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Transboundary environmental policy effects: Markets and emission leakages

Abstract:
According to the Environmental Kuznets Curve (EKC) literature, several mechanisms within rich economies, including increased willingness to conduct abatement policies, contribute to reduce environmental problems. Unilateral environmental policies in open economies may affect other countries negatively through trade inter-linkages. A relocation of dirty production and environmental pressure to economies with laxer abatement regimes can be one of many explanations to the apparent EKCs for rich countries. Further, the economic costs of national abatement policies may to some extent be shared with foreigners, both through lower demand for imports and through market share losses for foreign competitors producing cleaner products. In this paper, we quantify the effects of endogenous carbon tax policy in a rich and open economy, Norway, by means of a CGE model. We find that the environmental benefits fall and the economic costs rise when a global rather than a national perspective is employed.

Keywords: Climate policy; Dynamic CGE Model, Endogenous Policy; Environmental Kuznets Curve; Pollution leakage

JEL classification: D58, O11, Q25, Q28, Q48

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1. Introduction

Over the last decade, a large number of studies have pointed to a first increasing, then decreasing relationship between many types of emissions and income, the so-called Environmental Kuznets Curves (EKC)[1]. One explanation is that with increasing income, environmental quality appears to become more important for peoples' well-being (Hökby and Söderqvist, 2003, Kristrøm and Riera, 1996), and the internal pressure and acceptance for national environmental regulations increases. Although this involves environmental improvements along with economic growth, there is a concern in the EKC literature that the counterpart of a cleaner domestic production pattern may be increased import and less export of dirty products, implying environmental load displacement (Muradian et al., 2003) or *pollution leakages* across borders.

In a global sense, environmental benefits of national abatement policy will be smaller when possible pollution leakages are accounted for. Actually, increases in foreign emissions may even be higher than the emissions avoided at home, if the relocation takes place in countries with more dirty production processes. Leakages raise concerns for the efficiency of abatement policies, as well as for the desired environmental distribution. The efficiency problems are of particular relevance to transboundary pollution and for greenhouse gases, as pointed out in the so-called carbon leakage literature; see e.g. Barker (1999) and Jacoby et al. (1997). Since the environmental effects of climate gas emissions are independent of the pollutants' location, if not accounted for, the environmental benefits will be overestimated for the regulating country. Also, while willingness to pay differences can legitimate emission variations among countries, it could on the other side be argued that leakages constitute an ethical dilemma. One point of view is that leakages imply that part of the abatement costs related to environmental gains in rich countries is carried by developing countries. Further, today's relatively less developed countries will not be able to follow the same path when comes to environmental improvements. When they reach higher levels of income and willingness to pay for environmental improvements, the potential for exporting pollution problems will be smaller and hence the abatement costs higher.

In this paper, we will look into the pollution leakage hypothesis behind the EKC by quantifying how growth-induced environmental policy affects foreign and domestic emissions. We use a CGE approach that enables us to isolate the different effects of abatement policy, and hence supplement the present, econometrically oriented literature on load displacement. Several earlier studies reveal such effects. Cole (2000) indicates that a necessary condition for pollution leakages is present: In the devel-

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[1] See e.g. Grossman and Krueger (1993, 1995), Shafik and Bandyopadhyay (1992), and Selden and Song (1994) for initial papers, or Borghesi (1999) for an empirical and theoretical survey.

oped countries, cleaner composition of the manufacturing sector is, at least partly, responsible for their reduced pollution. Suri and Chapman (1998) find that industrialised countries have reduced their energy requirements, and hence fossil fuel based emissions, by importing manufactured goods. In a study of Austria, Friedl and Getzner (2003) find the import/GDP ratio to be significant in explaining CO_2 reductions. Muradian et al. (2002) conclude that the industrial world has an ecological trade deficit vis à vis the developing world, in the sense that the pollution content in imports tends to be larger than in exports. Lucas et al. (1992) and Birdsall and Wheeler (1993) indicate that environmental policy within richer countries appear to be one of the explanations behind emission leakages to relatively poor countries.

This paper also addresses the potential *economic* burdens transferred to our trade partners when imposing unilateral environmental regulations. The so-called pollution haven hypothesis claims that competitors abroad will become relatively better off, as a tighter domestic environmental policy increases their market shares and profits. Competitiveness arguments are frequently used by the emission-intensive industries against introducing unilateral abatement policies. While domestic competitiveness losses in some industries seem intuitively plausible, at least as a first round effect, modifying aspects appear if the perspective is broadened. First, sooner or later a sustainable development of the current account requires improving domestic competitiveness in *other* markets through adjustments in factor prices and exchange rates. Necessary structural adjustments will modify the argument taken by the most heavily regulated firms and imply that at least in the longer run, foreigners, as well, are likely to lose shares in other markets. In other words, forcing producers to pay for pollution changes the *comparative* advantages. *Absolute* advantages are irrelevant as long as the effective exchange rates are flexible. Second, decreasing domestic demand affects not only domestic firms but also competitors from abroad. These aspects tend to counteract the relative economic benefits of foreign firms. On the other side, they also modify the pollution leakages abroad.

The empirical literature does not univocally confirm the pollution haven hypothesis (see e.g. Cole, 2004, for an overview). Econometric analyses have failed to find strong evidence that tighter environmental policies significantly affect investment patterns (see e.g. Zarsky, 1999; Eskeland and Harrison, 2003; Smarzynska and Wei, 2001) or trade patterns (see e.g. Jaffe et al., 1995, Janicke et al., 1997). Jaffe et al. (1995) point to a number of possible problems concerning data measurement as reasons why the effects may be difficult to detect in econometric analyses. By employing a CGE approach, as in Ho and Jorgenson (1997a,b), it is possible to quantify the isolated effects of changes in the environmental policy. They find significant costs in terms of international competitiveness on behalf of the domestic emission-intensive industries, but also emphasise that in the long run, impacts on competitiveness vary considerably among markets. A key factor to understand the differences is the influence of counteracting adjustments in factor prices and exchange rates in order to ensure a sustainable economic development. Due to the long-term nature of environmental problems in general, and global warming in particular, we find the long-term perspective the most relevant when addressing the competitiveness and pollution leakage issues simultaneously. By employing a CGE framework, we are able to take into account how long-term effects of unilateral environmental policy differ among industries, both within and across the domestic borders. By this choice of perspective, we leave out an analysis of shorter run intertia problems and adjustment costs.

We compute the emission leakages by linking country- and commodity-specific technological emission coefficients for our trade partners to the simulated international trade flows at a detailed level. Contrary to related calculations by Antweiler (1996) and Muradian et al. (2002), we account for differences in abatement and energy technology among countries. We add to the leakage literature, which primarily focuses on CO_2 emissions, by calculating leakages of several emissions to air, including the Kyoto climate gases as well as pollutants with local and regional effects.

