Working Paper No. 56/00

Will Cross-Ownership Reestablish Market Power in the Nordic Power Market?

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Eirik S. Amundsen and Lars Bergman

SNF-project No. 3412
Modellering av markedsmakt i det nordiske el-marked

The project is financed by Statoil

FOUNDATION FOR RESEARCH IN ECONOMICS AND BUSINESS ADMINISTRATION
BERGEN, OKTOBER 2000
ISSN 0803-4028

Will Cross-Ownership Reestablish Market Power in the Nordic Power Market?

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Eirik S. Amundsen[1] and Lars Bergman[2]

Abstract

The integration of the power markets in Norway and Sweden in 1996 significantly constrained the major power companies' ability to exercise market power within their national borders. In recent years, however, mergers and reciprocal acquisition of shares have reduced the number of independent players on the Norwegian-Swedish power market. The aim of this paper is to explore to what extent increasing cross-ownership among major power companies in Norway and Sweden might re-establish the market power that was lost when the two national power markets were integrated. The analysis is based on a numerical model, assuming Cournot quantity setting behavior, of the Norwegian-Swedish power market. The simulation results suggest that partial ownership relations between major generators and other power-producing firms tend to increase horizontal market power and thus the market price of electricity.

JEL classification code: L13, L41.
Keywords: electricity, cross ownership, market power
Date of this version: October 5, 2000

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[1] Department of Economics, University of Bergen, Norway, Fosswinckelsgt. 6, N-5007 Bergen, Tel.: 4755589205, Fax.: 4755589210, e-mail: eirik.amundsen@econ.uib.no

[2] Stockholm School of Economics, Box 6501, SE-113 83 Stockholm, Sweden. Tel.: 46 8 736 92 12 , Fax.:46 8 31 32 07, e-mail: Lars.Bergman@hhs.se

1. Introduction[3]

The deregulation of the Swedish power market in 1996, aimed at increasing productivity and reducing electricity prices, was coupled with serious concerns about market power. The reason for this was the high degree of concentration on the seller side of the market, indicated by CR1 and CR3 being approximately 0.5 and 0.8, respectively, and HHI being slightly above 0.3. The conclusion suggested by these simple concentration measures was supported by the analysis of hypothetical Cournot equilibria on the Swedish power market presented in Andersson and Bergman (1995). Their analysis also showed that a split of the state-owned company Vattenfall, the major player on the Swedish power market, would significantly reduce the impact of market power on electricity prices.

Instead of considering a split of Vattenfall, however, the Swedish government opted for an integration of the national electricity markets in the Nordic countries. As the degree of concentration was much lower in Finland and Norway (with HHI being 0.16 and 0.10, respectively) integration across the national borders seemed to be an efficient way of diluting market power in Sweden. This conclusion was supported by the results presented in Amundsen, Bergman and Andersson (1999)[4]. The integration of the Norwegian and Swedish power markets began in 1996 with the formation of a common power exchange, Nord Pool, and the elimination of border tariffs. In 1998 the integrated market expanded to include Finland, and in 1999 major steps towards including Denmark were taken.

However, the power companies in the Nordic countries have not remained passive. In addition to internal reorganizations in order to prepare for increased competition there has been a wave of mergers and acquisitions, within individual countries[5] as well as across the national borders. Companies with a strong position in generation, like Vattenfall in Sweden and Statkraft in Norway, have acquired holdings in distribution and supply companies. But generation companies have also acquired shares of other generation companies. For instance, Statkraft has bought 17 percent of Sydkraft, the second largest power producer in Sweden, and Sydkraft has bought 20 percent of Graninge, another Swedish power company. In addition two major generation companies, Stockholm Energi and Gullspång, have merged and formed Birka Energi, which is now the third largest power producer in Sweden[6].

The question then is if and to what extent the creation of ownership ties between generation companies is about to reestablish market power and thus undo what the integration of the Nordic power markets has achieved. The purpose of this paper is to assess the impact of ownership ties on competition and prices on the power market. The analysis is based on a

[3] Financial support from Project No. 4412, STATOIL-programme and the AES-programme of the National Swedish Energy Administration is gratefully acknowledged.

[4] Using a numerical model to simulate Nash-Cournot equilibria on the Norwegian-Swedish power market Amundsen, Bergman and Andersson showed that integration of the two national electricity markets significantly reduced the impact of market power on prices whenever there is no congestion in intercountry transmission links. Generally these links are congested during winter peak periods, as well as during extremely wet or dry years. In terms of annual average prices, however, the model results sugegsted that integration of the two national electricity markets to a very large extent would reduce Vattenfall´s possibilities to influence the market price.

[5] Public ownership is the dominant ownership form in Norway and accounts for about 85% of all power companies. The new integration process does not, however, seem to imply an increased privatisation of the power sector.

[6] In addition to ownership changes within Sweden and the entrance of Norwegian Statkraft as a major owner in Sydkraft the degree of foreign ownership has increased significantly on the Swedish power market. Thus the German power company Preussen Elektra has acquired a major share of Sydkraft, the Finnish energy company Fortum owns 50 percent of Birka Energi, and the French power company EdF is a minority owner of Graninge.

numerical model of hourly price determination on the Norwegian-Swedish power market. A key feature of the model is that a firm may own shares in one or several other firms. Thus the value of a firm depends not only on the profitability of that firm's own power market operations, but also on the profits of the firm(s) in which it is an owner. The reason for using a model is that explicit consideration of both supply and demand conditions allows for a richer analysis of market power issues than the use of simple concentration measures such as HHI[7].

