The Kyoto Protocol, the price of CO_2 permits and consequences for the Norwegian petroleum sector*

Lars Lindholt

The Kyoto Protocol sets limits on CO_2 emissions from Annex B countries. The Kyoto targets can be achieved with the help of sufficiently high prices for tradeable emission permits. This study tries to calculate both the international price of emission permits and the Kyoto Protocol's implications for Norway's oil and gas wealth. The results presented here indicate a permit price which rises from about $14-24 per tonne CO_2 in the year 2010 to $36-57 in 2030. Emission limitations will result in reduced demand and lower producer prices for fossil fuels, thereby reducing Norway's oil and gas wealth. An implementation of the Kyoto Protocol may result in a reduction in oil wealth of 15-30 per cent and a reduction in gas wealth of about 20 per cent. Both the level of the permit price and the loss of oil wealth depend on OPEC's market power.

Introduction

The Kyoto Protocol to the Framework Convention on Climate Change (FCCC) was completed in December 1997. The most prominent feature of the Kyoto Protocol is the quantified emissions limitation and reduction commitments of greenhouse gases (GHGs) in Annex B countries[1]. The combined result of individual country targets is estimated to lead to an overall reduction in Annex B parties' GHG emissions by 5.2 per cent from the 1990 levels by the commitment period 2008-2012 (averaged across the period).

The most important GHG is carbon dioxide. The main source of anthropogenic CO_2 emissions is the combustion of fossil fuels, such as oil, natural gas and coal. The point of departure in this study is that emissions of CO_2 shall be reduced by 5.2 per cent in the Annex B area. As CO_2 accounts for most of the GHG emissions in the region, it may be reasonable to assume that the reduction of CO_2 does not deviate substantially from the emission reduction targets for all six GHGs.

Under a system with tradeable permits, CO_2 emissions will be reduced until the cost of further emission reductions is equal to the price of the permits. With a tax system, the emissions are reduced until the cost of further emission reductions is equal to the tax on CO_2 emissions. An efficient international tradeable permit market will result in a permit price which corresponds to the tax required to achieve the same emission reductions. Under certain assumptions, taxes and tradeable permits will therefore produce the same result. In this study, we look at the taxes or permit prices necessary in order to fulfill the Kyoto Protocol commitments, based on different assumptions concerning OPEC's behavior. We will also analyse to what extent emission reductions will result in reduced demand and lower producer prices for oil and gas, and thereby the consequences for Norway's revenues from petroleum resources.

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Petroleum wealth is often defined as the present value of future petroleum rent. Petroleum rent refers to the difference between production revenues and the costs of oil and gas production. Oil and gas extraction normally provides an excess return to capital compared with other economic activity because they are non-renewable resources.

The size of petroleum wealth is naturally dependent on the prices received by those producing oil and gas. If an international CO_2 tax (or a system with tradeable permits) results in a reduction in these prices, petroleum wealth will be reduced. It is therefore interesting to study the potential effects on oil and gas prices of the introduction of a CO_2 tax. At a given point in time a CO_2 tax will usually result in both a lower producer price (crude oil price) and a higher oil price for consumers (end-product price). If the supply of oil or gas varies substantially with a change in prices, the effect on the consumer price will be greatest whereas the price for producers will be affected to a lesser extent. Taxes will in that case have a considerable influence on the volume sold and thus a substantial impact on CO_2

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[1] This is OECD-countries (except Mexico, Korea and Turkey), Russian Federation, Ukraine, Estonia, Latvia, Lithuania, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Liechtenstein and Monaco.

Description of the model

The PETRO model is described in Berg et al. (1996, 1997). Compared with Berg et al., the model has been expanded to include an extra region on the demand side consisting of the Russian Federation, the Ukraine, and the former Central and Eastern European countries. See also Lindholt (1998) for new numerical specifications as a result of this.

The model has a long time horizon and describes international markets for oil, gas and coal. As fossil fuels are finite and non-renewable resources, the extraction of one unit today will reduce the availability of the resource in the future. Producers will therefore demand an excess return to capital for selling the resource today. It is assumed that producers have perfect knowledge, and in the model they therefore take account of not only existing prices and market conditions, but also future movements in these variables. The supply of fossil fuels is a function of both historical facts and expectations concerning the future. Producers attempt to extract their resources at a rate which results in maximum petroleum wealth. Consumer demand, on the other hand, is assumed to depend only on income and prices in each period.

There are four demand regions in the model: OECD-Europe, Rest of OECD, a region consisting of the former Central and Eastern European countries, the Russian Federation and the Ukraine and a region consisting of the rest of the world (Non-Annex B). The model specifies three fossil fuels: oil, gas and coal. The demand for a fossil fuel declines with the price of this fuel and increases with the price of the other two fuels. Demand rises over time due to economic growth, which is determined exogenously for each region. Annual GDP growth is highest in Non-Annex B. A rise in income outside the OECD area results in a slightly higher increase in demand than in the OECD. A carbon-free, alternative energy source (backstop technology) exists at a specific cost at any given time. Due to technological progress, this cost is reduced over time. There will be no consumer demand for a fossil fuel if the price of the fuel is higher than the price of the alternative energy source. It is available in unlimited quantities and is a perfect substitute for oil.

