CICERO Working Paper 2000: 10

The Kyoto Protocol and the fossil fuel markets under different emission trading regimes

Bjart Holtsmark* and Ottar Mæstad**

7 September 2000

CICERO
Center for International Climate
and Environmental Research
P.O. Box 1129 Blindern
N-0318 Oslo, Norway
Phone: +47 22 85 87 50
Fax: +47 22 85 87 51
E-mail: admin@cicero.uio.no
Web: www.cicero.uio.no

CICERO Senter for klimaforskning
P.B. 1129 Blindern
0318 Oslo
Telefon: 22 85 87 50
Faks: 22 85 87 51
E-post: admin@cicero.uio.no
Nett: www.cicero.uio.no

* Center for International Climate and Environmental Research – Oslo (CICERO)

** Foundation for Research in Economics and Business Administration (SNF)
Address of correspondence: Norwegian School of Economics and Business Administration / SIØS
Helleveien 30, 5045 Bergen, Norway. E-mail: Ottar.Maestad@snf.no

Abstract
The consequences of the Kyoto Protocol for the fossil fuel markets depend on which policy instruments that are used in order to reach the emission targets. This paper uses a numerical model to assess the significance of international emission trading for the oil, coal and gas markets. Three different trading regimes are compared. Particular attention is devoted to the EU proposal about limits on acquisitions and transfers of emission permits. We find that the EU proposal will be non-binding for buyers of emission permits but will significantly constrain the sale of emission permits from Eastern Europe. The EU proposal will increase the level of abatement in Annex B countries and will cause a sharp increase in the price of permits compared to the free trade equilibrium.

Key words: Kyoto Protocol, fossil fuel markets, emissions trading, numerical model, EU

Acknowledgements

Financial support from STATOIL and the Norwegian Research Council is gratefully acknowledged.

Contents

Non-technical summary

- The Kyoto Protocol will not lead to large reductions in the demand for oil and gas, but it will significantly reduce coal demand.
- The producer prices of fossil fuels will not fall dramatically.
- The EU proposal about restrictions on international emission permit trade will increase the level of abatement, as it significantly reduces the amount of hot air available in the market. Most buyers of emission permits will however not be effectively constrained by the suggested trading limits.
- The EU proposal causes a sharp increase in the permit price compared to the case with free emission trading.

These are some of the results from this joint SNF/CICERO project.

The Kyoto Protocol puts a cap on the emission of greenhouse gases in the industrialised countries. On average, the industrialised countries have committed themselves to keeping their emissions within 95% of the 1990 emission level in the period 2008-12.

The combustion of oil, coal and gas is the main source of anthropogenic greenhouse gas emissions. Emission reductions will therefore affect the demand for fossil fuels.

The consequences for the fossil fuel markets depend crucially on which policies that are used in order to reach the emission targets. In this project, we have devoted particular attention to the role of international emission trading. Three different trading regimes are compared:

- Free emission trading
- No emission trading
- The EU proposal on limits on the acquistions and transfers of emission permits

We apply a numerical model of the fossil fuel markets. The model was originally developed at CICERO, but it has been modified and updated for this project as a joint effort by CICERO and SNF. The model includes a global oil market, a global coal market, and three regional gas markets (North America, Asia, and Europe including Russia) The model should be considered as an analytical tool that can be used to obtain information about important mechanisms and some orders of magnitudes. However, it is not intended as a forecasting device.

Some of our key findings are:

- The Kyoto Protocol will significantly reduce coal demand, but it will not lead to very large reductions in oil and gas demand. In the industrialised countries, coal demand is reduced by some 34-44%, oil demand by 5-7%, and gas demand by 2-3% (relative to our business-as-usual scenario for 2010).
- These results are based on the assumption that all fuels are taxed in proportion to their true carbon content. However, if coal is somehow favoured, oil and gas markets will be more badly hurt.
- Demand reductions are generally smaller with free international emission trading, because substantial amounts of hot air then will be released on the market.

- Emission trading generally leads to more abatement in Eastern Europe and less abatement in North America.
- The EU proposal will be non-binding for buyers of emission permits, but will significantly constrain the sale of emission permits from Eastern Europe. The amount of hot air released on the market is reduced by some 65%.
- The EU proposal causes a rise in the international permit price from 15 to 23 USD per ton CO2.
- Western Europe is special in several respects. First, there are already very high taxes on oil relative to other fuels. This implies that substituion from oil to gas will be not as pronounced here as in other regions. While oil demand in Western Europe declines by 4-6%, gas demand is reduced by 4-8%.
- Secondly, Western Europe is a net importer of emission permits with low permit prices (free trade) and a net exporter with high permit prices (the EU proposal). Thus, a gradual "liberalisation" of international emission trading might first lead to lower fuel demand, then to higher fuel demand in Western Europe.
- The producer prices of fossil fuels do not fall dramatically. Coal prices fall by 7-9%. The oil price falls by 2-3%. This small price reduction is partly due to cartel behaviour in OPEC, which cuts back its oil production by around 5-6%. Oil and gas prices decline most without emission trading, because less hot air then is released on the market
- The European gas price falls by 3-5%. The price declines most with free emission trading, because Eastern Europe then will economise on their use of fossil fuels.

1 Introduction

The Kyoto Protocol puts a cap on the emissions of greenhouse gases (GHGs) in the countries listed in Annex B of the Protocol. On average, the industrialised countries have committed themselves to keeping their emissions below 95% of the 1990 emission level in the period 2008-12. Since CO_2 is the most important GHG, and since emissions of CO_2 mainly are attached to combustion of fossil fuels, the Kyoto Protocol will directly affect the demand for fossil fuels. But the exact consequences for the fuel markets depend on which policy instruments that are used to reach the emission targets. This paper analyses how three different regimes for international emission trading may lead to different effects for the oil, coal and gas markets.

Several mechanisms are built into the Kyoto Protocol, which allow countries to fulfil their national commitments in cooperation with other countries. The opportunity of international trade in emission permits among Annex B countries is one of them. The parties of the Protocol do not yet agree, though, about the rules that should govern the emission trading. While some insist on free trade, others want to put restrictions on the number of emission permits that each country will be allowed to buy or sell. Such restrictions are defended by reference to Article 17 of the Protocol, which states that emission trading “shall be supplemental to domestic actions…”. The term “supplemental” is, however, not defined in the Protocol. Recently, the European Union Council of Ministers agreed on recommendations on definitions of this concept. Specifically, the Ministers proposed limits both on acquisitions and transfers of emission permits. This paper offers an operationalisation of this proposal and compares its consequences with a scenario with free emissions trading and a scenario without emissions trading.

We apply a numerical equilibrium model developed at Centre for International Climate and Environmental Research in Oslo (CICERO). The model divides the world into 32 countries and regions. Demand and supply functions for oil, coal and gas are specified for each country. All countries are assumed to establish a national market for emission permits in order to meet their obligations according to the Protocol. With no international emission trading, these national markets operate independently, and the permit price may therefore differ substantially between countries. International trade in emission permits will establish a link between these national markets. Countries with a high permit price in the absence of emission trading will buy emission permits from countries with a lower permit price. If the international trade in emission permits is unrestricted, a single price of permits will eventually be established throughout the whole Annex B area.

Restrictions on the international trade in emission permits will have two types of effects. First, the international permit price may rise or fall, depending on whether it is the acquisition or the transfer of permits that is most severely restricted. Secondly, the price of emission permits in countries where the trade restrictions are binding will differ from the international permit price. In countries that are not allowed to buy as many emission permits as they want, the national permit price will be higher than the international price. The converse will be true in countries that are not allowed to sell as much as they want.

Restrictions on the international emission trading are costly, because differences in the national permit prices will lead to differences in marginal costs of abatement. Thus, the costs of reaching a given emission target are not minimised. So what are the benefits? One of the benefits is related to the prospects of reducing the amount of hot air. There is concern that international emission trading will not only shuffle around the emission permits among the Annex B countries; it may also increase the total number of permits available. This will happen if some countries are assigned a larger emission quota in the Kyoto Protocol than they are able to use in the no trade equilibrium. In order to limit the amount of hot air, restrictions on the sale of emission permits might be appropriate. But it does not justify restrictions on the acquisition of permits. The benefit of such restrictions is often thought to be that it will ensure a relatively high permit price in some well-developed, permit-importing countries, and thereby stimulate R&D activities that will reduce the costs of abatement throughout the world in the long run. One aim of this paper will be to investigate how well designed the EU proposal on trade restrictions is to achieve any of these benefits.