In section 2 the basic features of the model are presented, while section 3 deals with the modeling of supply decisions. In section 4 the empirical basis of the study is discussed. Simulation results are presented in section 5, and concluding remarks are made in section 6.

2. The Basic Model

In recent years several approaches to the modeling of competition and price formation on electricity markets have been proposed. One is the so called supply-function equilibrium approach suggested by Klemperer and Meyer (1989) and used in several studies, for instance Bolle (1992), Green and Newbery (1992), Green (1996) and Green (1999). Another is the auction theory approach suggested by von der Fehr and Harbord (1993). A common feature of these approaches is that a well defined institutional framework for bidding and market clearing is assumed, and that the analysis is focused on price determination in the very short run. The obvious real world example of such an institutional framework is the mandatory pool in England and Wales.

In a somewhat longer perspective, i.e. a few months up to a year, however, the market price of electricity is less dependent on bidding strategies at the spot market and more dependent on the capacity decisions of the generators. Even if the number of existing power plants is given during the period in question, the amount of available generation capacity is not. Units with relatively high operation costs can be kept idle in such a way that the start-up time is very long. Alternatively even high-cost reserve capacity can be kept available at short notice. The time allocated for regular maintenance of other units can be adjusted to the market situation and the strategy of the generator owning the unit in question. Within relatively wide margins the possibility of storing water makes it possible for a generator to choose a suitable annual production capacity in its hydroelectric units[8]. Against this background it seems that the Cournot model of competition in quantities is a reasonable approximation of real world conditions in a time perspective between a few months and up to one year.

The numerical model used in this study is an extended version of the two-country model with inter-country transmission links presented in Amundsen, Bergman and Andersson (1999). In order to capture the impact of transmission capacity constraints in a realistic way it is a model of hourly production decisions and price determination. However, as equlibrium quantities and prices are computed only for ”representative” hours in various seasons of the year it is not a full-fledged real-time model. In line with the reasoning above Cournot quantity setting behavior on the part of the major generators is assumed. Minor producers, however, are assumed to behave as a price-taking “competitive fringe”. It should be pointed out that the model does not incorporate strategies (of the type discussed in Hogan (1999)) aimed at

[7] In von der Fehr et.al. (1998) it is shown how the HHI measure can be adjusted in order to take ownership relations between the firms into account.
[8] For a discussion of the role of quantity decisions on power markets, see Borenstein and Bushnell (1999) and Borenstein, Bushnell and Knittel (1999).

creating transmission congestion and thus local market power. In the next few sub-sections the basic structure of the model is described.

a. Countries and firms

Each firm has a country location, and F_c firms are assumed to be located in country *c*. The number of firms in country *c* may differ from the number of firms in country *r*. Each individual firm f_c in country c operates a set of generating units, all located in country c. Firms may be of different size, and may have different ”portfolios” of generating units. There is an inter-connector between the two countries, owned and operated by an independent grid operator. Transmission constraints within an individual country, however, are disregarded.

The generating units are divided into two categories, i and j. Category i consists of hydro and nuclear power plants, while category j consists of condensing power plants and combined heat and power (CHP) plants. Thus, with obvious notation the total output of firm f_c, measured in MW:s, is defined by the following equation:

$$X_{f_c} = \sum_{i=1}^{2} X_{f_{ci}} + \sum_{j=1}^{2} X_{f_{cj}} \; ; \qquad f_c=1,2, \dots ,F_c. \tag{1}$$

The total generation of power in country c, X_c, obviously is equal to the total generation in plants located in country *c*:

$$X_c = \sum_{f_c} X_{f_c} \; ; \tag{2}$$

The major power companies are both generators and suppliers of electricity, and the supply operation is typically organized as a separate business for buying and selling electricity. This means that the amount generated by a given firm during a specific hour may differ from the amount sold, or ”supplied”, by the same firm during that hour. For simplicity we disregard this feature of reality and assume that the amount of power supplied by an individual firm is equal to the amount of power generated. Yet the spatial allocation of generation and consumption, in conjunction with inter-connector capacity limitations, makes it important to distinguish between the amount of electricity generated and the amount of electricity supplied in different regions by a given firm. Thus, we let Z denote supply and use r as an index for the location of the consumers (Norway or Sweden). For each firm it then holds that

$$X_{f_c} = \sum_{r} Z_{f_{cr}} \; ; \quad f_c = 1,2,\dots,F_c \; . \tag{3}$$

b. Demand and prices

The demand for electricity by consumers in country r, E_r, is assumed to depend only on the relevant area price of electricity, P_r. In practice hourly prices are determined at the spot market organized by Nord Pool where, as was mentioned above, around 1/5 of the generated power is traded. The current model is intended to be a model of the entire market for power rather than a model of the spot market. Thus P_r should be interpreted as an indicator of the prices at which power is traded, according to bilateral contracts and on the spot market, during the season for which the model is solved[9]. Note that the model is solved only for one representative hour during the season in question, and that a “season” is defined by the assumptions about the level of demand[10].

