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Richer and cleaner - at others' expense?

Abstract:
Pollution intensive production can be avoided domestically by increased imports and less exports of dirty products. Such trade effects may imply more emissions abroad, or pollution leakages. We study whether such leakages may contribute to the observed inverted relationship between emissions and economic growth - the Environmental Kuznets Curve (EKC). In our case, the rich, open Norwegian economy, we find little evidence for the hypothesis that pollution leakages contribute to explain the EKC. Despite an observed decoupling of emissions from economic growth over the past 20 years, there was no increase in pollution leakages over this period. Rather, emissions related to export increased far more than the foreign emissions embodied in import, implying reduced leakages. In future projections, we find a lower degree of decoupling than in the past, but no corresponding reductions in leakages. Instead, leakages increase. This conclusion is fairly invariant to assumptions about future climate policy.

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

While the standard understanding is that economic growth increases the environmental pressure, many pollutants prove to reverse when the income level is high enough, as discussed in the Environmental Kuznets Curves (EKC) literature.[1] Along with the general technological progress, increasing acceptance for environmental policies and a cleaner production and consumption structure outweigh the else negative environmental effects from growing economic activity in many cases. A cleaner production pattern could origin from changes in demand, insofar as budget shares of services, knowledge-intensive products and green-labeled products increase with income. It may also reflect increased home market shares of domestic firms within typically low-polluting, human-capital-intensive industries and increased export from these industries. The counterpart of theis kind of structural changes will be increased imports and less exports of dirty products. We will then obtain an environmental load displacement (Muradian, O'Connor and Martinez-Ailer, 2002) or *pollution leakages* across borders. Indeed, increases in foreign emissions may exceed the emissions avoided at home if the relocation takes place in countries with dirtier production processes. Importantly, the environmental benefits of national abatement will be smaller when increased pollution leakages follow, and we claim that this should be accounted for when evaluating the relation between economic growth and pollution.

This study investigates *the leakage hypothesis*, which claims that such relocations of production contribute to explain the relation between the growth in domestic emissions and income. Our case is the rich and open economy, Norway. We compute the effect of the economic growth on global emissions, including leakages, both in the past and in future scenarios. We further look into how policy changes may affect the leakages.

Efficiency impacts of pollution leakages are particularly relevant to transboundary pollution and global warming. The so-called "carbon leakage" literature, see, for example, Jacoby et al. (1997) and Barker (1999), analyzes CO_2 leakages caused by carbon policies. As the environmental effects of greenhouse gases are independent of the polluters' location, the benefits of national abatement are overestimated if pollution leakages are not accounted for. Further, such pollution leakages raise

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[1] See, for example, Grossman and Krueger (1993, 1995), Shafik and Bandyopadhyay (1992), and Selden and Song (1994) for original works, and Arrow et al. (1995) for critical comments to the policy implications. Dinda (2004) provided an empirical and theoretical survey. Bruvoll, Fæhn and Strøm (2003) quantified central EKC-hypotheses based on emission projections within a Norwegian macroeconomic model.

concerns about the distribution of environmental quality among nations. If emissions are displaced to less developed countries, low income countries carry part of the costs related to abatement in rich countries. Although differences in willingness to pay partly legitimate emission variations among countries, leakages constitute an ethical dilemma. Today's relatively less developed countries cannot follow the same path as today's rich countries when it comes to environmental improvements. When they reach higher levels of income and willingness to pay for environmental improvements, the potential for exporting pollution may be reduced, so that abatement costs increase.

Earlier econometric studies indicate leakage effects of economic growth. Cole (2004) showed that an increasingly cleaner composition of the manufacturing sector is partially responsible for reduced pollution in developed countries. This is a necessary condition for pollution leakages to exist. Suri and Chapman (1998) found that industrialized countries have reduced their energy requirements, and hence their fossil fuel-based emissions, by importing manufactured goods. In a study of Austria, Friedl and Getzner (2003) found the import/GDP ratio to be significant in explaining CO_2 reductions. Muradian, O'Connor and Martinez-Ailer (2002) investigated the pollution content in imports relative to that of exports and concluded that the industrial world has an ecological trade deficit vis-à-vis the developing world. Lucas, Wheeler and Hettige (1992) and Birdsall and Wheeler (1993) indicated that richer countries' environmental policies are one cause of emission leakages to relatively poor countries.

Our study supplements these econometric contributions by examining the occurrence of leakages not only in the past, but also in scenarios for the future. Our tool for the projections is a complex, computable general equilibrium (CGE) model that integrates economic and environmental mechanisms. This model captures changes in composition, technology, policy, and trade-related pollution leakages on a detailed level. We compute the emission leakages by linking country- and commodity-specific technological emission coefficients for the trade partners to the observed and simulated international trade flows, accounting for differences in abatement and energy technologies among countries. This is a refinement compared to earlier trade-related emission analyses by Antweiler (1996) and Muradian, O'Connor and Martinez-Ailer (2002), who assumed the same emission coefficients for all countries. The study adds to the leakage literature, which primarily focuses on CO_2 emissions, by also calculating leakages of pollutants with local and regional effects.

While there was a decoupling between Norwegian income and domestic emissions in the past (Bruvoll and Medin 2003), this seems to become weaker over the next decades (Bruvoll, Fæhn and Strøm

2003). According to the concern that leakages contribute to the EKC, one might expect to find that the historical decoupling was followed by increasing pollution leakages, and that leakages are smaller in the future, when decoupling is weaker. Our calculations do not confirm this. At the end of the last century, exports with high emission intensities increased far more than pollution embodied in imports, so that leakages decreased. Moreover, in future projections, a weaker decoupling than observed historically is not, as expected, reflected in even less pollution leakages. Rather, the projected leakages steadily rise over the next decades.

2. Methodological approach

We calculate changes in emission leakages over two periods: from 1980 to 2000, based on historical economic and environmental data, and from 2000 to 2030, based on model simulations.

2.1. Computing the leakages

We compute the leakages by linking country- and commodity-specific technological emission coefficients for our trade partners to the changes in trade flows. Each country is weighted according to its share of total imports or exports of the specific good. The *import-related leakages* for pollutant P at time t, $IRL^P{}_t$, denote *the emissions abroad* that are related to the production of goods imported by Norway:

(1) $$IRL^P{}_t = \sum_{c=1}^{C}\sum_{i=1}^{n} IM_{it}\,\overline{im_{ic}}\,\frac{E^P{}_{ic}}{Y_{ic}}\left(\frac{1}{1+\tau}\right)^{t-1995}, \qquad t = 1980, 2000, 2030$$

that is, the product of the import of good i, IM_{it}, the import share of good i from country c, $\overline{im_{ic}}$, the country- and sector-specific emission intensity, $E^P{}_{ic}/Y_{ic}$ (where Y_{ic} is output in the sector producing good i in country c, $E^P{}_{ic}$ is the emission of pollutant P in sector i and country c), and a factor capturing emission reducing technical changes, τ.

Correspondingly, the *export-related leakages*, ERL^P, denote *the emissions avoided abroad* when production takes place in Norway and the goods are exported abroad:

(2) $$ERL^P{}_t = \sum_{c=1}^{C}\sum_{i=1}^{n} EX_{it}\,\overline{ex_{ic}}\,\frac{E^P{}_{ic}}{Y_{ic}}\left(\frac{1}{1+\tau}\right)^{t-1995}, \qquad t = 1980, 2000, 2030$$

where EX_i refers to total exports of the good i, and $\overline{ex_{ic}}$ denotes the export share of good i from country c.

Net leakages, NL, equal import related leakages (relocated abroad), minus export related leakages (avoided abroad):

(3) $NL = IRL^P{}_t - ERL^P{}_t$.