Our case is climate gas abatement in the rich and open Norwegian economy thirty years ahead. The high degree of openness of the Norwegian economy accentuates the relevance of focusing on transboundary effects. In accordance with the EKC hypothesis, we model the abatement policy endogenously based on regression analyses (Bruvoll et al., 2003). Political economy mechanisms are extensively explored in the economic literature (see Drazen, 2000 for a survey), to some extent also in case of emission regulations; see e.g. Jones and Manuelli (2001). However, CGE analyses that account for such mechanisms are rare. Three recent exemptions are Ansuatega and Escapa (2002), Jansen (2001) and Bruvoll et al. (2003). As in the two latter papers, we account for the inter-linkages between environmental taxes and economic growth without explicitly including the environment in the object functions. Norwegian average income per capita is the third highest in the world, and for most emissions Norway is a good example of a country showing a concave relationship between income and emissions (Bruvoll and Medin 2003). When it comes to the CO_2 emissions, the current Norwegian policy is among the strictest in the world (Ekins and Speck, 1999). Abatement policies have been explicitly directed towards CO_2 for more than a decade, and before that the emissions were regulated through other, more indirect instruments.

Our computations confirm the existence of modest emission leakages abroad in the wake of a tighter carbon policy in Norway. Contrary to what is usually expected, the emission leakages are not related to replacement of domestic dirty production by imports, but rather to a loss of competitiveness in the Norwegian export industries. In economic terms, what foreigners gain in the non-Norwegian markets by taking over previous Norwegian market shares, they more than lose within the Norwegian borders. This is partly due to a general weakening of Norwegian demand and partly explained by the lon-run restrictions on the current account that increases competitiveness of domestic firms in typically import-competing, emission-extensive industries. Thus, by focusing beyond national borders we identify a case where environmental gains are smaller and economic costs are higher than borne by the regulating country itself.

The paper proceeds as follows: Section 2 describes the model and the method, Section 3 describes the compared scenarios, Section 4 presents the effects on markets and distribution of market shares, Section 5 analyses the effects on global emissions and their distribution among countries, and Section 6 concludes.

2. The model

We use a version of the dynamic, disaggregate CGE model MSG6[2], adapted to address domestic and transboundary effects of policy changes. The model specifies 60 commodities and 40 industries, classified with particular respect to capture important substitution possibilities with environmental implications. We keep the public budget unaltered through lump-sum transfers in order to exclude revenue recycling effects and isolate the pure effects of changing the CO_2 policy regime. Since the Norwegian economy is small and the exchange rate is normalised to unity, all agents face exogenous world market prices and real interest rates. Thus, financial capital is perfectly mobile across borders. Real capital, labour and products are perfectly mobile within the economy. As in most models in the CGE tradition, supply equals demand in all markets in every year. Parameters are estimated or calibrated on the basis of the 1995 Norwegian National Accounts and relevant econometric studies, see Fæhn and Holmøy (2000).

2.1. Consumer and producer behaviour

Households are rational and forward-looking, and determine their consumption and savings by maximising welfare over an infinite horizon. The intertemporal substitution elasticity is set to 0.3.[3] The endogenous treatment of savings brings about potentially interesting changes in the current account and trade balance, which is particularly important to conclusions concerning competitiveness and emission leakages. The intratemporal utility function has a detailed, nested CES structure, which distinguishes between activities with different emission profiles and reflects relevant price-induced substitution possibilities between commodities (see Figure A1 in Appendix). It forms the main basis for compositional effects on emissions from consumption. Aasness and Holtsmark (1995) document sub-

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[2] The core MSG6 model is developed in Statistics Norway. For a more detailed description, see Fæhn and Holmøy (2000).

[3] This is in line with other studies, see Steigum (1993).

stitution and Engel elasticities. Labour supply is assumed exogenous. External effects, and in particular repercussions from the environment to the utility of the household, are not explicitly modelled.[4]

Firms' input and output decisions determine the changes in emissions from the private business sector. Firms are run by rational, forward-looking managers who maximise the net present value of the cashflow to owners. In all industries there are decreasing returns to scale. At the firm level, scale elasticities lie between 0.8 and 0.9, contributing to decreasing returns to scale. Increasing the scale of production through entry also contributes somewhat to decreasing returns, as the marginal firms are the less productive. [5] In the primary industries, products and firms are homogenous, fixed costs are not specified, and markets are perfectly competitive. Consequently, the scale elasticities at the firm level are the main determinants of endogenous productivity variations within these industries. The demand for inputs is derived from industry-specific nested structures of linearly homogeneous CES-functions (see Appendix 1, Figure A2). Most elasticities of substitution are set in accordance with estimates presented in Alfsen, Bye and Holmøy (1996).

2.2. Trade

Imported services and manufactured goods are close, but imperfect substitutes for the domestically supplied products. According to the Armington hypothesis, import shares depend negatively on the ratio of the import price (world market price including tariffs and freight costs) to the domestic price index of domestic deliveries. The initial import shares are calibrated and vary according to commodity and users. The Armington elasticities are set to 4. 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. Thus, their domestic prices are equal to the corresponding import prices, and net imports cover the gap between domestic production and demand. Producers of manufactured goods and tradable services allocate their output between two segregated markets, the domestic and the foreign. It is costly to change this allocation, as output is a constant-elasticity-of-transformation function of deliveries to the export market and deliveries to the domestic market. The transformation elasticities are calibrated to 4.6. Prices of exports are exogenously determined in the world markets.

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[4] In the model, carbon policy only affects welfare through the costs of abating. Nevertheless, the employed policy rule, based on an estimated relationship between income and emissions, could be interpreted as though income growth stimulates demand for environmental quality and thus policy; see Section 3.

[5] These diseconomy of scale effects are slightly modified by the existence of fixed establishment costs on top of the variable costs, as well as by so-called *love of variety* effects in the firms' use of inputs. As intermediate goods are assumed to consist of differentiated varieties, the higher the number of varieties /suppliers the higher the productivity of the input. The empirical significance of these productivity sources is, however, small in the present study.

2.3. Domestic emissions

Emission calculations are linked to each economic activity at a detailed level for all compounds (Strøm, 2000). Table 1 provides an overview of the specified air pollutants, and their main sources in the benchmark scenario.

Energy combustion, including gas based electricity production, transport and heating, are heavily polluting activities with respect to CO_2 (carbon dioxide), NO_x (nitrous oxide), CO (carbon monoxide), NMVOC (non-methane volatile organic compounds) and NH_3 (ammonia). Both stationary and mobile combustion have imperfect substitutes, some that do not pollute (hydropower electricity, rail and tramway transport), some that cause emissions abroad via imports or in other sectors (gas power electricity, transport by road, sea and air) (see Figure A1 and A2). The process industries contribute the most to emissions. In particular, manufacture of metals and chemicals are the main emitters of SO_2 (sulphur dioxide) and N_2O (nitrous oxide). Further, agriculture along with landfills contribute to most of the CH_4 (methane) emissions. Emissions from the public sector are low and disregarded in the model.

