Competition and Prices on the Emerging Nordic Electricity Market

by

Eirik S. Amundsen[1], Lars Bergman[2] and Bo Andersson[3]

Working Paper Series in Economics and Finance No. 217

January 1998

Abstract

The purpose of this paper is to quantitatively evaluate the impact on electricity prices of deregulation and free trade in the Nordic countries. The analysis is focused on the impact of increased competition on market power and the degree of monopolistic pricing. The major tool for our analysis of electricity trade and prices is a numerical multicountry electricity market model in which losses and bottlenecks in the transmission system are taken into account. Moreover both Cournot and perfect competition equilibria with and without free trade in electricity can be simulated. According to the simulation results there are significant differences between the Cournot and perfect competition equilibrium prices under autarky. When inter-country trade is allowed, however, the Cournot equilibrium prices are quite close to the equilibrium prices under perfect competition. Yet the net inter-country physical flows of electricity are small and well within existing transmission capacities.

Keywords: Oligopoly, deregulation, electricity, trade**.**

JEL-Classification: D43, F14, L11, L94.

[1] Professor of economics. University of Bergen, Fosswinckelsgate 6, N-5007, Bergen, Norway.
Fax +47 55 58 92 10. E-mail: eirik.amundsen@econ.uib.no.
[2] Professor of economics. Stockholm School of Economics, Box 6501, S-113 83 Stockholm, Sweden.
Fax +46 8 31 32 07. E-mail: NELB@HHS.SE.
[3] PhD and Research Associate, Stockholm School of Economics, Box 6501, S-113 83 Stockholm, Sweden.
Fax +46 8 31 32 07. E-mail: NEBA@HHS.SE.

1. Introduction[4]

The reorganization of the electricity market in England and Wales is well known and widely conceived as “the” model of a deregulated electricity market. The deregulation of the electricity markets in Norway, Sweden and Finland is equally far reaching but perhaps less well known. The process was initiated in 1991 when the previously strictly regulated electricity market in Norway was opened up for competition in power generation and supply, while transmission and distribution continued to be regulated monopolies. Using the Norwegian electricity market as a “model” the Swedish electricity market was reorganized in 1996. At the same time a common Norwegian-Swedish spot market, Nord Pool, was opened, and major steps to remove barriers to inter-country trade in electricity were taken.

In Finland the deregulation process started somewhat later, but will be essentially completed by the end of 1997. Although the institutional framework of the new Finnish electricity market basically is the same as in Norway and Sweden, there is currently a separate spot market, ELEX, in Finland. It is very likely, however, that barriers to trade in electricity between Finland and Norway-Sweden will be removed, and that a common Finnish-Norwegian-Swedish electricity market will emerge before the turn of the century.

The main purpose of this paper is to quantitatively evaluate the impact on electricity prices of deregulation and free trade in the Nordic countries. It is well known that deregulation and free trade tends to induce cost reductions. But increased competition on concentrated markets also tends to reduce monopolistic pricing and thus increase welfare. In this paper we focus on the impact of increased competition on market power and the degree of monopolistic pricing. The major tool for our analysis of electricity trade and prices is a numerical model of the electricity markets in Norway, Sweden and Finland. However, before turning to our main issue, we want to briefly describe some of the institutional aspects of the emerging Nordic electricity market. In particular we want to point out the major differences between the “Nordic model” of a deregulated electricity market and the “British model” adopted in England and Wales.

2. Two “models” of electricity market deregulation

Needless to say there are many similarities between the British and the Nordic types of electricity market. For instance, in both cases there is a relatively strict separation between transmission and distribution, on the one hand, and generation and supply on the other. Transmission and distribution services are provided by regulated monopolies, and there is a central operator[5] responsible for the short term stability of voltage and frequency in the system. In addition to the organizational similarities seller concentration and potential market power are apparent features both of the British and some of the Nordic electricity markets. However, there are also some important differences.

---

[4] Financial support from NUTEK, Sydkrafts Forskningsstiftelse, the Foundation for Research in Economics and Business Administration and Statoil is greatfully acknowledged. The usual disclaimers apply.

[5] National Grid Company (NGC) in England and Wales, Statnett in Norway and Svenska Kraftnät in Sweden.

