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Simulating the Danish Electricity Reform

Jens Hauch

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Simulating the Danish Electricity Reform

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Working Paper 1999:3

Abstract:
A reform of the Danish electricity sector was decided in the spring 1999. One main purpose of the reform was to increase the efficiency in the electricity sector by introducing competition where possible and to regulate where necessary. Another main purpose was to ensure reductions in emissions of CO_2 from electricity production. In this paper I carry out an analysis that reveals several weaknesses in the reform. Some elements are either not necessary, other are not sufficient for achieving the targets. These elements create a risk of inefficiencies and that the purposes of the reform will not be met. Simulations of the reform with the Elephant model show that some of the less appealing elements will indeed imply inefficiencies, especially in achieving the environmental target. Several elements of the reform have not yet been developed in details. These details can have a large influence on the result.

Keywords: Electricity markets, Kyoto, environmental economics, Nordic, green certificates.

JEL: D4, Q2, Q4.

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1. Introduction [1]

Efficient production of electricity is a great challenge to policy makers. If the whole electricity production is left to the market mechanism, the optimal situation seen from the society's point of view is not likely to occur, see e.g. Joskow (1997). One reason is that there exist several natural monopolies in electricity production, e.g. in grid services. If such natural monopolies are not regulated, the equilibrium price will be inoptimally high. Another reason is that electricity production in many cases causes emissions of pollutants, e.g. CO_2. If these emissions are not regulated, the damages from pollution will not be internalised as a cost of electricity production and emissions can be higher than the society considers optimal.

These problems have in Denmark traditionally been solved by a strict regulation of all electricty production, transmission and distribution, i.e. also areas where a strict regulation is not necessary, see Olsen (1998). A non profit principle has been the dominating type of regulation. This does not give the companies incentives to produce at least costs, i.e. inefficiency can arise. Analyses of this inefficiency suggests that distribution costs could be reduced significantly if distribution was efficient, see PA Consulting Group (1999) and Hougaard (1994).

Several countries have in the nineties succeeded in introducing a regulation of the electricity sector where competition is created where possible, while regulation has been maintained where necessary. There exists a large literature on how this is done optimally see, e.g. Olsen (1998). Pioneering countries in liberalising the electricity were Norway and Great Britain, see, e.g. Eikland (1998), Newbery (1998), OECD (1996) or Green and McDaniel (1998). More recently Sweden and Finland have liberalised their electricity sectors, see Midttun and Summerton (1998). EU has decided upon a directive that introduces some competition at the electricity markets in the member countries.[2] The Danish parliament has most recently agreed upon an electricity reform that introduces competition in large shares of the market. One aim of this paper is to analyse whether the reform

1) The views posed in this paper are not necessarily shared by the Chairmanship of the Danish Economic Council. The author would like to thank Jan V. Hansen, Peter Brixen, Jørgen Birk Mortensen and several others for many helpful comments and clarifying discussions. The author is however solely responsible for the paper and problems and mistakes it may contain. Financial support form Nordic Energy Research Programme is greatly acknowledged.

2) See "The Transit of Electricity Through Transmission Grids" (90/547/EEC) and "A Community Procedure to Improve the Transparency of Gas and Electricity Prices Charged to Industrial End-users" (90/377/EEC).

corresponds to economic theory for optimal regulation of the electricity market. Another aim is to simulate the future consequences of the electricity reform using an empirical model including the Nordic countries.

In Section 2, a short discussion of the electricity reform is given. In Section 3, simulations of the future Nordic electricity market are carried out. In Section 4, the paper is concluded.

2. A Discussion of Elements of the Reform

The Danish electricity reform changes the electricity sector from being highly regulated to a situation with widely competition. Several institutional elements are included in the reform to ensure that competition will arise, that the liberalised market does not imply higher CO_2 emissions than the official targets[3] and that there is an increased public revenue from the changes. The reform text can be found in Miljø- og energiministeriet (1999) and further official information can be found in Energistyrelsen (1999). I will here only touch the elements of the reform briefly.

After a gradual introduction competition will be free in 2003. Electricity companies' activities will be split into two groups competitive activities and activities with natural monopolies that will be regulated to behave optimally.

A separate target for CO_2 emissions from electricity production has been decided. The target will be achieved using a system of tradeable emission permits for electricity producers. The target has been decided for the years 2000-2003 and can be seen in Figure 1. Companies that emit more than their possession of emission permits entitle them to will be fined by 40 DKK per ton CO_2. Banking of unused permits to a later year is possible. The fine for exceeding the emission limit on electricity production seems low compared with the marginal costs of emission reduction found in several studies, see, e.g. Hauch (1999) or Bohm (1997). It is therefore possible that electricity producers will pay the fine instead of reducing emissions, i.e. they will see the fine as an emission tax.