Table 1: Emissions in percent of total emissions in 2030, benchmark scenario

	CO_2	CH_4	N_2O	SO_2	NO_x	CO	NMVOC	NH_3
From production								
Agriculture	1	22	21	1	2	0	0	60
Fishing etc.	2	0	0	2	17	1	0	0
Manufacture of industrial chemicals	6	0	38	21	3	5	1	2
Manufacture of metals	9	0	0	36	4	1	1	0
Production of electricity	29	0	0	0	5	2	1	0
Production and pipeline of oil and gas	8	3	0	1	12	0	37	0
Road transport etc.	5	0	1	3	11	1	3	0
Coastal and inland water transport	2	0	0	4	15	0	1	0
Landfills	0	26	0	0	0	0	0	0
From consumption								
Fuels	3	3	1	6	2	31	6	0
Petrol and car maintenance	22	1	33	3	13	53	23	35
Gross rents	0	0	0	0	0	0	10	0
Landfills	0	43	0	0	0	0	0	0
Other	14	1	6	24	16	5	18	3
Total	100	100	100	100	100	100	100	100

2.4. Emissions abroad

We compute the emissions abroad associated to trade by linking country- and commodity-specific technological emission coefficients for our trade partners to the simulated international trade flows. Each country is weighed according to their share of total import or export of the specific good. The import-related leakages for pollutant *P*, IRL^P, express the emissions abroad related to the production of goods imported in Norway. We compute the import-related leakages as:

$$(1) \qquad IRL^P = \sum_{c=1}^{C} \sum_{i=1}^{n} IM_i \, \overline{im_{ic}} \, \frac{E^P{}_{ic}}{Y_{ic}} \frac{1}{\tau},$$

that is, the product of the import of good *i*, IM_i, the share of import of good *i* from country *c* of total import of the good, $\overline{im_{ic}}$, and the country- and sector specific emission intensity, $E^P{}_{ic}/Y_{ic}$. Y_{ic} is output in the production sector corresponding to good *i* of the good in country *c* exporting to Norway. $E^P{}_{ic}$ is the emission of pollutant *P* in the respective sector and country, and τ captures technical change.

Correspondingly, the export-related leakages, ERL^P, express the emissions avoided abroad, since the production takes place in Norway, and are computed as:

$$(2) \qquad ERL^P = -\sum_{c=1}^{C} \sum_{i=1}^{n} EX_i \, \overline{ex_{ic}} \, \frac{E^P{}_{ic}}{Y_{ic}} \frac{1}{\tau},$$

where EX_i refers to total exports of the good *i* and ex_{ic} to the share of export of good *i* from country *c* relative to total export of the good. Then, the export-related leakages reflect total volume of exports, the commodity composition of exports, the emission intensities in the countries of destination and technical change. Contrary to similar computations in the existing literature, see in particular Antweiler (1996) and Muradian et al. (2001), the inclusion of the country- and sector specific emission intensities captures the effect of different technological conditions on global emissions.

The emission coefficients are calculated for 1995, and adjusted for technological changes, τ, equal to the TFP used for Norwegian sectors in MSG of 1 percent annually. Our trading partners' country- and sector-specific technical emission intensities are based on emission and production statistics on an aggregation level of 41 sectors corresponding to the CGE model (see Table 4 in Section 4.2). The main data source is Eurostat, in addition to several national statistical offices or similar sources. The sources are reported in Straumann (2003), with the exception of the electricity sector for Sweden and Denmark (Nordel 2004)[6]. Data is collected from 17 of our main trading partners, comprising over 80

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[6] The coefficients are corrected according to observed reductions in the coefficients for CO_2, N_2O and SO_2 from 1995 to 2000. We interpret the reduction in the CO_2 coefficient as a composition effect between energy carriers, and we have applied the same reduction the remaining emissions.

percent of total import and export. The emission coefficients for the remaining world economies are computed as the average of the collected sample.

The calculation of leakages relies on some simplifying assumptions of significance to the policy analysis in this paper. These simplifications are obvious implications as we have chosen to conduct this study within a disaggregated national CGE model rather than a world model that is more aggregated with respect to domestic adjustments. First, we assume that the total size of the foreign demand, and thus emissions linked to consumer activities, are unaffected by our policy changes. This seems reasonable, given our small fraction of the world market. Then, changes in import and export will be absorbed by equivalent changes in production abroad. Another assumption is that our export changes are met by production changes in the importing country, i.e. no trade effects between third part countries. Within this framework we are not able to reveal whether this possible trade would be between more or less pollution intensive countries, and we find it reasonable to disregard these effects. Also, effects on emissions abroad due to changes in input deliveries are omitted, and the estimates neglect possible differences in composition between total production and production for export at the chosen aggregation level. Further, the composition of trading partners within each commodity is based on 1995 numbers and held constant over the entire estimation period. The sign of these possible implications are also hard to foresee.

However, two assumptions may contribute to overestimate the effects of policy changes. First, we assume that the foreign emission coefficients are unaffected by our policy. This might seem less reasonable. According to the EKC, leakages to other rich countries should motivate counteracting environmental policies and reduced emission intensities. The other assumption that might overestimate the effects is that the emission coefficients reflect the average emission intensities. Marginal intensities are probably lower and more relevant.

3. The policy scenarios

We illustrate the increased concern for the environment by a growth-induced strengthening of the CO_2 policy. In order to single out the effects, we compare two scenarios, one reflecting the present regime with exogenous and constant CO_2 policy, *The benchmark scenario*, and one with an endogenously determined CO_2 policy, *The endogenous policy scenario*. All other policy variables are constant between the scenarios. So are all other exogenous estimates, including the prices and interest rates in the world markets, demography, technological parameters and the output and export of offshore oil and gas. Most of the estimates are drawn from the Long Term Programme for Norway; see Norwegian Ministry of Finance (2001) and Bruvoll et al. (2003) for a detailed documentation.

In *The benchmark scenario*, all emissions are recursively calculated and linked to economic activity as described above. We keep the real CO_2 tax rates at their 2000 level. Due to competitiveness concerns, the present Norwegian carbon taxes are highly dispersed, see Table 2. In *The endogenous policy scenario*, we employ an endogenously determined uniform CO_2 tax that is consistent with an income-dependent level of CO_2 emissions. All other emissions than CO_2 are still recursively determined as in *The benchmark scenario*.

