade. Secondly, for a given wage rate and utility level, the current account surplus is further increased since the rise in export prices boosts exports. Since export supplies are quite price elastic, this effect dominates the impact of higher import shares caused by reduced import prices and industry subsidies. The positive shift of the BB-locus illustrates that the extra current account surplus is eliminated by raising wages and/or utility.

Figure 1: The determination of the stationary equilibrium utility level and wage rate in MSG-6



The upward shift in the LL-locus is mainly due to the increased labour demand following the rise in export prices. Due to the high price elasticities of export supplies, this effect dominates those implied by substitution of imports for domestic deliveries, substitution of capital and materials (that become cheaper when import barriers fall) for labour, as well as increased labour supply induced by the fall in consumer prices. The resulting excess demand for labour is eliminated by an increase in wages and/or decrease in utility.

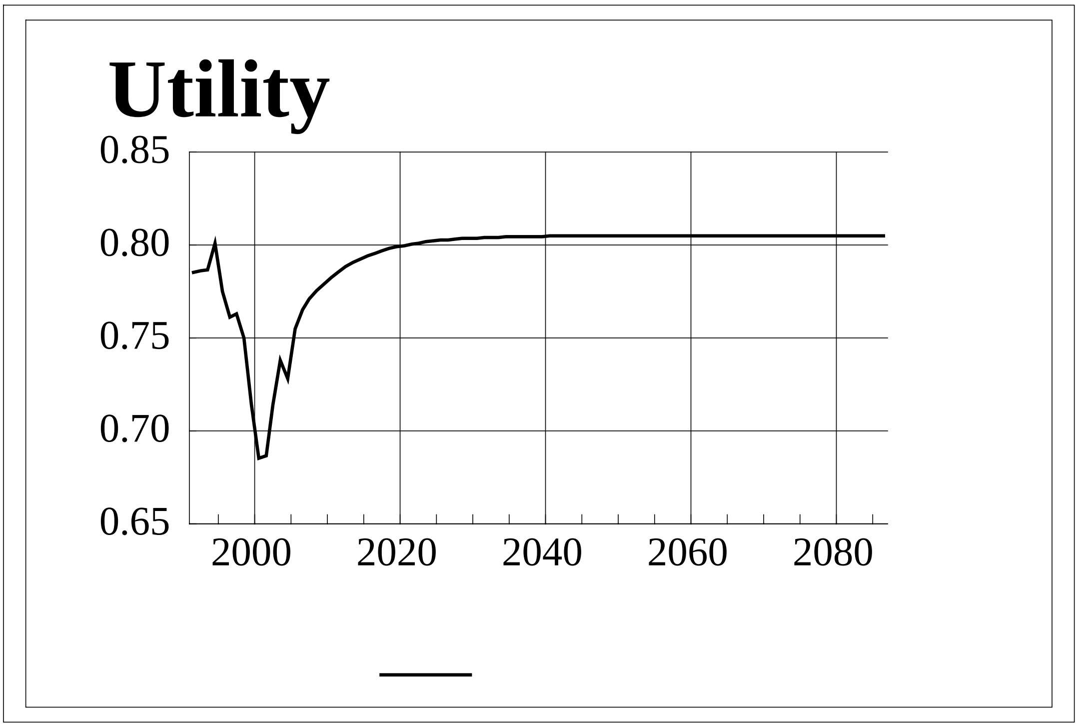
The results from the MSG-6 computation indicate that the effects of the trade policy reform on utility as well as on other macroeconomic factors are relatively small compared to for example the changes during one year with normal economic growth. The steady-state utility increases by 0.8 per cent, while the steady state wage rate increases by 1.8 per cent, see Table 3. Computing the present value of the utility changes produces a welfare gain slightly below 0.8 per cent. These modest results reflect that the Norwegian economy was a very open economy already prior to the trade liberalisation. In this respect our results are in line with the results in most other studies of recent trade liberalisation in the OECD countries.

Table 3: Key macroeconomic steady-state effects of the trade policy reform, percentage deviations between the post- and pre-reform scenarios

Utility	0.8
Consumption	1.0
Employment	-0.6
Price index for consumption	0.2
Wage rate	1.8
GDP	-0.1
Real Capital	0.1
Net foreign wealth	-21.4
Trade surplus	5.0
Export prices	0.6
Import prices	-1.1

A particular aspect of our results is that the utility improvement shows up as growth in both material consumption as well as leisure. The 0.6 per cent employment reduction reflects that the negative income effect on labour supply dominates the positive substitution effect caused by higher real wages. The GDP reduction is modified by the rise in the capital-labour ratio. This employment reduction contrasts the results of Keuschnigg and Kohler (1996), who find that increased European integration stimulates Austrian employment.