The link between the international market for emission permits and the fossil fuel markets is an important part of the model. Because the emission reduction commitments and marginal abatement costs vary between countries, and some countries have significant amounts of hot air, the different trading regimes that are analysed influence the regional distribution of abatement efforts. This has immediate implications for the demand pattern for the fossil fuels. Moreover, since not all fossil fuel markets are globally integrated, the regional distribution of abatement efforts also influences on the regional production pattern.

A lot of work has recently been put into numerical analysis of the consequences of the Kyoto agreement for the world economy. A special issue of the Energy Journal (1999) provides an excellent overview of this literature. Closely related to our study are the papers by Bernstein *et.al* (1999), MacCracken *et.al* (1999), and Bollen *et.al* (1999). This paper differs from previous studies by including the details of the EU proposal to limit acquisitions and transfers of emission permits. The model allows us to evaluate whether the EU proposal is likely to successfully achieve any of the suggested benefits of limited trading, and to assess its consequences for the fossil fuel markets.

The paper is organised as follows. The next section gives an overview of the numerical model. Section 3 provides information about the applied data sets and the calibration method. The different emissions trading regimes, including the EU-proposal to limit emissions trading, are described in section 4. Section 5 presents the simulation results, and Section 6 concludes.

2 The model

The numerical model is a simple, static partial equilibrium model. There are five markets for fossil fuels; one global oil market, one global coal market and three regional gas markets (North America (N), Asia (A), and Europe including Russia (E)). High transportation costs for natural gas are the reason why it is appropriate to regionalise the gas market. Then, there is an international market for emission permits among the Annex B countries, and finally, there are national markets for emission permits in each of the Annex B countries. 26 Annex B countries and 6 non-Annex B countries or regions are modelled. The model determines equilibrium prices in the fuel markets, the quantities of fossil fuels produced and consumed, each country's import or export of emission permits, the international price of emission permits, and the permit prices in the national permit markets.

In each country, a numeraire good is produced using four inputs; oil (1), coal (2), gas (3), and non-CO2 climate gases (4). The three fossil fuels are substitutes, while the marginal product of non-CO2 gases is independent of the use of fossil fuels. The assumed production technology yields linear demand function for all inputs. Let P_{in} and y_{in} denote the consumer price and the quantity used in country n of input i ($i = 1,2,3,4$). We assume price taking behaviour, and the demand functions in country n can then be written as follows:

$$y_{in} = a_{in} + \sum_{j=1}^{3} a_{ijn} P_{jn}, \quad i = 1,2,3$$
$$y_{4n} = a_{4n} + a_{44n} P_{4n}$$

where $a_i > 0$ and $a_{ij} < (>)\ 0$ for $i = j\ (i \neq j)$.

The consumer price of input i in country n, located in region *r*, is the sum of the (regional) producer price (p_{ir}), a national excise tax (t_{in}), and the emission factor of input i (e_i) times the price of emission permits in the national permit market (q_n). Note that it is only in the gas market that producer prices differ between regions.

$$P_{in} = p_{ir} + t_{in} + e_i q_n, \quad n \in r, \ r = N, A, E$$

The prices of emission permits in the national permit markets are defined as

$$q_n = q + \tilde{q}_n ,$$

where q is the international price of emission permits and $\tilde{q}_n$ is the price difference in country n between the national and the international price of emission permits. If there is free trade in emission permits, $\tilde{q}_n$ is zero in all countries. In countries that face a binding restriction on their imports (exports) of emission permits, $\tilde{q}_n$ must be positive (negative) in order to clear the national permit market.

When it comes to the supply of fossil fuels, we assume that OPEC behaves strategically and restricts its oil supply in order to increase the oil price. Let x_{in} denote the quantity of fuel i produced in country n, and let c_N denote the marginal costs of production in OPEC (country N). OPEC's oil supply is determined so that marginal revenue equals marginal costs;

$$\frac{\partial p_1}{\partial x_{1N}} x_{1N} + p_1 = c_N .$$

All other producers of fossil fuels are assumed to take prices as given. In the oil market, there is thus one strategic supplier with a competitive fringe.[1] The supply of all fuels from other regions, as well as OPEC's supply of gas (and coal), is defined by linear supply functions

$$x_{in} = s_{in} + b_{in} p_i ,$$

where s_{in} and b_{in} are parameters ($b_{in} \geq 0$).

In the Kyoto agreement, each of the Annex B countries is assigned with an emission quota of GHGs. Let E_n and Q_n denote the total emissions and the Kyoto quota for country n. Since the emission factors (e_i) are constants, we will measure all variables in terms of CO2 emission. As for non-CO2 climate gases, GWP-100 has been used as weights. We can then write

$$E_n = \sum_{i=1}^{4} y_{in} .$$

It would not be unreasonable to assume that some large countries, like the USA or Russia, might want to act strategically in the international market for emission permits. Such strategic considerations are not built into the present version of the model, though; all countries simply take the international price of emission permits as given.

With free emission trading, the net import of emission permits in country n is given by

$$m_n = m_n(P_{1n},..,P_{4n},Q_n) = \sum_{i=1}^{4} y_{in} - Q_n .$$

Restrictions on the trade in emission permits appear as upper and lower limits on the net import; $m_n \in [\underline{m}, \overline{m}]$. The case without emission trading is studied by setting $\underline{m} = \overline{m} = 0$.

Let K be the number of Annex B countries. The model determines the price vector $(p_1, p_2, p_{3N}, p_{3A}, p_{3E}, q, \tilde{q}_1,..,\tilde{q}_K)$ from the following conditions:

Equilibrium in the oil and coal markets:

$$\sum_n x_{in} = \sum_n y_{in}, \quad i = 1,2$$

[1] To model the oil supply in a static model is problematic because it is impossible to take into account that the oil producers are forward looking. For a discussion of OPEC being forward looking, see Berg et al. (1998).

Equilibrium in the three regional gas markets:

$$\sum_{n\in r} x_{3n} = \sum_{n\in r} y_{3n}, \quad r = N, A, E$$

No excess demand in the international market for emission permits. If there is excess supply, the international permit price should be zero:

$$\sum_{n=1}^{K} m_n \le 0, \quad q \ge 0, \quad q\sum_{n=1}^{K} m_n = 0$$

No excess demand in the national emission permits markets. If there is excess supply, the national permit price should be zero:

$$\sum_{i=1}^{4} y_{in} \le Q_n + m_n, \quad q_n \ge 0, \quad \left[\sum_{i=1}^{4} y_{in} - Q_n - m_n\right] q_n = 0, \qquad n = 1,..,K$$

It should be underlined that the present analysis does not take into account the opportunity of industrialised countries to acquire additional emission permits through the Clean Development Mechanism (CDM), i.e., by undertaking projects in developing countries that reduce GHG emissions. This means that there will be an upward bias in our estimates of the permit prices. The reason why CDM is not included is the large degree of uncertainty related to how CDM will be implemented. Note also that, due to lack of reliable data from several countries, the model does not include CO_2 emissions related to sources and removal by sinks.

3 Data and calibration

Studies of the consequences of the Kyoto Protocol must build on estimates of what the world would look like in the years 2008-12 without any climate agreement. Our model is calibrated to a scenario of the world economy and world energy markets in year 2010.

We have constructed our "business as usual" scenario by taking as our baseline the *Conventional Wisdom* (CW) scenario developed by the European Commission (1996). In particular, the projected production and consumption figures for oil, coal and gas in all EU countries are taken directly from the CW-scenario.[2]

However, the EU study does not provide sufficiently detailed figures for countries outside the EU. Only regional data are available. In our study, BAU estimates for individual countries outside the EU have been constructed by applying the regional growth rates for consumption and production of each fuel (from the EU study) directly to the individual countries of the respective region. Although this procedure worked reasonably well in most cases, it led to inconsistent predictions for the North American gas market. In order to correct these problems, the North American gas figures were reconstructed based on extrapolation of the trends from the period 1990-98. The general procedure was abandoned in the case of Norway as well, where production and consumption figures were derived from the most recent official documents. Figure 1 shows the BAU estimates for global fuel demand compared to 1990 levels.

