

Working Paper No. 2/03

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and Acquisitions in Networks**

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SNF Project No. 4355
Konkurransestrategier i det norske kraftmarkedet

The project is financed by Statkraft

INSTITUTE FOR RESEARCH IN ECONOMICS AND BUSINESS ADMINISTRATION

Bergen, Januar 2003

ISSN 1503-2140

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Temporary Bottlenecks, Hydropower and Acquisitions in Networks¹

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Preliminary draft

JEL classification: D43, L13, L41, L94

Keywords: Hydropower, acquisition, oligopoly, transmission

January 10, 2003

Abstract: The purpose of this article is to study the effects of an acquisition in an energy system dominated by hydropower and with temporary bottlenecks. We apply a model with four markets: two regions and two time periods. It is shown that an acquisition has an ambiguous effect on welfare. In some instances it would lead to larger differences in prices between different markets, which would lead to an increase in the dead weight loss. In other instances an acquisition would lead to a reduction in price differences between different markets. This may happen if the dominant firm acquires a firm that is active in the market where the dominant firm used to dump its energy capacity before the acquisition took place.

¹We are indebted to seminar participants at Institute for Research in Economics and Business Administration (SNF) for helpful comments and to Nils-Henrik M. von der Fehr for valuable comments on an earlier draft. This paper has been presented at the Nordic Energy Research conference in Copenhagen November 15, 2002 and a seminar at The Research Institute of Industrial Economics (IUI) in Stockholm November 27, 2002. The research has been partly financed by Statkraft through Institute for Research in Economics and Business Administration (SNF).

1 Introduction

During the last decade many countries have liberalized their electricity industry. There are several studies that analyse how well competition works in such an industry.² These studies are typically using one-period models with increasing marginal costs. Such models are well suited to analyse a system with thermal production. However, in several countries hydropower has a dominant position.³ An important feature in such a system is that a hydropower producer allocates its water resources between different periods by storage in water reservoirs. With a few notable exceptions, the large flexibility of hydropower producers to shift production across time is not modelled in the existing literature.⁴ The purpose of this article is to introduce a simple model with hydropower producers that allocate their production between different time periods and different geographical regions. We apply the model to study effects of acquisitions in a situation with temporary bottlenecks. It is shown that the idiosyncratic characteristics of the hydropower system may reverse the existing results in the literature concerning the consequences of higher concentration.

One main concern which has been raised is that in a hydropower system a dominant producer may exploit its unique flexibility to shift production across time. As shown in Bushnell (2000), this may lead to a further separation of geographically and temporally distinct markets and an increase in price differences between markets. This suggests that one should carefully watch any market where the production capacity of one large hydropower producer can not be replaced with that of other smaller competitors. Furthermore, a hydropower producer might violate a competitive outcome. It might behave in such a way that it induces a constraint on the transmission

²Green and Newbery (1992), von der Fehr and Harbord (1993), Green (1996), Newbery (1998) and Wolfram (1999) are all studies that are analysing the British electricity market, while Borenstein and Bushnell (1999) and Borenstein, Bushnell and Wolak (2000) are examples of studies of the Californian electricity industry. Two recent studies of competition in the Nordic electricity market are Hjalmarsson (1999) and Amundsen and Bergman (2000).

³In New Zealand 80% of production is from hydro, in Chile 70%, Brazil 97% and Norway close to 100%.

⁴Scott and Read (1997), Crampes and Moreaux (2001) and Bushnell (2000) all model a mixed system with hydropower and thermal production. None of them analyse the effects of a more concentrated industry, for example due to acquisitions. von der Fehr and Johnsen (2002) analyse a pure hydropower system, and they compare perfect competition with a situation with market power. In contrast, our main focus is on the effects of an acquisition in a situation where we have imperfect competition both before and after the acquisition.

line and thereby creates a deviation from a competitive outcome.⁵ As shown in Borenstein, Bushnell and Stoft (2000) the producer can by acting like this cause price differences.⁶

We share the concern that a hydropower producer might violate an outcome that otherwise would have been competitive, and that one should watch extra carefully a situation where a hydropower producer is the marginal producer in the marketplace. Indeed, our two first results replicate these two situations. However, in the intermediate situation, where we have an oligopoly situation at the outset, we find that an increase in concentration will not have such a clear-cut welfare deteriorating effect.