The inclusion of the country- and sector-specific emission intensities, $E^P{}_{ic}/Y_{ic}$, captures the effect of different technological conditions. These are calculated for 1995[2], and adjusted for technological changes, τ, equal to the 1 percent annual total factor productivity growth used for Norwegian sectors in the projection model. The coefficients are based on emission and production statistics on an aggregation level of 41 sectors[3]. The main data source is Eurostat, in addition to several national statistical offices and similar sources. The sources are reported in Straumann (2003), with the exception of the electricity sector for Sweden and Denmark.[4] Data is collected from 17 of Norway's main trading partners, which account for more than 80 percent of total imports and exports. The emission coefficients for the rest of the world are computed as the average of the collected sample.

The coefficients for import and export relative to total imports, $\overline{im_{ic}}$ and $\overline{ex_{ic}}$ are constant over time, equal to 1995 numbers. The calculations of leakages further rely on some other simplifying assumptions. First, we assume that the total level of foreign demand, and thus the emissions linked to consumer activities, are unaffected by changes in trade. This assumption seems reasonable, given Norway's small fraction of the world market. Then, changes in imports and exports will be absorbed by equivalent changes in production abroad. Further, we assume that all changes in Norwegian exports are met by production changes in the importing country; that is, there are no production effects in third-party countries. Our framework cannot determine trade effects among foreign countries. In addition, we omit the effects of changes in input deliveries on emissions abroad, and the estimates neglect possible differences in composition between total production and export production at the

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[2] This is chosen to be consistent with the calibration year of the projecting model.

[3] The sectors correspond to those in the CGE model.

[4] These coefficients are corrected according to observed reductions in our main trading partners Sweden and Denmark in the coefficients for CO_2, N_2O, and SO_2 from 1995 to 2000 (www.nordel.org). We interpret the reduction in the CO_2 coefficient as a composition effect between energy carriers, and we have applied the same reduction in N_2O, and SO_2 from electricity production.

chosen aggregation level. Finally, the composition of trading partners for each commodity is based on 1995 numbers and held constant over the entire time span, i.e from 1980 to 2030.

Statistics Norway provides all Norwegian data for the computation of historical leakages; trade data from National Accounts, and emission data from the Emission Accounts. For the computations of future leakages, we rely on model simulations.

2.2. The projection model

We use a dynamic, disaggregated CGE model for the Norwegian economy, adapted to address domestic and transboundary effects of policy changes. See Heide et al. (2004) for a more detailed description of the parameters and the model.[5] The model specifies 60 commodities and 40 industries, classified to capture important substitution possibilities with environmental implications. In the policy change scenarios, we keep the public budget unaltered by lump-sum transfers in order to exclude revenue-recycling effects and isolate the pure effects of increasing environmental taxes. As the Norwegian economy is small, and the exchange rate is normalized to unity, all agents face exogenous world market prices and real interest rates. Thus, financial capital is perfectly mobile across borders. Real capital and labor 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.

2.2.1. Consumer and producer behavior

Households are rational and forward-looking, and they determine their consumption and savings by maximizing welfare over an infinite horizon. The intertemporal substitution elasticity is set to 0.3.[6] The endogenous treatment of savings brings about potentially interesting changes in the current account and trade balance, which have important implications for competitiveness and emission leakages. The intratemporal utility function has a detailed, nested CES structure that distinguishes between activities with different emission profiles and reflects relevant price-induced substitution possibilities between commodities (see Figure A1 in the Appendix). It forms the main basis for examining the compositional effects on emissions arising from consumption. Price and Engel elasticities are based on Aasness and Holtsmark (1995). Labor supply is exogenous. External effects, in particular, environmental repercussions on the utility of the household, are not explicitly modeled.

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[5] The model is a version of the Multi Sector Growth model, MSG-6, developed by Statistics Norway.

[6] This result is in line with other studies, see for example Steigum (1993).

Firms' input and output decisions determine the changes in emissions from the private business sector. Firms are run by rational, forward-looking managers, who maximize the net present value of the cash-flow 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 somewhat contributes to decreasing returns, as the marginal firms are less productive. In the primary industries, products and firms are homogenous and markets are perfectly competitive. The demand for inputs is derived from industry-specific nested structures of linearly homogeneous CES functions (see Figure A2 in the Appendix). Most elasticities of substitution are set in accordance with estimates presented in Alfsen, Bye and Holmøy (1996).

2.2.2. 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 (the 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 the commodity and the user. The Armington elasticities are set to 4.0. Both Norwegian and foreign consumers consider *Electricity* and *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. Export prices are exogenous, determined in the world markets.

2.2.3. Domestic emissions

Emission calculations are linked to input activities, consumption activities and production processes at a detailed level for all compounds.[7] Table 1 provides an overview of the specified air pollutants and their main sources in the year 2000.

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[7] Strøm (2000) documents the emission module of the CGE model.

Energy combustion, mainly comprising gas-based electricity production, transport, and heating, are heavily polluting activities with respect to carbon dioxide (CO_2), nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (VOC), and ammonia (NH_3). Both stationary and mobile combustion have imperfect, domestically produced substitutes; see Figures A1 and A2. Some do not pollute (e.g. hydropower electricity, rail and tramway transport), while some cause domestic emissions (e.g. gaspowered electricity, transport by road, sea, and air). Domestic supply of electricity is at present almost exclusively based on hydropower. The marginal source is primarily gas power with substantial CO_2 emissions. The process industries producing metals and chemicals are significant sources of the emissions of SO_2, N_2O and CO_2 in 2000. The offshore industries main contributors of CO_2 and VOC. Further, agriculture, along with landfills, contributes to most of the CH_4 emissions. As emissions from the public sector are low, they are disregarded in the model.

Table 1: Main sources of emissions, percentage of domestic emissions in 2000

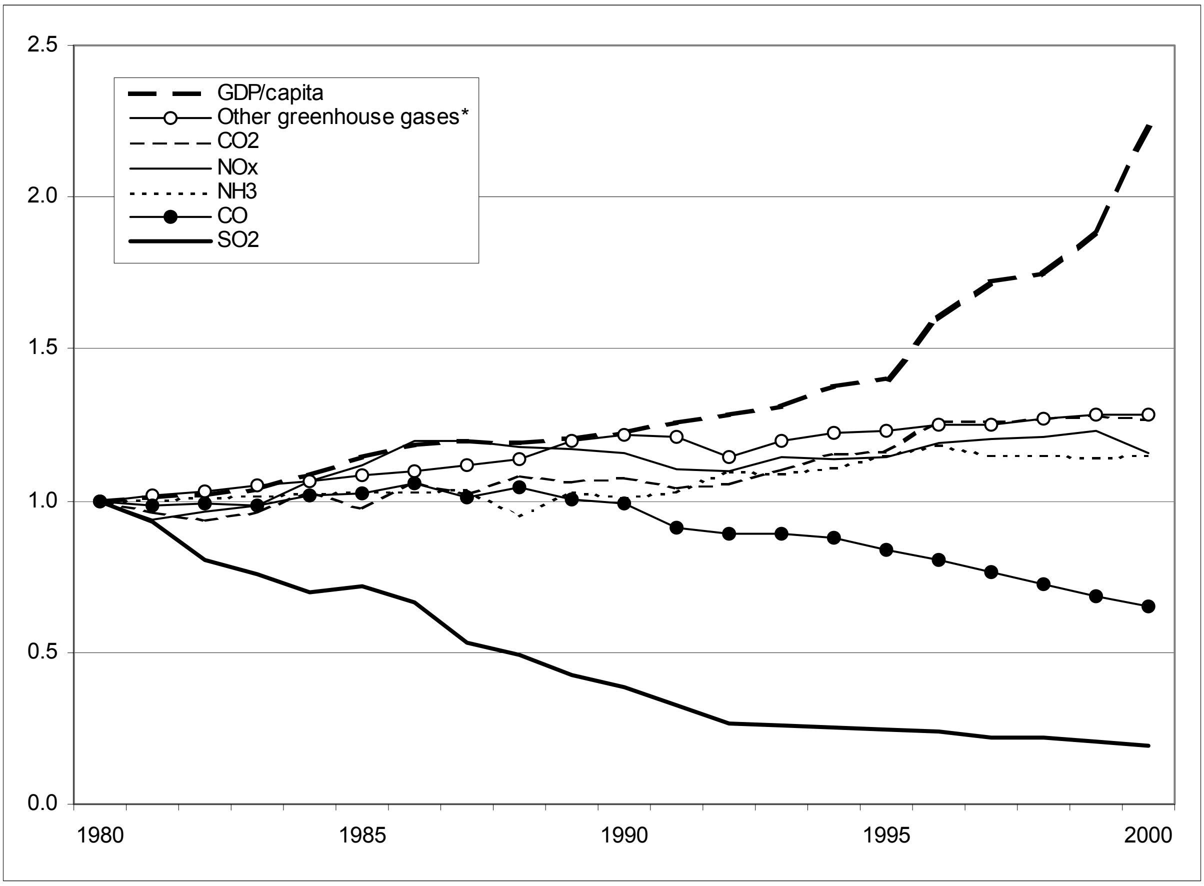
	CO_2	CH_4	N_2O	SO_2	NO_x	CO	VOC	NH_3
From production								
Agriculture	2	30	46	1	3	1	0	92
Fishing etc.	3	0	0	1	13	1	0	0
Manufacture of chemical and mineral products	6	1	0	8	4	0	3	0
Manufacture of industrial chemicals	8	0	41	22	3	9	1	2
Manufacture of metals	16	0	0	39	4	2	1	0
Production and pipeline of oil and gas	28	9	0	1	25	1	66	0
Road transport etc.	6	0	0	3	10	3	2	0
Coastal and inland water transport	3	0	0	4	14	0	0	0
From consumption								
Fuels	3	2	1	3	1	27	3	0
Petrol and car maintenance	9	0	5	1	7	43	9	5
Landfills	0	56	0	0	0	0	0	0
Other	17	0	6	18	17	13	15	2
TOTAL	100	100	100	100	100	100	100	100