The price elasticity of demand in country *r* faced by Norwegian and Swedish suppliers is denoted η_r and is assumed to be constant. Obviously the numerical value of this parameter reflects the short run price elasticity of the demand for electricity in country r. However, it also reflects the possibilities perceived by the customers in country *r* to switch from Norwegian or Swedish suppliers to Finnish, Danish or German suppliers. This ”elasticity of substitution” depends on season and available transmission capacity and is thus likely to vary between relatively high and relatively low values. However, it unequivocally makes the demand for Norwegian-Swedish electricity in country *r* more price-elastic than the total demand for electricity in that country. Given these assumptions about the structure of demand the inverse demand function for consumers in country *r* becomes

$$P_r = P_r^0 \left(\frac{E_r}{E_r^0}\right)^{1/\eta_r}; \tag{4}$$

where P_r^0 is the base year price and E_r^0 the base year consumption in area r. The total supply of power in country r, Z_r, is defined by

$$Z_r = \sum_c \sum_{f_c} Z_{f_c r}; \tag{5}$$

As long as the inter-connector capacity is sufficient the two countries are effectively one single market for electricity, and there is a single equilibrium price for electricity. The equilibrium condition for the integrated market can be written

$$\sum_r Z_r = \sum_r E_r; \tag{6}$$

When the inter-connector is congested, however, the market is divided into two markets with a separate equilibrium price for each market. The equilibrium condition for the segmented markets becomes

$$Z_r = E_r; \quad r = \text{Norway, Sweden.} \tag{7}$$

c. Inter-connector capacity and transmission prices

The demand for inter-connector capacity depends on the relation between generation and demand in the two countries. Thus, if the total demand for power in, say, Norway exceeds the total generation of power in Norway while the opposite holds in Sweden, there is a positive flow of power from Sweden to Norway. In the model there is one inter-country transmission link, and thus two inter-country transmission possibilities: from Norway to Sweden (NS) and

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[9] Our implicit assumption is that the spot market prices are anticipated by the agents and thus close to the prices agreed upon in bilateral contracts. Consequently the model is not suited for analysis of how unforeseen changes of supply or demand affect the hourly price of electricity. In order to be appropriate for such an anlysis the model should explicitly distinguish between the spot market and the bilateral contract market.

[10] The ”representative hour” approach makes it possible to solve the model for many individual firms and two regions, but it also makes it necessary to exogenously determine the allocation of hydro power production between seasons.

from Sweden to Norway (SN). Denoting the maximum capacity of the inter-connector by M and utilizing (7) the following equilibrium conditions have to be satisfied:

$$X_S - Z_S \leq M_{SN};\qquad (8)$$

$$X_N - Z_N \leq M_{NS};\qquad (9)$$

It should be noted that $X_S - Z_S$ must have the same absolute value as, but opposite sign of, $X_N - Z_N$. It is obvious that the transmission constraints (8) and (9) cannot both be binding.

The transmission grid operator is assumed to set the (marginal)[11] transmission prices on the basis of the marginal cost of congestion. The price of transmission from Sweden to Norway is denoted φ_{SN}, while the price of transmission from Norway to Sweden is denoted φ_{NS}. These prices are non-negative and defined by the following complementarity conditions:

$$\varphi_{SN}(X_S - E_S - M_{SN}) = 0;\qquad (10)$$

$$\varphi_{NS}(X_N - E_N - M_{NS}) = 0;\qquad (11)$$

These conditions imply that φ_{SN} is positive only if the interconnector capacity is fully utilized in the Sweden-to-Norway direction, and that φ_{NS} is positive if the interconnector capacity is fully utilized in the Norway-to-Sweden direction. It follows that φ_{SN} must be zero whenever φ_{NS} is positive, and vice versa. Moreover it holds that to the extent that there is a difference between the equilibrium price of power in the two countries this difference is equal to the price of transmission in the constrained direction. If the difference was bigger or smaller, the agents could increase their profit by increasing or decreasing trade across the national border. Thus, if the capacity of the interconnector is fully utilized in the Sweden-to-Norway direction, the power price in Norway is equal to the power price in Sweden plus the relevant price of transmission.

One implication of this is that the revenue per unit of output of a Norwegian (Swedish) generator is always equal to the price of power in Norway (Sweden). Thus the revenue per unit of output does not depend on the extent to which a Norwegian (Swedish) generator is the supplier of customers in Sweden (Norway). Formally the relation between power prices in the two countries can be written

$$P_S + \varphi_{SN} = P_N + \varphi_{NS};\qquad (12)$$

d. Cost functions

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 production between the different generating units in order to minimize cost. The solution of this cost minimization problem in effect defines the marginal cost function of the individual firm. This function reflects the marginal cost of operating the different generating units, with given capacities, at the firm´s disposal.