Figure 2: Equilibrium dynamics of utility, percentage deviations between the post- and pre-reform scenarios

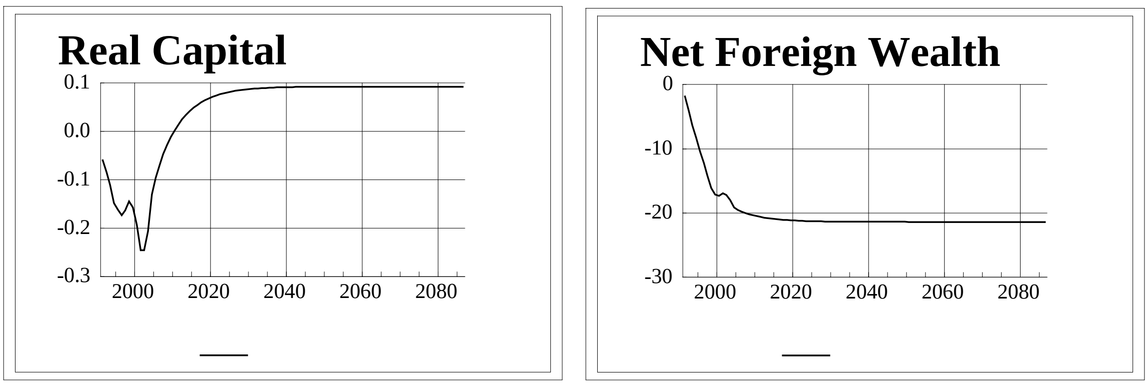


Endogenous saddle point dynamics, as well as the expected gradual implementation of the reforms from 1995 to 2005 determine the transition to the new trade policy regime. The changes in the utility flow are characterised by a utility increase in all periods following the announcement, see Figure 2. Intertemporal substitution creates dynamics that are inversely related to the changes in the annual cost-of-living index. The changes in this index reflect the wage rate adjustments necessary to balance the labour market. These adjustments dominate the influence from the exogenous import price reductions. The V-shape of the utility growth during the implementation of the reforms is first of all related to the phasing in of the reforms.

The dynamics of the investments are foremost determined by the exogenous time pattern of the changes in the import prices, which affect the user cost of capital in two respects. First, lower import prices contribute to reduce the market prices of new capital goods. Second, the expected gradual reduction of import prices contributes to an expected decline in the market price of capital goods, and such negative expected capital gains raise the user costs of capital. In the years before 2001, the cost effect of negative capital gains is sufficiently strong to bring about a reduction in aggregate investments. As expected capital losses fades out after 2001 the increase in the user cost of capital gradually declines, and producers find it profitable to increase their capital stocks again until the desired steady-state level, as shown in Figure 3.

Issuing foreign debt finances the main part of the immediate increase in consumption, see Figure 3. In order to service this additional debt, the trade surplus becomes positive after approximately 10 years, and the stationary post-reform surplus is 4.9 percent higher than the corresponding pre-reform surplus.

Figure 3: Equilibrium dynamics of real capital and net foreign wealth, percentage deviations between the post- and pre-reform scenarios



5. Changes in air pollution and waste generation

Total effects on air pollution and waste generation from the long-run equilibrium changes are summarised in the last column of Table 4. The welfare gain, attributable to growth in consumption and leisure, comes at a cost in terms of increased Norwegian contributions to air pollution. Long-run emissions of Kyoto gases[15] increase by 0.4 per cent. This is mainly due to increased emissions of *Carbon Dioxide* and *Perfluorcarbons*, which dominate reductions in emissions of *Methane* and *Nitrous Oxide*. Emissions of *Sulphur Dioxide*, *Suspended Particulates* and *Carbon Monoxide* increase by between 1 and 2 per cent, whereas emissions of *NMVOCs*, *Nitrogen Oxides* as well as deposition of solid waste are almost unaffected by the trade liberalisation. Only emissions of *Ammonia* fall.