The damages from CO_2 are independent of the source of the emission. An emission target is therefore most efficiently formulated as a common target for the

3) The official Danish CO_2 emission target is given by the Kyoto protocol and the agreed share between the EU countries, see United Nations (1998).

economy.[4] Formulating a separate target for emissions from electricity production can imply that emissions are not reduced cheapest possible.[5]

The reform states that 20 per cent of the Danish electricity consumption must be satisfied by Danish electricity production based on renewable energy. A market for this electricity share will be developed in the longer run. The CO_2-emission target for electricity production can, however, be met cost minimizing without the 20 per cent constraint, while the constraint can imply higher costs. It will, on the other hand, in Section 3.3 be shown that this constraint can be necessary if emission reductions are to be achieved in a world where other countries do not have binding emission constraints.

In the short run this "green" market will be regulated by public guaranteed prices for different types of production technologies. A pricing system depending on technology size etc. is created for this purpose.[6] If equilibrium prices were given by the market for green electricity, producers would have an average yield corresponding to the capital costs including a risk premium. With guaranteed prices there is a possibility that the yield to these producers is unnecessarily high.

A further problem caused by the fixed price on green electricity concerns the match between supply and demand. The exogenous price will in the long run determine the supply of green electricity and will with the 20 per cent constraint also determine the demand for green electricity. In the short run production capacity will determine supply. There is no reason to believe that the supply then exactly will match the demand neither in the short run nor in the long run. A thorough analysis of problems in this design can be found in Skytte (1999a). Some flexibility has been included in the reform to avoid the potential mismatch. However, a more straightforward solution would be to let the market determine the price and not the opposite.

4) Or even better, as a global target.

5) A justification of the separate target is, however, that it induces a development of new green technologies, see Smulders (1997)

6) New wind power production build until 2002 will for 10 years be guaranteed a price of 0.33 DKK per kWh plus additional 0.1 DKK per kWh for the green certificate For utilities build after 2002 the price of green electricity will be determined on a market basis Electricity produced from renewable energy sources at existing utilities owned by electricity production companies and financed by appropriations cannot achieve green certificates and must be sold at the free electricity market.

CHP (combined heat and power) production has by EU also been accepted as priority production, which implies that it can be protected against competition if it is not competitive. Small scale CHP will be regulated under the reform while large scale CHP producers can choose to be regulated.[7] This implies that competition has not necessarily been introduced at an important market segment. There is, however, no reason to believe that the large scale Danish CHP production should not be competitive in the long run, see Olsen and Munksgaard (1997).

A final potential problem of the reform is that creation of several different markets can imply more concentrated markets which can be an obstacle towards competition, see Smeers (1997), Newberry (1995), Skytte (1999b) and Hogan (1997). This problem can be very important in small economies like the Danish.

In the next section I will analyse whether some of the less appealing elements of the electricity reform result in a situation that is very different from the efficient regulation of electricity production.

3. An Analysis of the Reform

One suitable model for analysing the reform is the Elephant model, see Hauch (1999). The Elephant model is an partial equilibrium model covering the Nordic countries; Denmark, Sweden, Norway and Finland and simulating the energy markets from 1995 to 2020.[8] In each country are modelled five energy consuming sectors and one household that demands energy for final consumption. These sectors demand electricity, district heating, natural gas, coal, oil and an aggregate of other inputs following a top down system of nested production functions. Their demand level depends among other things on economic activity, energy prices, taxes, technological development.

An electricty and district heating producing sector is included by a bottom up modelling. This sector choose production level and technology use depending on relative input output prices and technological possibilities. Both supply level and choice of technology is determined endogenously in the model. The available

7) Companies that choose to be protected are permitted to earn profits, which is not necessarily an attractive situation.

8) Simulations of a liberalised electricity market in the period 1995-2000 are counter factual and will not be presented below.

technologies are described by technological parameters determining type of fuel, efficiency, electricity-district heating ratio, emissions of pollutants and business economics. The technologies use different fuel inputs, several technologies using coal, natural gas, hydro power, nuclear fuels, bio fuels and wind power are included. Technologies installed in the base year are included into the model and are through the simulation period depreciating with a speed depending on their type. Emissions of CO_2 depend on technology choice in electricity and district heating production and final consumption of fossil fuels. The level of emissions can, e.g. be regulated by emission constraint. Such constraints can be interpreted as emission taxes or tradeable emission permits and will affect final energy consumption and technology choice in electricity and district heating production.

International trade of electricity is possible through cable connections. Costs of transmission is transmission costs and costs of maintaining the cables. If the transmission capacity is insufficient it will endogenously be extended if the shadow value of capacity is sufficiently high.

The model includes several highly uncertain assumptions about future development in fuel prices and technological possibilities. Several simplifications are furthermore made to keep the model simple. A thorough descriptions of these simplifications is given in Hauch (1999). These reservations should be taken into consideration when interpreting the results of the analyses.