Source: MSG6 simulations, Statistics Norway.

3. Decoupling and decreasing leakages in the past

There was an obvious decoupling between Norwegian emissions and GDP per capita from 1980 and up to 2000, see Figure 1. Some emissions even declined, following the falling part of the EKC.

Figure 1: GDP per capita and domestic emissions, 1980-2000, 1980=1,00



* CH_4 and N_2O.
Source: Statistics Norway.

This decoupling picture would seem less compelling if the counterpart was increased pollution-intensive production abroad. An indication of this would be that changes in the domestic production structure contributed to the observed decoupling, as a cleaner production pattern in Norway can indicate replacement by foreign production. According to Bruvoll and Medin (2003), this condition was fulfilled for many emissions in Norway during the period from 1980 to 1996. For N_2O, NH_3, SO_2 and CO, changes in the production structure contributed to reduce emissions by 5-15 percent. For CO_2, CH_4 and NO_x, on the contrary, structural changes contributed to increase the domestic emissions, mainly due to the exploitation of the offshore resources. The decoupling observed for these gases was rather due to technological driving forces, such as reduced energy intensity, changes in the energy mix, and reduced emission coefficients. These were the emissions showing the weakest decoupling. A priori, one would expect that the leakages of these emissions decreased.

Despite decoupling for all emissions, our computations show that the emission leakages simultaneously decreased, not only for the emissions for which the structural changes contributed to increase domestic emissions, but also for the emissions where structural changes increased emissions. In other words, the changes in the Norwegian economy contributed to *reduce* all the types of emissions studied here at our trade partners. Indeed, there was an increase in import-related leakages, i.e. foreign emissions from the production of goods imported by Norway, in accordance with the leakage hypothesis. But the amounts of import-related leakages were far smaller than the export-related leakages, and more stable over time, see Table 2. This table shows the *level* of leakages, measured in percent of domestic emissions in 1980 and 2000.

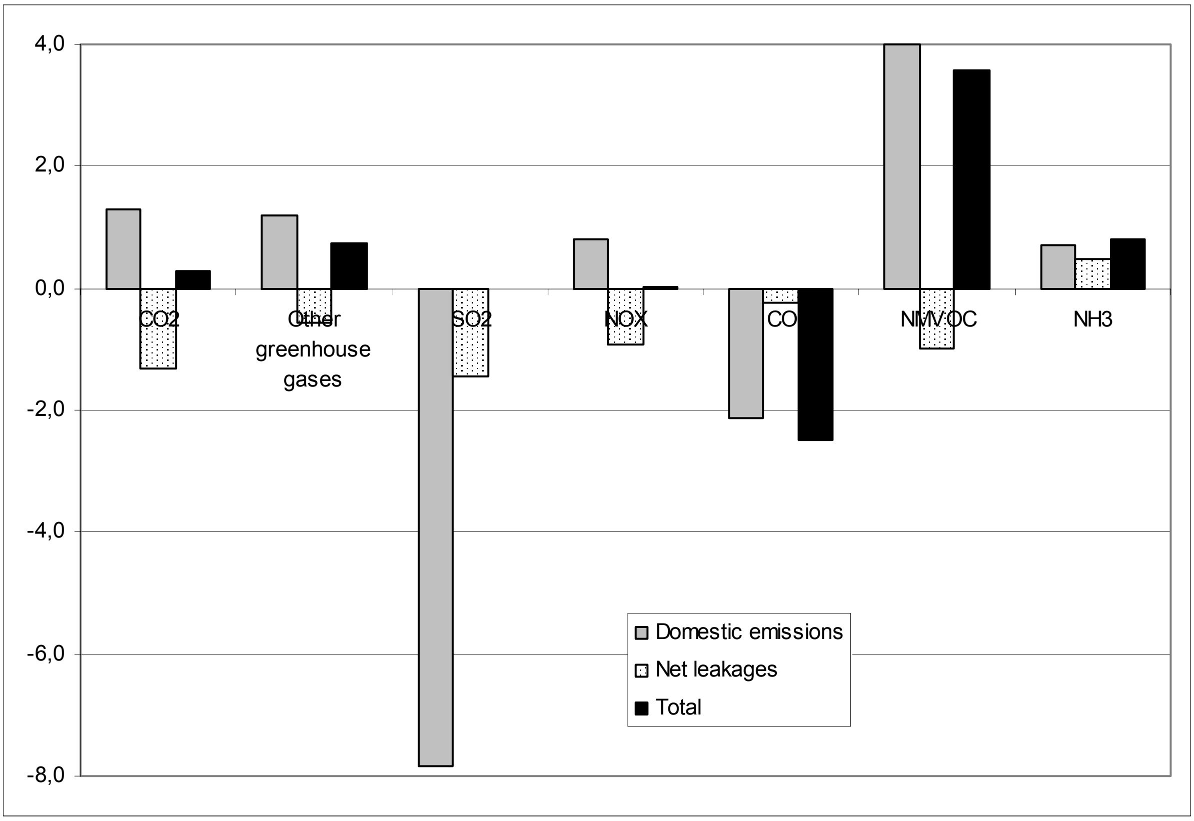
Table 2: Leakages in percent of domestic emissions, year 1980 and 2000.

	CO_2	Other greenhouse gases	SO_2	NO_x	CO	VOC	NH_3
Year 1980							
Import related leakages	15.9	12.6	12.1	6.2	5.5	11.2	24.8
- Export related leakages	-20.7	-8.3	-17.0	-8.3	-7.7	-11.2	-5.6
Net leakages	**-4.8**	**4.3**	**-4.9**	**-2.1**	**-2.2**	**0.0**	**19.3**
Year 2000							
Import related leakages	20.6	11.1	81.4	10.0	17.6	7.0	25.1
- Export related leakages	-39.9	-16.4	-191.5	-25.9	-28.1	-15.1	-6.4
Net leakages	**-19.3**	**-5.3**	**-110.1**	**-15.8**	**-10.5**	**-8.1**	**18.7**

Figure 2 shows the *average annual growth* in domestic emissions, net leakages, and total global emissions following changes in the Norwegian economy. The main reason for the decreasing leakages was the expanding oil sector and increasing exports of metals. Hence, export related leakages dominated, and the growth in global emissions was generally lower than the domestic. Consequently, larger amounts of emissions were avoided abroad. The result for SO_2 is particularly interesting. As seen in Table 2, the emissions avoided abroad in 2000 are even higher than the total Norwegian emissions (amounting to 116 per cent of domestic emissions).[8] This is due to much lower emission factors in Norway than at our trade partners, as reflected in the significant SO_2 reductions over the period 1980 - 2000 mainly caused by lower emission intensities, see Figure 1.