Table 2: Real CO_2 tax rates in the benchmark scenario, 2000, €[*] per tonne CO_2

	€ per tonne
Maximum taxes by fuels	
- Gasoline	48
- Coal for energy purposes	23
- Auto diesel and light fuel oils	21
- Heavy fuel oils	18
- Coke for energy purposes	17
Taxes by sectors and fuels	
North Sea petroleum extraction	
- Oil for burning	40
- Natural gas for burning	46
Pulp and paper industry, herring flour industry	10
Ferro alloys-, carbide- and aluminium industry, Cement and leca production, Air transport, Foreign carriage, fishing and catching by sea, Domestic fishing and goods traffic by sea	0
Average tax for all sources	20

[*] 1 € ≅ 8.3 NOK

Source: Statistics Norway

The endogenous policy scenario includes the political economy aspect as an explanatory factor behind the EKC hypothesis. Several studies confirm that income increases willingness to pay for environmental services (see e.g. Hökby and Söderqvist, 2003, or Kristrøm and Riera, 1996) and that rising incomes are associated with a falling income elasticity of demand for pollution intensive products (Cole, 2000). As claimed in Grossman and Krueger (1995), a higher emphasis on environmental quality may in turn induce increased internal pressure and acceptance for regulations through political economy mechanisms. This is consistent with the cross-country regression in Dasgupta et al. (1995), who find that environmental regulations steadily increase with income. We have not explicitly modelled the income effects on preferences and hence environmental regulation. Instead, we use an econometric model of the relationship between income and CO_2 emissions documented in Bruvoll et al. (2003). The carbon tax level adjusts to ensure fulfilment of this econometrically modelled income-induced restriction.

Although the evidence on Norway find falling EKCs only for emissions with local environmental effects, it indicates that CO_2 emissions are located on the increasing part of the concave EKC curve (Bruvoll and Medin, 2003, Bruvoll et al. 2003). Our choice of policy rule can be taken to reflect broader environmental concerns. Since CO_2 emissions cannot be abated, the response will be through less use of fossil fuels. In practical policy, increasing CO_2 regulations may substitute regulations towards other fossil fuel related emissions with local and regional effects, such as SO_2, NO_x, CO and NMVOC.

In spite of a highly differentiated tax system today, we suggest a uniform tax to all uses and users in *The endogenous policy scenario*. The present tax system involves efficiency losses with respect to emission targets. As shown in Bruvoll and Larsen (2004), the Norwegian industries in which the carbon tax would expectedly be most efficient, are the same industries that are exempted from the tax. Also theoretical models tend to suggest uniform systems as the most efficient (Sandmo, 1975). Although CGE studies that allow for numerous distortions within economies have less sharp-cut conclusions, several empirical studies conclude that in terms of welfare, the Norwegian differentiated energy policy regime is inferior to more uniform systems (see e.g. Bye et al., 1999 and Bye, 2000).

The simulated, uniform real carbon tax rate in *The endogenous policy scenario* is 58 € per tonne in the long run (2030), about three times as high as the benchmark average. Compared to *The benchmark scenario* emissions are reduced by 18 million tonnes, or 25 percent, thirty years ahead. For a comparison, Norwegian Ministry of the Environment (2001) estimates the necessary reduction sin all Kyoto gases to 11 million tonnes in 2010, in order to fulfil the Kyoto commitments by means of domestic measures, only, i.e. without a quota arrangement. What happens to international agreements after 2010 is obviously hard to predict. Our chosen policy rule has not tried to foresee this, but can rather be interpreted as reflecting the historic inclination to abate unilaterally that has been demonstrated by Norway. Our example illustrates one possible and plausible scenario, given the broad consensus within the Norwegian political environment for being a leading example internationally with respect to implementation of climate policies.

4. Effects on markets and market shares

We are concerned with how domestic and foreign firms are affected by changes in market demand and relative competitiveness. Domestic and foreign firms are affected differently, depending on the effects on their respective market shares, which are determined by their competitiveness in the markets within and outside Norway. We quantify industry-specific changes in domestic competitiveness as the changes in the prices of foreign substitutes relative to the prices of domestic deliveries. The foreign prices do not change in response to the unilateral policy change, nor do mark-ups. This leaves the international competitiveness for the Norwegian firms inversely proportional to their marginal costs. Our measure of competitiveness does not include other competition elements, such as quality, network, security of delivery etc. We will mainly focus on the long run, steady state, results, and also discuss their dependence on the transitional dynamics and comment on the intermediate consequences.

When comes to the size of the markets, domestic demand for most products falls. As shown in Table 3, demand for consumption goods at the aggregate level falls by 0.5 percent in the long run. Total Norwegian absorption of final goods, replacement investments, and other intermediates, falls by 0.8 percent. This aggregate result veils some industrial variation, as can be seen in Table 4, Column (I). Reduced demand reflects that the new CO_2 tax regime directly and immediately (before any equilibrium adjustments) worsens the long-run current account, due to deteriorated competitiveness of the emitting industries, in particular those with favourable treatment in the current regime. These industries are highly export-oriented. Raising their taxes on inputs increases theitr marginal costs, and export is reduced. These adjustments have a negative impact on the current account. The Norwegian demand for consumption goods falls and partly counteracts these adverse effects on the current account through modified import leakage.

These reductions in demand affect both domestic and foreign suppliers negatively. As barriers to imports are minor in the Norwegian trade regime, the potential effects on foreigners are significant. To settle the final distribution of output changes between domestic and foreign firms, we proceed by analysing the influence on market shares, both in the domestic and world markets. The domestic competitiveness losses are first of all found in industries with high carbon intensity and favourable tax treatment in the original system (cf. Table 1 and 5), as reflected in Table 4, Column (II). These are also the most export-oriented industries. However, simultaneous endogenous changes in wage rates and other factor prices play a significant modifying role and tend to increase the long-run competitiveness for domestic producers of services and several manufactures of between 2 and 4 per cent. These industries primarily compete with foreign firms within the domestic markets.

Table 3: Macro-economic long run effects, percentage deviation from benchmark

Consumption	-0.5
Total domestic absorption	-0.8
GDP	-0.5
Gross production	-0.7
Number of firms	-0.3
Transport fuels	24.3
Other fuel oils	8.8
Wage rates	-4.0
User cost of capital	-2.4
Price index of intermediate inputs	-1.9
Export	-2.7
Import	-1.7
Net foreign wealth	3.4

The long run factor price changes are reflected in Table 3. Wages fall by 4.0 percent. The prices of produced factors follow to some extent, though these are also influenced by the positive CO_2 tax impulses on domestic prices, as well as by the relatively high import prices. The prices of capital goods and other intermediates fall by 2.5 and 1.9 percent, respectively. Besides the import demand reductions explained above, these reductions in cost components, primarily wages, ensure that the long run constraint on the current account is met. The wage reductions are also driven by the influence of the CO_2 tax on labour demand: The industries directly hit by increased tax rates reduce their demand for labour. So do other industries, to the extent that they experience reduced demand for their products in the wake of increased consumer and input prices. Restoring the labour market equilibrium requires real wage reductions.