Table 4 decomposes the environmental effects into effects from changes in aggregate consumption and production (*scale effects*), and from changes in the composition of consumption, factor input, and industry structure (*composition effects*). As GDP slightly falls, the rise in emissions can be attributed to the 1 per cent growth in consumption, combined with significant composition effects. Emissions from firms increase first of all as a result of increased production of *Industrial Chemicals*, *Metals*, and *Pulp and Paper* (see Table A.1 in Appendix). The metal production processes emit *Sulphur Dioxide*, as well as the Kyoto gases *Perfluorcarbons* and *Sulphur Hexaflourids*. Production of nitric acid (in *Industrial Chemicals*) emits the Kyoto gas *Nitrous Oxide*. The industries are also significant consumers of fossil fuels for combustion and reduction processes, thus contributing to increased emissions of *Carbon Dioxide*, *Methane*, *Sulphur Dioxide*, *Nitrogen Oxides* and *Carbon Monoxide*. The long run expansion of these industries is due to higher export prices as about 2/3 of their output is sold in foreign markets. Furthermore, labour intensities are low in these industries, which implies that the feedback from higher wages has but a modest contractive effect on output. The expansion of these export-oriented industries mirrors the long-run increase in aggregate savings and trade surplus described in the previous section[16]. During the first part of the simulation period, when foreign debt is issued and resources are reallocated from net exports to consumption and real capital formation, these industries temporarily contract.

The expansion of the export industries also underlies another composition effect on the emissions from firms. All the three industries are highly intensive with respect to hydropower-based electricity, and due to almost completely inelastic electricity supply, their expansion causes an increase of 7 - 9 percent in the electricity price. This motivates firms throughout the economy to increase the share of

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[15] See Table 1 for a list of the Kyoto gases. Their aggregate emissions are measured in CO_2-equivalents.

[16] Recall that the *Crude Oil and Natural Gas* export, which is by far the most important, is assumed to be unaffected by the trade agreements.

fossil fuels in their energy demand, and emissions from combustion increase. A discussion of the assumptions underlying the modelling of the electricity market is provided in Section 6.

Some changes in the industry composition contribute to reduce air pollution. Most significantly, the contraction of *Agriculture*, which is negatively affected by both the trade barrier reductions and the rise in labour costs, contributes to reduce emissions of *Ammonia*, *Suspended Particulates*, and the Kyoto gases *Nitrous Oxide*, and *Methane*. The downscaling of *Manufacture of Chemical and Mineral Products*, which is left less protected by the reforms, contributes somewhat to reduce emissions from combustion, as this industry is an important fossil fuel consumer.

Table 4: Long-run changes in emissions and waste generation, percentage deviations between the post- and pre-reform scenarios

	Emission changes from households, contribution from:			Emission changes from firms, contribution from:			Changes in total emissions
	Scale effects	Composition effects	Total	Scale effects	Composition effects	Total	
Kyoto gases	1.0	-0.1	0.9	-0.1	0.4	0.3	0.4
Sulphur Dioxide	1.0	0.5	1.5	-0.1	2.1	2.0	2.0
Nitrogen Oxides	1.0	-0.2	0.8	-0.1	0.0	-0.1	0.0
Ammonia	1.0	-0.3	0.7	-0.1	-2.6	-2.8	-2.7
NMVOC	1.0	-0.1	0.9	-0.1	-0.4	-0.6	0.0
Carbon Monoxide	1.0	0.0	1.0	-0.1	0.9	0.8	0.9
Particulate Matter	1.0	0.7	1.7	-0.1	-0.4	-0.5	1.0
Waste generation	1.0	-0.4	0.6	-0.1	-0.5	-0.6	0.0

The model takes into account that foreign trade stimulates domestic transport activities[17]. However, in our analysis this effect is to a great extent crowded out by reduced transport demand from domestic firms, so that only small impulses are left to the domestic transport activities (see Table A.1). Within the transport sector, non-polluting *Railway and Tramway Transport* is relatively hard hit by the price increase of electricity and looses market shares. So do *Coastal and Inland Water Transport*, which is negatively affected by increased prices of ships following the subsidy prohibitions. Note that our analysis ignores changes in the rest of the world, including transport within Norway carried by foreign firms.