To explain our counterintuitive results, let us describe our model approach. There are two different regions and two different time periods in our model, implying that there is a potential for four separate sub-markets. Each hydropower producer has a total fixed energy capacity, determined by water available in their reservoirs, and allocates its total capacity between the sub-markets.⁷ Each producer can shift production in time by storing water in its reservoir, and shift production between regions by exporting through a transmission line. The transmission lines are owned by an independent operator, who acts as an arbitrage player between regions and always exports to the high price region.⁸ We focus on the case with tempo-

⁵Schmalensee and Golub (1984) pointed at the potential problems associated with congestion on transmission lines. However, with no satisfactory definition of how the scarce transmission resources should be allocated (the pricing issue) and due to lack of area specific data they were forced to define geographic market areas on a more ad hoc basis. Schweppe *et al.* (1988) develops a spot pricing theory where the special features of electric networks are considered. This model, known as "nodal pricing", ensures short-run economic dispatch of load subject to network and generation constraints. Later we have seen several studies of the problems associated with congested transmission lines, such as the pricing of transmission and incentives for investing in transmission lines. See for example Hogan (1992), Oren *et al.* (1995), Bushnell and Stoft (1996), Chao and Peck (1996) and Cardell *et al.* (1997) for analysis of energy systems as networks.

⁶Note, though, that Borenstein, Bushnell and Stoft (2000) applies a model with only thermal production. Whether this phenomena is more profound in a hydropower system than in a thermal system is an open question. Hydropower producers are flexible, and due to this such a producer can easily create a bottleneck. On the other hand, other hydropower producers can react quickly and thereby dampen or even eliminate the attempt to create a bottleneck. In any case, endogenous bottlenecks can emerge in hydropower systems as in other energy systems. Note that von der Fehr and Johnsen (2002) show that strategic behaviour in a hydropower system can lead to larger price differences.

⁷We also introduce thermal production in one of the regions, but we show that even then we may have counter-intuitive results.

⁸Our approach is consistent with the institutional setting in the Nordic market, and it is also in line with the "nodal pricing" system first introduced in Schweppe *et al.* (1988).

rary bottlenecks, where transmission lines can be capacity constrained only in one of the two periods. A dominant producer can exploit the potential for bottlenecks strategically. For example, it can withdraw sales in a period so that the capacity constraint is binding. By doing so it is able to increase the price in that particular region in that period, and dump the withheld quantity in the other period where there is no capacity constraint on transmission between the two regions. Although the setting is different, these results are analogous to the one found in Borenstein, Bushnell and Stoft (2000).

Given that one of the transmission lines is a binding constraint and there are price differences between sub-markets initially, how would an acquisition influence the market equilibrium? It turns out that an acquisition might lead to a reduction in price differences between sub-markets. This may happen if the dominant firm acquires a firm that is active in the market where the dominant firm used to dump its energy capacity before the acquisition took place.

Two examples, both relevant in the Nordic hydropower market, illustrate how this may happen.⁹ First, it can be due to asymmetries in location. Consider the case where one producer has production in both regions (or only in the high price region), and it acquires a producer that has production only in the low price region. After the acquisition the large producer would sell a lower quantity in the 'dumping' region, thereby increasing the revenues generated from the acquired firm. Second, it can be due to asymmetries in storage. Let us assume that one producer has multiyear reservoirs, and another producer cannot store water from one year to another. They are located in the same region. In one year with large rainfall and large amounts of water in the reservoirs, the producer with no flexibility has to produce in that year despite a low price. The other producer, with large flexibility concerning storage, can dump some water in the season with a low price and store the remaining water for production next year. After an acquisition, the producer with a multiyear reservoir might dump less production in the year with a large water inflow, the year the inflexible producer has to produce a large quantity. By doing so the revenues from the acquired firm increase.