The relevant consumer price of a fuel in a region is the sum of the producer price, delivery costs and existing taxes and subsidies. The CO_2 tax comes in addition to delivery costs and existing taxes. The CO_2 taxes are imposed on the consumption of fossil fuels and vary with the carbon content of the fuel.

The price of the alternative energy source less these taxes and delivery costs represents a ceiling for the producer price of each fuel at any given time, and will in the following be referred to as the *maximum producer price*.

The oil market is divided into two groups of producers: OPEC, which has low costs, and a fringe of high-cost countries. In order to examine the importance of market power, two different situations are studied. In the first model version, OPEC acts as a cartel and takes into account that their own production influences prices. They consider production from the fringe as given. The fringe is a competitive producer, deciding production on the basis of the given price. In the second version, the entire oil market is a competitive market. The prices and volumes which satisfy the maximization problem of both types of producers are the equilibrium solution. Initial unit costs are set equal to $3.30 and $10.90 per barrel of oil for OPEC and the fringe, respectively. The unit costs of producers are assumed to rise as oil resources are gradually depleted. Moreover, technological progress in the extraction of oil is assumed.

The market for natural gas is divided into three regions: OECD-Europe, Rest of OECD, and Non-OECD. Because gas is costly to transport, no trade takes place between the regions. The producers' cost structure is modelled in the same way as for the oil market. All three regions are modelled as competitive markets. Since we are studying the consequences for Norway, we focus on the results for OECD-Europe. Initial unit costs are set equal to $7.00 per barrel of oil equivalents for OECD-Europe.

The coal market is modelled as a global competitive market. Due to substantial international coal reserves, extraction today is not assumed to increase costs at a later time. Producers will therefore focus on each individual period. Technological progress result in lower costs over time. Initial unit costs are set equal to $8.80 per barrel of oil equivalents.

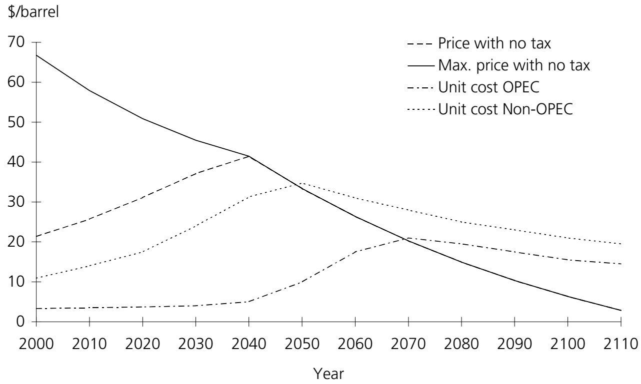
The model extends to 2130 with periods of 10 years. For example, the result for the year 2010 can be interpreted as an average for the period 2005-2015.

emissions. As fossil fuels are non-renewable resources, producers will take into account that extraction today will reduce the availability of the resource in the future. The distribution of the burden between consumers and producers may therefore change over time.

A model for oil, natural gas and coal markets (PETRO model) is used in this study in order to analyze the effect of CO_2 taxes on the supply of and demand for fossil fuels, thereby allowing us to assess the impact on Norway's oil and gas wealth. The PETRO model is a dynamic model which takes into account (expectations concerning) future market conditions.

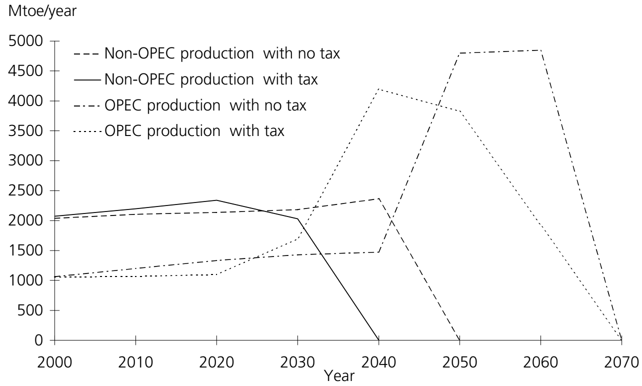
The study is a follow up of Berg et al. (1996 and 1997), which looks at how a CO_2 tax of $10 per barrel of oil equivalents influences the petroleum wealth of oil and gas producers. The PETRO model has now been expanded to include an additional region on the demand side in order to study the Annex B area. In addition, this study looks at the CO_2 taxes (permit prices) which are necessary to fulfill the specified emission reduction commitments *over time*. The

Figure 1. Oil producer price and unit costs with OPEC as a cartel



Source: Statistics Norway.

Figure 2. Oil production with and without Kyoto targets, and with OPEC as a cartel



Source: Statistics Norway.

main focus will be on the oil market, but the gas market in OECD-Europe will also be discussed. The model is described in a text box.