[11] Fixed access charges as well as transmission loss dependent charges are disregarded

Hydro and nuclear generating units are assumed to be homogenous, i.e. for each type of plant the marginal cost is independent of the level of capacity utilization and equal to c_i (= hydro, nuclear). The total available capacity in plants of type *i* in firm f_c is denoted $K_{f_c i}$. Condensing and CHP generating units, however, are assumed to be heterogeneous. Thus the marginal cost depends on the level of capacity utilization. The reason for this assumption is that both condensing and CHP plants generally differ with respect to fuel input and thermal efficiency. Instead of including a large number of different types of plants the mentioned heterogeneity is reflected in the marginal cost function of condensing and CHP plants, respectively. These functions are written

$$C_{f_c j} = a_j + b_j \left(\frac{X_{f_c j}}{K_{f_c j}} \right)^{\rho}; \qquad j=1,2. \tag{13}$$

where a_j represents the marginal cost of operating the least expensive generating unit of type *j*, while a_j+b_j represents the marginal cost of operating the most expensive generating unit of type *j* close to full capacity utilization. The term in brackets indicates the ratio of output to capacity in generating units of type *j* and is intended to be a ”smooth” capacity constraint. Consequently the parameter ρ is positive and has a high, arbitrarily chosen, absolute value so that any tendency to more than full capacity utilization leads to a major increase in marginal cost. The parameters a_j, b_j and c_j can be estimated on the basis of engineering data, while data on available capacities in different types of plants can be found in annual reports from individual power companies.

With this background the cost minimization problem of an individual firm can be written

$$\text{Minimize} \sum_i c_i X_{f_c i} + \sum_j a_j X_{f_c j} + \sum_j b_j \left(\frac{X_{f_c j}}{K_{f_c j}} \right)^{\rho} X_{f_c j}; \tag{14}$$

subject to

$$X_{f_c i} \le K_{f_c i}; \quad i = 1,2$$

$$\sum_i X_{f_c i} + \sum_j X_{f_c j} = X_{f_c}$$

$$X_{f_c i}, X_{f_c j} \ge 0$$

The solution to this problem defines the marginal cost function of firm f_c . This function does not appear in closed form in the model, but for the purpose of presenting the modeling of output and supply decisions in the next section it is useful to have an explicit formulation of the marginal cost function of an individual firm. Thus, in the following we let the function

$$C_{f_c} = C_{f_c}(X_{f_c}, K_{f_c i}, K_{f_c j}); \qquad f_c = 1,2,\ldots,F_c. \tag{15}$$

represent the marginal cost of output in firm f_c. We also make the simplifying assumption that the marginal cost function is differentiable at all output levels[12].

[12] To be precise this is not the case when output is equal to the available hydro capacity as well as when output is equal to the sum of available hydro and nuclear capacity in firm f_c.

3. Partial Ownership and Supply Decisions

As was indicated above there are two categories of firms in both countries. The first consists of the relatively big firms, all of which are assumed to behave in accordance with the Cournot model of competition in quantities. These firms are referred to as the "Cournot players". The remaining firms are aggregated into a price-taking "competitive fringe" in each country. Both types of firms are assumed to maximize profit, but the specification of the necessary conditions for profit maximization obviously differs between the two categories of firms. It is only for the Cournot players that ownership may have an impact on supply decisions. However, the specification of the relation between the structure of ownership and the supply decisions of a firm is less than obvious.

The motives for acquiring shares in rival companies and participating in various forms of co-operation may be complex and case-specific. According to von der Fehr et al. (1998) three types of motives can be distinguished. The first is expected synergies, for example cost reduction through sales co-operation. The second is financial considerations, e.g. investing funds into other companies as a part of the company's management of financial assets. The third is learning, e.g. to get information from the other company on how to deal with a certain production process. However, irrespective of the main motive for inter company relationships, they may all result in significant effects on market prices and quantities produced. For the purposes of this study the most important distinction is between a passive (or silent) ownership arrangement and an active ownership arrangement.

With a passive ownership arrangement a company owning a share of another company has no direct influence on the production decision of that company. The company can, however, indirectly influence the profit of the other company (and thereby its own proceeds) via the price effect that its own production decision gives rise to. Hence with a passive ownership arrangement the optimal decision for the company in question is to adjust its own production in such a way that all direct and indirect effects on its profit is taken account of. It is a well established result in the literature that when Cournot oligopolists have a passive ownership arrangement with partial equity interests in one another, they jointly will act less competitively and, hence, promote higher prices (Bresnahan and Salop (1986); Reynolds and Snapp (1986) and Flath (1991))[13].

An active ownership arrangement is characterized by a co-ordinated production decision between the firm and some of its potential competitors. This may take place in a situation where the firm possesses sufficiently large ownership shares in other firms to be able to exercise at least some control over their production decisions. It may also take place if the firm has external owners that have important shares in some of the other competing firms. In this case the firms involved may co-ordinate their production decisions so as to benefit their

[13] However, while it is true that increasing partial ownership among rivals results in a more profitable non-cooperative equilibrium, it is not necessarily true that all participants gain from increasing their cross ownership share. Flath (1991) shows that in Cournot industries it would not be rational for a firm to acquire partial equity interests in rivals, while it may be rational for a firm in a Bertrand duopoly to acquire a silent interest in the other. Similar results are obtained in Reitman (1994). The essential point is how aggressive the remaining participants in the market respond to an increasing degree of cross ownership. Under Cournot competition remaining competitors will expand production and thus lower market price, while Bertrand competitors will increase price. Furthermore, Malueg (1992) shows that in a repeated game the collusive element for those companies owning shares in each other is not necessarily strengthened by increased cross ownership. In particular he shows that whether an increase in cross ownership will bring about a reduction in cheating depends critically on the demand function.

common owners. For this case, however, there exists no obvious equilibrium concept for co-ordination of production decisions (von der Fehr et al., (1998)).