Concerning the composition effects on the emissions from households, positive contributions are only found for *Sulphur Dioxide* and *Suspended Particulates*. Use of fuels for heating increases its share of consumption (see Table A.2). Again, this is a result of the increased electricity prices. Most other

[17] It is worth noting that, for technical reasons, no emissions are linked to the model industry *Ocean Transport*. For much of the same reasons, the Kyoto Protocol excludes these emissions as well.

pollutive consumption activities lower their budget shares. The results show, however, that consumption of transport services is shifted in favour of own use of cars at the expense of public services.

6. Discussion of some crucial assumptions

In such a large disaggregated model as MSG-6, a huge number of parameters, reflecting assumptions about technologies and preferences, will influence the simulated results. Based on the experience with the model, we emphasise the sensitivity of the results to three sets of assumptions, one concerning the *labour supply behaviour*, one affecting the *terms-of-trade gain*, and the last determining the *functioning of the energy market*.

The parameterisation of the *labour supply behaviour* implies that the negative income effect dominates the positive substitution effect of an increase in the real wage rate. In other studies, e.g. Keuschnigg and Kohler (1996), the opposite is true. We have regarded Aaberge et al. (1995) as the best available econometric source for calibrating the relevant parameters in the aggregate CES preference structure over consumption and leisure. This is a panel study of the labour supply decision for various groups of Norwegian spouses. However, in addition to the uncertainty associated with these parameter estimates, it is not obvious how the heterogeneous behaviour in Aaberge et al. (1995) should be transformed into the aggregate representation in MSG-6. The aggregate labour supply behaviour in our study must therefore be considered as rather uncertain. At the same time, alternative parameter values are significant for our results. With a positive uncompensated wage elasticity of labour supply the trade liberalisation would have caused a general expansion of employment and production, and the consumption growth would have been stronger. Subsequently, emissions and waste generation would have risen. Economic welfare would increase as well, due to the large effective tax rate on labour.

The *terms-of-trade gain* resulting from the trade reforms origins from two sources. The far most important source in our analysis is the reduction of domestic import barriers that affects import prices before border crossing. The dimensions and characteristics of non-tariff trade barriers are difficult to identify. In addition, the estimates of the changes in world prices are also quite uncertain. They have, however, minor influence on the terms-of-trade gain, because they affect import and export prices similarly. Their only terms-of-trade effects appear as a result of different weights.

If the terms-of-trade gain were smaller than what follows from the assumptions in Section 3, the effects on air pollution would be ambiguous. First, due to the high price elasticities of exports, the intertemporal budget constraint on net foreign debt would have been satisfied with smaller gross trade flows. This change would have reduced air pollution since resources would have been reallocated from the relatively “dirty” export industries to import competing industries. Furthermore, a lower terms-of-trade gain would reduce welfare. This would have generated less emissions and waste from final consumption. On the other side, the income reduction would have stimulated labour supply and, in turn, production activities. This would have led to increased emissions and waste generation.

Our specific modelling assumptions concerning the *functioning of the energy market* (see Section 2.4) have three important consequences for the results on emissions. The first two are related to the choice of excluding major growth processes in the reference path. This choice is not quite harmless in its interplay with the energy market modelling. First, the model opens for exploitation of gas power, provided electricity price levels become sufficiently high. However, due to the low growth, gas power production remains unprofitable also in the post-reform scenario. If parts of the trade reform effects were to take place in a regime where gas power were the marginal energy source, an increase in energy production would surely cause more emissions to air. The second implication is related to the two-price system for electricity deliveries to the energy intensive industries (*Manufacture of Metals*, *Manufacture of Industrial Chemicals* and *Manufacture of Pulp and Paper*). As described in Section 2.2, these industries enjoy subsidised prices as long as their total annual use of hydropower is less than 30 TWh. Low general economic growth in the pre-reform scenario implies that the total demand from these three industries never exceeds this quota. In a scenario with stronger growth, the quota constraint could at some point have become effective and turned marginal electricity prices higher than in the low-growth scenario. This would have dampened the expansion of these industries in the wake of trade reforms. Since their activities are relatively “dirty”, emissions would have been reduced. Also, via their demand for electricity, less pressure would arise on electricity prices and less substitution of fuel-based energy for electricity would take place.

The third critical assumption concerns the foreign trade of electricity. Until now the transferring capacity across borders has been limited. However, recent liberalisation efforts and expansion of the international transport grids are gradually reducing trade barriers. If alternatively, we had assumed marginal supplies of electricity to be available at fixed import prices, the substitution in favour of fuels would have been reduced. Most realistically, however, this would have taken place at the expense of higher emissions abroad, as Norwegian import of power first of all origins from coal-based power plants in Denmark.