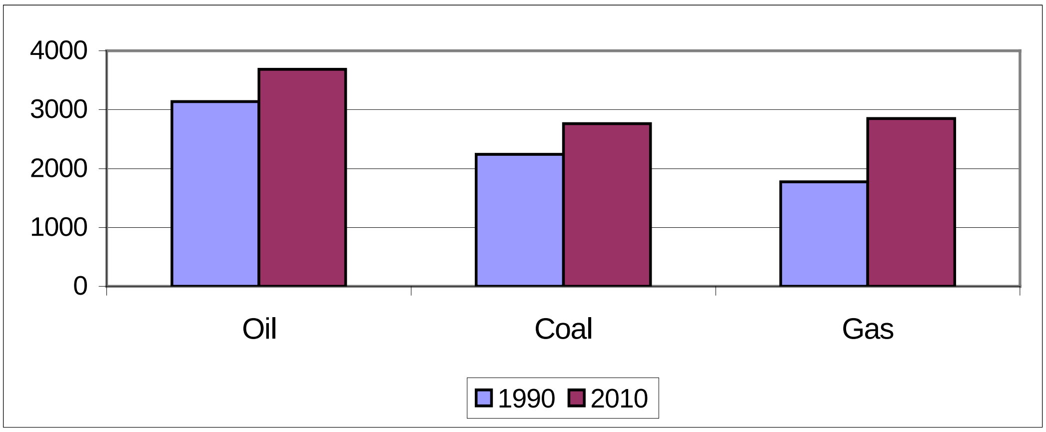

Figure 1: Actual and projected fuel consumption (mtoe)

[2] This is a business as usual scenario, representing a conventional wisdom view of events: Economic growth gradually weakens as demographic changes mean slower growth of the labour force. Productivity growth remains stable, but well below growth rates experienced before mid-1970s. Many of the world's structural social and economic problems remain unsolved. Unemployment rates decline, but not much. Public deficits are stabilised but not eliminated. The contribution of industry to European GDP declines. The production share of energy-intensive industries falls. Energy prices increase smoothly. The price of crude oil reaches 31 USD/bbl in 2020, measured in 1995 dollars. Deregulation and growing networks bring lower prices of gas relative to oil after 2000, a trend that is reinforced by an increasing gas to oil price competition. Coal prices remain stable. The penetration of new energy technology is limited. The environment is given no great attention in public policy.

The abatement cost functions have been calibrated by imposing a measure of the elasticity of demand for each fuel in each country. There is no consensus in the literature about demand elasticities in fossil fuel markets. Estimates range from –0.15 (Smith *et.al*, 1995) to less than –1.0 (see e.g. Golombek and Bråten (1994) and Golombek, Hagem and Hoel (1995)). In lack of decisive evidence, we have chosen a middle road by assuming average demand elasticities of –0.5 for all fossil fuels. But demand elasticities for oil and coal have been differentiated across countries in order to reflect the different structure of fuel demand in different countries. The following procedure has been followed for this purpose: By using detailed information from the IEA statistics, the consumption of oil and coal in each country has been divided into two parts, one which is inelastic and one which presumably is more elastic. Oil demand for transport is assumed to be inelastic relative to other demand components. Coal used as input in the industry sector is assumed to be inelastic relative to other demand components (such as power generation). In those countries where the share of inelastic (elastic) demand components is greater than the world average, demand is assumed to be less (more) elastic than –0.5. The degree of adjustment of elasticities is arbitrarily chosen to be of the same relative magnitude as the relative variation in the share of elastic demand components. In this way, the model captures the fact that marginal abatement costs differ among countries (see Table 1 for details).

Projected producer prices in 2010 are taken directly from the EU study, except in the case of the gas market, where the EU study reports only one gas price. We have taken the gas price from the EU study to be the European gas price, while the other gas prices have been calculated under the assumption that relative gas prices between the three markets will be as projected by the IEA in their *World Energy Outlook* (1998).

Consumer prices in the BAU scenario are obtained by adding existing fiscal taxes to the producer prices. The tax rates are taken from ECON (1995), which presents average fossil fuel taxes in the OECD countries up to 1994. The tax rates are based on weighting energy taxes by product and sector. The information on taxes is based on IEA Energy Prices and Taxes, IEA (1995). The information on taxes has been supplemented with EU's oil price statistics, 'Oil Bulletin' and with direct contact with national administrations. The weights are based on 'Basic Energy Statistics'. The Basic Energy Statistics have been supplemented with oil industry information and EU statistics on the use of leaded and unleaded gasoline and on the breakdown of heavy fuel oil according to sulphur content (relevant for countries differentiating heavy fuel oil taxes according to sulphur content).

As for the fuel supply, it is generally recognised that the supply of coal is more elastic than the supply of other fuels. We have followed Golombek and Bråten (1994) by assuming supply elasticities of 2.0 for coal producers and .75 both for gas producers and for competitive oil producers.

4 The emissions trading regimes

The paper presents the consequences of three different ways of implementing the Kyoto Protocol. In all three scenarios, the governments of the Annex B countries meet their commitments to limit GHG emissions by implementing national tradable permit systems.[3] In the free trade scenario, all the national permit markets are fully integrated. Therefore, the permit price will be the same in all markets. Then there is a scenario without international trade in emission permits. The national emission permit markets are then completely segregated from one another. This may lead to substantial differences in permit prices across countries. Finally, we assess the consequences of the EU-proposal to limit emissions trading.

Before we present model simulations of the different scenarios this section provides a detailed presentation of the restrictions on permit transfers and acquisitions proposed by the European Commission.

4.1 The EU proposal to limit acquisitions

The EU has proposed the following limit on a party's right to acquire emission permits (or *Assigned Amount Units, AAUs*) beyond its Kyoto quota:

> Net acquisitions of AAUs must not exceed the higher of two ceilings:
>
> (a) 5 per cent of the average of its base year emissions and its number of AAUs, or
>
> (b) 50 per cent of the difference between its annual actual emissions in any year of the period from 1994 to 2002 and its number of AAUs.

But "the ceiling on net acquisitions can be increased to the extent that a Party included in Annex B achieves emission reductions larger than the relevant ceiling in the commitment period through domestic action taken after 1993 if demonstrated by the Party in a verifiable manner and subject to the expert review process to be developed."

Define the following variables:

E_n^{BAU}	BAU emissions in country *n* in the commitment period 2008-12
E_n^{B}	Base year emissions
E_n^{max}	The highest actual emission level in the period from 1994 to 2002
A_n	Abatement, defined as $A_n \equiv E_n^{BAU} - E_n$

[3] As shown in Holtsmark (1999a,b) national tradable permit systems and emissions taxes are similar systems. The model could therefore also be interpreted as if the countries instead implement emissions taxes on top of existing fiscal taxes and that the governments take care of transnational emission trading.

We interpret "emission reductions" to be equivalent to our "abatement". The last statement of the EU proposal then implies that acquisitions can take place insofar as the abatement level is not exceeded;

$$m_n \leq A_n \equiv E_n^{BAU} - E_n = E_n^{BAU} - (Q_n + m_n)$$

which is equivalent to

$$m_n \leq 0.5\left(E_n^{BAU} - Q_n\right)$$

In other words, domestic abatement must constitute at least 50% of the required abatement level. By combining this with the limits defined by (a) and (b), the proposed limit on acquisitions can be written as

$$\bar{m}_n = max\left(0.05\frac{E_n^B + Q_n}{2}, 0.5\left(E_n^{max} - Q_n\right), 0.5\left(E_n^{BAU} - Q_n\right)\right).$$

The EU proposal may seem to indicate that a country that imports emission permits may increase its import allowance through abatement, but that is not the case. Increased abatement will always lead to a one for one reduction in the imports of permits. Therefore, the level of abatement is not included in the expression for $\bar{m}_n$.