[8] Note that the growth rate for the global contribution, that is measured relative to domestic emissions, is thus not computable in Figure 2.

Figure 2: Changes in domestic emissions and net leakages relative to domestic emissions in 2000, average yearly growth rate, 1980-2000



To summarize: we experienced a decoupling between GDP and emission growth for all emissions over the period from 1980 to 2000. Further, structural changes contributed to decoupling for some emissions, and contrary for other. And, finally, leakages decreased despite decoupling, for all emissions. Thus, the results counter the leakage hypothesis. It also nuances the basis underlying the EKC theory of structural change, that countries with relatively low income and human capital levels are relatively competitive within resource-based, emission-intensive productions. Instead, other forces have been at work behind the decoupling and the EKC structure as seen in Figure 1, such as emission reducing abatement technologies and reduced emission intensities (Bruvoll and Medin 2003).

It is important to note that the growth in the Norwegian offshore sector dominated these decades. While the reduction in exploitation of raw material industries is typically important to the explanation of EKC, the development of the offshore petroleum sector does not fit the typical structural changes underlying the EKC. The development benefits from advanced technologies, high competence, and preferably a well-functioning government able to organize the development of infrastructure and handle risk. What we observed the last decades could merely be *delayed competitive advantages* within emission-intensive Norwegian export production. Norway's comparative advantages within oil and gas exploitation are simultaneously high-tech and highly emitting. This sector is most important to the export related leakages. Still, the conclusions hold also for the rest of the economy too, if we keep the offshore petroleum sector aside. All other sectors together still involved negative net leakages. If disregarding the petroleum sector, net CO_2 leakages are about -1.6 percent relative to domestic emissions in 1980 (-4.8 when the petroleum sector is included, cf. Table 2) and -4.4 percent in 2000 (versus -17.4 percent). The same picture applies for the other emissions also, if disregarding the petroleum sector.

4. Less decoupling and increasing leakages in the future

We develop one main scenario, based on a prolonged environmental policy, and two scenarios with alternative environmental policies, for the period 2000 to 2030.

4.1. Important exogenous assumptions

Most exogenous estimates are drawn from the Norwegian Ministry of Finance (2001). As for most European countries, we expect a low growth in total employment over the next 30 years, due to an ageing population. While the population is expected to increase by on average 0.4 percent annually, the corresponding growth of employment is 0.2 percent. During the last 10 years of the projection period, the growth is negative. Annual total factor productivity growth rates are exogenously set to 1.0 percent in the private sector and 0.5 percent in the public sector.

The economy is past the sharp growth of the Norwegian offshore industry. The oil and gas exploitation as share of GDP is anticipated to fall from 14.0 to 3.6 percent, according to the exogenous assumptions. The long run international oil and gas prices are assumed to grow by 1.5 percent, which is in line with the projected development in other international prices. The former natural resource wealth turn into financial assets to a large extent, which ensures Norway a substantial currency income flow also in the future. The return flow is based on a 4.0 percent international real interest rate.

In the main scenario we keep all policy variables constant. Particularly, the real CO_2 tax rates are kept constant at their factual 2000 levels. The CO_2 taxes vary over sectors and energy carriers, see Table 3.

Table 3: Real CO_2 tax rates in 2000, €[*] per tonne of CO_2-emissions

	€ 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 aluminum industries, production of cement and lightweight expanded clay aggregate (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

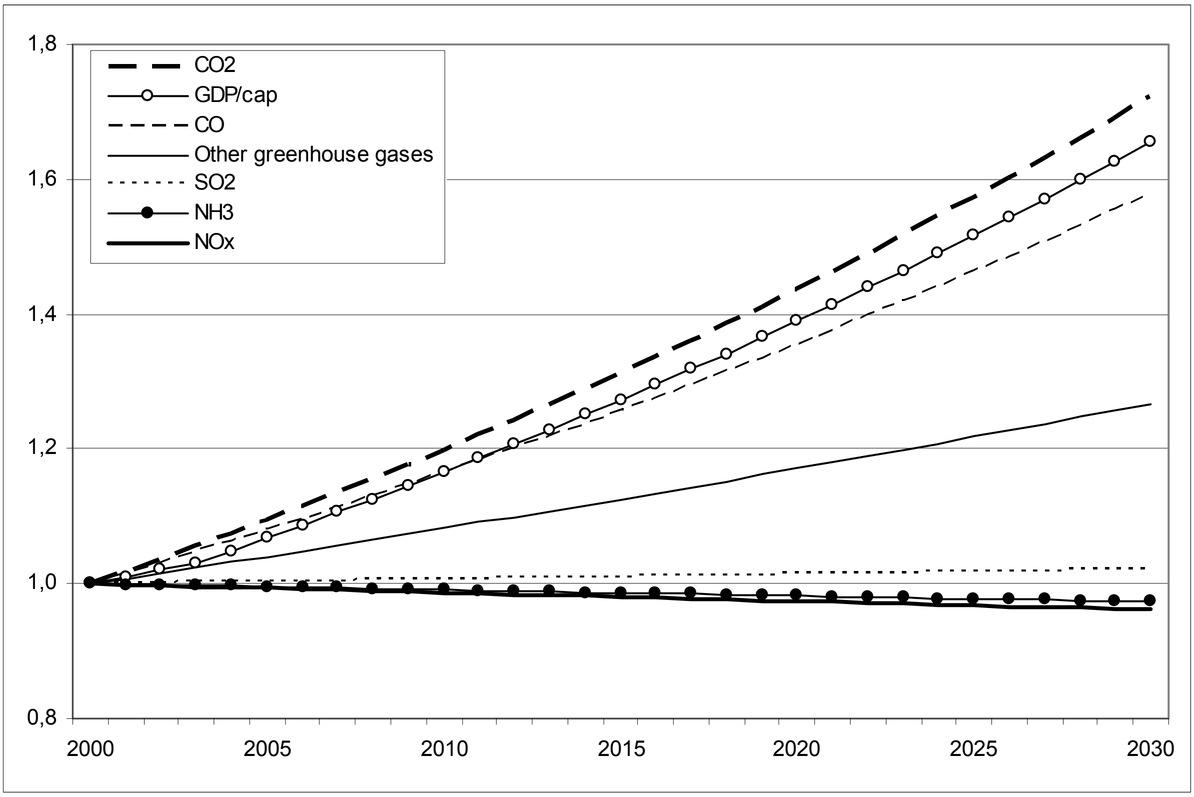
[*] 1 € ≅ 8.3 NOK.

Source: Statistics Norway.

4.2. Domestic emissions and leakages

Our emission projections predict a continued decoupling from economic growth in the main scenario. However, compared to the past, the decoupling becomes weaker, contrary to the EKC hypothesis of growing, rich countries, see Figure 3. Most emissions stabilize or increase. The emissions of CO_2 grow most rapidly, and, in contrast to history, cf. Figure 1, even exceed the GDP per capita growth.

Figure 3: GDP per capita and domestic emissions, 2000-2030, 2000=1,00



In a study based on the same exogenous assumptions, Bruvoll, Fæhn and Strøm (2003) decompose the future emission trends into contributions from increased economic *scale*, *technical changes* in production and emission, and effects of *structural changes*, and find that changes in the production structure significantly contribute to decoupling for *all* the gases, see Table 4. The reason for this is partly found in the expected downscaling of the offshore industry over the next decades. Thus, the projections seem to support the hypothesis of a delayed competitiveness within emission-intensive export production, compared to the common EKC pattern. But the significant effect of structural changes along with a general technological progress is offset, or even outperformed, by the growth in the economic scale.