7. Conclusions

Our general equilibrium assessment of the consequences for Norway of the recent international agreements on trade indicates that most effects will be small compared to the changes that will take place during a normal growth process. However, even a modest gain equal to 0.8 per cent in an aggregate welfare index of consumption and leisure cannot be realised without increased air pollution from Norwegian sources. We find that the total emissions of Kyoto gases increase by 0.4 per cent in the long run. As a reference, Norway has to confine the growth in greenhouse gas emissions to 1 per cent, only, from 1990 to the period 2008 to 2012, according to the Kyoto protocol. Consequently, our findings on the *isolated* effects of the trade reform suggest that Norway reduces the scope for fulfilling the Kyoto commitments by 40 per cent[18]. Moreover, emissions of *Sulphur Dioxide*, *Carbon Monoxide* and *Suspended Particulates* increase by between 1 and 2 per cent. Only emissions of *Ammonia* show a significant reduction, of 2.7 per cent.

The rise in pollution occurs despite a reduction of the GDP. Foremost, this result reflects that most of the economic welfare gain can be attributed to improved terms of trade. Thus, while domestic production is scaled down, consumption and emissions from consumption rise. In addition, the restructuring of the economy implies reallocations in the long run in favour of export-oriented industries. Their production is “dirty” and their consumption of electricity implies scarcity of “clean” power and substitution in favour of fuels.

The assumption of constant and similar technologies in the pre- and post-reform paths implies that there are no endogenous links between trade policy and technology. However, trade is a potential channel of technology diffusion. Also, to the extent that economic activities expand as trade reforms are undertaken one could expect some degree of embedded growth, as it would be rational to invest in the most efficient capital equipment available. Whether such improvements would gain the environment, would depend on the existing incentives to invest in “cleaner” technology.

The reported negative effects on air pollution should not be used as an argument against trade liberalisation. The first best policy would be to correct the direct sources to imperfections. This implies that more direct policy tools than trade policy instruments should be applied to control environmentally harmful activities. In this respect it is interesting that the heavy polluting, exporting manufactures are subject to favourable policy conditions in terms of low energy prices and low carbon taxes.

[18] Compared to qualified forecasts on Norwegian Kyoto gas emissions, which aim to take into account all realistic growth processes, this simulated contribution from the trade reforms is, however, modest (see e.g. Norwegian Ministry of Finance (2001).

Our model analysis leaves plenty of issues deserving further research. One interesting project would be to take the harmful feedback effects from air pollution and waste deposition more explicitly into account when calculating changes in welfare. In particular, including environmental quality in the welfare function would give insight into the balancing between environmental and pure economic considerations. Introducing endogenous political actions or technology improvements would enable the model to grasp further aspects of the relationship between trade reforms, economic growth and the environment. Moreover, our analysis shows that the responses in the energy markets may affect the effects on air pollution. A better description of the possibilities of trading electricity internationally should therefore be a part of further research in this field.