The ownership arrangement observed on the Norwegian-Swedish power market seem to come closest to a passive arrangement although some of the participants have significant shares in other firms. For instance, it is reasonable to believe that Statkraft may exercise some influence through its Board representatives in Sydkraft, Oslo Energi and BKK. However, these are not majority representations, and Statkraft is clearly not in a position to freely control the operations of these companies.

Some of the motives for entering into partial ownership arrangements mentioned above are also valid for the Norwegian-Swedish power market. For instance, companies have joined into sales co-operations (e.g. Nordenfjeldske Energi) and the learning argument seems to have been present when Statkraft bought a share in Sydkraft, as Statkraft claimed that it wanted to acquire information on how to operate wind power plants (von der Fehr et al., (1998)). However, in the following we are not concerned with any particular reason why the power companies in Sweden and Norway entered into the ownership arrangements but rather observe that these arrangements exist and concentrate on optimal production decisions. Hence, we set out to investigate the effects on quantities and prices assuming Cournot-Nash competition (as explained above) and a passive ownership arrangement among the companies.

a. Definitions

In order to incorporate ownership aspect into the model a complete listing of firms is called for. We denote elements in the list of firms by *l* or *k*. Thus it holds that $l,k = 1_S,...,f_S,...,F_S,1_N,...,f_N,...,F_N$, where S denotes Swedish firms and N denotes Norwegian firms. Furthermore, we let δ_{lk} denote firm l's share of the value of firm k, while V_k denotes the value of firm k and Π_l denotes the operating profit of firm l. Following Flath (1991) and von der Fehr et al. (1998), the value of firm l may then be expressed as follows

$$V_l = \Pi_l + \sum_{k \neq l}^{F} \delta_{lk} V_k \quad ,\forall l,k; \tag{16}$$

To solve for the values of V_l's, express the system of equations as

$$[\mathbf{I} - \mathbf{D}]\mathbf{V}' = \mathbf{\Pi}' \tag{17}$$

where $\mathbf{I}$ is the unitary matrix, $\mathbf{D}$ is the $(F_S + F_N)x(F_S + F_N)$ matrix of $\delta_{lk}, l \neq k$, $\mathbf{V} = [V_{1_S},...,V_{f_S},...,V_{F_S},V_{1_N},...,V_{f_N},...,V_{F_N}]$ and $\mathbf{\Pi} = [\Pi_{1_S},...,\Pi_{f_S},...,\Pi_{F_S},\Pi_{1_N},...,\Pi_{f_N},...,\Pi_{F_N}]$.

The solution of $V's$ may be found as

$$\mathbf{V} = [\mathbf{I} - \mathbf{D}]^{-1}\mathbf{\Pi} \tag{18}$$

The elements of the inverted matrix are denoted d_{lk}. In order to express the value of a firm it is convenient to list firms by their nationalities. Hence, we let $l_S, k_S = 1_S,...,f_S,...,F_S$ and $l_N, k_N = 1_N,...,f_N,...,F_N$. The value of a firm in country c, f_c may then be written

$$V_{f_c} = \sum_{l_S=1}^{F_S} d_{f_c l_S} \Pi_{l_S} + \sum_{l_N=1}^{F_N} d_{f_c l_N} \Pi_{l_N} \tag{19}$$

The operating profit of a Swedish and a Norwegian firm, respectively, may be expressed as

$$\Pi_{l_S} = P_S Z_{l_S S} + P_N Z_{l_S N} - C(Z_{l_S}) - \varphi_{SN} Z_{l_S N}; \tag{20}$$

$$\Pi_{l_N} = P_S Z_{l_N S} + P_N Z_{l_N N} - C(Z_{l_N}) - \varphi_{NS} Z_{l_N S}; \tag{21}$$

b. Supply decisions

The point of departure for the modeling of supply decision is the conclusion that partial ownership arrangements on the Nordic power market at least approximately can be regarded as "passive". Thus it is assumed that a firm that owns a share of another firm, the “owner firm”, does not directly influence the output and supply decisions of the partially owned firm. However, the output and supply decisions of the owner firm may indirectly influence the profit of the firms in which it owns shares. Thus the output and supply decisions of the owner firm affect both the revenues and costs of that firm and the value of its shares in the partially owned firms. We seek the Nash-Cournot equilibrium for this case. The first order conditions of an optimum for a Swedish firm are

$$\frac{\partial V_{f_S}}{\partial Z_{f_S c}} = \sum_{l_S=1}^{F_S} d_{f_S l_S} \frac{\partial \Pi_{l_S}}{\partial Z_{f_S c}} + \sum_{l_N=1}^{F_N} d_{f_S l_N} \frac{\partial \Pi_{l_N}}{\partial Z_{f_S c}} = 0, \quad c = S, N$$

and correspondingly for a Norwegian firm

$$\frac{\partial V_{f_N}}{\partial Z_{f_N c}} = \sum_{l_S=1}^{F_S} d_{f_N l_S} \frac{\partial \Pi_{l_S}}{\partial Z_{f_N c}} + \sum_{l_N=1}^{F_N} d_{f_N l_N} \frac{\partial \Pi_{l_N}}{\partial Z_{f_N c}} = 0, \quad c = S, N$$