Elephant is based on the assumption that the modelled markets are either competitive or regulated optimally. The reform does not, however, give all consumers a free choice of where to buy electricity in the period 2000-2002, i.e. the competition assumption may not be realistic for some segments of the market. Also this should be remembered when interpreting the results.

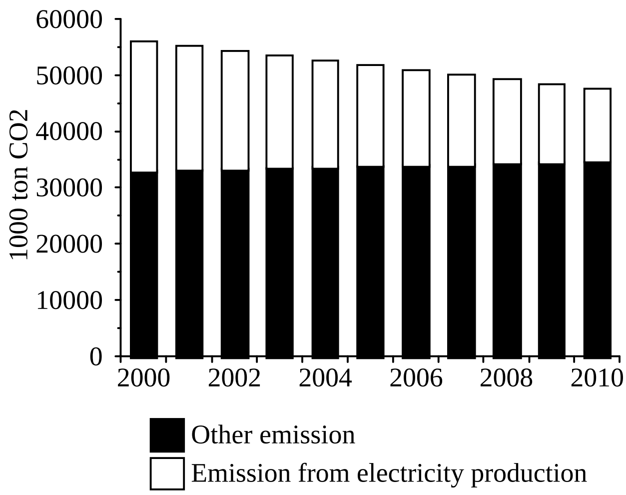
The emission targets in the electricity reform are steps towards achieving the Danish Kyoto emission target in 2008-2012. I have therefore chosen to analyse all the years in the period 2000-2010 assuming that the emission target is met in 2010. This implies that the emission targets in the intermediate period are not officially decided. In Figure 1 the assumed emission targets are shown.[9] Total emissions are assumed to decrease linearly to ensure that the Kyoto target is

9) The possibility of banking emission permits is not included in the analyses presented here. A banking system is primarily important because of variation in precipitation. Here average precipation is assumed, i.e. the importance of including banking in the model is minor.

achieved in 2010. For total emissions only the 2010 target has been decided. In the electricity reform, the emissions from electricity and district heating production have been determined for the years 2000-2003. The decided emission reductions are assumed to continue after 2003 with equal annual reductions.

The other Nordic countries are assumed to achieve the total emission targets agreed upon in Kyoto and total emission levels are as in Denmark assumed to develop linearly from the present emission level to the 2010 target level (except in the analyses in Section 3.4, see below). The other countries are not assumed to introduce separate emission targets for electricity production and other emission sources. Electricity is assumed to be traded freely between the countries. Sweden is furthermore assumed to phase out nuclear power production linearly from 2000 to 2020, i.e. Swedish nuclear power production is in 2010 assumed to be halved compared with today's capacity [10], see Nordhaus (1995).

Figure 1 Danish CO_2 emission target from electricity production and other sources



Source: The Danish electricity reform, the Kyoto agreement and own assumptions.

10) It is assumed that new investments in coal based technologies are not politically realistic in any of the countries. This assumption is not binding as an achievement of the emission targets imply that coal technologies will not be used anyway.

In Section 3.1 the analysis of the electricity reform is carried out. In Section 3.2 it is analysed how the targets from the reform could be achieved in a cheaper way under the assumption that other countries also achieve their emission targets in the Kyoto agreement. Finally in Section 3.3, the importance of the renewable electricity condition is analysed if other countries do not fulfill their emission targets.

3.1 Implementing the Reform in Elephant

The emission targets in Figure 1 are introduced into the model as separate conditions on emissions from electricity and district heating production in Denmark. It is assumed that emission permits determined by the reform can be traded freely between Danish electricity producers. The possibility to pay the 40 DKK per ton CO_2 fine for excess emissions is excluded in this analysis as the parties behind the reform have agreed upon some flexibility as long as the emission target for electricity production is achieved. It will be analysed whether 40 DKK per ton CO_2 is sufficient for achieving the emission target. It is also assumed that emission permits can be traded freely between the other sources than electricity production.This possibility has not yet been decided, but the market for emissions from electricity production indicates a political willingness for creating such markets.

Nordic consequences of the Kyoto agreement are among others analysed by Lindholt (1998) and Hauch (1999). In Hauch (1999) it is found that Denmark in the long run will import emission permits, especially after 2010. Here it is assumed, however, that international trade of emission quotas is not possible.[11] The argument for leaving out international trade is that it is not a central issue here and that leaving it out makes it possible to highlight the elements in the reform more clearly as fewer effects are in play. International consequences of the emission trading part of the Kyoto agreement have been analysed by Gielen and Koopmans (1998).