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Appendix

Figure A.1: The preference structure of the household in MSG-6

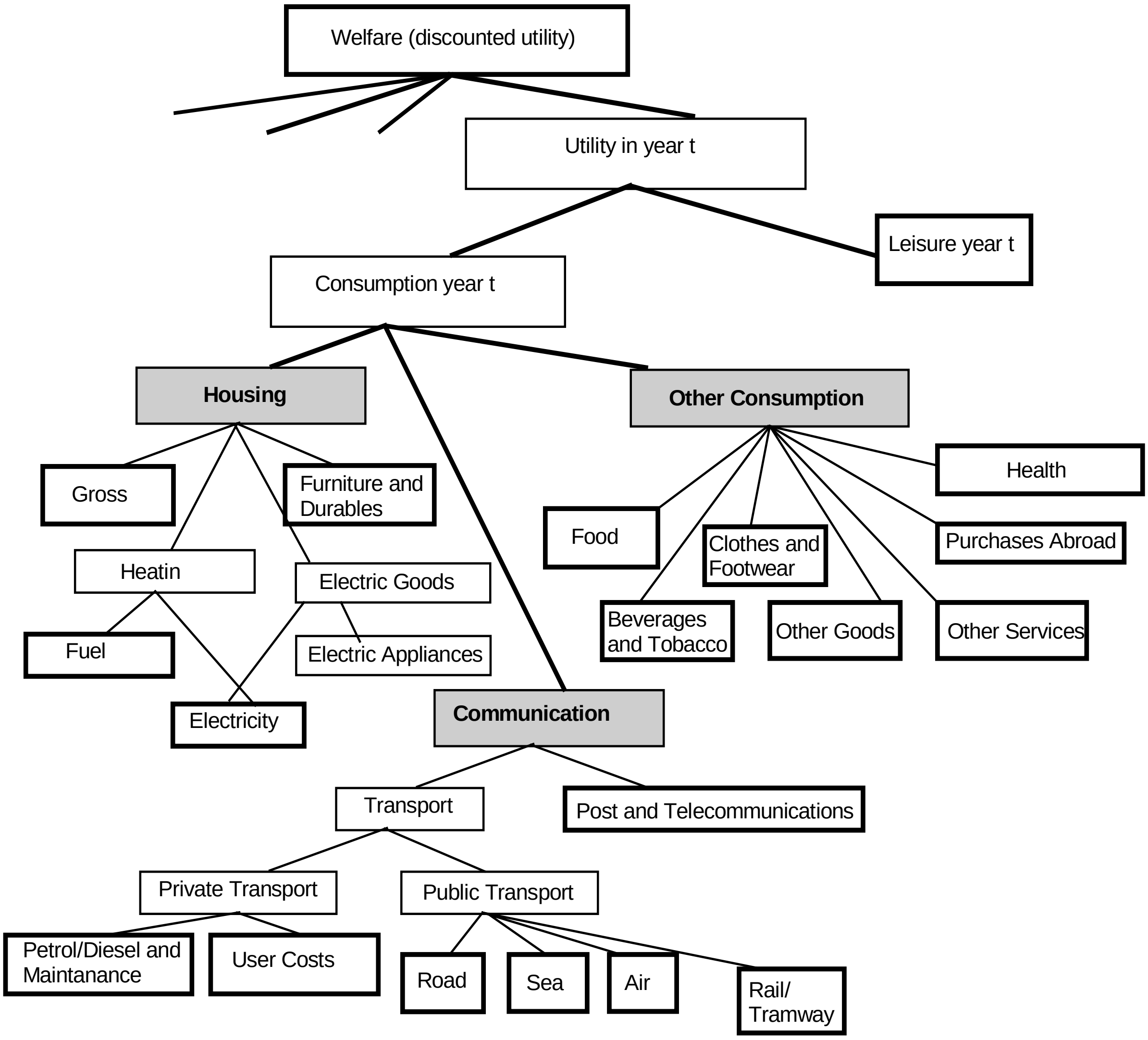

Figure A.2: The separable structure of production structure of the firms in MSG-6