As a consequence of relative labour cost reductions, firms substitute labour for other inputs. This second-order factor substitution effect on costs strengthens the competitiveness effects of reduced wages, especially in the most labour intensive part of the economy. Table 3 indicates that also scales of production tend to fall and contribute somewhat to improved competitiveness; aggregate gross production falls by 0.7 percent and number of firms by 0.3 per cent. Table 4 shows how effects on scales vary considerably among industries.

Consequences of the marginal cost changes on market shares are reported in Columns (III) and (IV) in Table 4. The responses of the relative market shares of domestic and foreign firms within the home markets rely on the Armington elasticities (see Section 2.2). Column (III) reports the effects on home market shares of domestic firms. While these shares fall for the most fossil fuel intensive industries, they increase markedly for labour intensive industries, including the service industries. However, services are in general less exposed to foreign competition than manufacturers. In sum, domestic firms increase their market shares by 0.3 percent. The sum of Column (I) and (III) reflects the total effects on the domestic demand directed towards the domestic firms. At the aggregate level, the combined effect of the 0.8 percent deterioration of the total market size and their market share improvement of 0.3 percent renders the demand directed towards them 0.5 percent smaller than in the scenario with constant CO$_2$ policy.

Table 4: Changes in markets, competitiveness, market shares and trade, percentage (ranked according to competitiveness loss)

	(I)	(II)	(III)	(IV)	(V)	(VI)
Products	Dom. market	Competi-tiveness1)	Dom. share	Imp. share	Import	Export
Chemical and Mineral Products	-0.5	-7.3	-15.5	3.7	3.2	-24.3
Wood and Wood Products	-0.5	-3.2	-4.1	5.4	4.9	-15.4
Petrol	-3.2	-2.9	-3.6	5.9	2.4	-18.0
Other Fuels	-2.0	-2.9	-6.5	2.0	2.4	-17.9
Metals	-12.7	-2.3	-4.9	1.5	-11.5	-16.8
Industrial Chemicals	-5.3	-0.7	-0.9	1.1	-4.3	-4.5
Agricultural commodities2)	0.7	0.0	-0.7	1.5	2.1	0.1
Commodities from Forestry2)	1.1	0.0	12.3	-5.5	-4.5	0.6
Commodities from Fishery2)	5.6	0.0	-5.3	124.0	140.2	0
Crude Oil2)	-1.7	0.0	0.8	-18.9	-49.2	0
Natural Gas2)	-44.9	0.0	-29.4	81.6	0	5.6
Electricity2)	-1.4	0.0	-0.1	0.9	0	70.3
Air Transport	-0.3	0.6	0.4	-1.4	-1.7	0.1
Coastal and Inland Water Transp.	-0.7	1.1	0.5	-3.4	-4.0	0.2
Fish Products	3.2	1.2	1.0	-3.2	-0.1	8.3
Meat and Dairy Products	0.5	1.8	0.1	-4.8	-4.3	9.1
Pulp and Paper	0.3	1.8	4.2	-2.4	-2.1	10.3
Land Transport	-0.4	1.8	0.0	-4.8	-5.2	7.9
Other Processed Food	0.2	1.9	1.5	-4.3	-4.1	10.5
Beverages and Tobacco	-0.3	1.9	2.0	-3.7	-4.1	9.9
Commodities from Fish Farming	7.5	2.0	0.0	-5.1	2.0	14.4
Textiles and Clothes	-0.5	2.1	5.8	-0.4	-0.9	12.4
Ships	-0.1	2.1	4.5	-2.2	-2.4	12.0
Railway and Tramway Transport	1.2	2.3	0.6	-5.7	-4.6	1.0
Hardware and Machinery	-1.9	2.4	6.5	-1.0	-2.9	4.9
Repair	-1.1	2.4	1.6	-5.1	-6.2	-11.2
Construction services	-1.1	2.4	0.0	-7.1	-8.2	-5.7
Post and Telecom. Services	0.0	2.6	0.5	-6.8	-6.8	0.4
Prints and Publications	-0.7	2.7	2.3	-5.9	-6.5	14.1
Wholesale and Retail Trade	-0.9	3.0	0.2	-8.2	-9.0	-23.9
Other Private Services	-0.2	3.0	0.6	-7.7	-7.9	11.0
Oil Platforms	0.1	3.1	0.7	-8.4	-8.4	15.1
Finance and Insurance Services	-1.1	3.2	3.4	-5.7	-6.7	16.6
Total	-0.8		0.3	-0.9	-1.7	-2.7

1) Competitiveness is defined as the ratio of foreign to domestic prices.

2) For these products, prices are exogenous, hence competitiveness is per definition unchanged. Their gross trade flows are not determined within the model, only net trade. Gross import and export are computed by assuming they constitute constant shares of net trade, unless this renders gross figures negative.

The counterpart is market share reductions within Norway of foreign suppliers. Their shares fall, in aggregate, by 0.9 percent; see Column (IV). Adding this to the general market loss of 0.8 percent in Column (I) gives a reduction in demand directed towards import of 1.7 percent NOK. This results in a stronger market loss for foreign than for Norwegian firms within the Norwegian markets. Foreigners' losses within the Norwegian borders are, however, counteracted by their gain of market shares in the world markets. Changes in Norwegian export are reported in Table 4, Column (VI). The share of the domestic production devoted to export deliveries responds to the relative price changes according to the elasticities of transformation between, respectively, the domestic and foreign markets (see Section 2.2). The adverse effects on exports are first of all concentrated within the fossil fuel intensive industries. These industries dominate the Norwegian total export and contribute to an overall export reduction of 2.7 percent, which is substituted by foreign deliveries.

To sum up, the Norwegian firms reduce their deliveries both in the home markets and abroad. Foreign firms also lose markets in Norway, but they gain in the world markets. All in all, their deliveries slightly fall in the long run. While Norwegian total gross production falls by 0.8 percent, the production fall is 0.1 percentage points larger when the loss of foreigners is accounted for.[7] What is important to note is that these long-run results are dependent on the transitional dynamics of the savings of the forward-looking domestic consumers. Due to positive savings along the path, the export surplus is higher in earlier periods and the output reductions for foreign firms even higher (less export substitution in the world markets and less imports). The foreigners' output losses are thus higher in the transitional periods than in the long run. Reduced production abroad indicates that the abatement costs are to some extent borne by other countries due to the openness of the regulating economy. The *global* costs of the policy efforts will then exceed the costs that are borne domestically and accounted for in the unilateral decision-making.