It is assumed that 20 per cent of the Danish electricity consumption must be satisfied by renewable electricity production. and that a competitive market is

11) It is also assumed that the Nordic countries as a whole have zero net trade of emission permits. If imports of cheap emission permits is possible, which is not unrealistic, the results will change.

created for this.[12] Existing renewable electricity production receives the subsidies agreed upon in the reform, while new renewable production is assumed to compete freely at the renewable market without subsidies. This competitive structure is in the reform agreed upon from 2003.

Small scale CHP production is assumed to be priority production if it is not competitive.

3.2 Consequences of the Reform

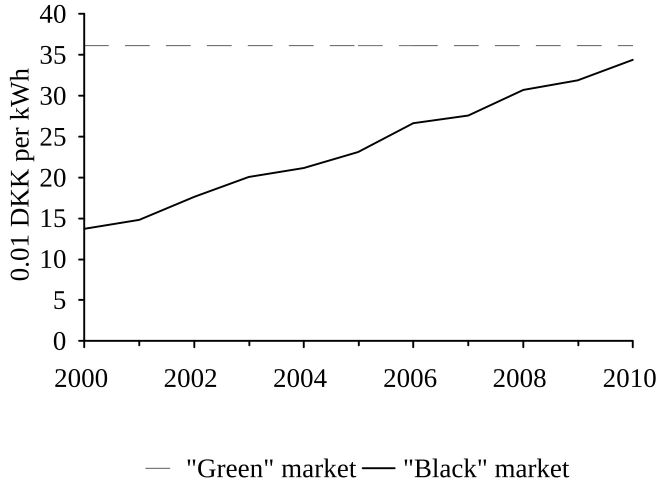
The simulation reveals that investments are in Denmark made in several new technologies because of new environmental targets, depreciation of existing technologies, demand development and relative prices. The largest investments are made in new Danish wind power capacity. These investments are made through the whole period to satisfy an increasing Danish demand for green electricity. Investments are also made in technologies based on natural gas. New investments in large scale production capacity are primarily based on combined cycle technology production from 2003, while small scale production will be based on new gas turbines. Both small and large scale production will be combined with district heating production. In the other countries, the largest investments are made in Norwegian hydro power capacity. These investments will begin early in the simulation period and continue until much of the potential is utilized by the end of the period.

In Figure 2 the development in the electricity supply price at the conventional and green electricity markets is shown. At the green market the 20 per cent renewable Danish electricity is traded. The conventional market is the common Nordic electricity market for electricity without technological constraints. The conventional market supplies all electricity in other countries than Denmark and 80 per cent of the Danish electricity consumption.[13] National equilibrium prices at the conventional market are almost equal, but transmission costs imply small differences.

12) It is as agreed in the reform assumed that production of renewable electricity on existing utilities owned by electricity companies is not calculated as a part of the renewable electricity production.

13) A part of these 80 per cent is potentially priority production.

Figure 2 Equilibrium prices at the green and conventional electricity markets



Source: Scenarios with Elephant.

The equilibrium price at the conventional market is more than doubled through the simulation period. One reason for this development is increases in fuel input prices in electricity production. Another reason is the still tighter environmental targets that call for more expensive technologies and fuels in the electricity production. A third explanation is a higher tendency to long run cost pricing in the last part of the period. In the short run, excess capacity will imply short run cost pricing.

The price at the green market is unchanged through the period. The price is given by the long run marginal cost for wind power production.[14] This price of 0.36 DKK per kWh gives a yield to the owners of wind power utilities of 5 per cent annually of the investment.[15] The price level indicates that a guaranteed price from the electricity reform of 0.33 DKK per kWh at the green market in an intermediate period is very close to the price that occurs at a free market. Additional guaranteed 0.1 DKK per kWh for green certificates as agreed in the reform will, however, increase the equilibrium consumer price above the level necessary for meeting the targets. This increased price could alternatively have given a public

14) If techonological development of windpower was assumed a decreasing price would result.

15) Potential producers of green electricity may want at a higher yield to invest, due to e.g. uncertainty, which will give a higher equilibrium price than found here.

revenue of around 500 million DKK annually. I.e., green electricity producers receives an unnecessary subsidy of 500 million DKK annually.

In 2010 the prices at the green and conventional markets are almost equal, i.e. the price developments and environmental targets almost make the 20 per cent renewable share a non binding restriction by the end of the period, i.e. wind power is almost competitive.