We observe that the limit defined by (b) will not be binding unless $E_n^{max} > E_n^{BAU}$, i.e., unless the BAU emissions in 2008-12 are smaller than the maximal emissions in any year between 1994-2002. Since the BAU emissions in most permit importing countries typically will be increasing over time, the limit (b) is unlikely to bind. By comparing the two other possible limits, we observe that limit (a) will bind if

$$E_n^{BAU} < 0.05E_n^B + 1.05Q_n,$$

that is, if the BAU emissions are low compared to a weighted average of the Kyoto quota and the base year emissions.

The government of a country that is constrained by $\bar{m}_n$ can use different policies in order to limit permit acquisitions. One alternative is to establish an additional permit liability that commits emitters in the country to keep two types of permits, both types in a number corresponding to the actual emissions. The first type of permit is one that is accepted and traded internationally. The second has to be issued by the national government and is not accepted in any other country. The government should not issue more of this second type than the amount corresponding to $Q_n + \bar{m}_n$.

4.2 The EU-proposal to limit transfers

The EU proposal about a ceiling on the transfer (or sale) of emission permits states that
"net transfers of AAUs must not exceed 5 per cent of the average of its base year emissions and its number of AAUs."

But in the same way as in the case of acquisitions, there is an opportunity to *exceed this ceiling insofar as a Party carries out abatement larger than the ceiling.*

This latter statement implies that the restrictions on transfers will only apply for countries with hot air, i.e., countries where the Kyoto quota exceeds the BAU emissions. In order to see this, just realise that, per definition, a country without hot air will abate more than the amount of emission permits that is transferred to other countries. (Since $A \equiv E^{BAU} - (Q + m)$, the assumption that $E^{BAU} > Q$ implies that $A > -m$).

For a country with hot air, the constraint on the transfer of emission permits can be written as

$$-\underline{m}_n = max\left(0.05\frac{E_n^B + Q_n}{2}, A_n\right).$$

In contrast to the importers of emission permits, the exporting countries may be able to increase their export allowance through abatement. In principle, the permit exporters are allowed to sell as much as their whole BAU emission level, provided that they abate the same amount domestically. In a permit exporting country that faces a binding export limit, we will have $E_n < Q_n + \underline{m}_n$. Hence, there is no direct connection between the abatement level and the export of emission permits.

Diagram 1 illustrates the situation for a country with hot air and with no incentive to abate in order to increase its export allowance. $-m$ is the export allowance as defined by the first term in brackets in the expression above, and the hatched area is the income from selling this allowance to the international permit price q. The figure is drawn so that no domestic abatement is needed in order to be able to sell the whole allowance. Therefore, the price of emission permits in the domestic market will be zero in this case.

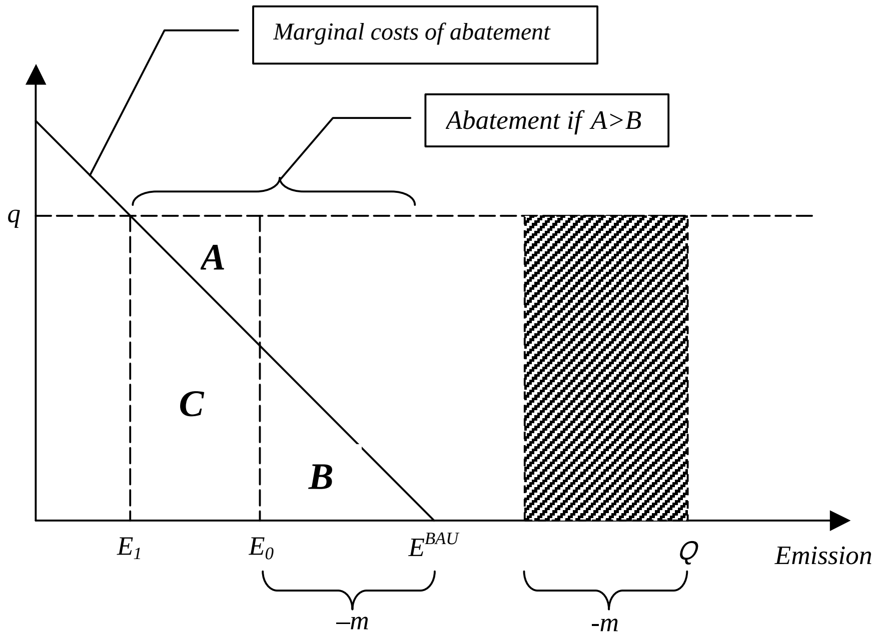

Diagram 1: Party with hot air and no incentive to increase its export allowance through abatement.

The country can transfer more permits than $-m$ if it abates more than $-m$. In other words; domestic emissions must be lower than E_0 in order to be allowed to transfer additional permits. If the country decides to abate in order to increase its export allowance, it will be optimal to reduce domestic emissions to E_1, because the marginal costs of abatement then are equalised with the marginal income (q). By reducing emissions to E_1, the income from permit exports will increase by $A+C$. The costs of abatement are $B+C$. Hence, abatement will only be carried out when $A>B$. We notice that the probability that countries with hot air actually will carry out abatement increases by reducing $-m$ in the diagram, i.e. by lowering the amount of permits that can be sold without abating.

Note that the decision whether or not to reduce emissions all the way down to E_1 involves a discrete decision by the government. Such a big jump in the emission levels and consequently in the supply of permits on the international market might affect the international permit price and thus the incentives for other countries to abate. We have made sure that the reported equilibria are in fact Nash equilibria.

5 Consequences for fossil fuel markets

We are interested in the consequences of the Kyoto Protocol for fossil fuel markets under different emission trading regimes. The Annex B countries have committed to a 5.2% reduction in GHG emissions compared to 1990-levels. This commitment is equivalent to a 12.6% reduction relative to our BAU projections for 2010 for the Annex B countries, which amounts to a 7.7% reduction in the projected global emissions in 2010. In order to assess how strongly this reduction will affect fossil fuel markets, we will need to know the following:

- Will reduced prices of fossil fuels lead to increased emission from non-parties to the agreement?
- How much will CO_2-emissions be reduced relative to other GHGs?
- What will happen to relative prices of the fossil fuels and thus to relative demand?

5.1 Greenhouse gas emissions

Our simulations predict that the equilibrium reduction in world GHG emissions in 2010 will be between 7.0 % and 8.8 %, depending on trading regime. With free emissions trading, the emission reduction in the Annex B countries will be equal to the commitment of 7.7%. Due to reductions in fossil fuel prices, emissions will increase in non-Annex B countries, implying that global emissions are reduced by only 7.0%. The amount of leakage is around 10 % of the initial emission reduction in all three cases.

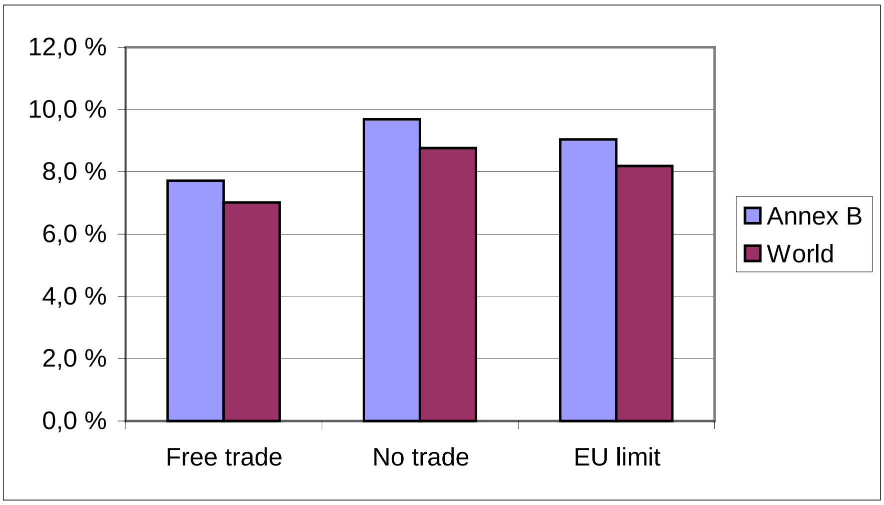

Figure 2: GHG emission reduction relative to world BAU

Emission reductions are larger than the Kyoto commitment when emission trading is restricted. A ban on emission trading increases the emission reduction in the Annex B countries from 7.7% to 9.7%. The EU proposal also achieves significantly higher emission reductions than the free trade regime (9.0%). The explanation for this increase in abatement is that BAU emissions in 2010 are lower than the assigned Kyoto emission quota in all Eastern European countries, as well as in Spain and Greece, thus giving rise to hot air. By placing limits on the opportunity to sell emission permits, there will be less hot air on the market, and emission reductions will increase significantly.