Table 5: Unit CO_2 emissions (tonnes/NOK) in the most carbon-intensive industries, year 2000

Industry	Unit CO_2 emissions
Fishery	0.15
Manufacture of Industrial Chemicals	0.13
Manufacture of Metals	0.13
Oil refining	0.10
Extraction and Transport of Crude Oil and Gas	0.07
Manufacture of Chemical and Mineral Products	0.05
Land Transport	0.05

[*] 1 € ≅ 8.3 NOK

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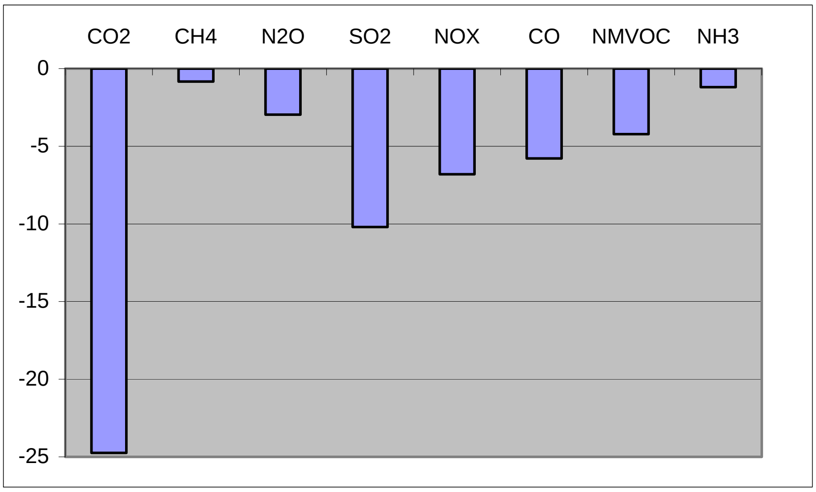
[7] Measured relative to Norwegian benchmark gross production.

5. The environmental effects

5.1. Domestic environmental benefits

As anticipated, the benefit from the endogenous policy is reductions of both emissions with local damage and of climate gases. A considerable contraction of the production of carbon-intensive commodities contributes heavily to reductions of the domestic emissions. The long run CO_2 emissions are reduced by almost 25 percent - see Figure 1. Of other gases, the fossil fuel related emissions SO_2, NO_x and CO are reduced the most, by 10, 7 and 6 percent, respectively. NMVOC emissions decrease by 4 percent, while the effects on CH_4, N_2O and NH_3 are 3 percent or less.

Figure 1: Long run changes in national emissions due to the endogenous tax compared to benchmark, percent



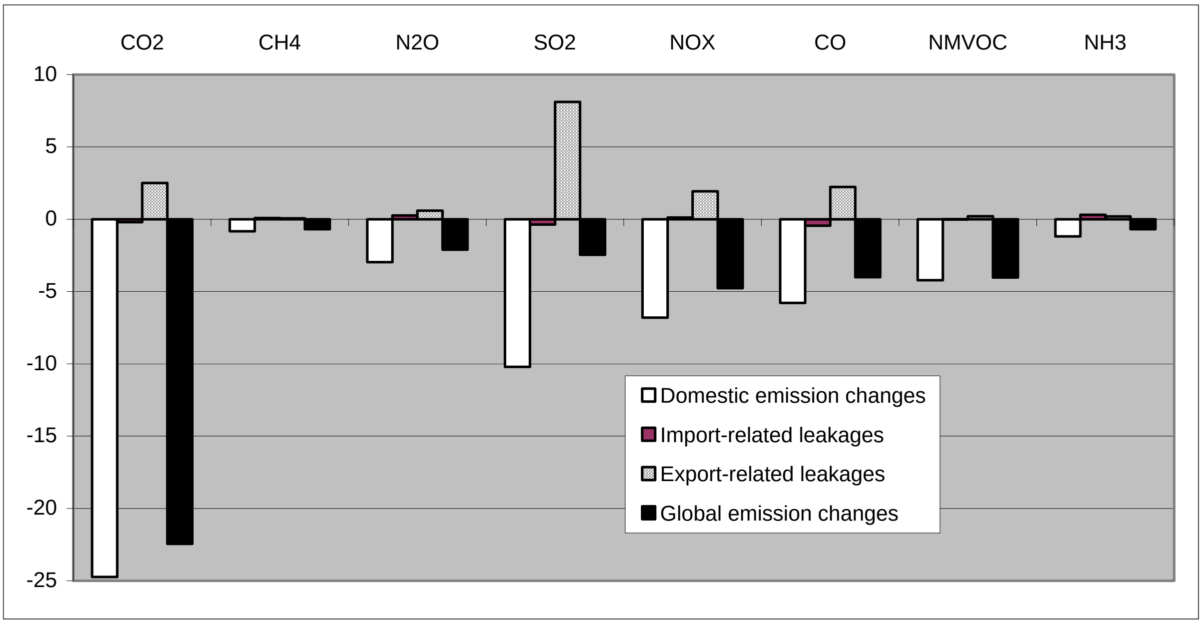
The major consequence of the computed CO_2 policy is a relative decrease in the use of fossil fuels for heating, petrol and diesel. The endogenous policy effects on emissions are smaller for households than for firms, as households already have high tax burdens in the current regime.

5.2. Emission leakages

In line with the EKC, one might expect that competitiveness disadvantages due to environmental regulations would increase import of dirty products, which would again lead to increased production and emissions abroad, i.e. *import-related leakages*. Further, reduced competitiveness contributes to losses in market shares and reduced export of fossil fuel intensive products. This in turn increases foreign production and emissions abroad, i.e. *export-related leakages*.

However, opposed to what is usually advocated as the major concern, we find that in the long run, the *import-related leakages* are small, and even negative for most emissions. Import is limited both by a general demand reduction and by reduced domestic costs in the longer run, in order to ensure a sustainable foreign debt development. Figure 2 displays the total computed effect on *global* emissions, i.e. the sum of *national emission changes* and import- and export-related *leakages*. As we see, the global environmental gain is lower than the national gain, mainly explained by export-related leakages.

Figure 2: Changes in domestic emissions, leakages and global emissions due to the carbon taxes compared to benchmark, percent



When we take leakages into account, the reductions in CO_2 emissions are 2.3 percentage points lower than the 25 percent domestic emission reductions. For SO_2, national emissions are reduced by 10 percent, but due to the leakages, our analysis shows an increase in emissions abroad of 7.7 percent, leaving the total reduction in total global emissions 2.5 percent (all numbers compared to the national benchmark level).

One of the most important leakage effects comes through reduced export of metals and (gas based) electricity, see Table 6.