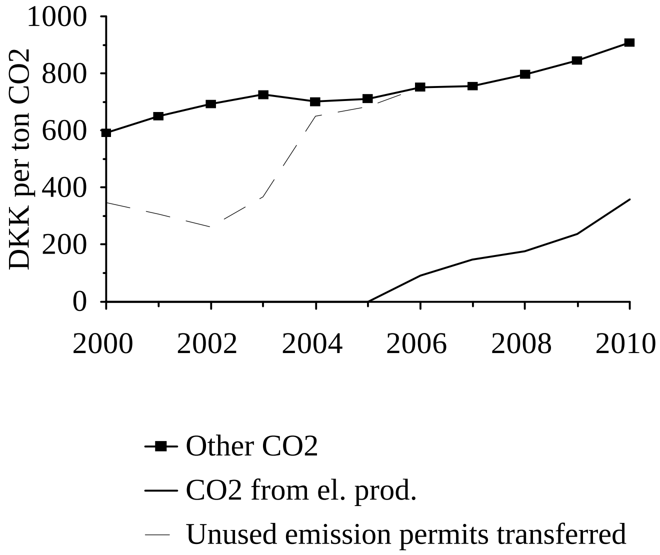
Although small scale CHP technologies are generally expensive, only small protection is necessary. The primary reason is that district heating must be supplied using small scale production in sparsely populated areas as large scale production would imply too high transmission losses. Production of pure district heating is an alternative to small scale CHP with respect to the district heating production. Given the equilibrium electricity price, the marginal cost of CHP-based district heating is lower than pure district heating. Small scale CHP is therefore competitive compared with pure district heating and higher electricity prices are consequently almost not necessary to secure this production.

Having separate targets for CO_2-emissions from electricity production and other production will only by coincidence imply equal shadow values on the targets, which is a cost minimizing situation. The shadow values on the CO_2-restrictions are shown in Figure 3.

The shadow value of the emission restriction for electricity production is in the whole simulation period zero or relatively low. This indicates that the emission target for electricity is inoptimally weak compared with the target for other emissions. Shadow values on other emissions are very high through the whole period. When the shadow values in electricity production equals zero there will be unused permits. If these permits are transferred to the target for other emissions the shadow value on this will be much lower than if their permits are not transferred, cf. Figure 3.

The shadow value for electricity-based emissions is in by the end of the period above 40 DKK per ton CO_2. This implies that electricity producers will have incentive to pay the 40 DKK fine and exceed the emission target by the end of the simulation horizon.

Figure 3 Shadow values on CO_2 emission restrictions



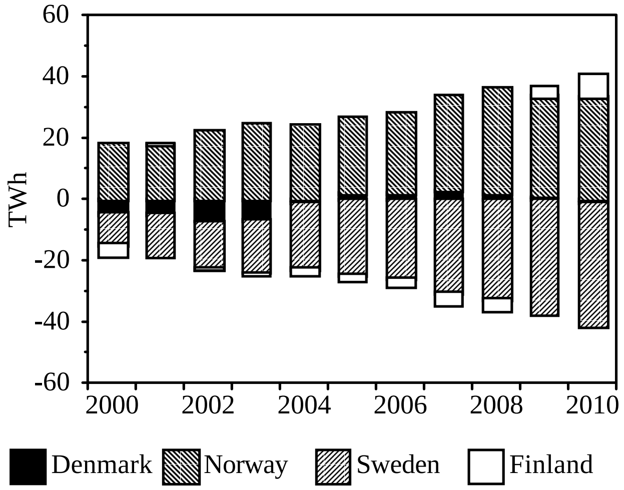
Note: Two different scenarios are presented here. In the main reform scenario excess emission permits from electricity production are not used for easing the target for emissions from other souces than electricity production. In an alternative scenario these excess permits are added to the emission target for other sources.

Source: Scenarios with Elephant.

Equilibrium prices of emission permits in the other Nordic countries are very similar to the prices shown in Figure 6. Also these prices will be equal if an international emission permit market is created. Equilibrium prices at such an international market are presented in Hauch (1999).

Electricity will be widely traded internationally. Net electricity trade is shown in Figure 4.

Figure 4 Net electricity export



Source: Scenarios with Elephant.

Denmark imports in the beginning of the simulation period electricity from Norway that has a potential for extending the hydro power capacity. Sweden will also import electricity from Norway. The main reason for this is the phase out of Swedish nuclear power production. This production capacity must be substituted by another source of electricity, but the tight Swedish emission target makes it inoptimal to extend the electricity production based on fossil fuels. The equilibrium electricity price is, as known from Figure 3, lower than the price of green electricity, i.e. the best solution for Sweden is to import electricity. Norway does not get increased problems with achieving the emission target as there are no emissions from the increased hydro power production.

3.3 A Superior Alternative in a Green World

In this section I will analyse how the reform could have been designed to improve the economic performance. The simulation of the superior design is called "base scenario". The base scenario differs from the reform scenario in three respects:

- The renewable electricity share condition is removed in the base scenario as it is a means for achieving the emission target. It is not a target in itself.

- There is only one target for the total CO_2 emission in the base scenario. It is in this way possible to avoid the inoptimal allocation of emission reductions as indicated by Figure 3.