Since CO_2-emissions account for as much as 85% of total GHG-emissions in 2010, we should expect that CO_2-emissions are reduced by about the same percentage amounts as total GHG emissions. This prediction turns out to be correct. Although CO_2-emissions are reduced somewhat more than other GHG-emissions in Annex B countries, we can for all practical purposes use the diagram above as an indication of reductions in CO_2-emissions as well.

5.2 Permit trade and marginal abatement costs

With free emissions trading, the international permit price is 15 USD/tCO_2.[4] There is large export of permits from Eastern Europe to North America. Western Europe is a net importer as well. As shown in figure 3, the EU proposal to limit emissions trading, reduces trade volumes significantly. The EU proposal places limits both on the selling and the buying of permits. Our simulations suggest that the proposal in practice almost exclusively will put limits on the seller side of the permit market. This is reflected in the permit price, which increases to 23 USD/tCO2 under the EU regime. For details about individual countries, see Table 2.

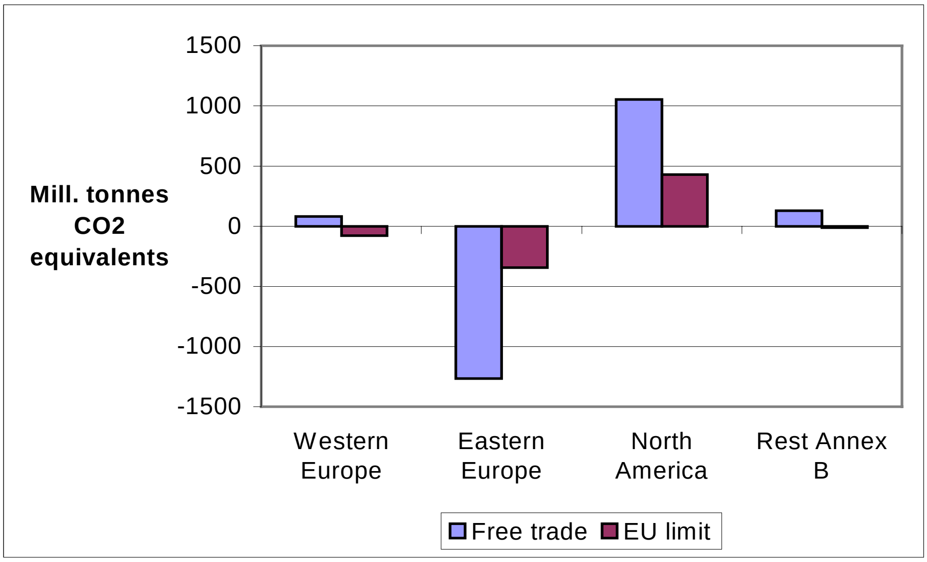

Figure 3: Net quota import

Under the EU proposal, marginal abatement costs will differ among Annex B countries. In countries that are not restricted by the trading limits, marginal abatement costs will be equal to the international permit price. Countries that are restricted on the export (import) side, will have lower (higher) marginal abatement costs. In countries with hot air, marginal abatement costs will be zero if the maximal export quota is smaller than the amount of hot air. Most Annex B countries will not be effectively restricted by the EU trading rules and thus face marginal abatement costs of 23 USD/tCO_2. However, most Eastern European countries, as well as Greece and Spain, have zero marginal abatement costs.

[4] This estimate fits quite nicely with other studies. It is about the same level as predicted by the RICE-98 model. Most models predict permit prices in the range 13-27 USD/tCO_2 (see the Energy Journal (1999) for details).

When there is no emissions trading, marginal abatement costs differ even more among countries. Obviously, countries with zero abatement costs under the EU regime have zero abatement costs with no trade as well. Moreover, net importers, such as USA, Canada, Japan and most countries in Western Europe, experience marginal abatement costs above 23 USD/tCO_2, while countries like Germany and France face costs in the range 15-17 USD.

5.3 Fossil fuel markets in Annex B countries

Figures 4 and 5 show how the Kyoto Protocol affects fuel prices and fuel demand in Annex B countries in our model. Consider first the case with free emissions trading. There are three reasons for the relatively large increase in consumer prices of coal. First, coal is far more carbon intensive than the other fuels (about 30% more carbon than oil and 70% more than gas). Secondly, the supply of coal is relatively elastic, implying that consumer prices increase relatively more. Thirdly, there are low fiscal taxes on coal at the outset in most countries, especially when compared to the taxes on oil products. Therefore, a positive price on emissions leads to a bigger relative increase in coal prices than in the prices of other fuels.

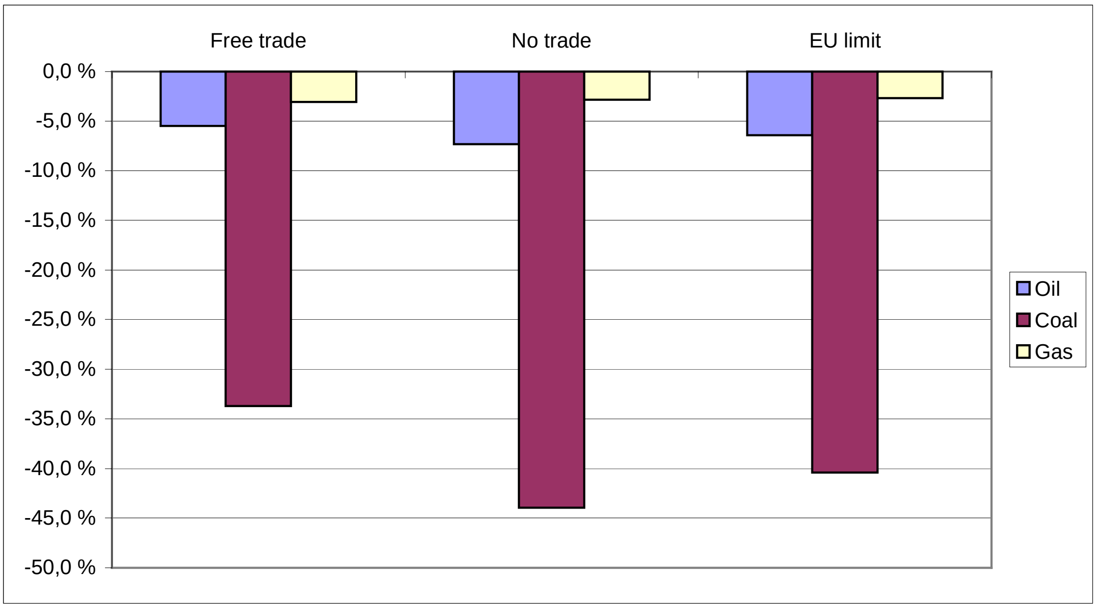

Figure 4: Annex B fuel demand relative to BAU

The relatively large price increase of coal leads to substitution towards oil and gas. While coal demand is projected to decrease by more than 30% under free trade, the reductions in oil and gas demand are 5% and 3%, respectively. Hence, there is also some substitution from oil to gas, but much less than we would expect on the basis of relative carbon intensities. The explanation for the modest substitution effect from oil to gas is that fiscal taxes are far higher on oil than on gas, especially in Europe, but also in North America. Hence, the increase in the price of oil relative to gas is smaller than suggested by the underlying emission factors. As we will come back to later, fiscal taxes on oil are so high in some regions that climate regulations might lead to substitution from gas to oil.