Under Cournot competition the necessary conditions for profit maximization for a Swedish “non-fringe” firm selling both to consumers in Sweden and to consumers in Norway can be written:

$$P_S + \frac{\partial P_S}{\partial Z_{f_S S}} \left\{ \sum_{l_S=1}^{F_S} \frac{d_{f_S l_S}}{d_{f_s f_s}} Z_{l_S S} + \sum_{l_N=1}^{F_N} \frac{d_{f_S l_N}}{d_{f_s f_s}} Z_{l_N S} \right\} - C_{f_S} \leq 0; \tag{11}$$

$$Z_{f_S S} (P_S + \frac{\partial P_S}{\partial Z_{f_S S}} \left\{ \sum_{l_S=1}^{F_S} \frac{d_{f_S l_S}}{d_{f_s f_s}} Z_{l_S S} + \sum_{l_N=1}^{F_N} \frac{d_{f_S l_N}}{d_{f_s f_s}} Z_{l_N S} \right\} - C_{f_S}) = 0; \tag{12}$$

$$P_N + \frac{\partial P_N}{\partial Z_{f_S N}} \left\{ \sum_{l_S=1}^{F_S} \frac{d_{f_S l_S}}{d_{f_s f_s}} Z_{l_S N} + \sum_{l_N=1}^{F_N} \frac{d_{f_S l_N}}{d_{f_s f_s}} Z_{l_N N} \right\} - C_{f_S} - \varphi_{SN} \leq 0; \tag{13}$$

$$Z_{f_S N}(P_N + \frac{\partial P_N}{\partial Z_{f_S N}} \left\{ \sum_{l_S=1}^{F_S} \frac{d_{f_s l_S}}{d_{f_s f_s}} Z_{l_S N} + \sum_{l_N=1}^{F_N} \frac{d_{f_s l_N}}{d_{f_s f_s}} Z_{l_N N} \right\} - C_{f_S} - \varphi_{SN}) = 0\,; \tag{14}$$

In the same way the necessary conditions for profit maximization for a Norwegian "non-fringe" firm under Cournot competition can be written:

$$P_S + \frac{\partial P_S}{\partial Z_{f_N S}} \left\{ \sum_{l_N=1}^{F_N} \frac{d_{f_N l_N}}{d_{f_N f_N}} Z_{l_N S} + \sum_{l_S=1}^{F_S} \frac{d_{f_N l_S}}{d_{f_N f_N}} Z_{l_S S} \right\} - C_{f_N} - \varphi_{NS} \le 0\,; \tag{15}$$

$$Z_{f_N S}(P_S + \frac{\partial P_S}{\partial Z_{f_N S}} \left\{ \sum_{l_N=1}^{F_N} \frac{d_{f_N l_N}}{d_{f_N f_N}} Z_{l_N S} + \sum_{l_S=1}^{F_S} \frac{d_{f_N l_S}}{d_{f_N f_N}} Z_{l_S S} \right\} - C_{f_N} - \varphi_{NS}) = 0\,; \tag{16}$$

$$P_N + \frac{\partial P_N}{\partial Z_{f_N N}} \left\{ \sum_{l_N=1}^{F_N} \frac{d_{f_N l_N}}{d_{f_N f_N}} Z_{l_N N} + \sum_{l_S=1}^{F_S} \frac{d_{f_N l_S}}{d_{f_N f_N}} Z_{l_S N} \right\} - C_{f_N} \le 0\,; \tag{17}$$

$$Z_{f_N N}(P_N + \frac{\partial P_N}{\partial Z_{f_N N}} \left\{ \sum_{l_N=1}^{F_N} \frac{d_{f_N l_N}}{d_{f_N f_N}} Z_{l_N N} + \sum_{l_S=1}^{F_S} \frac{d_{f_N l_S}}{d_{f_N f_N}} Z_{l_S N} \right\} - C_{f_N}) = 0\,; \tag{18}$$

For a "fringe" firm the impact on the market price of an individual firm's output decision is assumed to be zero. Hence, the assumption of profit maximization implies that each fringe firm equates marginal cost to price and sells to that consumer area where the price is the largest. This leads to price equalization between consumer areas unless, of course, transmission capacity is binding.

4. Empirical Basis

The cost and demand data used in this study are the same as those used in Andersson (1997). The operating cost of hydro power is defined as the opportunity cost of using stored water during other parts of the year, and estimated on the basis of observed production patterns. The price elasticity of demand for electricity generated by Norwegian or Swedish producers is assumed to be -0.5 both in Norway and Sweden. The total installed capacity is assumed to be given for all firms. In Table 1 data on total installed capacity for the Cournot players and the competitive fringe in both countries is presented. Almost all of the installed capacity of the Norwegian firms is hydro power, while the Swedish firms have a mix of hydro and nuclear power. In addition some of the Swedish firms have CHP plants, and Vattenfall has a considerable amount of reserve capacity based on fossil fuels.

Even though approximately 15 percent of Vattenfall´s available production resources is reserve capacity with relatively high operating costs the figures in Table 1 suggest that Vattenfall is a dominating player with potential market power both on the Swedish and the Norwegian-Swedish power market. This is particularly the case during peak-load periods when all or most of the available capacity of the other producers is fully utilized. However, in this paper we disregard these aspects of the competitive environment during peak-load period[14].