We decompose the effect of changes in the production structure into the *trade related structural effects* and the effect of structural changes related to production for the *domestic market*, see Table 4. To compute the *trade related structural effects* we calculate the domestic export related emissions and subtract the emissions "avoided" domestically due to changes in import, all at domestic emission coefficients. As seen in Table 4, the changes in trade constitute important shares of the emission reducing structural effects. The main reason is increasing net import, reducing the production for home markets and hence domestic emissions. Hence, this calculation confirms the concern in the EKC literature that a cleaner production structure partly is explained by changes in market shares.

Table 4: Decomposition of changes in domestic emissions over the period 2000 - 2030, percent of 2000 level, average yearly growth rate

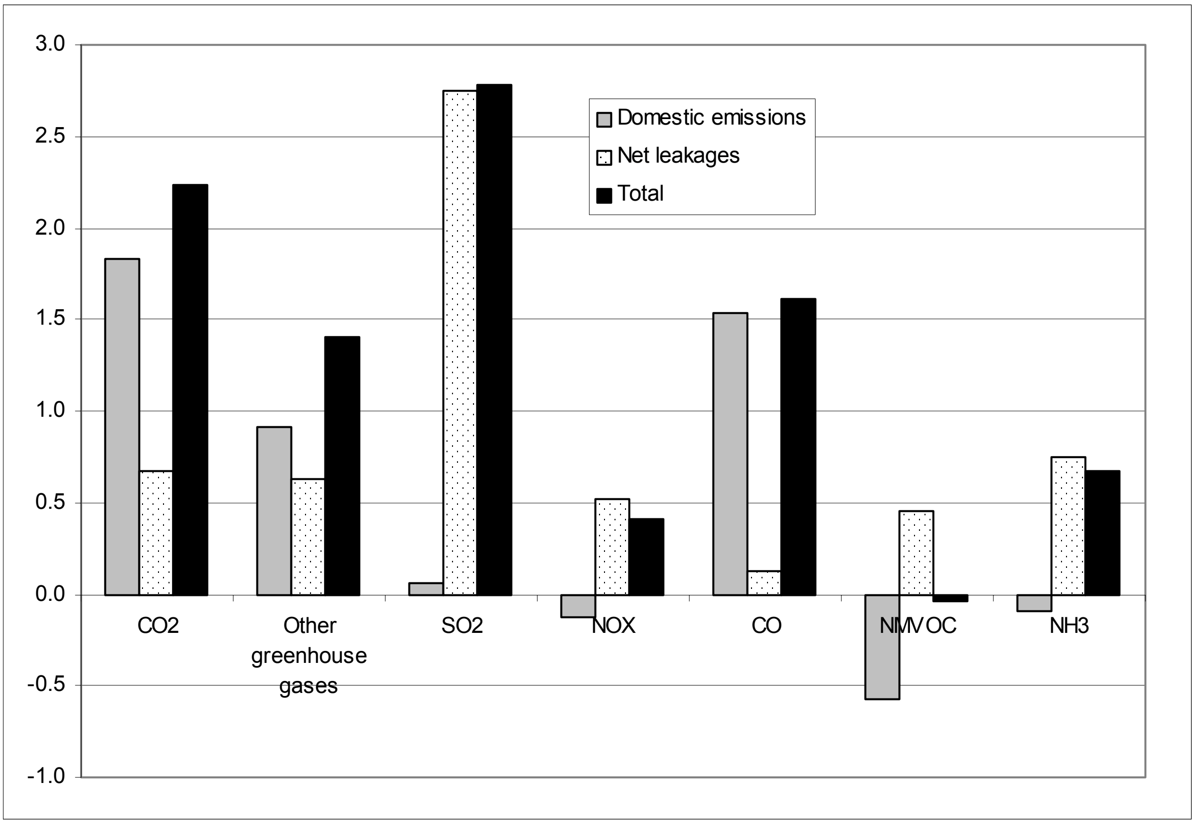
	CO_2	Other greenhouse gases	SO_2	NO_x	CO	VOC	NH_3
Total domestic change	1,8	0,9	0,1	-0,1	1,5	-0,6	-0,1
Scale effects	2,2	2,2	1,9	2,0	3,5	2,2	1,9
Technique effects	0,3	-0,6	-1,7	-1,4	-1,8	-1,0	-1,0
Structural effects	-0,6	-0,7	-0,1	-0,7	-0,1	-1,8	-1,0
- Trade related	0,0	-0,2	0,1	0,0	0,0	-0,1	-0,4
- Domestic market	-0,6	-0,5	-0,3	-0,8	-0,2	-1,7	-0,6

As seen in Table 5, *net leakages* to other countries due to changes in the Norwegian economy turn from negative to positive from 2000 to 2030 for five out of seven pollutants. To an increasing degree, the emissions related to our import will be higher than the avoided emissions abroad related to export of Norwegian products.

Table 5: Leakages in percent of domestic emissions, year 2000 and 2030

	CO_2	Other greenhouse gases	SO_2	NO_x	CO	VOC	NH_3
Year 2000							
Import related leakages	20.6	11.1	81.4	10.0	17.6	7.0	25.1
- Export related leakages	-39.9	-16.4	-191.5	-25.9	-28.1	-15.1	-6.4
Net leakages	**-19.3**	**-5.3**	**-110.1**	**-15.8**	**-10.5**	**-8.1**	**18.7**
Year 2030							
Import related leakages	15,0	16,2	101,8	13,7	9,1	13,0	52,0
- Export related leakages	-13,3	-4,7	-86,5	-12,8	-13,4	-5,2	-7,0
Net leakages	**1,6**	**11,6**	**15,4**	**0,9**	**-4,2**	**7,8**	**45,0**

Figure 4: Changes in domestic emissions and net leakages relative to domestic emissions in 2000, average yearly growth rate, 2000-2030



Also *increased imports* of pollution-intensive products contribute to increase emissions abroad. For Other greenhouse gases, VOC, and NH_3 this is mainly because of increased imports of agricultural products. For SO_2 it originates from increased import of electricity, crude oil and chemical products. For CO, *import-related leakages* are somewhat reduced, despite increasing imports of the CO-intensive production of metals. The reason is the exogenous reduction in foreign emission coefficients along with technological improvements, causing total foreign emissions related to metal production to fall. For NO_x, the growth in domestic emissions is negative. But both due to increased import of pollution intensive chemical products and less export, particularly of farmed fish, emissions related to Norwegian trade increase abroad, and, in total global NO_x emissions increase.

In summary, the projections indicate increasing emission leakages over the next decades. In isolation, this will contribute to decouple emission growth from economic growth. But rather, decoupling tends to weaken compared to the two previous decades. This is mainly explained by the increasing scale of the economy. The increase in leakages is mainly due to the reduction in offshore production and export. Contrary to many high-polluting activities, offshore oil and gas exploitation is highly reliant on technological progress and knowledge accumulation and has caused a delayed beneficial impact on the environment through changes in the production structure. A consequence is that emission leakages may also be delayed. Still, the tendency is the same when looking at the rest of the economy aside from the offshore petroleum sector. Then, net leakages in percent of domestic emissions increase from -4.4 percent in 1980 (-17.4 percent when including the petroleum sector, cf Table 5) to 2.5 percent in 2030 (1.6 percent for all sectors).

5. Alternative future policy scenarios

While abatement policy influenced historical emissions, we have disregarded such effects in the main scenario. In light of the broad national and international consensus that the climate problem is a main environmental challenge in the decades to come, it is reasonable to expect a tightening climate policy in the future. The current Norwegian climate policy is among the strictest in the world, and the government still has ambitions to be a leading example internationally with respect to the implementation of climate policies. To account for recent policy signals and initiatives, we simulate two scenarios with stronger CO_2 policy as alternatives to the main scenario presented above. We focus on climate policy, and disregard other probable environmental policy shifts. This does not imply a neglect of local and regional environmental problems. As CO_2 emissions cannot be treated but at high costs, the responses will involve less usage of fossil fuels and implicitly regulate several other emissions from combustion, like SO_2, NO_x, CO, and NMVOC. Further, many emissions with local and regional effects have for long been subject to strict regulations, relative to the challenge of climate change.