The article is organised as follows. In the next section we introduce our model, and we characterise perfect competition and monopoly, respectively. In section 3 we analyse the effects of acquisitions, and discuss how asym-

⁹There are asymmetries between hydropower producers in this market. Some producers have hydropower production in several regions as well as multiyear reservoirs, while other hydropower producers are located in only one region and have limited or no ability to store water from one year to another.

metries on location and storage as well as the number of producers and the introduction of thermal production may change our results. In section 4 we offer some concluding remarks.

2 The model

Let us consider a market with two different geographical regions, called East (E) and West (W). In addition there are two time periods, called 1 and 2. The combination of geography and time implies that we have four different sub-markets. Time can either be interpreted as short run or long run. In the short run each producer decides to produce either at, say, day versus night. In the long run, producers with multiyear reservoirs have to decide whether to produce this year or to store the water for production next year.

For the moment, let us assume that there are four different hydropower producers, $j = U, X, Y, Z$.¹⁰ Except for producer X , each producer has plants (one or several) in only one region. In principle, though, each producer can sell in all four sub-markets. First, reservoirs enables each producer to store water and thereby allocate its total production between the two time periods in the region where the reservoir is located. Second, transmission lines allows each producer to sell in the neighbouring region.

To simplify, let us for the moment assume that at each hydropower plant the producer is able to produce all the available energy at that site in one time period (no binding constraint on effect capacity). However, total production in one region is constrained by the available energy capacity (water in the reservoir). Then each producer has the following constraint on production in region i :

$$\sum_{t=1}^2 q_{it}^j \leq \bar{q}_i^j, \text{ where } i = W, E \text{ and } j = U, X, Y, Z \quad (1)$$

\bar{q}_i^j denotes the total energy capacity available to producer j for sale in region i . We assume that all the water that is available is used for production of energy, so that there are no spill of water.¹¹ Then the energy constraint

¹⁰Later on we will extend the model by (i) allowing for more hydropower producers and (ii) introducing a thermal producer.

¹¹Whether this assumption is realistic or not is an open question. However, it is often used in the literature (see Johnsen T. A., S. K. Verma and C. Wolfram, 1999 and Crampes, C. and M. Moreaux, 2001). Also, and more important, this assumption has recently been advocated by the Norwegian Competition Authority in relation to the the Authority's evaluation of Statkraft AS's acquisition of shares in Agder Energi AS. In what we could

in (1) holds with equality. While we assume that both X and Y are single producers, we interpret U and Z as competitive fringes. It implies that each of them consists of a number of small producers, behaving as price takers. The competitive fringe U is located in region W , while Z is located in region E .

Let us now introduce transmission lines between the two regions. Electricity flows between the regions according to physical laws where regions with demand surplus (high prices) import until the transmission capacity is a binding constraint. In line with the institutional arrangement in the Nordic market, we assume that the transmission lines between regions are operated by independent system operators. At times of congestion the market is divided into different market regions where demand equals supply in each region. When lines are congested the price difference between two regions corresponds to the cost of transmission or the congestion rent. This rent is collected by the grid operator. Thus, we might say that the grid operator behave as a competitive arbitrage agent between regions. If we think of the regions as market nodes, we can describe the pricing by the term "nodal pricing". It refers to the term used by Schweppe *et al.* (1988). This pricing regime implies that a seller located in region i will receive the market price in that region, even if its production is exported to the neighbouring region.

We assume there is one market node in each region and one transmission line between these nodes. This line has a capacity of \bar{K}_t and an actual flow of K_t in period t . Prices in the two regions can only differ when the capacity is fully utilized. In this case we would have that $K_t = \bar{K}_t$.