Table 1. Installed capacity (MW) of Norwegian and Swedish power producers 1997

Norwegian power producers		Swedish power producers	
Statkraft	8 260	Vattenfall	16 720
Hydro Energi	2 260	Sydkraft	6 500
Oslo Energi	1 720	Birka Energi	4 900
BKK	1 520	STORA Kraft	1 470
Lyse Kraft	1 440	Skellefteå Kraft	580
Competitive Fringe	9 040	Graninge	560
		Competitive Fringe	1 720

As of 1998 there are some partial ownership arrangements between Norwegian and Swedish power companies. Thus Statkraft owns 17 percent of the shares in Sydkraft, 20 percent of the shares in Oslo Energi, and 26 percent of the shares in BKK. In addition the Finnish energy company Fortum is a major owner in Birka Energi, while Preussen Elektra is a major owner in Sydkraft and EdF is a major owner in Graninge. The possible impact of these owners on the behavior of the Norwegian and Swedish power companies, however, is disregarded. The ownership relations between these companies are summarized in Table 2.

Table 2. Partial ownership structure in 1998 (percent of owned company).

	Sydkraft	Birka Energi	Graninge	Oslo Energi	BKK
Sydkraft			20		
Graninge		8			
Statkraft	17			20	26

5. Simulation Results

The first issue to explore is to what extent the current pattern of partial ownership on the Nordic power market influences the output of the major firms and the level of equilibrium prices in Norway and Sweden. By “major firms” is in the following meant Vattenfall, Statkraft, Sydkraft and Birka. In order to elucidate this issue the model is solved under two different sets of assumptions. In the first case, which is referred to as the “Base Case”, the actual pattern of partial ownership arrangements is assumed to prevail. In the second, referred to as the “No Ownership Case”, it is assumed that no partial ownership arrangements exist. Both cases refer to the winter season, i.e. the season in which demand is close to the maximum production capacity in both countries. Table 3 below summarizes the model simulation results.

Statkraft is the only firm with significant holdings in other firms. The results presented in Table 3 suggest these holdings in conjunction with the behavior implied by the conditions (24) – (31) in Section 3 have a significant impact both on the profit maximizing output level of Statkraft and on the prices of electricity in Norway and Sweden. More precisely Statkraft reduces its level of output, and thus manages to increase electricity prices in both countries.

[14] See Amundsen and Bergman (1999) for a discussion about the relation between demand and the competitive environment on the Norwegian-Swedish power market.

As both Sydkraft and Birka Energi are producing at a level where the marginal cost curve is steeply increasing, their output levels remain constant. Vattenfall, on the other, hand responds to the actions of Statkraft by slightly reducing its own output.

It should be noted that in the “No Ownership” case the electricity prices differ between the two countries, reflecting congestion in the Norwegian-Swedish interconnector. Thus the total supply in Sweden is equal to the sum of generation in Sweden and full capacity import (2 500 MW) from Norway. The price for transmitting power from Norway to Sweden is 6.6 SEK/MWh, while the price for transmission in the opposite direction is -6.6 SEK/MWh. In the “Base Case” it is profitable for Statkraft to reduce output in order to increase the market price. As a consequence of that the flow of power from Norway to Sweden is reduced, and the interconnector capacity is no longer binding. Accordingly the difference between the Norwegian and the Swedish electricity prices disappears (except for a small difference reflecting transmission losses).

Table 3. Computed equilibrium prices (SEK/MWh) and quantities (MW) with and without partial ownership relations between firms

	Sweden				Norway	
	Price	Production, Vattenfall	Production, Sydkraft	Production, Birka	Price	Production, Statkraft
Base Case	147.0	6 770	4 850	4 150	146.9	5 200
No Ownership	145.3	6 870	4 850	4 150	138.7	5 880

The “No Ownership” case, however, can be interpreted in another way. Given that, say, Statkraft owns shares in other firms producing power to be sold on the Norwegian-Swedish market it can choose between different “behavior models”. One alternative is to behave in accordance with the conditions defined in Section 3, i.e. to make to output and supply decisions with an eye to the values of the partially owned firms. This is equivalent to the “Base Case”. The other alternative is that Statkraft choose to neglect the impact of its output and supply decisions on the profits of the partially owned firms. From a computational point of view this is equivalent to the “No Ownership” case. In Table 4 the profit of Statkraft, defined as the hourly operating surplus, in the two cases is presented.

Table 4. Calculated profit of Statkraft (MSEK/h) under different behavior assumptions

	Base Case	No Ownership
Profit in Statkraft	0.244	0.247
Share of profit in Sydkraft	0.047	0.043
Share of profit in Oslo Energi	0.016	0.014
Share of profit in BKK	0.018	0.017
Total calculated profit	0.325	0.321

The results presented in Table 4 suggest that Statkraft should behave in accordance with the principles discussed in Section 3. Although the reduction of output leads to a lower profit in

Statkraft itself this is more than fully compensated by profit increases in the firms partially owned by Statkraft.