Already, both unilateral and multinational greenhouse gas abatement systems have been established. The Kyoto Protocol is by now the most comprehensive in terms of participants. But its emission reduction potential in the implementation period 2008 - 2012 is questioned (see e.g. Springer and Varilek, 2004). Whether the multinational coordination will be prolonged beyond the implementation period is also uncertain. We therefore study two alternative scenarios; one unilateral scenario with a strengthened climate policy *(Alternative scenario I)*, and a scenario that prolongs the multinational coordination of greenhouse gases *(Alternative scenario II)*.

In the alternative scenarios, all policy variables other than climate policy are held at the same level as in the main scenario with constant policy. So are all other exogenous estimates, including world prices and interest rates, demography, and the production and exports of offshore oil and gas. Also, all

technological parameters are unchanged, in other words, we do not account for technological responses to the tightening of policy.
The motivation for the *Alternative scenario I*, is the increased concern for the environment by a growth-induced strengthening of the CO_2 policy. Several studies have confirmed that a higher income increases the willingness to pay for environmental services (see, for example, Kristrøm and Riera, 1996, or Hökby and Söderqvist, 2003). As claimed in Grossman and Krueger (1995), a stronger emphasis on the environmental quality may lead to greater internal pressure for, and acceptance of, environmental regulations through political economy mechanisms. This is consistent with the cross-country regression in Dasgupta et al. (1995), which revealed that environmental regulations steadily increase with income.

We conduct an econometric analysis of the historical relation between CO_2 emissions and GDP/capita[9]. This relationship is partly influenced by environmental policy measures. We include this relationship into the model, and close the model by endogenous variation in a uniform CO_2 tax on all emission sources. In other words, changes in emissions that are not explained by the remaining endogenous or exogenous driving forces within the model, are defined as results of changes in future climate policy. For further details on the modeling of this mechanism, see Bruvoll, Fæhn and Strøm (2003).

In the *Alternative scenario II*, we account for the Kyoto protocol, and assume a post-Kyoto policy that is no weaker than the Kyoto arrangements applying for the years 2008 to 2012. We base this multilateral policy scenario on a study of the Kyoto agreement and beyond (Strøm 2001). *Alternative scenario II* differs from the other scenarios in that electricity trade is assumed unaffected by the policy changes. This seems unrealistic, given the extensive trade among the Nordic countries. The effect of this model disparity is discussed below.

The main difference between the policy designs in *Alternative scenario I* and *II* relates to the determination and level of the price of emitting CO_2. In *Alternative I*, the price is represented as a uniform tax that increases endogenously over time as the economy grows. The simulated, uniform real carbon tax rate reaches 58 €/tonne in the long run (in 2030), about three times higher than the exogenous, constant average tax rate in the main scenario (see Table 3). In *Alternative II* the price

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[9] We have estimated a standard EKC model of the relationship between income per capita and CO_2 emissions (see, for example, Dinda, 2004) on Norwegian time series data over the period 1949–2000: $ln\ CO_{2,t} = \alpha + \beta_1 lnY_t + \beta_2 (lnY_t)^2 + \beta_3 (lnY_t)^3 + \varepsilon_t$, where Y is a five-year moving average of income per capita. α=6.64, β_1=64.53, β_2=2.39, β_1=0.46

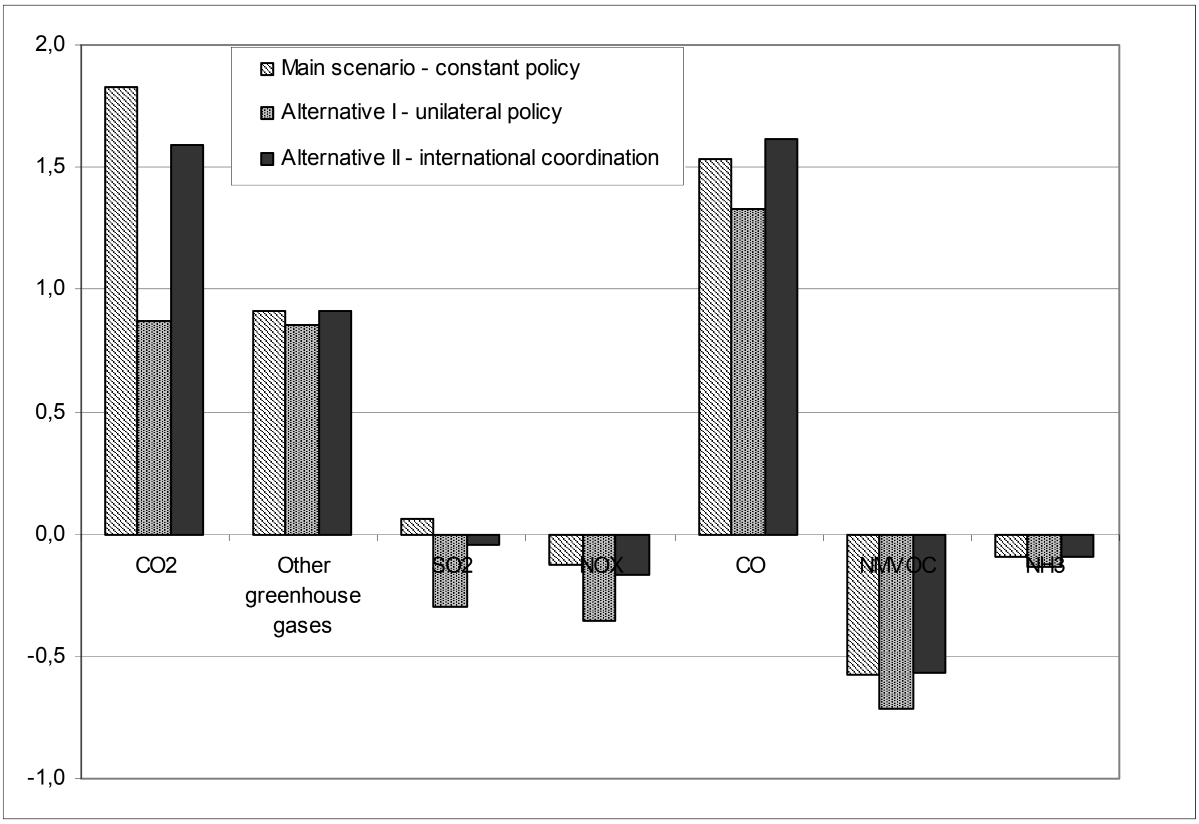
takes on the form of an international emission quota price determined by factors outside Norway in the international quota market. It is assumed to be 16 €/tonne CO_2-equivalents from 2008 and onwards. This may overstate the probable quota price for the Kyoto period from 2008-2012. A survey by Springer and Varilek (2004) indicates an interval between 3 and 10 €/tonne. On the other hand, as a price for the post-Kyoto period until 2030, a price of 16 €/tonne may seem too low (Eurelectric, 2004). As an average price for the entire period from 2008 - 2030, 16 €/tonne can be regarded as reasonable, though subject to large uncertainty.

Another important difference between the two alternative scenarios is the effects on competitiveness. In a multilateral initiative, many of Norway's most dominant competitors will face the same cost increases as domestic firms, implying that not only the Norwegian, but also the international costs of emission-intensive goods, will increase. Competitiveness effects are thus considerably weaker.

5.1. Domestic emissions decrease

In the unilateral scenario, *Alternative I*, both the domestic emissions causing local damage and greenhouse gases are reduced compared to the main scenario, see Figure 5. This is mainly due to a considerable contraction in the production of carbon-intensive commodities. The growth in the long-run CO_2 emissions is bisected. The largest reductions in the other emissions occur in fossil fuel-related emissions like SO_2, NO_x, and CO, as well as NMVOC. Competitiveness is reduced in the most emitting industries that received favorable tax treatment under the original system (cf. Table 3). At the same time, competitiveness is strengthened for most domestic producers of services and labor-intensive manufactures.