Even though developing countries were not subject to any commitments in the Kyoto Protocol, these countries may be facing emission reduction requirements at a later stage. We will therefore also look at a scenario with global emission targets. In the scenario involving additional emission reduction targets, it is assumed that the entire world shall achieve the Kyoto targets by reducing emissions by 5.2 per cent in 2010. Furthermore, global emissions shall be 20 per cent lower than the 1990 level in the year 2020. In both scenarios it is assumed that emissions are held constant when the targets have been reached.

We will first look at the reference scenario with no CO_2 tax in the model version where OPEC acts as a cartel. We will then look at the effects of an implementation of the Kyoto Protocol before examining the consequences of a more extensive climate treaty. This will be followed by a discussion of the effect of perfect competition in the oil market. This is done because the assumption concerning the situation in the oil market will influence both the level of the CO_2 permit price and the loss of oil wealth as a result of a climate treaty. Due to differing carbon content, a tax of $1 per barrel of oil equivalents will correspond to $0.71 per barrel of oil equivalents for gas and $1.24 per barrel of oil equivalents for coal.[2]

Reference scenario with OPEC as a cartel

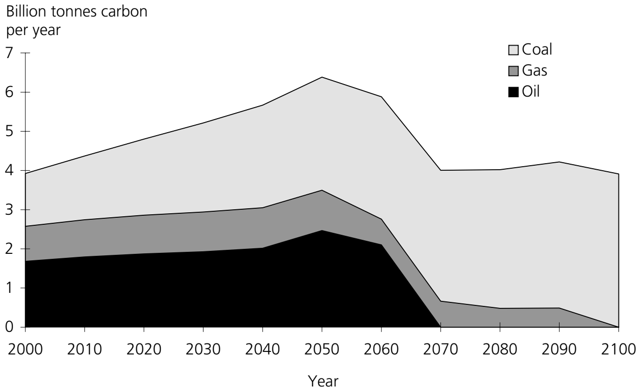
Figure 1 shows the model's projections of movements in the oil price and unit costs for OPEC and the fringe, in the scenario without emission reduction targets and where OPEC acts as a cartel. The oil price in the year 2000 is about $21 per barrel. This is considerably higher than the current oil price. In the current situation, it cannot be said that OPEC is acting as a coherent cartel where participants have coinciding interests. In reality, members of the cartel will be less willing to reduce production to achieve a higher price. Moreover, the model provides a long-term price path, entailing that short-term changes are not captured. The current low price of oil partly reflects the prevailing market, with lower demand for oil due to the crisis in Asia.

The price rises from about $21 per barrel in the first period until it reaches a peak of $41 in 2040. Starting with this period, the producer price is at its maximum level, determined by the price of the alternative energy source, existing taxes and delivery costs. After this time, the producer price is reduced due to technological progress for the alternative, carbon-free energy source. The figure shows that unit costs increase faster in the fringe. The reason is that they produce more than the cartel in the first periods while, at the same time, OPEC has greater resources which can be extracted at lower costs.

Figure 2 shows production in the fringe and OPEC prior to the introduction of taxes. The fringe produces approximately twice as much as the cartel in the first period. Because higher production in a period increases costs in the future, both OPEC and the fringe have incentives to limit production. The cartel has market power and takes into account that higher production results in a lower price in the same period. This is the reason why OPEC produces less than the fringe, even though costs are lower. The fringe produces the first 50 years before unit costs reach the maximum producer price between 2040 and 2050. Further extraction is then no longer profitable. OPEC also increases production somewhat in the first periods before the cartel takes over the entire market. The cartel stops extracting oil in 2070 when it is no longer profitable for the cartel to produce oil, as the alternative energy source has become sufficiently low.

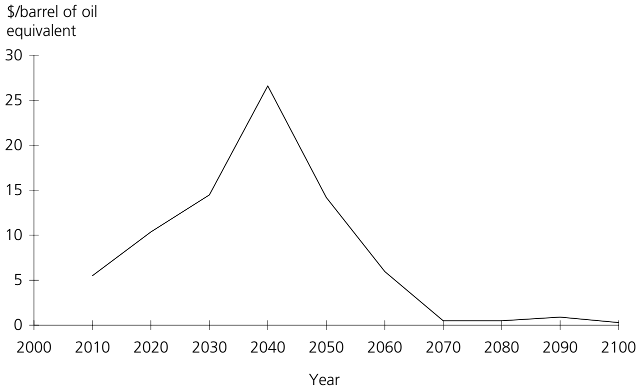
2 In the scenario with Kyoto targets, the tax is imposed on consumption *outside* Annex B in 2040. This must be done in the model for technical reasons. It may nevertheless be realistic, as it is likely that emission reduction targets will gradually also apply to the rest of the world.

Figure 3. Carbon emissions from oil, gas and coal in Annex B, with OPEC as a cartel



Source: Statistics Norway.

Figure 4. Time-path of a CO_2 tax with Kyoto targets in Annex B and OPEC as a cartel



Source: Statistics Norway.