Let S_{it} denote the demand in region i in period t . We can then define the equilibrium condition for the two regions as:

$$S_{Wt} = q_{Wt}^X + q_{Wt}^U + K_t \text{ and } S_{Et} = q_{Et}^X + q_{Et}^Y + q_{Et}^Z - K_t \quad (2)$$

If $K_t > 0$ and transmission has reached the capacity limit in period t , we have that electricity flows from region E to W and that at period t the price in region W can exceed the price in region E .

We are concerned about the situations where a transmission line becomes a bottleneck and may lead to price differences between different sub-markets. However, the extreme case where transmission lines are binding in both time

call the Authority's Statement of Objections issued on January 23 2002 the Authority notes on page 26 that [our translation]:

"Producers do not need to renounce production (send water past turbines that are ready for production) in order to exert market power. As mentioned earlier, the low production costs associated with hydro-power production implies that there is a low probability of spill of water taking place."

periods is not of interest. In such a case the two regions are separated, and we could analyse each region in isolation. On the other hand, the case with no binding transmission constraint in any of the two time periods is neither of interest. In this case the two markets can be seen as one integrated market, and the questions concerning bottlenecks are ruled out.¹² More interestingly, we focus on a situation where the lines are congested in just one of the two periods. In such a case the regions are partially integrated or, put another way, the transmission line is temporarily congested (temporary bottlenecks).

To analyse a situation with temporary bottlenecks, we assume that in period 2 the regions are integrated with a common price and no congestion on the transmission line. We call this new market $WE2$. Even if the price is the same in both regions we might have transmission on the line between them. However, actual flows (K_2) have to be less than capacity (\overline{K}_2). If not, the prices would differ and result in separate markets. We can now define the equilibrium condition for our new market:

$$S_{W2} + S_{E2} = q_{W2}^X + q_{W2}^U + K_2 + q_{E2}^X + q_{E2}^Y + q_{E2}^Z - K_2 \quad (3)$$

As a benchmark for our analysis of an acquisition, let us contrast perfect competition with monopoly:

Proposition 1 (i) *Perfect competition (all producers are price takers): the prices in all four sub-markets are identical.*

(ii) *Monopoly (one owner of all production): If identical price elasticities (e_{it}) in all sub-markets and $|e_{it}| > 1$, then prices are identical in all sub-markets, and identical to prices in a situation with perfect competition. Otherwise, prices in time period 2 are identical while prices in time period 1 is either lower or higher than in period 2.*

Proof. (i) The competitive fringes U and Z act as arbitrage players between period 1 and 2 in region W and E , respectively. Since prices are identical in period 2 (no transmission constraint), then all four sub-markets have identical price.

¹²However, this might not always be true. Any change in markets structure, such as an acquisition, may lead to a change in the behaviour so that one or both transmission lines suddenly bites. We will return to this question in our analysis (see Proposition 2).

(ii) A monopolist would choose prices across markets it and $\widehat{it} \neq it$ such that:

$$p_{it}[1 - \frac{1}{e_{it}}] = p_{\widehat{it}}[1 - \frac{1}{\widehat{e_{it}}}], \text{ where } i = W, E \text{ and } t = 1, 2.$$

If the price elasticities across all sub-markets are identical and $|e_{it}| > 1$, we then have equal prices across all sub-markets. It is also straight forward to see that if price elasticities differ, then prices between markets would also differ. If $|e_{it}| < 1$, it is well known that the monopolist's second order conditions are not met. Then we have a corner solution. If negative prices are ruled out, then prices will be equal to zero in one (or several) sub-market(s), and prices are high in one (or several) sub-market(s). ■

First, note that perfect competition implies that prices in all four sub-markets are identical. If there had been any price differences, then it would lead to shift in sales from one sub-market to another one. For example, a higher price in time period 1 than in time period 2 in region W would imply that both producers in that particular region, which by assumption are price takers, would have incentives to shift production from period 2 to period 1 until prices are identical.