Public ownership

One apparent difference concerns the role of public ownership. Thus, while the electricity market reform in England and Wales was driven by the aim to privatize the electricity supply industry, the corresponding reforms in Norway and Sweden were primarily motivated by efficiency considerations. The basic aim was to secure low electricity prices, and increased competition was seen as a means to attain that objective. Consequently the degree of public ownership in the electricity supply industry is essentially unaffected by the electricity market reforms both in Norway and Sweden. However, the degree of public ownership is considerably higher in Norway than in Sweden.

The spot market and merit order dispatch

In the British model "The Pool", i.e. the half-hourly spot market operated by the central grid operator (the NGC), plays a crucial role. On the basis of bids by the generators NGC, taking the transmission constraints into account, determines both the real time dispatch and the merit order dispatch of available generating units. At the same time half-hourly spot prices, reflecting the bids of the marginal generators at different times of the day, are determined. As all physical trade in electricity has to go through the Pool, the British model has a strong flavor of a central dispatch system where the utilization of available generation and transmission capacity is determined by a central operator.

In the Nordic model there is a strict separation between the real time dispatch and the merit order dispatch. Thus, while the real time dispatch is determined by the central grid operator in much the same way as in the British system, the merit order dispatch is determined by the outcome of decentralized trading at an independent hourly spot market. This spot market is operated by Nord Pool[6], which is an independent market place owned by Statnett and Svenska Kraftnät. A crucial feature of the system is that there is no obligation to buy and sell electricity via Nord Pool. Currently a very significant share (around 85% in 1996) of the physical trade in electricity is in fact carried out within the frame of bilateral contracts outside Nord Pool. In other words the Nordic type of deregulated electricity market to a large extent functions like an ordinary commodity market.

Transmission and transmission pricing

In the British system the price paid to the Pool by the buyers often exceeds the price paid by the Pool to the generators. One reason for this is that a price on capacity is charged during peak-load

[6] Nord Pool operates both a spot market and a set of futures markets. As of October 1996, Nord Pool is also open to registered firms in Denmark and Finland. Currently Nord Pool has around 150 members from Norway, Sweden, Finland and Denmark. The spot market at Nord Pool is organized in a very simple way. Until noon the day before delivery the participants are allowed to make bids indicating the amount of power they want to buy or sell at different price levels during each one of the day's 24 hours. On the basis of these bids Nord Pool constructs aggregated demand and supply schedules for each hour and computes the corresponding market clearing prices. The trades implied by the accepted bids are settled at the computed market clearing prices. Formally the sellers are selling power to Nord Pool, while the buyers are buying from Nord Pool. This also applies for the futures markets. The contracts traded on these markets are entirely financial in nature and aimed at providing buyers and sellers possibilities to hedge against price risks associated with spot market trade. The futures contracts are highly standardized and defined in terms of a given number of megawatts of electricity for delivery during a given future week. The currently available futures contracts make it possible to secure electricity prices up to three years in advance.

periods. Another reason for deviations between buyer and seller prices at the Pool is congestion in the transmission system. Thus the production plan determined by the NGC on the basis of the merit order dispatch, the so called unconstrained plan, may not be feasible under the existing capacity limitations in the transmission system. Consequently deviations from the cost-minimizing production plan are necessary, and these deviations are, by definition costly.

The cost increases due to congestion in the transmission system are added as an “uplift” to the Pool price. The “uplift” also includes cost increases due to deviations from the forecasted demand and unexpected outages of generation capacity. In other words the costs due to transmission congestion are reflected in the Pool´s selling prices, but the marginal cost of congestion is not exclusively paid by those causing the congestion.

In Norway and Sweden so called point tariffs for transmission services are used. This means that at each location there is a given price per unit of power fed into the transmission system, and this price is independent of the location of the buyer of that power. In the same way there is a location-specific price per unit of power tapped from the system, and that price is independent of the location of the generator of that power. In other words the geographical distance between a seller and a buyer does not affect the price of the corresponding transmission service. The system of point tariffs helps to establish a nation-wide electricity market where generators can compete on equal terms, and the point tariffs are also consistent with the cost structure for transmitting power over the grid.