Developments in gas markets vary between regions. The producer price of gas in OECD-Europe rises from a little less than $10 per barrel of oil equivalents until it reaches its maximum level of $24 in 2070 in the reference scenario with no taxes. Production is relatively stable until gas production is no longer profitable in 2080, and the alternative energy source takes over. The year 2050 is the last year with production in Rest of OECD, while gas is produced and consumed until 2090 in Non-OECD. Production extends over a longer period here because the region has considerable gas resources with lower extraction costs and taxes.

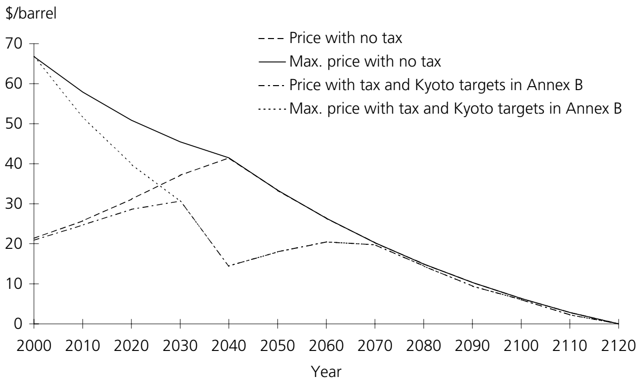
Coal is produced and consumed throughout the whole period and will not be replaced by the alternative energy source due to low prices and low existing taxes on coal.

Figure 3 shows carbon emissions in Annex B in the reference scenario with no taxes when OPEC operates as a cartel. Emissions rise from 3.9 billion tonnes of carbon a year in 2000 and reach a peak of 6.4 billion in 2050. Carbon emissions from coal more than double in the period to 2050. Oil consumption will gradually be replaced by the carbon-free, alternative energy source from 2050 to 2070 because the cost of the alternative energy source falls over time. Total emissions will therefore be reduced in this period. Inasmuch as the consumption of coal increases somewhat after this time, emissions rise slightly until the alternative energy source has displaced gas in 2100.

Effects of an implementation of the Kyoto Protocol

In order to achieve the Kyoto emission reduction targets, Annex B countries must reduce emissions to 3.77 billion tonnes of carbon from 2010. It is presupposed that emissions are kept at this level in subsequent periods. The tax is now imposed on the consumption of fossil fuels in each period, given the emission reduction targets in the Kyoto Protocol. Because the tax level in a period also influences

Figure 5. Oil producer price with and without Kyoto targets, and with OPEC as a cartel



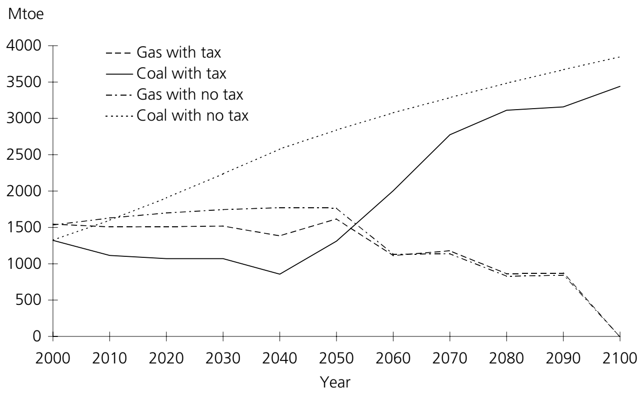
Source: Statistics Norway.

emissions in other periods, the taxes must be introduced simultaneously in the model. In order to limit steadily rising emissions in the first periods, as shown in figure 3, it seems reasonable that the tax will first rise. As emissions gradually decline, it also seems reasonable to assume that taxes may be reduced. Figure 4 shows the development in the CO_2 tax per barrel of oil equivalents over time, which is necessary if Annex B countries are to fulfill the commitments in the Kyoto Protocol. It is assumed that the tax is first introduced in 2010.[3] When OPEC functions as a cartel, the tax must increase from about $6 in the year 2010 to $15 in 2030, thereafter rising to a peak level of $27 in the year 2040. The tax then declines slightly to just under $1 in 2070. It is then no longer profitable to produce oil because the carbon-free energy source has become very cheap.

Figure 5 shows changes in the producer price after the tax has been introduced. Since the maximum producer price is the price of the alternative energy source less taxes, the maximum producer price is reduced by the entire tax in each period. We see that the effect on the producer price is minimal at the beginning. In the year 2000 the price is

3 If the tax was introduced in 2000, this would have resulted in a marginally lower tax level in the first two periods.

Figure 6. Gas and coal consumption in Annex B



Source: Statistics Norway.

reduced marginally because the tax is not introduced until 2010. In the year 2010 the producer price is reduced by only $1.10. The tax is $6.20, which means that the consumer price rises by $5.10. Consumers will thus bear almost the entire tax burden at the beginning. The introduction of the tax entails that the oil price reaches its peak level in 2030, one period earlier than in the scenario with no tax. The price is then $6.50 lower than it would have been without a tax. It is not until 2040 that the producer price is reduced by the entire tax of $27. This means that in the first 40 years the consumer price shows the greatest change as a result of the tax, whereas it is the producers who bear the entire tax burden after this time. The reason for this is found on the supply side in the model, which we will now examine more closely.