More surprisingly, a monopoly might end up with the same prices as would have been the case with perfect competition. The reason is that total production is by assumption given. It is determined by the total amount of water that is available. Then the monopolist must allocate its production between the four sub-markets. As is well known, a monopolist would discriminate between different market segments according to differences in price elasticities between market segments. Given that price elasticities do not differ between segments, prices are identical in all four sub-markets. Since total production is given, those prices are identical to the prices in a situation with perfect competition.

This result is modified if we have a price unelastic demand. Then it is well known that there are no solution to the traditional monopolist's pricing problem, since it would always increase profits by reducing its production. In this particular case it implies that the monopolist can find it profitable to sell a large amount in one or several sub-markets so that prices are zero (assuming negative price is ruled out), and then sell the restricted residual production at high prices in the remaining sub-market(s).

Our main topic is the effects of an acquisition. Then, obviously, the right comparison is not between perfect competition and monopoly. A more realistic comparison would be to analyse something inbetween, for example oligopoly both before and after an acquisition. To analyse such a case, we specify a more detailed model.

Demand in the four sub-markets are described by the following linear inverse-demand functions:

$$p_{it} = \alpha_{it} - \beta_{it}S_{it}, i = E, W; t = 1, 2 \quad (4)$$

We assign the following values to the constant coefficients of the inverse-demand functions above:

$$\alpha_{W1} = 1, \alpha_{W2} = \alpha_{E1} = \alpha_{E2} = V \text{ and } \beta_{W1} = \beta_{W2} = 1, \beta_{E1} = \beta_{E2} = 1/b$$

If $V = b = 1$, then demand in all four sub-markets are identical. To allow for any possible asymmetry between sub-markets, we assume that both V and b can differ from 1. If $V < 1$, we change the maximum willingness to pay in three of the sub-markets. The linear inverse-demand curve is shifted downwards in all sub-markets except region W in period 1. The willingness to pay in region W in period 1 is then higher than in all three other sub-markets. If $b > 1$, then the maximum willingness to pay is unchanged while the size of the sub-markets are changed. The demand curves in the two sub-markets in region E are becoming flatter compared to the two sub-markets in region W . The interpretation is that the two sub-markets in region E are of larger size than the two submarkets in region W .

The two sub-markets in period 2 are by assumption integrated (see above). The aggregated linear inverse-demand function for this integrated market becomes:

$$p_{WE2} = V - \frac{1}{1+b}(S_{W2} + S_{E2}) \quad (5)$$

One reason why the transmission lines are only congested in one of the two periods could be that $V < 1$. This implies at least as far as region W is concerned that demand in period 2 is lower than demand in period 1. Given the same transmission capacity in the two periods, less transmission is needed to equate prices in period 2. We assume that the transmission capacity in period 2 is sufficiently large to prevent any incentives to act strategically in order to congest the transmission line in that period.¹³

The fact that the two regions are integrated into one market in period 2 changes the nature of the energy constraint facing producer X . Now X can rely on capacity from both regions when supplying the market in period 2. The new constraint in period 2 becomes:

¹³See Borenstein, Bushnell and Stoft (2000) for an extensive analysis of producer incentives to induce congestion on transmission lines. We will come back to this situation later on (see Proposition 2).

$$\sum_i q_{i2}^X \leq \sum_i \bar{q}_i^X, \text{ where } i = E, W \quad (6)$$

In period 1, where we have the potential for two separate markets, producer X is now able to produce all the available energy capacity within a region in this period;

$$q_{i1}^X \leq \bar{q}_i^X \quad (7)$$

and still be able to sell in the same region in period 2 by the use of energy capacity located in the other region. However, these new constraints can not both hold with equality at the same time for positive production levels in both periods and regions. This would result in overall production in excess of available energy capacity. Thus the following must hold:

$$\sum_i \sum_t q_{it}^X \leq \sum_i \bar{q}_i^X, \text{ where } i = E, W; t = 1, 2 \quad (8)$$