Figure 5: Domestic emissions in the main scenario, and the two alternative scenarios I and II, average yearly percentage growth rates



In *Alternative II*, where the Norwegian climate policy is part of a multinational effort, the effects on domestic emissions are minor. The annual growth rate of CO_2 emissions falls by only 0.2 percentage points. The remaining emissions face even smaller effects. These results reflect that GDP and consumption growth are hardly affected, and that the competitiveness changes are weak. Gas power production is most affected, as it contracts by 23 percent in 2030. This reduction is nevertheless small compared to *Alternative I*, where the fall is 69 percent. These conclusions would probably be strengthened with more realistic electricity trade assumptions (see above). More realistic assumptions in *Alternative II* with flexible electricity trade may contribute to higher market shares and even lower leakages. A common quota market would impose relatively less tax burden on the Norwegian power production based on natural gas, given that the Nordic and European power producers still rely on more CO_2 intensive technologies in energy production.

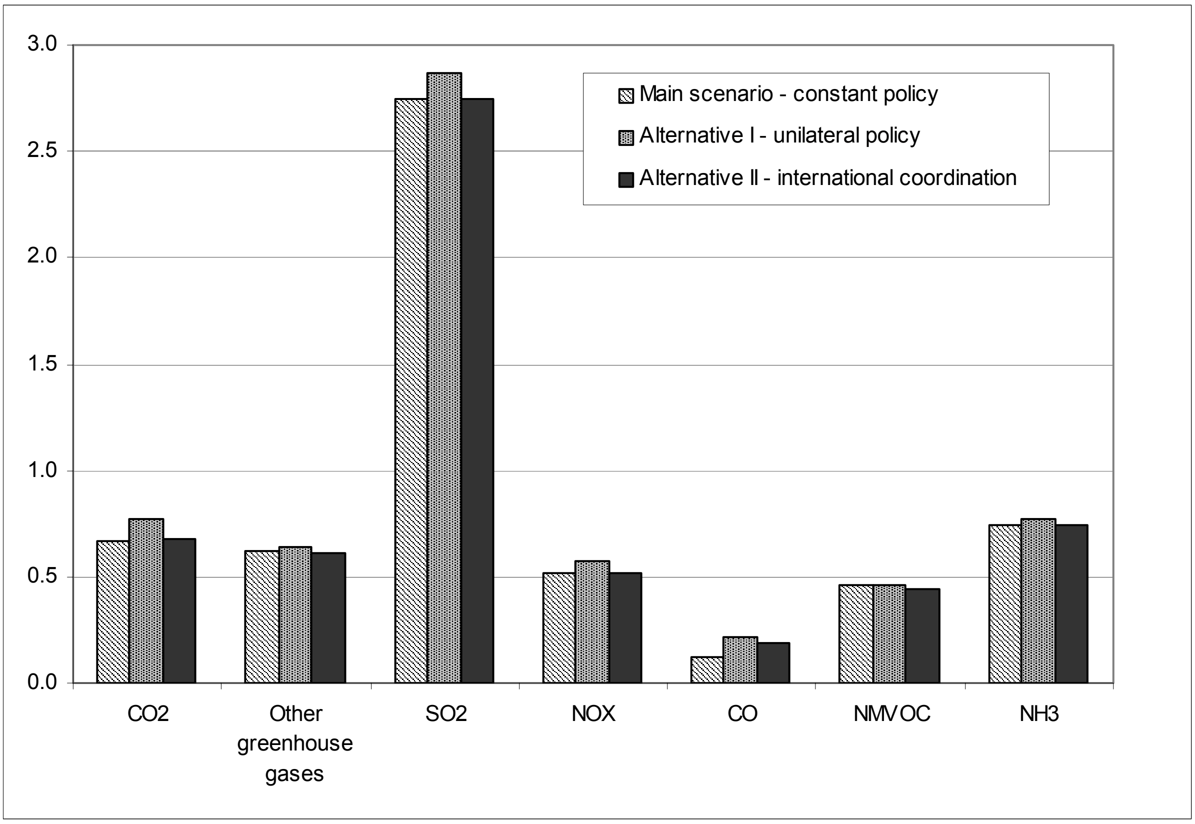
Note that the Norwegian commitments are not smaller in *Alternative II* than in *Alternative I*. Rather, while emissions in *Alternative I* are reduced by 25 percent in year 2030, the quotas allocated to

Norway in *Alternative II* represent a 25 percent reduction in foreign emissions already in 2010.[10] The reason for the low *domestic* abatement in *Alternative II* is that the emission quota system allows for the purchase of quotas as an alternative to domestic abatement. This proves to be highly profitable for Norwegian emitters. Almost 90 percent of the commitments are met by quotas, and 10 percent by domestic reductions.

5.2. Rather small effects on leakages

Leakages increase somewhat due to policy effects in the unilateral *Alternative 1*, see Figure 6. The CO_2 policy effects are naturally most prominent for CO_2, and SO_2, mainly because of increased costs in the metal and power generation industries. In *Alternative II*, when the leakages are at about the same level as in the main scenario.

Figure 6: Net leakages, average yearly growth rate 2000-2030 in scenarios (I) (II) and (III)



[10] The reductions in foreign emissions through the commitments related to the Norwegian purchase of quotas is an extra effect, aside from the trade related leakages accounted for in this study. Importantly, this effect is highly uncertain. Due to the large amount of so-called *hot air* in the market, no effect is expected during the Kyoto period (Springer and Varilek, 2004). Large supplies of quotas are allocated to countries based on too high, anticipated levels of emissions in case of no Kyoto agreement who can sell quotas without any real reductions in emissions.

In a long-term perspective, the *Alternative II* is most likely, as partial policy reforms from one single country may seem unrealistic for most types of international environmental problems. Hence, given the degree of international policy coordination, our finding does not support the so-called Pollution Haven Hypothesis (Eskeland and Harrison 2003), claiming that strengthened abatement policy will significantly deteriorate competitiveness of emission-intensive firms and move production abroad.

Table 6 shows the total leakages in Figure 6, decomposed into the import- and export related elements. The policy effects on import-related leakages are actually negative for many emissions. Imports are limited by a general reduction in demand due to CO_2 policy, as well as by reduced domestic factor prices in the longer run, in order to ensure a sustainable foreign debt development. Increased import-related leakages apply only to a few of the emissions components, namely NH_3 and other greenhouse gases, and only in the unilateral *Alternative I.* It is explained by greater imports of chemical and mineral products and of forestry commodities, where Norwegian firms lose competitiveness.

The export-related leakages tend to increase in both alternatives. This follows reduced Norwegian exports of fossil fuel-intensive products, basically metals and gas-based electricity. Denmark and Sweden increase their market shares in the Nordic electricity market, and both countries maintain higher emission intensities than Norway because of their shares of coal-based thermal power. For instance, the foreign increase in SO_2 emissions due to a heavier climate gas policy is significantly larger than the decrease in such emissions in Norway.

Table 6: Emission leakages, average yearly growth rate 2000-2030 in the scenarios

	CO_2	Other greenhouse gases	SO_2	NO_x	CO	VOC	NH_3
Import related leakages							
Baseline (constant policy)	0,58	2,04	0,64	0,75	-0,83	1,34	2,19
Alternative I (unilat. policy)	0,52	2,15	0,57	0,71	-1,00	1,37	2,35
Alternative II (coordin. policy)	0,42	1,96	0,51	0,66	-0,99	1,23	2,18
Export related leakages							
Baseline (constant policy)	1,99	3,39	2,72	2,60	1,12	4,21	-0,07
Alternative I (unilat. policy)	2,66	3,42	3,10	3,20	1,70	4,27	-0,74
Alternative II (coordin. policy)	2,22	3,36	2,87	2,66	1,55	4,18	-0,09

6. Concluding remarks

Our empirical analysis gives reason to question *the leakage hypothesis*, which claims that a relocation of emission-intensive productions abroad follows growth and decoupling within rich countries. Rather, while we observed a decoupling over the past decades for several emissions, the emission leakages abroad decreased.