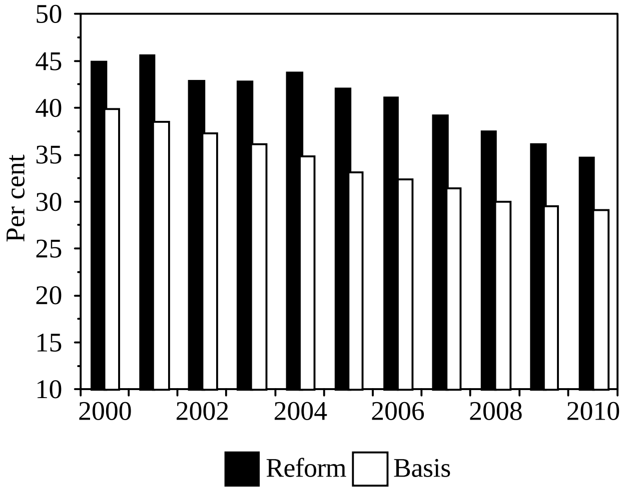
- The priority electricity condition is removed in the base scenario. The argument is that "forcing" the use of technologies that are not competitive is not optimal. The importance of removing this condition is small as it was not binding.

The total Nordic emission target will therefore also be met in the base scenario, but in the cheapest possible way. International trade of emission permits is an optimal solution to the emission problem. I have, however, also in the base scenario chosen to exclude this possibility to improve the comparability with the reform scenario.

Also in the base scenario there will be invested in several different technologies. Compared with the reform scenario, the largest difference is that there are no investments in wind power production in the base scenario except in 2010. Instead, there will be larger investments in both combined cycle and gas turbines in Denmark. The Norwegian investments in new hydro power capacity shows the same pattern as in the reform scenario, but investments are larger and are made earlier in the base scenario. The most important difference between the results in the two scenarios is an increased Danish import of electricity from the other Nordic countries which explains how the Danish emission target can be met also without wind power production, see below.

In Figure 5, the shares of CO_2 emission from electricity production in the base and the reform scenario are shown. Emission shares from electricity production are in the whole simulation period smaller in the base scenario than in the reform. This result supports the result from Section 3.1 that emissions from electricity production are optimally smaller than decided in the reform.

Figure 5 CO_2 emissions from electricity production in the base and the reform scenarios. Share of total national emissions

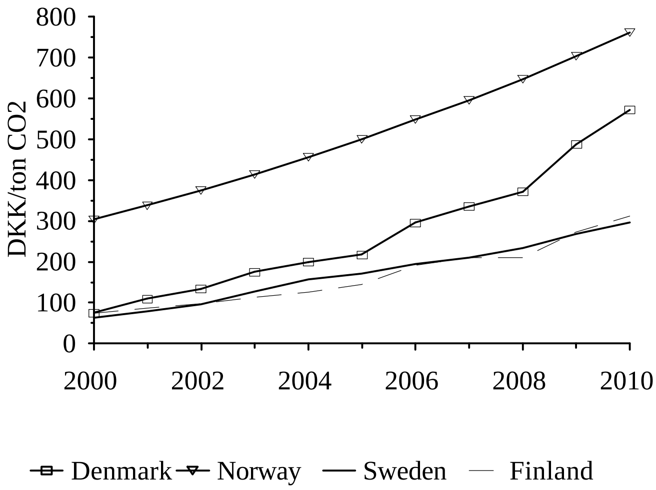


Note: The share in the reform case does not correspond with Figure 1 because of the unused permits in electricity production.
Source: Scenarios with Elephant.

In Figure 6, the equilibrium prices on CO_2 emission permits in the Nordic countries are shown.

The Norwegian price is the highest through the whole period, indicating that Norway has accepted a relatively tight emission target in the Kyoto agreement. Achieving the Swedish emission target is again eased by electricity import from Norway that reduces the Swedish price to the lowest together with the Finnish price. That the Danish price is higher than the Swedish and Finnish prices is a consequence of the ambitious emission target that cannot all be met by importing electricity from other countries. In Hauch (1999) it is shown that Denmark will import emission permits if international trade of emission permits is allowed. This result is supported among others by Bohm (1997) and Ammundsen et al. (1998).

Figure 6 Shadow values on CO_2 emission restrictions

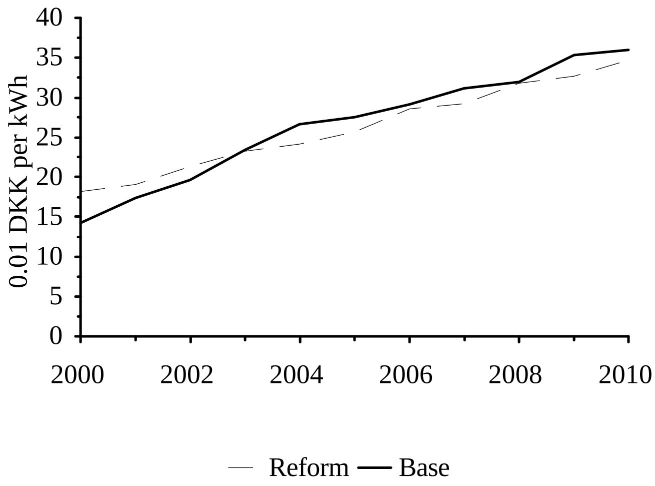


Source: Scenarios with Elephant.