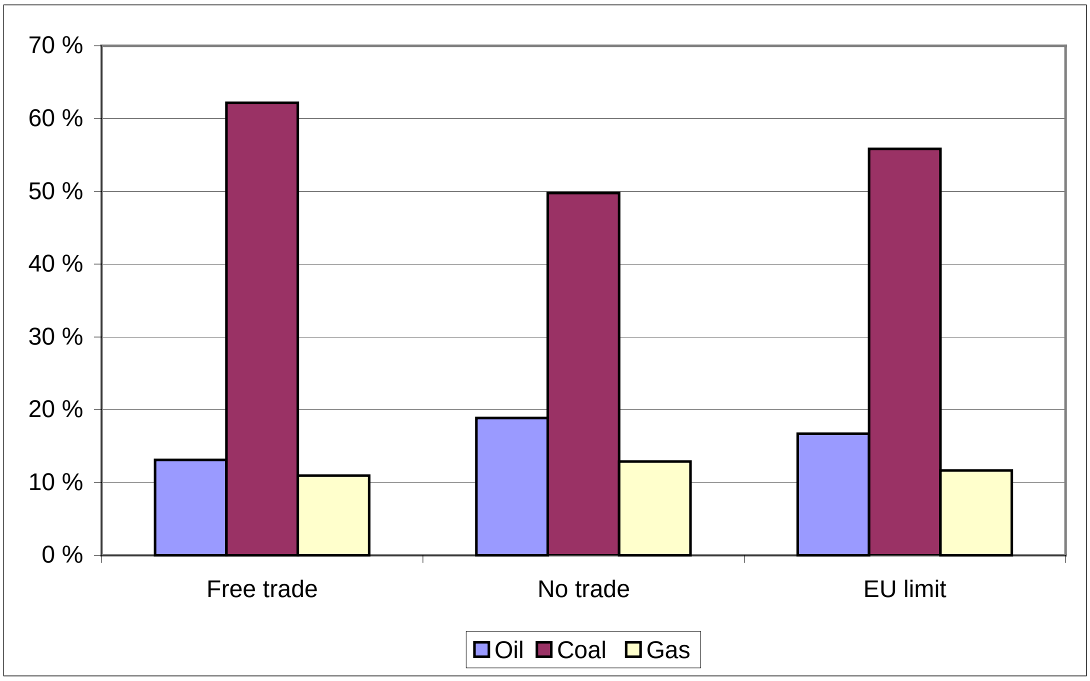

Figure 5: Annex B consumer prices relative to BAU

Consider next the EU trading regime. Generally, restrictions on emission trading lead to even lower demand for coal and oil, but no change in gas demand in the Annex B area. The decrease in coal demand occurs despite a lower average coal price in the Annex B area. The explanation for the price drop is that the domestic permit price in Eastern Europe is zero under the EU regime. Since these countries are large coal consumers, this price fall has a significant impact on the average coal price. However, the resulting increase in coal demand in Eastern Europe is not large enough to compensate for huge demand reductions in other Annex B countries. North America, in particular, experiences a large increase in the coal price and a correspondingly low coal demand (about 55% less than BAU) under the EU trading regime.

The decrease in oil demand goes together with an increase in the average oil price. The reason why the oil price increases while the coal price drops is simply that a larger share of oil consumption takes place in countries which experience an increase in marginal abatement costs as the EU restrictions on emission trading are implemented. Under the EU trade regime, oil demand in North America and Western Europe is 6-7% lower than in BAU.

Gas demand in the Annex B countries is slightly higher with EU trading rules than with free trade (0.4%). However, gas demand is not that stable in all regions. In Eastern Europe, gas demand is 5% higher with EU rules than with free trade due to lower emission costs. In most other Annex B countries, gas demand is reduced relative to free trade. The reduction is quite small in North America (less than 1%) due to substitution towards gas as the costs of emissions increase. In Western Europe, however, gas demand is 4% lower than with free trade. This is a large number compared to the decrease in oil demand of only 1.7%. What these numbers suggest is that as the costs of emission increase from 15 to 23 USD/tCO2, there will be substitution from oil to gas in Western Europe.

Figures 6 and 7 show consumer prices and demand for fuels in Western Europe under the different trading regimes. We observe that both under the EU trading regime and with no emission trading, the consumer price of gas increases relative to the oil price. Hence, there will be substitution from gas to oil. This result conflicts with conventional views of the effect of climate regulations on oil and gas demand. The explanation is that Western European countries have imposed large fiscal taxes on oil products. In fact, the average consumer price of oil is almost 70% higher than the average consumer price of gas per energy unit. But since the CO2 emission factor of oil per energy unit is only 30% higher than for gas, higher costs of CO2 emissions will always reduce the price of oil relative to the gas price.