In Norway the transmission tariffs explicitly reflect congestion costs and are thus relatively close to “efficient” tariffs. As a result the prices of electricity differ across regions whenever there is congestion in the transmission system. Thus the spot prices determined at Nord Pool might differ from those a buyer has to pay, or a seller will get, in various regions of the country. This means that congestion in the transmission system causes additional price risks, and currently Nord Pool does not offer any possibility to hedge against transmission price risks.

In Sweden the transmission tariff is designed in a slightly different way. Thus the variable part of the tariffs does not reflect congestion costs. This obviously means that from time to time there is excess demand for transmission capacity. In order to cope with this problem the grid operator, Svenska Kraftnät, enters the market during the periods when there is congestion in the transmission system. More precisely Svenska Kraftnät buys power in net “export” regions, and sells power in net “import” regions. This power is generated within the net import region, using reserve capacity called into operation on the basis of contracts between Svenska Kraftnät and the owners of the generating capacity. The extra costs caused by these interventions are covered by fixed charges on the users of the transmission system[7].

The Swedish system for transmission pricing tends to enhance competition, but may lead to inefficient investments in transmission capacity. For transmission across the borders, however, the Norwegian type of transmission tariffs with explicit congestion charges are used. As a result Swedish and Norwegian prices may differ, and Nord Pool currently does not offer any possibility

[7] The reform of the Finnish transmission system has not yet come very far. A key component has been to merge Finland’s two grid systems, which traditionally have been two separate systems. The grid owners have signed an agreement on the main principles for setting up a new national transmission company in charge of a common grid. The main transmission lines to Sweden and Russia will also be owned by this company. At the distribution level competition has been a totally unknown phenomenon. Customers can only buy from local distributors and in many cases small and medium size industries must pay more than the market price.

to hedge against the price risks faced by participants in power deals across the Swedish-Norwegian border.

This concludes our comments on the institutional aspects of the Nordic model of a deregulated electricity market. Next we turn to an analysis of electricity price formation and intercountry trade in the Nordic area. The prices we are concerned with are one-year averages of wholesale prices before tax. Our modeling approach implies that there is one national market and one price of electricity in each country. This is an acceptable approximation of the real world provided that the spot and futures markets operated by Nord Pool are sufficiently efficient. Whether this is actually the case is the topic for another study that we have recently initiated.

3. Market power and trade

For a long time there has been trade in electricity between the Nordic countries. However, the trade has taken place between the power companies and been motivated by temporary cost differences between the water power system in Norway and the thermal power plants in the neighboring countries. Thus the net trade on an annual basis has normally been close to zero. In recent years, however, there has also been some trade between the Nordic countries based on long term bilateral contracts. With the deregulation of the domestic electricity markets, the elimination of electricity export restrictions and the establishment of Nord Pool a completely new situation emerges. Under the new institutional conditions significant net trade on the basis of comparative advantages is a feasible outcome.

This possibility is particularly interesting since the national electricity markets in Sweden and Finland are quite concentrated on the seller side. (See Table 1 below). Thus, trade between the Nordic countries can increase welfare by reducing the degree of monopolistic pricing in Sweden and Finland. In the following we will use a numerical model to simulate perfect competition and Cournot equilibria both under autarky and free trade in order to shed some light on the impact of intercountry trade on electricity prices in Norway, Sweden and Finland.

Table 1. Measures of concentration on Nordic electricity markets

	Norway*	Sweden**	Finland**
Market share of largest firm	27.3	52.9	35.6
Market share of the three largest firms	43.1	78.6	55.8
Market share of the five largest firms	52.8	88.7	63.5
Herfindahl´s index	0.10	0.33	0.16
Total production, TWh	111.9	137.6	62.2

* = 1992, ** = 1994

4. Modeling electricity price formation and trade[8]

In order to model price formation and trade we envisage the electricity market in country c as a market where F_c independent firms are competing. Intercountry transmission services are supplied by a single grid operator at marginal cost, i.e. at prices equal to the sum of the marginal cost of

[8] The model briefly described in this section is an expanded version of the models presented in Andersson and Bergman (1995) and Andersson (1997).

losses and the marginal cost of congestion. Each individual firm f_c in country c owns and operates a set of generating units, all located in country c[9]. The generating units are divided into two generic categories, i and j. Category i consists of hydro and nuclear power plants, while category j is an aggregate of different types of condensing power plants and combined heat and power plants. Thus, with obvious notation the total output of firm f is defined by the following equation:

$$X_{fc} = \sum_{i=1}^{2} X_{fci} + X_{fcj}\,; \qquad fc=1,2,...,F_c. \qquad (1)$$