Table 6. Percentage difference in export, and changes in export-related leakages due to the increased carbon tax

	Percent change, export	Changes in export related leakages, tonnes (1000 tonnes for CO_2)							
		CO_2	CH_4	N_2O	SO_2	NO_x	CO	NMVOC	NH_3
Chemical and mineral products	-24	101	274	57	365	245	326	349	19
Industrial chemicals	-5	57	177	41	184	145	201	204	16
Metals	-17	1117	186	43	2743	1305	22422	507	18
Electricity	-70	1236	29	94	946	3291	2824	65	13
Other		-98	-317	-14	-476	-648	-703	-285	-9
Total		2413	349	221	3762	4338	25070	840	57

The counterpart of less production and export from the metal industries is increased production and hence emissions of fossil fuel related pollution abroad. Also, reduced export of electricity implies increased coal based electricity production in other Nordic countries. Although the export of electricity to Denmark constitute only 10 percent of total export, reductions in Norwegian export increase emissions markedly due to the high share of coal relative to gas and wind power in Danish electricity production. The same applies for Sweden, who receives about 90 percent of our electricity export. These results hinge on the assumption of the exogenous reduction in emission coefficients, the unchanged trade pattern and hence production pattern abroad. Given the present energy production structure, coal based foreign electricity production substitutes future Norwegian gas power production with low SO_2 emissions, and the foreign increase in SO_2 emissions is significantly larger than the general decrease in Norway. Another possible future perspective is increasing European gas markets and lower foreign emission coefficients for electricity production than used in the model.

In total, import is reduced by 1.7 percent (cf. Table 3), while import-related emissions leakages vary between -0.4 and 0.3 percent with respect to different pollutants. Since the import-related leakages are smaller than the reduction in import, the import reduction comprises primarily clean products. For NH_3 and CH_4, the import related leakages are positive, and in accordance with our original hypothesis. This is mainly due to increased import of chemical and mineral products and agricultural commodities. The negative leakages for most of the other emissions reflect the overall reduction of the home markets.

In summary, this study does confirm that national abatement and environmental improvements are to some degree at the cost of other countries. However, when conferring the detailed country specific leakages, we do not find support for the concern that this is at the cost of less developed countries: the predominant share of the leakages is to our rich, technologically advanced neighbours in western Europe. The sparse results are mirrored in the trade weighed emission coefficients: when comparing these to the Norwegian coefficients, we find that our trading partners' emission coefficients are higher for only half of the emissions, see Table 7. Since most of the trade is between Norway and other high-income countries, the higher emission coefficients in less developed countries get low weights in the average index. It is important to bear in mind that the conclusion hinges on the constant composition of trading partners based on 1995 numbers. However, we cannot predict whether more or less trade will be directed towards developing countries with higher emission coefficients in the future.

Table 7: Foreign relative to Norwegian emission coefficients, year 2000.[8]

CO	2,31
NH_3	1,89
SO_2	1,72
CH_4	1,11
CO_2	0,62
NO_x	0,46
N_2O	0,18
NMVOC	0,16

Another important explanation for the higher Norwegian average emission coefficients is the energy intensive and heavily oil-based Norwegian production structure. While a large portion of our export is based on the oil-producing offshore sector and process industries with fossil fuel related emissions, CO_2-intensive industries have less weight in the average foreign production sectors. Likewise, NMVOC are related to oil loading, and N_2O to the energy intensive process industries. Thus, the below unity numbers in Table 7 do not necessarily contradict the idea that the Norwegian environmental policies are relatively strict and the production processes clean. As explained above, the Norwegian climate gas regulations are among the most restrictive in the world. When it comes to SO_2 and the other emissions, it is reasonable to assume that the higher emission coefficients abroad are related to significant measures taken to reduce pollution over the last decades in Norway.

8. Concluding remarks

This study quantifies two related impacts on other countries of a more stringent domestic CO_2 policy. One question we pose is to what extent a cleaner environment in rich countries, cf. the Environmental Kuznets Curve (EKC), comes at the cost of more pollution in other countries through trade effects. The other problem we address is to what extent abatement costs are shared with foreign suppliers

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[8] The relative export weighed emission coefficient for each emission P, α^P, is calculated as

$$\alpha^P = \sum_{c=1}^{C}\sum_{i=1}^{n} EXP_{ic} \frac{E^P{}_{ic}}{Y_{ic}} \frac{1}{\tau} / \sum_{i=1}^{n} EXP_{i,Norway} \frac{E^P{}_{i,Norway}}{Y_{i,Norway}} .$$

through market reductions and altered relative competitiveness. The analysis confirms the concern advocated by many that the EKC relationship to some degree works through environmental deterioration abroad. But given the current composition of trading partners, the predominant pollution leakages go to other developed countries with laxer environmental regulations. An interesting finding is that, contrary to common predictions, the long-run import element in leakages is rather small. Due to general equilibrium effects, the main leakages consist of emissions abroad associated with reduced export of heavily emitting commodities.

We find that due to leakages, the total *global* environmental benefits are significantly lower than the *national* effects for all emissions. For CO_2, the reduction in emissions due to the tax on the national level is 2.3 percentage points lower when leakages are taken into account. Thus, the leakages contribute significantly to reduce the effect of steps taken to the fulfilment of national commitments to international climate gas emission targets. Pollution abroad increases also for all other pollutants. It is important to bear in mind that this analysis is limited to a unilateral policy reform. According to the EKC hypothesis we should expect our trade partners to take similar steps along with their economic growth. There are, in other words, reasons to expect joint abatement efforts - maybe also coordinated efforts, particularly in the case of climate and regional emissions. Further, the emission coefficients, reflecting the average technologies, may overestimate emissions related to the rather marginal effects on production.

We also find that foreign market participants are adversely affected and thus bear parts of the abatement costs. First, the shrinking Norwegian demand implies lower import demand. Further, even though we find support for the pollution haven hypothesis, and thus higher market shares for foreigners in the export markets, there will be significant competitiveness losses for foreign firms in the Norwegian markets for fossil fuel extensive, labour intensive products. This results from the constraints on net foreign debt to obtain a sustainable economic development in the long run. If accounting for such effects abroad, the global costs of the unilateral climate policy will be higher than seen from a national perspective, both with respect to environmental and economic costs.