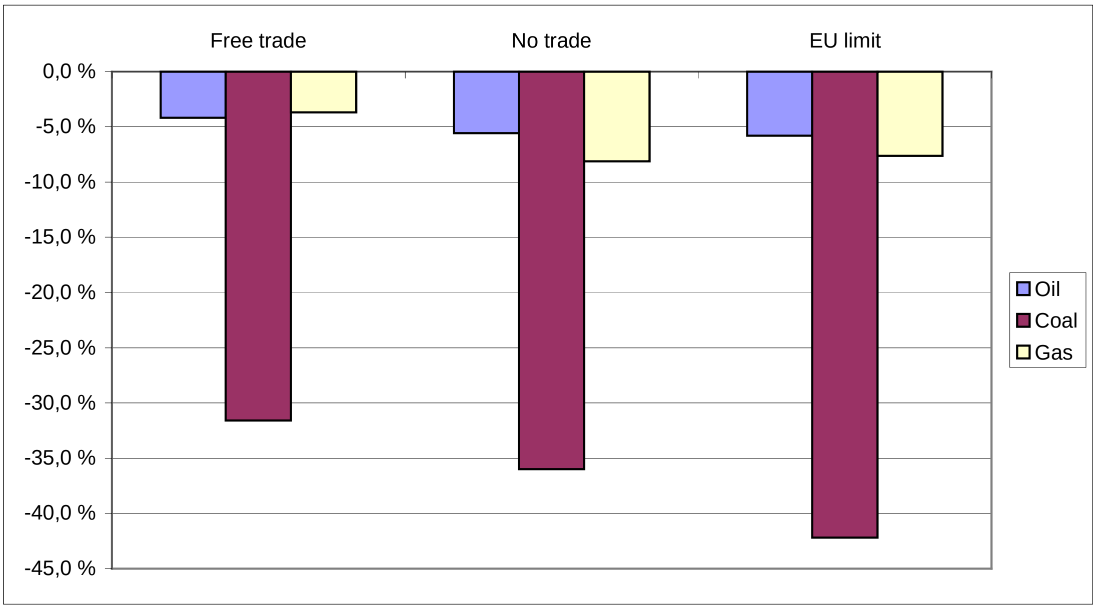

Figure 6: Western Europe fuel demand relative to BAU

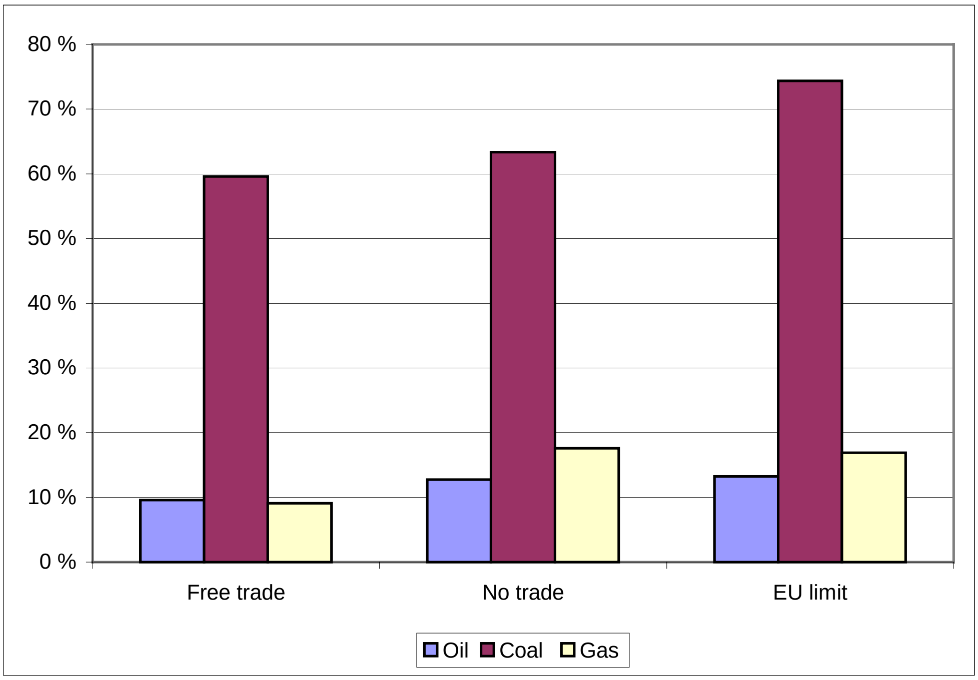

Figure 7: Western Europe consumer prices relative to BAU

This conclusion is of course only valid if there is no change in relative producer prices from one regime to the other. If the producer price of gas is reduced relative to the producer price of oil as the costs of emissions increase, there is still a possibility that the consumer price of gas may fall relative to the oil price. This is indeed what happens under free trade (see discussion about producer prices below).

It might be argued that our analysis overstates the substitution effects from gas to oil in Western Europe because we do not take into account the fact that fiscal taxes on oil typically are differentiated across sectors. High taxes are observed in the transport sector where the substitution possibilities between oil and gas are relatively small, while the taxes are smaller in the industry sector where substitution possibilities are greater. Hence, the relative price of oil might in fact increase in sectors with real opportunities for substitution, thus giving rise to substitution effects in the opposite direction to that predicted by our model. Anyway, our analysis highlights the importance of the level of fiscal taxes for the consequences of climate regulations on fuel markets.

5.4 Global fuel markets and producer prices

The different trading regimes do not have dramatically different impacts on fuel demand in non-Annex B countries. The broad picture is that there is an increase in oil demand of about 1.5% and in coal demand of 3-4%, due to lower world market prices of fossil fuels. There is no carbon leakage in the gas sector due to the regional structure of this market. Restrictions on emission trading turn out to cause more leakage than free emission trading. Nevertheless, trade restrictions reduce global GHG emissions significantly, because the prevention of hot air is far more important than the leakage effects.

Small changes in fuel demand in non-Annex B countries imply that the general pattern observed in the Annex B area is valid at the global level as well (see Figure 8). Relative changes are of course smaller, especially in the coal market where global demand is reduced by 14-18% as compared to 34-44% in the Annex B area. Significant interfuel substitution is observed in the global markets as well, as gas and oil demand is reduced by only 2% and 3-4%, respectively.

Figure 8: World fossil fuel demand relative to BAU

Finally, consider the effect of emission trading regimes on the producer prices of fossil fuels (Figure 9). We observe that even though coal supply is relatively elastic, the producer price of coal is reduced most. This reflects that the high carbon content of coal gives rise to large increases in consumer prices and thus to a sharp reduction in coal demand.

While the producer price of coal falls by 7-9%, the oil price is reduced by only 2-3%. This small reduction in oil prices is partly due to monopolistic behaviour in OPEC. While non-OPEC oil producers are predicted to reduce their supply by 1.6-2.1%, OPEC reduces oil production by 4.8-6.4%. This contraction in production contributes to a modest fall in the oil price.

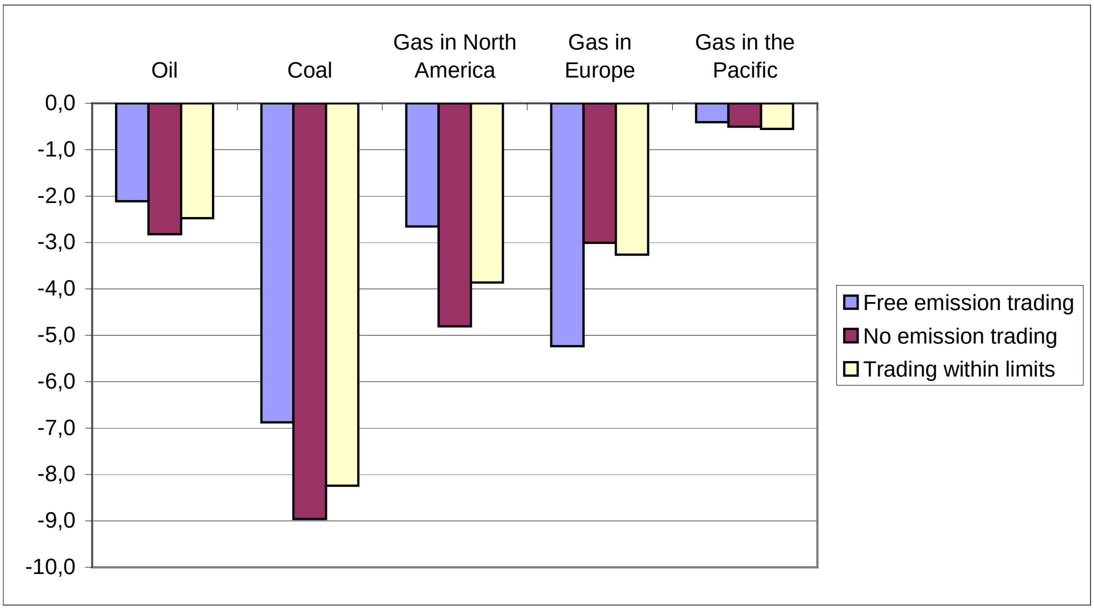

Figure 9: Producer prices relative to BAU (%)

In most cases, producer prices are reduced more when emission trading is restricted than with free trade. The reason is that average costs of emissions in the Annex B area tend to increase as less hot air from Eastern Europe is released into the international permit market. However, the producer price of gas in Europe exhibits a completely different pattern. While the European gas price is reduced by more than 5% with free emission trading, the reduction is only around 3% in the cases with trade restrictions. The explanation is that Europe is a large net exporter of emission permits under the free trade regime. Thus, the European gas demand is relatively low in this case, leading to a downward pressure on gas prices. European oil and coal demand is of course also lower with free trade, but since these are global markets, the price pattern is dominated by the development in other regions. Hence, while European gas producers undoubtedly will benefit from restrictions on emission trading, the consequences are more ambiguous for those who produce oil and coal for the European market. While trade restrictions will increase the European demand, producer prices will at the same time be reduced.

6 Concluding remarks

According to our model simulations, the Kyoto Protocol will lead to surprisingly small reductions in the producer prices of fossil fuels. In particular, the fall in the oil price is small (2-3%). There are several reasons for this result. The strategic behaviour of OPEC on the supply side is one of them. Another reason is that in many countries it is efficient to fulfil most of the Kyoto commitment through reductions in coal consumption. Therefore, the reductions in oil and gas consumption need not be as large as otherwise. However, it is not obvious that such efficient policies will be followed in practice. This raises another interesting question; what will happen to the oil market if the coal sector is not exposed to its full environmental costs? In order to assess the significance of such discrimination, we have run the model under the assumptions that only oil consumption is included in the permit system. We found that the oil price then may fall by up to 20%. Hence, even in this extreme case, the price change in the oil market will be small in comparison with the historic price volatility of this market.

We find that the EU proposal on limits on acquisitions and transfers of emission permits is effective in limiting the amount of hot air released through the international market for emission permits. The EU proposal leads to a sharp increase in the international permit price compared to the free trade equilibrium. In this way, the proposal will also stimulate R&D efforts in many of the Annex B countries, perhaps leading to lower costs of abatement in the long run. Thus, the proposal seems to achieve what it was intended to do.

Whether or not it is possible to implement the EU proposal in practice is, however, a more difficult issue. One big difficulty with the proposal seems to be that the rules for acquiring additional permits through abatement presuppose that information is available about the level of emissions in a hypothetical business-as-usual scenario. But the biggest problem is probably that the EU proposal does not serve the interests of Russia and USA, the main beneficiaries of a free trading regime, and two countries that together may prevent the very ratification of the Kyoto Protocol.