The level of output at the firm level is determined on the basis of profit maximization considerations in a way to be discussed later. However, for each given level of output the individual firm allocates output between the different generating units in order to minimize cost. The solution of this cost minimization problem in effect defines the cost function of the individual firm. On the basis of the cost function it is possible to derive a convex marginal cost function

$$C_{fc} = C_{fc}(X_{fc}, K_{fc})\,; \quad fc=1,2,...,F_c. \qquad (2)$$

where K_{fc} is a vector indicating the maximum capacity of the generating units at the disposal of the firm.

The output of firm fc is sold to consumers in country c and, when intercountry trade is allowed, country c' where thus $c \neq c'$. Thus letting S denote sales and using r as an index for the country of destination, it holds that

$$X_{fc} = \sum_{r} S_{fcr}\,; \qquad fc=1,2,...,F_c. \qquad (3)$$

However, due to losses in the intercountry transmission system the supply of electricity in country r is less than the aggregate supply at the firm level whenever there is intercountry trade. Denoting the transmission loss per unit of sales from country c to country r by δ_{cr}[10], with $\delta_{rr} = 0$, and the total supply of electricity in country r by S_r, the supply of electricity in country r can be written

$$S_r = \sum_{c} \sum_{fc} (1-\delta_{cr}) S_{fcr}\,; \qquad (4)$$

The demand for electricity in country r is assumed to depend only on the price of electricity in country r, i.e. P_r. Moreover it is assumed that the price elasticity of demand is constant and equal to η_r. Consequently the equilibrium price in country r is given by

[9] Recently the major generating companies in Norway, Sweden and Finland have bought shares both in generating and distribution companies in the other Nordic countries. Thus there might be reason to change this modeling assumption in the future.

[10] In order to simplify the model it is assumed that the transmission loss parameters are constant, i.e. independent of the load on the transmission system. In general this is a rather innocent simplification. However, in some of the simulations the gross intercountry trade is quite significant, while the net trade is close to zero. In these cases the model tends to exaggerate the transmission losses and thus the intercountry price differences.

$$P_r = P_r^0 (\frac{S_r}{E_r^0})^{1/\eta_r} ; \qquad (5)$$

where P_r^0 is the base year price and E_r^0 the base year consumption in country *r*.

As was indicated in equation *(4)* there are intercountry transmission losses. In addition the intercountry transmission lines might be congested. In the model three two-way intercountry transmission lines are defined, namely Norway-Sweden, Norway-Finland and Sweden-Finland[11]. Thus intercountry transmission line *g* belongs to a set *G* with three elements. Denoting the use of transmission line *g* per unit of sales from country *c* to country *r* by μ_{gcr} and the maximum capacity of intercountry transmission line *g* by M_g the following constraint has to be satisfied for each pair of *c* and *r* ($c \neq r$):

$$\sum_{fc} \mu_{gcr} S_{fcr} + \sum_{fr} \mu_{grc} S_{frc} \leq M_g \quad \text{for all } g \qquad (6)$$

The first term on the left hand side represents the flow from country *c* to country *r*, while the second term represents the flow in the opposite direction. This formulation of the constraint reflects the fact that the need for transmission capacity depends on the net flow over the transmission line in question.

The marginal cost of congestion on intercountry transmission line *g*, φ_g, is obviously greater than or equal to zero. It is equal to zero when *(6)* is not binding. However, when *(6)* is binding φ_g might be positive. Thus in equilibrium the following complementary condition must hold for each pair of *c* and *r*:

$$\varphi_g (\sum_{fc} \mu_{gcr} S_{fcr} + \sum_{fr} \mu_{grc} S_{frc} - M_g) = 0 \text{ for all } g \qquad (7)$$