Figure 2 in the previous section shows how the production profiles in OPEC and the fringe change as a result of the CO_2 tax. OPEC reduces production by 11 per cent in 2010 and by 18 per cent in 2020. The cartel reduces production to maintain oil prices at about the same level which prevailed before the tax was introduced. The fringe consider the oil price as given. The fringe finds it optimal to increase production in 2000, 2010 and 2020 when the reduction in the producer price is minimal. When the price is reduced by the entire tax in 2040, it is no longer profitable for the fringe to produce oil. Since the oil price is lower than the original path over all time periods, the fringe's accumulated production is reduced by 20 per cent. Oil wealth outside OPEC is reduced by about 15 per cent (as measured by the present value of future petroleum rent). Beginning in 2040 OPEC satisfies all demand at the maximum producer price as long as the cartel's unit costs do not exceed this. In 2070 the renewable, alternative energy source has become cheaper than oil, and it is not profitable for OPEC to produce oil.

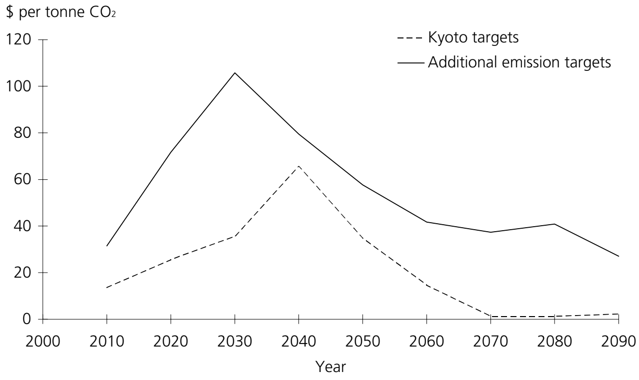
Even after the introduction of the tax, oil consumption rises slightly in Annex B over time up to 2040, as is the case with global oil production. We see in figure 6 that it is particularly the consumption of coal which is reduced throughout this period after the tax has been introduced. In 2020, coal consumption has already been reduced by half in relation to the reference scenario. Coal contains more carbon so that the tax in relative terms is higher than for gas and oil. The tax also results in a slight reduction in the consumption of gas the first decades. The reason is that the tax results in relatively higher prices for gas and especially coal in relation to oil because the oil price is higher per barrel of oil equivalents. This occurs for natural gas even though it is a cleaner fuel, and is ascribable to the fact that it is movements in relative and not absolute prices which influence the choice of energy source. The demand for oil will therefore be relatively higher in the first periods. When the tax reaches a peak in 2040, figure 2 showed that the fringe stops producing oil, and the cartel's oil production starts to decline. Inasmuch as production falls until it comes to a complete halt in 2070, the tax is also reduced in this period. Figure 6 shows that from 2050 coal consumption begins to increase in line with the decline in the CO_2 tax. Gas consumption in Annex B moves along approximately the same path as in the reference scenario (with no tax) beginning in 2050. Gas consumption falls gradually in this period because gas production becomes unprofitable and is phased out in the three production regions.

A key point is that if only the OECD had been subject to emission reduction targets in Kyoto, the taxes (and the permit price) would initially have to bee higher. If an efficient tradeable permit market is assumed, the model shows that the OECD can actually increase emissions by 2.4 per cent from 1990 to 2010 due to substantial emission reductions in Russian Federation, the Ukraine and the former Eastern European countries. As a result of the collapse and dissolution of the Soviet Union at the beginning of the 1990s, emissions from this category of Annex B were about 26 per cent lower in 1994 than in 1990. These countries have thus been allocated commitments they will be able to fulfill by a wide margin without having to implement measures (with this phenomenon referred to as "hot air").

Effects in natural gas markets

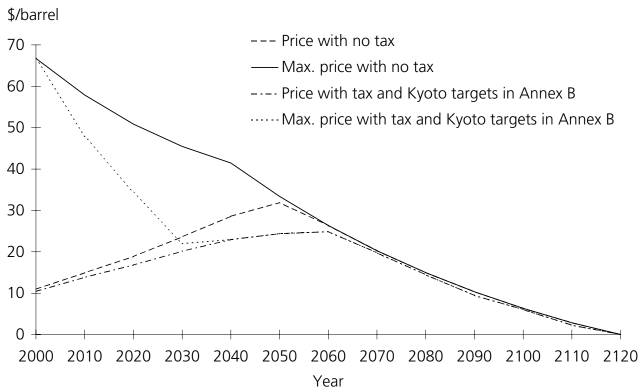
When taxes are introduced, the producer price is reduced slightly over the entire horizon in the three regions which produce gas. As in the oil market, however, most of the burden falls on consumers in the first periods. Total production is reduced by 11 per cent in OECD-Europe, 6 per cent in Rest of OECD and 5 per cent in Non-OECD. As noted earlier, the reason for lower production following the introduction of the CO_2 tax is that the tax results in relatively higher prices for gas than for oil because the oil price (including other taxes) is higher per barrel of oil equivalents. This occurs even though gas is a cleaner fuel than oil. The level of extraction in OECD-Europe is reduced in the first five periods, but production is higher in 2060-2070 compared with the reference scenario with no CO_2 tax because the CO_2 tax then is low. Gas wealth in OECD-Europe is reduced by about 18 per cent following the introduction of the CO_2 tax. The reduction in Norway's oil and gas wealth is summarized in figure 11. It is assumed that the relative reduction in Norway's oil and gas wealth is