With these new constraints, producer X has gained increased flexibility in production. With four separate markets we had that sales of electricity to customers located in one region was limited by the energy capacity in that region, $q_{i1}^X + q_{i2}^X \leq \bar{q}_i^X$. Now with integrated regions (one market) in period 2 this is no longer a limitation on sales and we might very well have that $q_{i1}^X + q_{i2}^X > \bar{q}_i^X$. This implies that producer X can de facto move production from period 1 in region E to period 1 in region W *without* using the transmission line in period 1 between the two regions. The reason is that the producer is able to reshuffle its sale in period 2, when regions are integrated, in such a way that sales in period 1 is increasing in region W and decreasing in region E .

Even though the two sub-markets in period 2 are by assumption integrated, we still may have three different sub-markets: region W in period 1, region E in period 1, and the integrated market consisting of both regions in period 2. However, note that we have one competitive fringe in region E and one in region W . Given that the competitive fringes are sufficiently large, they will ensure that there are no price differences between period 1 and 2. For example, let us consider region E . If producer Y (or X) reduces sales in one of the two periods in order to increase the price, the competitive fringe Z would immediately increase sales in this period, giving producer Y no room for such strategic behavior. In a similar manner, the competitive fringe U will ensure that the prices are identical in the two time periods in region W .

3 The effect of acquisitions

The starting point is, as described, that all four sub-markets are integrated. This replicates the perfect competition outcome described in Proposition 1. However, there is a potential for the transmission line in periode 1 to be congested. Then we ask the question of how an acquisitions may change the equilibrium outcome. First, we let X acquire the competitive fringe U . Given such an acquisition, we next consider what happens when X acquires Y .

3.1 An endogenous bottleneck?

If X acquires U , there are no longer any players present that guarantees identical prices in region W in time periode 1 and 2. With potential congestion on the transmission line between the two regions in period 1, producer X has three alternatives. One alternative is that producer X after the acquisition acts so that prices in all four sub-markets are identical, as was the case before the acquisition. Alternatively, producer X might reduce its production in region W in time period 1 in order to cause the line to be congested with full *imports* to region W . By doing so it could achieve a higher price in that sub-market than the price of the three other integrated sub-markets. The third alternative would be to increase production in region W in period 1, causing congestion and full *exports* from region W to E . To check the conditions associated with these three strategies, let us apply the specific model we introduced above. To simplify the exposition, we let production by producer X , denoted q_{it}^X , include production from producer U .

If three of the four sub-markets are integrated, then the aggregated inverse linear demand for this integrated market (market 2) becomes:

$$p_2 = V - \frac{1}{1 + 2b}(S_{W2} + S_{E1} + S_{E2}) \quad (9)$$

With two markets to analyse, we have the result that both producer Y and the competitive fringe Z only have energy capacity available for production in market 2. Producer X , however, can produce in both markets. Given that all the water is used to produce energy, we can express production in market 2 by:

$$q_2^X = \bar{q}_W^X + \bar{q}_E^X - q_{W1}^X \quad (10)$$

The production in market 2 consists of the energy capacity available in region E and the difference between capacity in region W and production in the same region in period 1 (market $W1$). To simplify the analysis, let us here assume that $V = 1$ in (9). If producer X reduces production in market $W1$ enough to create congestion, we know that $p_{W1} > p_2$. Then we can find the level of production from producer X in sub-market $W1$ corresponding to separate markets, where $W1$ is the high price market. In a similar manner we can find the production levels corresponding to the integrated market case when all four sub-markets are integrated and the case where sub-market 2 is the high price market, respectively:

$$\left[\begin{array}{l} p_{W1} > p_2 \quad \text{if} \quad q_{W1}^X < \frac{1}{2+2b}Q - \bar{K}_1 \\ p_{W1} = p_2 \quad \text{if} \quad \frac{1}{2+2b}Q - K_1 < q_{W1}^X < \frac{1}{2+2b}Q + K_1 \\ p_{W1} < p_2 \quad \text{if} \quad q_{W1}^X > \frac{1}{2+2b}Q + \bar{K}_1 \end{array} \right] \quad (11)$$