As the intercountry grid operator is supposed to apply marginal cost pricing, an individual firm has to take both transmission losses and congestion charges into account when defining its profit maximization output level. Our basic assumption about the competitive environment is that each one of the national electricity markets can be described by the Cournot model of quantity competition. Consequently the equilibrium condition for the individual firm can be written

$$(P_r + S_{fcr} \frac{\partial P_r}{\partial S_{fcr}})(1 - \delta_{cr}) - C_{fc} - \sum_g \varphi_g \mu_{gcr} \leq 0 \qquad \text{for all } fc \text{ and } r. \qquad (8)$$

given that the output decision by firm *fc* does not affect the output decision by any other firm. If the marginal revenue in country *r* is strictly lower than the marginal cost of generation and transmission the profit maximizing sales of firm *fc* in country *r* is zero. Thus S_{fcr}, which obviously must be non-negative, is positive only if *(8)* is satisfied as an equality. It follows that in equilibrium the following complementary condition has to be satisfied.

[11] This means that in the current version of the model only direct connections are defined. Thus, a delivery from, say, Norway to Sweden cannot go from Norway to Finland and then from Finland to Sweden. The simulation results obtained so far suggest that this is not a serious drawback of the model.

$$S_{fcr}((P_r + S_{fcr}\frac{\partial P_r}{\partial S_{fcr}})(1-\delta_{cr}) - C_{fc} - \sum_g \varphi_g \mu_{gcr}) = 0 \quad \text{for all } fc \text{ and } r. \qquad (9)$$

As an alternative to the Cournot equilibria we also compute perfect competition equilibria. Technically this amounts to assuming that all the partial derivatives $\partial P_r / \partial S_{fcr}$ are equal to zero.

The model is solved using the GAMS software (Brooke et.al. (1988)). For further details about the model the reader is referred to Andersson (1997).

5. Price formation and trade between two countries

In connection with the deregulation of the Swedish electricity market there were serious concerns about market power and the risk for monopolistic pricing. The discussion focused on the state owned company Vattenfall and the fact that Vattenfall's share of the wholesale market is more than 50 percent (see Table 1). One of the proposals put forward in the debate was to split Vattenfall. As was shown by Andersson and Bergman (1995) such a measure would significantly reduce the equilibrium price under Cournot competition. However, there was no split of Vattenfall. One of the reasons for this was the expectation that a common Nordic market for electricity would be established in the near future, and that the market power of Vattenfall would be much smaller on a Nordic than on the Swedish market.

Using the model presented in the preceding section we have simulated the electricity price formation in Sweden and Norway under various assumptions about the trade regime and the competitive environment in the two countries. In Table 2 the computed equilibrium autarky[12] prices are presented. As can be seen in the table there is a significant difference between the Cournot and the perfect competition prices in Sweden, while the corresponding difference is quite small in the case of Norway. This is of course consistent with the values of the Herfindahl index for the two countries reported in Table 1.

Table 2. Computed equilibrium autarky prices in Sweden and Norway

	Sweden	Norway
Perfect competition (SEK/kWh)*	0.151	0.160
Cournot competition (SEK/kWh)*	0.245	0.168

Note: The prices are excluding V.A.T. and electricity tax per kWh.
* 1 SEK is approximately 1/8 USD.

As the autarky prices differ between the countries, there are potential gains from trade. This is particularly the case under Cournot competition. It is interesting to note, however, that under perfect competition there are incentives to export electricity from Sweden to Norway, while a flow in the opposite direction should be expected under Cournot competition. In Table 3 the computed equilibrium free trade prices are reported. As can be seen in the table free trade tends to equalize Swedish and Norwegian electricity prices. Moreover, it also tends to wipe out most of

[12] In the model autarky implies that $\delta_{cr} = 1$ for all *c* and *r*.

the difference between Cournot and perfect competition prices in Sweden. This result suggests that free trade on a common Norwegian-Swedish electricity market essentially solves the market power problem on the Swedish electricity market.

Table 3. Computed equilibrium free trade prices in Sweden and Norway

	Sweden	Norway
Perfect competition (SEK/kWh)	0.153	0.159
Cournot competition (SEK/kWh)	0.174	0.171

Note: The prices are excluding V.A.T. and electricity tax per kWh.

The computed intercountry flows of electricity in the free trade case are reported in Table 4. It is interesting to note that the gross intercountry flows under Cournot competition are quite significant, while the net flows are close to zero[13]. One can say that there is a massive flow of contracts, but only a tiny flow of electrons across the border. This suggest that not much transmission capacity is in fact needed in order to make active import competition possible.