Figure 7. Time-path of a CO_2 permit price with OPEC as a cartel



Source: Statistics Norway.

Figure 8. Oil producer price with and without Kyoto targets, and competitive oil market



Source: Statistics Norway.

equal to the percentage decline in the fringe's oil wealth and OECD-Europe's gas wealth, respectively.

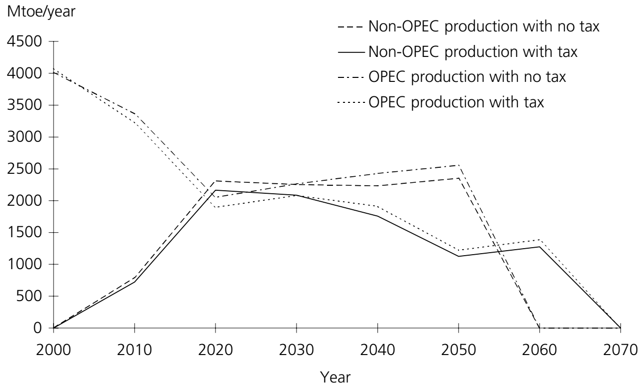
Consequences of additional emission reduction targets

Global emissions rise from 5.9 billion tonnes of carbon in 1990 and reach a peak level in the reference scenario (with no CO_2 tax) of 12.1 billion in 2060. Emissions also rise more rapidly outside Annex B due to stronger economic growth and because a given income growth in this region results in higher demand for fossil fuels. In particular, the consumption of coal rises faster outside Annex B.

Additional emission reduction targets refer to a situation where the entire world first reduces emissions by 5.2 per cent in 2010 compared with the level in 1990, and then reduces them further by 20 per cent in 2020 compared with 1990. The global tax is imposed on consumption from 2010. Figure 7 shows the tax converted to a CO_2 permit price. With an efficient international tradeable permit market, the permit price will correspond to the tax necessary to achieve the same reduction in emissions. A CO_2 tax of $1 per barrel of oil with an efficient international tradeable permit market will be equivalent to about $2.5 per tonne CO_2.

As a result of additional emission reduction targets, the tax, and thus the CO_2 permit price must in all periods be higher than the tax level in the case with commitments only for Annex B. This is particularly due to the much higher consumption of coal inasmuch as we are considering global consumption. The tax now rises sharply from $10 per barrel of oil equivalents in 2010 and up to $40.70 in 2030. For OPEC, it is now profitable to reduce production only in the first period in order to maintain oil prices, compared with the situation with Kyoto targets in figure 2. The high tax gradually results in a dramatic decline in the producer price, entailing that it is not profitable for the fringe to produce more than in the first two periods. With additional emission reduction targets, the fringe's oil wealth is reduced as much as 42 per cent. With regard to the gas market

Figure 9. Oil production with and without Kyoto targets, and competitive oil market



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in OECD-Europe, the producer price is reduced further compared with the case with Kyoto targets, and production is slightly lower. Gas wealth in OECD-Europe is now reduced by 34 per cent, compared with 18 per cent with emission reduction commitments applying only to Annex B. The wealth effects for Norway are summarized in figure 11.

Perfect competition in the oil market

This section will particularly focus on the oil market because the results in natural gas markets are approximately the same as in the cartel model.

If OPEC is dissolved and the oil market becomes a competitive market, the model-based calculations show that this will have major consequences for prices and production, as shown in figures 8 and 9. OPEC no longer restrains production in order to maintain oil prices. They now quadruple their production in the first period, bringing the initial oil price down to about $11 in the year 2000, i.e. at about the same level as the current oil price. This does not necessarily mean that the current oil market more closely resembles a competitive market than a market where

OPEC functions as an effective cartel. Short-term phenomena with reduced demand for a small period may have resulted in the current low oil prices. Such phenomena will not be captured in the model's long-term price paths. Moreover, it is a sign of cartel behavior that OPEC has carried out two relatively large production cuts in 1998 with the aim of increasing oil prices. The scenario with perfect competition is therefore intended to be a hypothetical case. The discussion of who shall reduce production may, for example, result in such considerable strains that the various member countries completely disregard the production quotas.