Next we explore the impact of new ownership relations between firms, i.e. ownership relations in addition to those already existing. In order to make the different alternatives comparable it is throughout assumed that the shares that a firm acquires in some other firm corresponds to 1 200 MW generating capacity. This amount of capacity, which is arbitrarily chosen, is equal to the capacity of two major power plants. Using the model several alternatives are compared, but the whole exercise is aimed at elucidating two issues, the “where” and the “who” issue. The “where” issue is whether it makes any significant difference if a given firm acquires shares corresponding to 1 200 MW installed capacity in the home country or in the foreign country, or in a big, a medium sized or a set of small firms. The “who” issue is whether it makes any significant difference if shares corresponding to a given amount of installed capacity is acquired by a big or a medium sized firm. We begin with the “where” issue.

First we study the impact of reciprocal ownership relations between Vattenfall and Statkraft, i.e. the two biggest firms. Thus it is assumed that Vattenfall acquires shares corresponding to 1 200 MW generation capacity in Statkraft, while Statkraft acquires shares corresponding to the same amount of capacity in Vattenfall. This case is referred to as “Reciprocal”. In the next case Vattenfall and Statkraft are assumed to acquire shares corresponding to 1 200 MW installed capacity in Sydkraft and Hydro Energi, respectively. As these firms are the second biggest power producing firms in Sweden and Norway, respectively, this case is denoted “Second”. In the third case Vattenfall and Statkraft acquire shares, again corresponding to 1 200 MW installed capacity, in firms in the “competitive fringe” in Sweden and Norway, respectively. This case is denoted “Fringe”. The simulation results are summarized in Table 5.

Table 5. Calculated impact of additional ownership relations

	Sweden				Norway		
	Price	Generation, Vattenfall	Generation, Sydkraft	Generation, Birka	Price	Generation, Statkraft	Generation, Hydro
Base Case	147.0	6 770	4 850	4 150	146,9	5 200	2 270
Reciprocal	150.4	6 310	4 850	4 170	152.3	4 970	2 270
Second	154.3	6 370	4 850	4 170	154.4	4 490	2 270
Fringe	154.6	6 250	4 850	4 170	154.7	4 560	2 270

The results presented in Table 5 suggest that additional partial ownership relations would in general increase the potential market power of Vattenfall and Statkraft, and thus would lead to higher Cournot equilibrium prices. The results also suggest that the impact on Cournot equilibrium prices of partial ownership of firms located on the other side of the national border is less significant than partial ownership of firms located within the national borders. The reason for this is that interconnector congestion may reduce the possibilities of a major firm in Norway (Sweden) to increase the price level in Sweden (Norway). However, there are only minor differences between “Second” and “Fringe”. The conclusion is that the location of the owned firm seems to make some difference, while the size of that firm does not.

Next we will explore the ”who” issue, using Sydkraft and Hydro Energi as main actors. In the first case, denoted ”Reciprocal 2”, it is assumed that these two firms acquire shares corresponding to 1 200 MW installed capacity in each other. In the second case, denoted ”Fringe 2”, Sydkraft acquires shares in the competitive fringe in Sweden, while Hydro Energi acquires shares in the competitive fringe in Norway. The simulation results are summarized in Table 6. The most striking result is that both cases differ very little from the Base Case. In other words it seems that the impact of partial ownership relations to a large extent depends on who the owning firm is. If the biggest firms acquires shares in other firms equilibium prices and quantities are significantly affected, but if the acquiring firms are only medium sized the impact is almost neglible.

Table 6. Calculated impact of additional ownership relations

	Sweden				Norway		
	Price	Generation, Vattenfall	Generation, Sydkraft	Generation, Birka	Price	Generation, Statkraft	Generation, Hydro
Base Case	147.0	6 770	4 850	4 150	146,9	5 200	2 270
Reciprocal 2	146.9	6 770	4 850	4 170	147.1	5 190	2 270
Fringe 2	147.9	6 840	4 850	4 170	148.0	4 970	2 270

6. Concluding Remarks

The unbundling of generation and transmission in order to counteract vertical market power has been a key element of electricity market reform in the Nordic countries. In Sweden legal separation of generation and transmission is required, while accounting and management separation is required in Norway and Finland. When it comes to horizontal market power, however, less far-reaching methods have used. Thus the preferred method to counteract this type of market power has been to integrate the national electricity markets, thus enlarging the relevant market for the major generators and in effect diluting horizontal market power. In terms of simple concentration measures such as HHI or CR-X this policy has been successful. For instance Vattenfall, the biggest company on the Nordic electricity market, used to operate on a national market with HHI above 0.30 and a CR-1 above 0.50 is currently operating on an integrated Nordic market with HHI below 0.15 and CR-1 around 0.20.

It is obvious that mergers between generators operating on the Nordic market would reestablish at least part of the horizontal market that recently disappeared, particularly if some of the major generators would merge. However, our analysis suggests that outright mergers may not be necessary; the major generators can reestablish part of the lost horizontal market power by becoming passive minority owners in other generating companies. With minority positions in other generating companies the major firms have incentives to produce less than under Cournot competition between independent firms, thus accepting lower profit in the own operations in exchange for a share of the higher profit in other companies resulting from a higher market price.

The competition policy conclusion of this finding is obvious: The competition authority should not only look after mergers and complete take-overs on the electricity market. It should also keep an eye on acquisitions of minority shares, particularly when the buyer is one of the major generators.

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