Table 4. Computed electricity sales by firms from the other country

Electricity sales (TWh)	In Sweden (By Norwegian firms)	In Norway (By Swedish firms)
Perfect competition	0.0	0.1
Cournot competition	53.8	53.1

The results in Table 4 can be seen as an example of so called reciprocal dumping[14]. Thus, for each firm the autarky marginal revenue on the home market is lower than the price on the foreign market. Consequently each individual firm expects to benefit from selling on the foreign rather than on the home market. Thus, when the barriers to trade are removed each individual firm has strong incentives to find customers on the foreign market. As all firms behave in the same way, however, the final outcome is that competition has increased and squeezed profit margins on both markets. Moreover, for each individual firm the equilibrium marginal revenue is the same on all markets.

6. Price formation and trade between three countries

The next question is whether the results would be much different if a third country, Finland, would join the common electricity market. The simulation results are summarized in Table 5 and Table 6. The short answer is that there is no significant difference; like in the two-country case free trade tends to equalize prices across countries and to reduce the difference between Cournot and perfect competition prices. A somewhat longer answer also includes the observation that the Cournot prices are somewhat higher in the three-country case than in the two-country case.

In order to discuss this result we note that before including Finland in the free-trade area the Cournot prices are 0.171 and 0.174 SEK/kWh in Norway and Sweden, respectively, and 0.209 SEK/kWh in Finland. With a sufficiently high degree of pre-integration monopolistic pricing so

[13] See also footnote 7.
[14] See Brander and Krugman (1983).

called reciprocal dumping tends to increase supply in both countries. As a result the free-trade price is lower than the autarky prices. If, on the other hand, the degree of pre-integration monopolistic pricing is low, i.e. there is close to perfect competition under autarky, the free-trade equilibrium prices on the expanded common electricity market should be somewhere between the autarky prices. As can be seen in Table 6 the free-trade price is in the range 0.171-0.209 SEK/kWh, i.e. in the range given by the autarky prices. In other words the "reciprocal dumping effect" of integrating Norway-Sweden and Finland is not very significant.

Table 5. Computed equilibrium autarky prices in Sweden, Norway and Finland

	Sweden	Norway	Finland
Perfect competition (SEK/kWh)	0.151	0.160	0.175
Cournot competition (SEK/kWh)	0.245	0.168	0.209

Table 6. Computed equilibrium free trade prices in Sweden, Norway and Finland

	Sweden	Norway	Finland
Perfect competition (SEK/kWh)	0.154	0.160	0.163
Cournot competition (SEK/kWh)	0.188	0.179	0.185

Note: The prices in Table 5 and Table 6 are excluding V.A.T. and electricity tax per kWh.

7. Concluding remarks

The results presented in the preceding sections suggest that a switch from autarky to free trade in electricity might be a good substitute for domestic competition policy measures in the presence of market power and monopolistic pricing. This is particularly the case when a high-price country such as Sweden (in the case of Cournot competition) can open up for free trade with a low-price country such as Norway. Thus, the emerging Nordic electricity market is likely to produce lower electricity prices and thus benefit electricity consumers in Sweden. The same conclusion applies to Finland.

In the case of Norway, however, free trade leads to higher electricity prices. In the aggregate Norwegian firms and households benefit from the gains from trade associated with free trade in electricity. These gains are distributed to the Norwegian electricity consumers in one way or another. However, for an individual electricity consumer in Norway the dividend from the gains from trade is uncertain, while the higher price of electricity is certain. In this perspective it is not surprising that Norway, at least compared to Sweden, has been somewhat hesitant towards free trade in electricity.

References

Andersson, B. (1997), Essays on the Swedish electricity market. Mimeo. Stockholm School of Economics.

Andersson, B. and L. Bergman (1995), "Market Structure and the Price of Electricity: An Ex Ante Analysis of the Deregulated Swedish Electricity Market", *Energy Journal*, Vol. 16, No 2.

Brander, J. and P. Krugman (1983), “A ‘Reciprocal Dumping’ Model of International Trade”, *Journal of International Economics* (15), p. 313-321.

Brooke, A., D. Kendrick and A. Meeraus (1988), GAMS. A User’s Guide. Redwood City: Scientific Press.