The low oil price entails that high-cost countries find it optimal to postpone production until a later period, and it is not until the third period that these countries achieve the same production level that they have when OPEC operates as a cartel. Due to high production initially, OPEC halts production one period earlier, while the fringe produces one period longer compared with the cartel case. The dissolution of OPEC has major negative consequences for the other producer countries. The fringe's oil wealth is reduced as much as 71 per cent.

The Kyoto targets for Annex B and the introduction of a tax in a situation with perfect competition result in a further reduction in the producer price. We see from figure 8 that the impact is greater up to 2040 than in a situation with OPEC acting as a cartel. This is because OPEC countries do not find it optimal to limit their production to the same extent. A larger burden therefore falls on producers in high-cost countries, and the reduction in the fringe's oil wealth as a result of the tax is greater, about 30 per cent. The wealth effects for Norway are summarized in figure 11. All in all, the combination of perfect competition and a CO_2 tax results in a reduction of as much as 80 per cent in the fringe's oil wealth compared with the cartel situation without a tax. Figure 9 also shows that it is profitable for both OPEC and the fringe to postpone oil production so that they produce one period longer than in the case without a tax. The reason is that the CO_2 tax is low in 2060 and 2070 and the producer price only shows a slight reduction.

Global oil production is thus higher in the case with perfect competition in the first periods. It also appears that oil *consumption* in Annex B is higher than when OPEC acts as a cartel. With perfect competition, the initial oil consumption is now almost 30 per cent higher. As a result, the tax in Annex B must be higher in the period up to 2030 in the case with perfect competition. Figure 10 shows movements in the permit price which correspond to this tax, and thus assumes an efficient international tradeable permit market. The permit price rises up to 2030, and in this period it is particularly coal consumption which declines. After 2030 oil consumption in Annex B falls, and the permit price declines. Emissions, and thereby the permit price, are the same in the case with perfect competition as with OPEC operating as a cartel when oil production ceases in 2070.

Figure 10. Time-path of a CO_2 permit price with Kyoto targets and competitive oil market

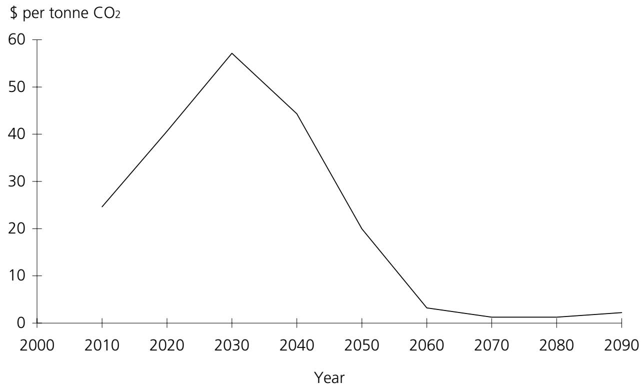

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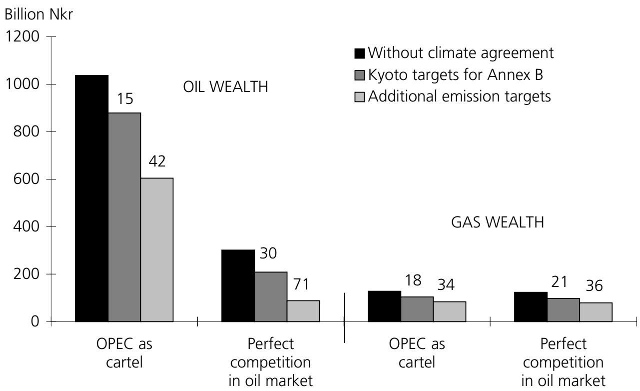
Figure 7 shows changes in the CO_2 permit price in the case with Kyoto targets and OPEC as a cartel. When this is compared with the case with the competitive market situation above, it may generally be said that irrespective of the assumption concerning OPEC's behavior, the permit price will rise from about $14-24 per tonne CO_2 in 2010 to about $36-57 in 2030. The Ministry of the Environment (1998) of Norway refers to calculations of permit prices from a number of institutions both in Norway and other countries, including CICERO and the OECD. Using different assumptions, the price estimates vary from $7-27 per tonne CO_2 in 2010, and an average estimate of $17 per tonne is selected for the period 2008-2012. This estimate is thus within the price interval provided by the model here, but in addition this study points to possible development paths after 2010.

As in the case with a cartel situation, *additional emission reduction targets* entail that the tax, and thus the permit price, must now be higher in all periods than the tax level in the case with the Kyoto targets. The producer price of oil is now considerably lower during the period in which the fringe produces compared with the situation with perfect competition and emission targets for Annex B in figure 8. The fringe's production is therefore also reduced through the entire period and is 36 per cent lower than in the case without emission reduction commitments. As a result, the fringe's oil wealth is now reduced as much as 71 per cent, against 30 per cent with the current Kyoto targets. The effects in the gas market show little change compared with the cartel case and additional emission reduction targets.