An important explanation to the decreasing emission leakages over the last couple of decades is that the Norwegian exploration of her natural offshore resources benefited from a certain level of economic maturity and technological advancement to effectively exploit the comparative advantages. We have posed the hypothesis of a delayed exploitation of the high-tech emission-intensive production in rich countries, compared to the common EKC pattern of a decreasing reliance on emission-intensive industries as the economy grows. Our findings confirm this effect. While Norway expanded her offshore activities markedly during the last three decades, her role as a petroleum exporter is presently at its most prominent level. We find that emission leakages will first of all take place in the future decades, and that the reduction in offshore production is an important contributor to the shift from negative to positive leakages. Still, the effects are the same, although weaker, if considering the rest of the economy aside from the petroleum sector.

Norway is an example of an economy exploiting natural resources by means of highly technologically advanced investments. This lack of linkages between leakages and decoupling may be a relevant example for other economies relying on new technologies for pollution-intensive exhaustion of natural resources in developed countries. An advantage of emission-intensive industrial booms at relatively high-income levels is the benefits from the interplay between advanced technological know-how and high environmental consciousness. For instance, the Norwegian oil and gas production has low emission coefficients in an international context.

Our analysis finds some support for the leakage hypothesis in that leakages to our trade partners seem to increase in the future. We find that structural changes contribute both to leakages and to decoupling. However, the increasing scale of the economy in particular counteracts the structural change and emission reducing technology effects, and compared to the two previous decades, decoupling tend to weaken for most gases. The leakage hypothesis suggests a correspondingly weaker leakage effect in the years to come. This interpretation of the leakage hypothesis is not confirmed by our results.

Even if leakages do not explain much of the future domestic emission growth, it is of relevance to concern about the higher environmental pressure the Norwegian growth may impose on the trading partners. The anticipated increase in future leakages supports the need for broadening the perspective beyond national borders in studies of EKCs. National emission accounts may underestimate the future global environmental impacts of the nations' economic growth. This is especially worrying if the burden is placed on the poorer economies. Our study cannot be taken to support this claim. Given the current composition of trading partners, the predominant part of the leakages goes to developed countries.

Our study also cast some doubt on *the pollution haven hypothesis*, claiming that strengthened abatement policies deteriorate competitiveness of polluting industries and move production to less regulated countries. We find that competitiveness and emission leakages seem rather insensitive to various assumptions about climate policy. Our findings do however confirm, as expected, that a coordination of policy among trading partners reduce the competitiveness effects.

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Appendix

The consumption and production structure

Figure A1: The preference structure of the household in the model

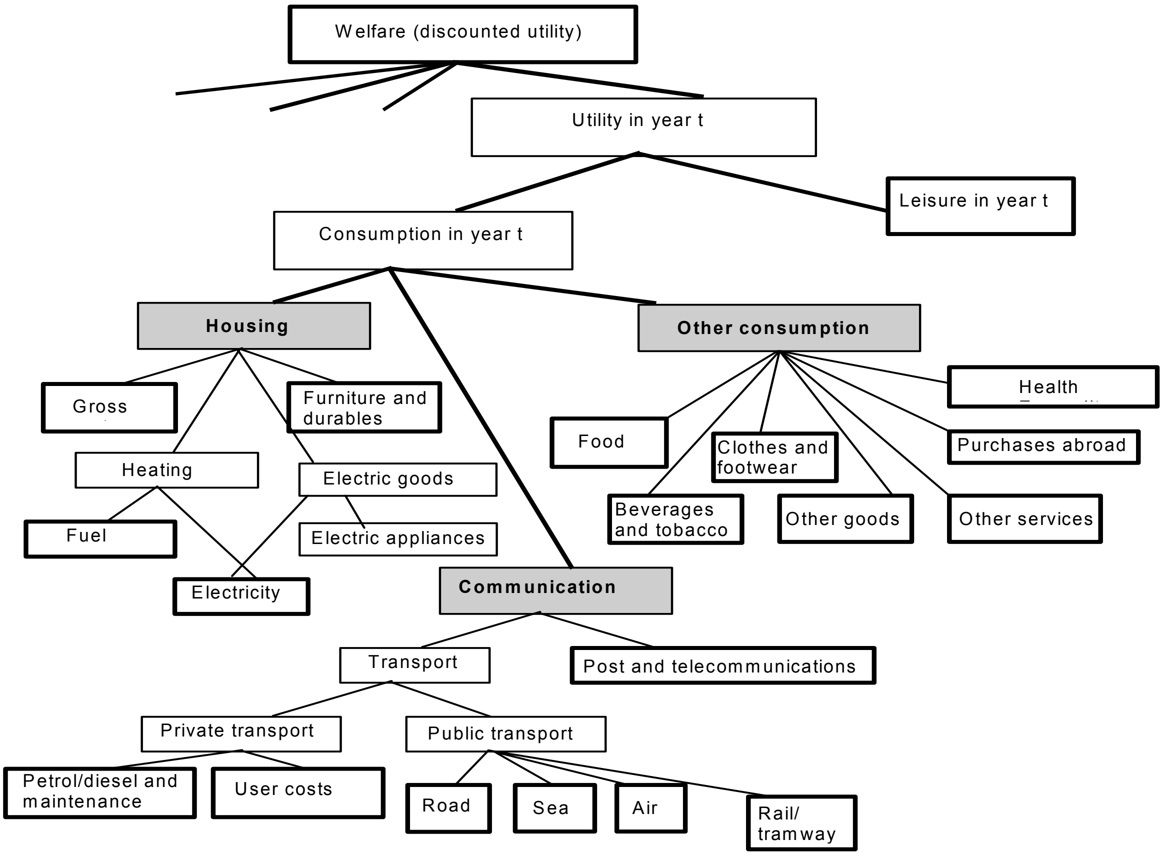
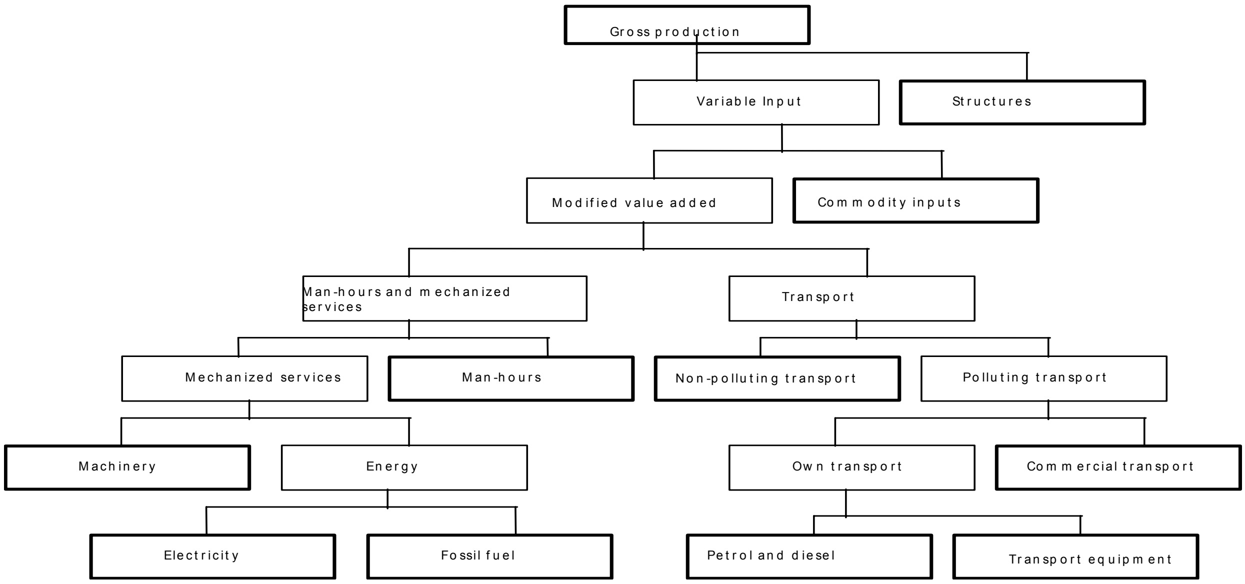


Figure A2: The separable production structure of the firms in the model



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