7 References

Berg, E., S. Kverndokk and K.E. Rosendahl (1998) Market Power, International CO_2 Taxation and Oil Wealth, *The Energy Journal 18,* 33-71.

Bernstein, P., W.D. Montgomery, T. Rutherford, and G. Yang (1999) Effects of Restrictions on International Permit Trading: The MS-MRT Model, *The Energy Journal*, special issue.

Bollen, J., A. Gielen, and H. Timmer (1999) Clubs, Ceilings and CDM, *The Energy Journal*, special issue.

ECON (1995) Energy Taxes in the OECD. ECON-report no. 332.

Energy Journal (1999) *The Costs of the Kyoto Protocol: a Multi-Model Evaluation*. Special issue, International Association for Energy Economics.

European Commission (1996) *European Energy to 2020 – a Scenario Approach.* Directorate General for Energy (DG XVII), Brussels.

Golombek, R. and J. Bråten (1994) Incomplete International Climate Agreements. Optimal Carbon Taxes, Market Failures and Welfare Effects, *The Energy Journal 15,* 141-165.

Golombek, R., C. Hagem and M. Hoel (1995) Efficient Incomplete International Climate Agreements. *Resource and Energy Economics 17,* 25-46.

IEA (1995) *Energy Prices and Taxes*. OECD/IEA, Paris.

MacCracken, C., J. Edmonds, S. Kim and R. Sands (1999) Economics of the Kyoto Protocol, *The Energy Journal*, special issue.

Ringius, L., A. Torvanger and B. Holtsmark (1998) Sharing the Costs Equitably: Results from three Burden Sharing Rules Applied to an OECD Climate Protocol, *Energy Policy 26*, 777-793.

Smith, C., S. Hall, and N. Mabey (1995) Econometric modelling of international carbon tax regimes, *Energy Economics* 17, 133-46.

8 Tables

Table 1. Price elasticities of demand in the BAU equilibrium, (1=oil, 2=coal, 3=gas).

	e.11	e.12	e.13	e.21	*e.22*	e.23	e.31	e.32	*e.33*
US	*-0.33*	0.00	0.01	0.01	*-0.66*	0.27	0.02	0.08	*-0.57*
Canada	*-0.47*	0.02	0.13	0.20	*-0.60*	0.10	0.20	0.01	*-0.50*
Austria	*-0.45*	0.01	0.03	0.15	*-0.41*	0.11	0.10	0.03	*-0.48*
Belgium	*-0.63*	0.02	0.12	0.25	*-0.40*	0.00	0.30	0.00	*-0.58*
Denmark	*-0.47*	0.03	0.00	0.16	*-0.68*	0.05	0.00	0.05	*-0.46*
Finland	*-0.58*	0.05	0.04	0.30	*-0.58*	0.13	0.13	0.07	*-0.51*
France	*-0.52*	0.00	0.01	0.01	*-0.37*	0.15	0.04	0.01	*-0.55*
Germany	*-0.58*	0.02	0.02	0.15	*-0.61*	0.04	0.05	0.02	*-0.54*
Greece	*-0.51*	0.03	0.03	0.15	*-0.62*	0.16	0.13	0.16	*-0.70*
Ireland	*-0.58*	0.02	0.02	0.20	*-0.67*	0.08	0.12	0.04	*-0.59*
Italy	*-0.44*	0.00	0.05	0.02	*-0.42*	0.15	0.10	0.01	*-0.60*
Netherlands	*-0.42*	0.00	0.00	0.00	*-0.49*	0.14	0.00	0.01	*-0.51*
Portugal	*-0.58*	0.02	0.04	0.16	*-0.57*	0.00	0.21	0.00	*-0.81*
Spain	*-0.45*	0.00	0.02	0.01	*-0.60*	0.20	0.09	0.05	*-0.69*
Sweden	*-0.56*	0.01	0.00	0.04	*-0.35*	0.08	0.00	0.03	*-0.60*
UK	*-0.39*	0.00	0.01	0.00	*-0.58*	0.08	0.02	0.01	*-0.54*
Norway	*-0.54*	0.00	0.01	0.05	*-0.02*	0.13	0.04	0.01	*-0.54*
RestWest	*-0.58*	0.00	0.00	0.00	*-0.05*	0.00	0.05	0.00	*-0.50*
Czech	*-0.60*	0.08	0.05	0.05	*-0.49*	0.11	0.05	0.15	*-0.50*
Ukraine	*-0.69*	0.03	0.01	0.06	*-0.40*	0.00	0.00	0.00	*-0.53*
Poland	*-0.43*	0.00	0.09	0.00	*-0.57*	0.07	0.09	0.13	*-0.50*
Russia	*-0.80*	0.05	0.00	0.20	*-0.59*	0.20	0.00	0.02	*-0.55*
RestEast	*-0.80*	0.07	0.20	0.20	*-0.59*	0.20	0.09	0.03	*-0.57*
Japan	*-0.65*	0.00	0.08	0.00	*-0.35*	0.00	0.29	0.00	*-0.50*
Australia	*-0.29*	0.03	0.00	0.12	*-0.61*	0.03	0.00	0.01	*-0.52*
NZ	*-0.19*	0.00	0.00	0.00	*-0.29*	0.00	0.00	0.00	*-0.45*
China	*-0.71*	0.00	0.00	0.00	*-0.38*	0.00	0.00	0.00	*-0.58*
Indonesia	*-0.57*	0.00	0.01	0.01	*-0.46*	0.00	0.01	0.00	*-0.60*
India	*-0.54*	0.01	0.00	0.01	*-0.49*	0.06	0.00	0.05	*-0.50*
BRASIL	*-0.52*	0.00	0.02	0.00	*-0.71*	0.27	0.10	0.12	*-0.50*
ROW	*-0.50*	-0.02	0.02	-0.09	*-0.50*	0.19	0.02	0.04	*-0.50*
OPEC	*-0.50*	0.00	0.04	0.20	*-0.50*	0.00	0.03	0.00	*-0.50*

Table 2. Emissions, quotas, hot air, permit trade (*mill. tonnes CO_2-eqv*). Abatement costs (*USD per ton CO_2-eqv*).

	1990 - emissions	BAU 2010	Kyoto quota	Hot air	Permit import		Marginal costs of abatement		
					Free trade	*EU limit**	*No trade*	*Free trade*	*EU limit**
US	5847	7481	5437	-	949	312	27	15	23
Canada	561	697	527	-	105	67	38	15	23
Austria	77	85	67	-	12	7	38	15	23
Belgium	149	153	142	-	-2	-10	13	15	23
Denmark	72	76	57	-	12	8	41	15	23
Finland	65	92	65	-	17	10	36	15	23
France	494	531	494	-	-0	-24	15	15	23
Germany	1214	1149	959	-	18	-85	17	15	23
Greece	97	102	121	19	-35	**-5**	-	15	-
Ireland	57	63	64	1	-10	-15	-	15	23
Italy	530	589	496	-	53	28	33	15	23
Netherlands	219	248	206	-	23	10	30	15	23
Portugal	63	90	81	-	-4	-12	11	15	23
Spain	336	349	386	37	-72	**-18**	-	15	**-**
Sweden	73	108	76	-	27	**16**	72	15	**37**
UK	732	744	640	-	34	-12	21	15	23
Norway	56	66	56	-	5	3	31	15	23
RestWest	57	61	53	-	5	3	34	15	23
Czech	196	149	181	32	-60	**-9**	-	15	**-**
Ukraine	906	803	906	103	-199	**-45**	-	15	**-**
Poland	503	359	472	113	-197	**-24**	-	15	**-**
Russia	3057	2644	3057	412	-736	**-153**	-	15	**-**
Other ec. in transition	617	567	569	2	-73	**-30**	-	15	**7**
Japan	1338	1582	1257	-	159	62	29	15	23
Australia	426	517	461	-	-31	-82	11	15	23
NZ	77	85	77	-	1	-2	18	15	23
China	-	4400	-						
Indonesia	-	377	-						
India	-	1130	-						
Brasil	-	350	-						
ROW	-	4693	-						
OPEC	-	1373	-						

**Bold figures are countries where the trade restrictions bind*