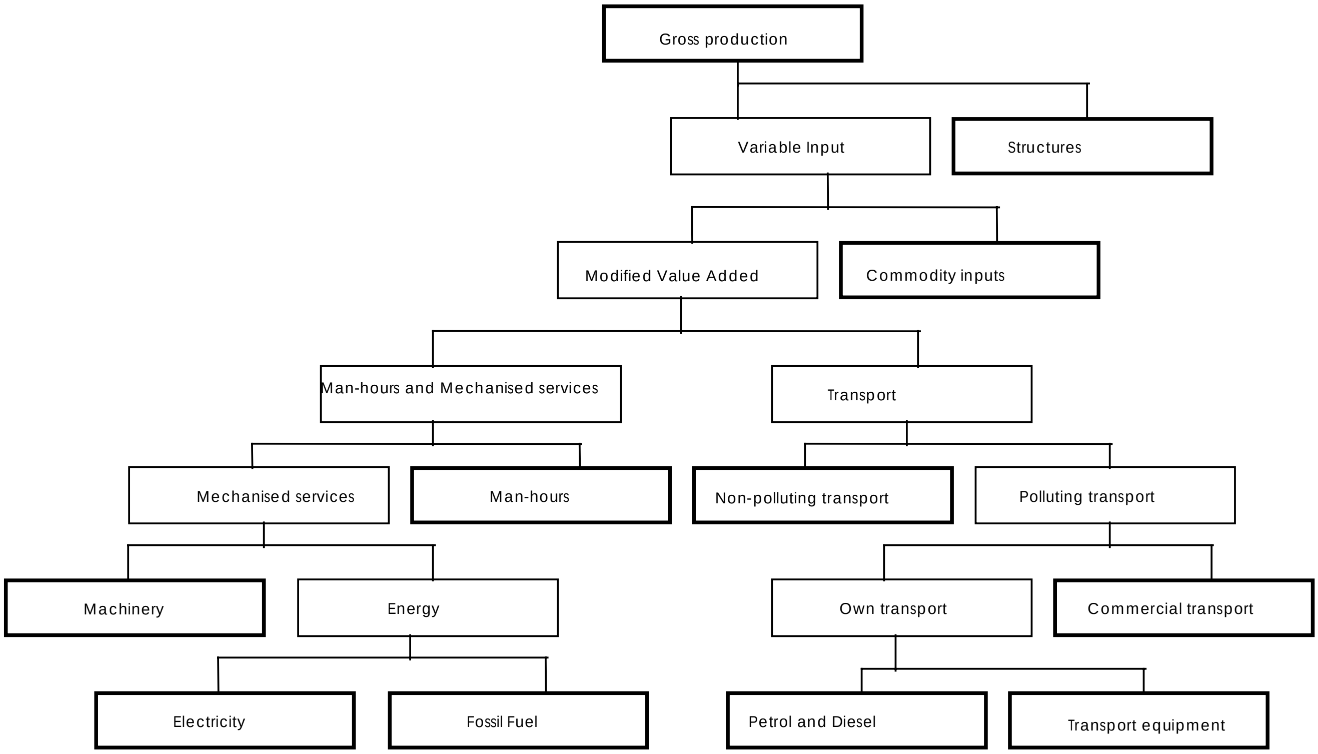

Table A.1: Long-run changes in gross production by industry, percentage deviations between the post- and pre-reform scenarios

Industries in MSG-6	Percentage change in gross production
Manufacture of Metals	3.9
Manufacture of Industrial Chemicals	3.8
Fish Farming	2.1
Manufacture of Pulp and Paper	2.0
Manufacture of Dairy and Meat Products	0.7
Preserving and Processing of Fish	0.7
Dwelling Services	0.6
Air Transport	0.2
Coastal and Inland Water Transport	0.0
Wholesale and Retail Trade	0.0
Fisheries	0.0[1)]
Extraction and Transport of Crude Oil and Gas	0.0[1)]
Oil and Gas Exploration	0.0[1)]
Defence	0.0[1)]
Government Education, Central	0.0[1)]
Government Education, Local	0.0[1)]
Government Health Care, Central	0.0[1)]
Government Health Care, Local	0.0[1)]
Other Government Services, Central	0.0[1)]
Other Government Services, Local	0.0[1)]
Water Supply and Sanitary Services	0.0[1)]
Land Transport	0.0
Ocean Transport	0.0
Construction	0.0
Printing and Publishing	0.0
Manufacture of Wood and Wood Products	-0.1
Railway and Tramway Transport	-0.1
Other Private Services	-0.1
Finance and Insurance	-0.3
Post and Telecommunications	-0.3
Manufacture of Other Consumption Goods[2)]	-0.4
Forestry	-0.5
Textile and Clothing Industry	-0.5
Production of Electricity	-0.7
Manufacture of Oil Platforms	-0.8
Oil Refining	-0.8
Agriculture	-1.6
Manufacture of Hardware and Machinery	-2.5
Manufacture of Chemical and Mineral Products	-4.2
Shipbuilding	-14.9
TOTAL	**-0.3**

[1)] The changes are exogenously set to zero

[2)] The industry mainly produces *Other Processed Food* and *Beverages and Tobacco*.

Table A.2: Long-run changes in consumption by good, percentage deviations between the post- and pre-reform scenarios

Consumer goods in MSG-6	Percentage change in consumption
Fuel	1.9
Beverages and Tobacco	1.3
Furniture and Durable Goods	1.3
User Cost of Cars	1.0
Purchases Abroad	1.0
Petrol/Diesel and Car Maintenance	0.7
Gross Rents	0.6
Air Transport	0.5
Other Goods	0.5
Clothing and Footwear	0.4
Health Expenditures	0.4
Food	0.2
Electric Appliances	0.2
Other Services	0.1
Post and Telecommunications	0.0
Water Transport	-0.1
Road transport	-0.1
Rail/Tramway Transport	-0.2
Electricity	-1.2
TOTAL	**1.0**

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