If the Danish shadow value is compared with the prices in Figure 3, it is seen that the price in the base scenario is between the two emission permit prices in Figure 3, which should be no surprise. As reductions are carried out in the cheapest possible way in base, one would expect the base price to be lower than the weighted average of the prices in Figure 3. One should, however, be aware that the 20 per cent renewable electricity condition in the reform scenario lowers the necessity to reduce emissions from the remaining electricity production. By that also the permit price is reduced. The emission price in the base scenario is actually in periods higher than the weighted average price in the reform scenario. This should, however, not lead the reader to the false conclusion that the 20 per cent renewable electricity condition lowers the costs of achieving the emission target.

In Figure 7, the Danish electricity supply prices in the base scenario and in the reform scenario are shown. The price in the reform scenario is given as the weighted average price at the green and the conventional market presented in Figure 2. The price in the base scenario is the price at the common Nordic electricity market.

Figure 7 Electricity supply price to Danish consumers



Source: Scenarios with Elephant.

The differences between the two scenarios affect the electricity price in opposite directions. Removing the renewable electricity share and the priority production share improves the efficiency in the electricity production. This will ceteris paribus give a lower electricity price. A common CO_2-target implies on the other hand larger reductions in emissions from electricity production. This will ceteris paribus increase the electricity price.[16]

The result of these different effects turns out to be a lower electricity price in the base scenario in the beginning of the simulation period, i.e. not only is there a larger emission reduction from electricity production, achieving it is possible at a lower electricity price and by that a higher demand level.

The prices of other energy commodities than electricity for final consumption are all lower in the base scenario than in the reform scenario. These prices are determined by exogenous world market prices, by constant distribution costs and by shadow values from emission constraints.[17] All prices are because of the

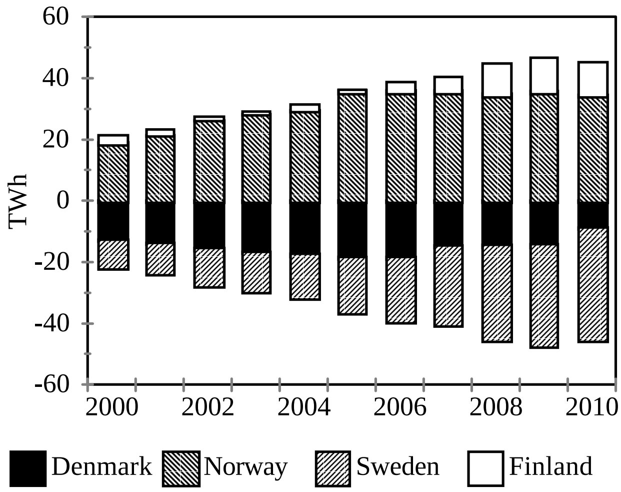
16) A decomposition of the differences between the scenarios shows that the equilibrium price will be almost equal to the price in the base scenario if the renewable share condition is not introduced in the reform scenario. I.e. the most important explanation of the price difference is the renewable share condition.

17) The district heating price is as the electricity price partly determined from the bottom up modelling of technological possibilities.

changed CO_2-regulation lower in the base scenario than in the reform scenario. This gives in total a higher welfare level in the base scenario than in the reform scenario.

Also the electricity trade pattern is as mentioned different in the base scenario, see Figure 8. Comparing Figure 8 and Figure 4, shows that the Danish electricity import is generally higher in the base scenario. This shows that the Danish emission target from electricity production can be achieved cheaper by importing electricity than by producing electricity domestically based on renewable fuels.[18]

Figure 8 Net electricity export



Source: Scenarios with Elephant.

A further point is that the electricity import serves as a substitute for import of emission permits. If an international market for emission permits was created, it is likely that the Danish import of electricity would be reduced. This point has been analysed in Hauch (1999) and Ammundsen et al. (1998).

The above leads us to the conclusion that some of the elements in the electricity reform imply a loss of efficiency. Especially the target of 20 per cent renewable

18) An import of this size may not be politically acceptable in Denmark event though it is optimal seen from the society's point of view. Technical limitations can make the necessary extentions the Norwegian hydro power capacity impossiblein such a short run.

electricity consumption seems unnecessary. This conclusion is, however, based on the assumption that the other countries also achieve their emission targets. In the next section I will analyse the importance of the renewable electricity condition if the other countries do not achieve a binding emission constraint.