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Appendix

The consumption and production structure

Figure A1: The preference structure of the household in MSG-6

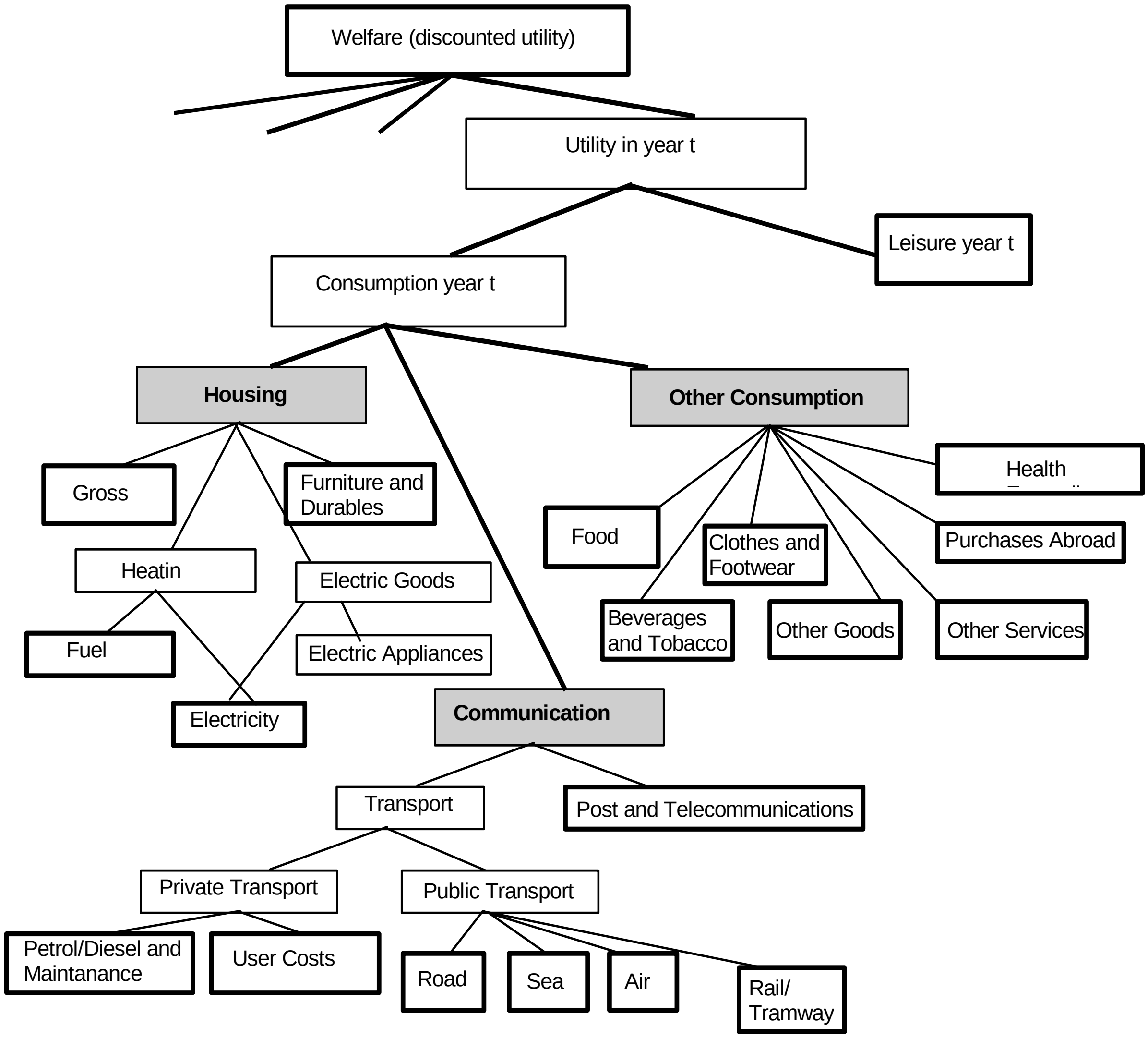
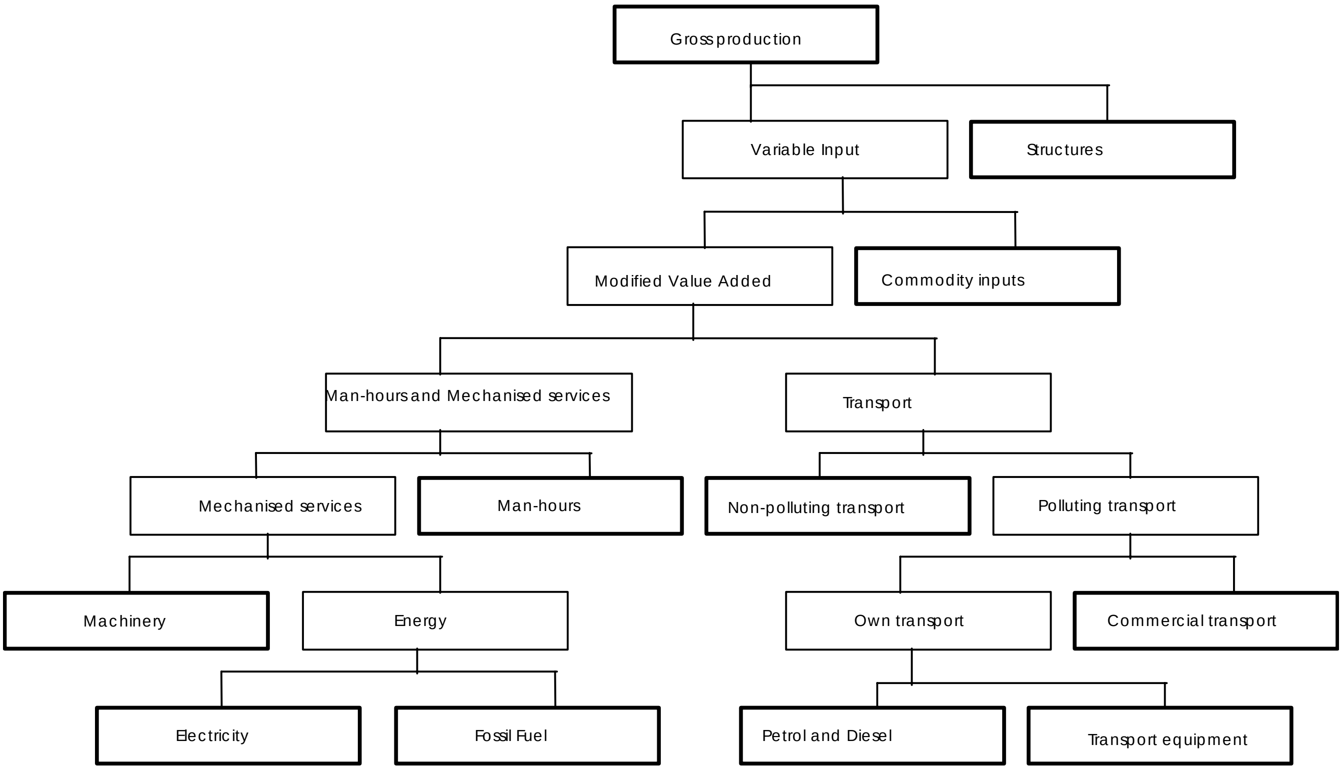


Figure A2: The separable structure of production structure of the firms in MSG-6.



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