Summary of wealth effects for Norway

The results in the model have thus far referred to the fringe and OECD-Europe as a whole. The relative loss of oil wealth is now assumed to be the same for Norway as for the fringe as a whole. The figure for oil wealth in figure 11 is obtained by using the proportion of the fringe's oil wealth in the model which corresponds to Norway's share of oil reserves in the fringe in 1994. Similarly, the relative loss of gas wealth is assumed to be the same for Norway as

Figure 11. Norway's oil and gas wealth based on different emission targets. The figures above the columns are the percentage decline from the reference scenario without climate treaty



Kilde: Statistisk sentralbyrå.

for OECD-Europe as a whole. Gas wealth is estimated as a percentage of the gas wealth in OECD-Europe which corresponds to Norway's share of the respective gas reserves in the region in 1994.

The Ministry of Finance (1997) estimates that Norway's total petroleum wealth in 1997 amounted to NKr 750 billion (after deducting the value of the sector's real capital), i.e. $100 billion. The Ministry of Finance applies a constant oil price of Nkr 115, or about $15. The estimate for total petroleum wealth in the case with OPEC as a cartel and without a climate treaty is higher in this study, partly because the oil price rises somewhat. The estimate for gas wealth is more uncertain, because the gas market is modelled more simply.

It is important to point out that both the case with a unified cartel and perfect competition are constructed market situations. It may be said that the current oil market shares some features with both these cases.

Uncertainty and sensitivity analyses

A characteristic feature of markets for fossil fuels is that there is imperfect competition. Since natural gas markets are modelled as competitive markets, there is greater uncertainty associated with the results here. Greater criticism may perhaps be made of the description of the coal market, which is also modelled as a competitive market with a very simple cost function. It is uncertain how this affects the results.

There is considerable uncertainty associated with the value of several parameters. Some sensitivity analyses have been carried out to examine the degree to which the results depend on special numerical assumptions. The results apply to the oil market in the cartel case.

More rapid *technological progress* in the fringe will result in higher production. However, inasmuch as total production and thereby emission also increase, the CO_2 tax must be higher if the emission targets are to be achieved. The result will be approximately the same relative reduction in oil wealth even though it has risen in nominal terms compared with situations with less rapid technological progress. Similar effects are seen the higher the price of the *alternative energy source* and the less rapid the technological progress is for this energy source. The conclusion is that if various factors result in higher production both in the fringe and as a whole, taxes will then have to be set at a higher level and the relative impact on oil wealth shows little change. On the other hand, the tax and permit price of CO_2 will rise so that the size of these is more sensitive to changes in such conditions.

Conclusion

This study shows that in order to achieve the emission reduction targets for Annex B parties in the Kyoto Protocol, international CO_2 taxes must rise in the 30-40 years after the turn of the millennium. This is necessary in order to reduce in particular a steadily rising consumption of coal in Annex B. If the rest of the world were to be subject to additional emission reduction commitments, the result is higher taxes. Irrespective of the emission reduction targets, taxes will have to be reduced substantially when global oil production begins to fall because an alternative carbon-free energy source replaces oil.

The results for the oil market show that in the first periods it is consumers who bear the greatest burden of the introduction of the CO_2 tax if OPEC functions as a cartel. The reason is that OPEC reduces production to maintain oil prices, entailing that the reduction in the producer price is not as great as in the first periods. With an efficient international tradeable permit market, the results indicate a CO_2 permit price which rises from $14 per tonne in 2010 to $36 in 2030. If the oil market becomes competitive, oil production will be higher in the first periods, resulting in a higher permit price in order to achieve a given emission target. In addition, the fall in the producer price is greater under perfect competition because the producers consider the oil price as given. The results indicate that the permit price in this case will rise from $24 per tonne CO_2 in 2010 to $57 in 2030.

The current oil market cannot be fully described as a situation with a cartel having coinciding interests or as a competitive market where all producers consider the price as given. The current situation can be said to share features from both market descriptions. If OPEC acts as a cartel, the simulations show that the Kyoto commitments result in a reduction in Norway's oil wealth of about 15 per cent. As an oil producer, Norway will lose considerably more if OPEC is dissolved than if the Kyoto Protocol is fulfilled. If OPEC were to be dissolved, or the various member countries begin to disregard their production quotas, Norway might lose about 70 per cent of its oil wealth in the case *with no* emission targets. If the oil market becomes a competitive market, the achievement of the Kyoto targets might reduce the oil wealth by 30 per cent after taxes are introduced. The reason is that in this market the producer price of oil will fall by a greater margin, thereby resulting in a greater reduction in oil wealth. Even though the relative loss as a result of the Kyoto targets is greater than in the case with a cartel, the loss in nominal terms is less because the fringe's initial wealth is already considerably lower in the competitive market case. The combination of perfect competition and the Kyoto commitments may reduce the wealth by almost 80 per cent. The results suggest that Norway loses about 20 per cent of its gas wealth with the achievement of the Kyoto Protocol, irrespective of OPEC's behavior.

The results are amplified if the emission reduction targets set out in the Kyoto Protocol were to be applied globally and with additional emission reduction commitments. This would result in higher CO_2 permit prices and a greater reduction in Norway's oil and gas wealth.

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