3.4 Implications of the Renewable Electricity Share Condition in a Black World

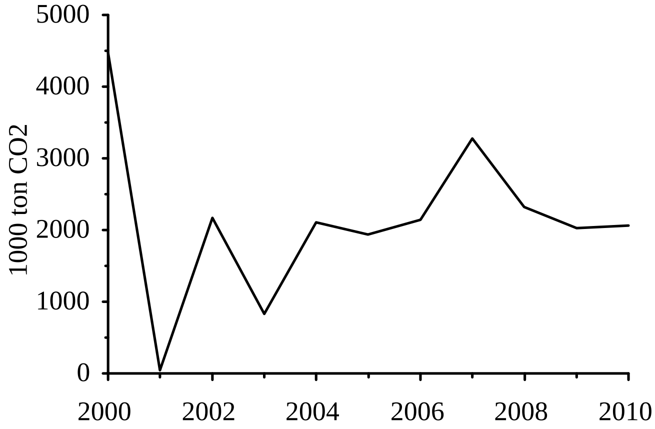
Imagine that Denmark is the only country that has a binding target for emissions of CO_2. It is as seen above possible that Denmark could achieve the emission target by importing large amounts of electricity. This electricity may be produced using fossil fuels and by that increase the emissions from the country that exports electricity to Denmark. It is therefore possible that the global emission reduction is less than the Danish emission reduction and that the environmental improvement is not realised.

Introducing the renewable electricity consumption share as decided in the electricity reform can help preventing such a situation from arising. This constraint will force at least a part of the emission target to be met by production with renewable technologies.

We analyse this situation by comparing two new scenarios, the “renewable constraint” scenario and the “no renewable constraint” scenario. The renewable constraint scenario is equal to the reform scenario in all respects except that no emission constraint is imposed on other countries than Denmark. The no renewable constraint scenario is equal to the renewable constraint scenario except that the renewable electricity constraint is not imposed.

In both scenarios the Danish emission target is met, but total Nordic emisssions differ. The Nordic emission redution implied by the Danish renewable electricity constraint is shown in Figure 9.

Figure 9 Nordic emission reductions



Source: Scenarios with Elephant.

Total Nordic emissions are in each year are lowest in the renewable constraint scenario. The difference in emissions between the two scenarios fluctuates between a little more than nothing and 4.5 million tons CO_2 annually. It is on average 2.1 million tons CO_2.[19]

We have therefore an important argument in favour of the renewable electricity constraint. It will imply a reduction in global emissions which is closer to the Danish emission reduction target if other countries do not have binding emission targets.

4. Conclusion

The electricity reform contains several elements that are not included in details in the model that also in other respects gives a rough description of the real world. This should be remembered when the results are interpreted. The uncertainty, e.g., on future technological development is another factor that reduces the validity of the analyses.

The electricity reform represents a step towards competition by creating an institutional setup that can induce competition in large parts of the electricity

19) The fluctuations may seem dramatic, but are small compared withe the total Nordic emissions.

sector. This competition must be expected to increase efficiency. Several elements in the reform create, however, potential problems for a cost minimizing electricity production and the achievement of environmental targets for electricity production. It turns out that the problems in the reform relate primarily to the achievement of the environmental target.

A low fine has been set for firms that emit more CO_2 than they are holding emission permits. The analyses show that this fine is so low that firms can have incentives to pay the fine and pollute, i.e. the emission target will not be necessarily be met.

The emission target for the electricity sector is relatively weak compared with the implicitly determined target for the rest of the economy. I.e., some of the emission reductions that must be carried out by other sources could have been carried out by the electricity sector at lower costs.

The decision that 20 per cent of the Danish electricity consumption must be satisfied from Danish production of electricity based on renewable energy sources is not necessary for meeting the environmental target if other countries are also meeting binding emission reductions. It implies that the emission target is not met in the cheapest possible way. It can, however, be argued that the 20 per cent constraint is necessary if other countries do not follow binding emission restrictions. Global emissions will then be reduced more with the constraint than without. The other less appealing elements in the reform can, however, not be justified by this argument.

Electricity production based on renewable sources is guaranteed fixed prices. This is not necessary for ensuring that the 20 per cent target is met and it creates a risk that the market for green electricity will not clear. It is furthermore shown that the guaranteed price in unnecessarily high.

We find that imports of electricity can help achieving the Danish emission target in a cost minimizing way. This will not increase the emissions from the other countries if they are also meeting binding emission targets.

Flexibility is a key word for several elements in the reform. If the flexibility is used in a constructive way, it is possible that the less tractable elements in the reform will only reduce the efficiency of the reform slightly. It should on the other hand be clear that some elements in the reform imply a risk that the electricity reform and the achievement of the environmental targets will not be met at least costs.

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