where $Q = \bar{q}_W^X + 2\bar{q}_E^X + \bar{q}_E^Y + \bar{q}_E^Z$. We can observe from (11) that the production range (q_{W1}^X) for which we have integrated markets increases with higher transmission capacity in place between the two sub-markets. Remember that before X 's acquisition of U all sub-markets are by assumption integrated ($p_{W1} = p_2$), because U acted as a competitive fringe. After the acquisition producer X would face different profit maximization problems depending on whether the markets are separated or not:

$$\left[\begin{array}{l} \max_{q_{W1}^X} \pi^{XM} = p_{W1}(q_{W1}^X) + p_2(q_2^X) \quad \text{if} \quad q_{W1}^X < \frac{1}{2+2b}Q - \bar{K}_1 \\ \pi^{XI} = p(\bar{q}_W^X + \bar{q}_E^X) \quad \text{if} \quad \frac{1}{2+2b}Q - K_1 < q_{W1}^X < \frac{1}{2+2b}Q + K_1 \\ \max_{q_{W1}^X} \pi^{XL} = p_{W1}(q_{W1}^X) + p_2(q_2^X) \quad \text{if} \quad q_{W1}^X > \frac{1}{2+2b}Q + \bar{K}_1 \end{array} \right] \quad (12)$$

The producer maximizes profit by choosing production in both sub-markets subject to the constraints on energy production in the two markets; $q_{W1}^X \leq \bar{q}_W^X$ and $q_2^X \leq \bar{q}_W^X + \bar{q}_E^X$.¹⁴ When all four sub-markets are integrated,

¹⁴In the situation $p_{W1} - p_2 > 0$, we have two possibilities. First, we may have a situation where one (both can not bind at the same time) of these two constraints are binding before the acquisition. If one of these constraints are binding we have a corner solution. Second, we may have a situation where all the energy is used and none of the two constraints are binding, implying that producer X in equilibrium sells in both markets. If we have

the inverse linear demand function is given by; $p = 1 - \frac{1}{2+2b}(S_{W1} + S_{W2} + S_{E1} + S_{E2})$, assuming that $V = 1$. Accordingly, the profit function becomes:

$$\pi^{XI} = p(\bar{q}_W^X + \bar{q}_E^X) \quad (13)$$

where we let π^{XI} denote profit associated with the integrated market case. Thus, in the case of integrated markets, producer X 's profit is the same regardless of how production is allocated between the two sub-markets. In a similar manner, we can define the profit functions corresponding to the case where production in market $W1$ is reduced sufficiently to create congestion and full import to $W1$ (π^{XM}) and full export from $W1$ (π^{XL}). We can now state our proposition 2:

Proposition 2 *If X acquires U , then after the acquisition $p_{W1} - p_2 > 0$ if the profit maximization level of q_{W1}^X is positive but low enough to cause congestion on the line between the two regions ($0 < q_{W1}^X < \frac{1}{2+2b}Q - \bar{K}_1$).*

Assuming that $p_{W1} - p_2 > 0$, we can find the exact price difference after the acquisition of U by inserting the solution to producer X 's maximization problem (q_{W1}^X) into the two inverse demand functions

$$\Delta p \equiv p_{W1} - p_2 = \frac{1 - (K_1 + V - 1)(1 + 2b) - \bar{K}_1 + \bar{q}_E^Y + \bar{q}_E^Z}{2(1 + 2b)} \quad (14)$$

Proposition 2 can be illustrated by a numerical example (see figure 1). Let us assume that $\bar{K}_1 = (\frac{1}{32})$, $b = 0.5$ and $\sum_{ji} \bar{q}_i^j = 1$ with $\bar{q}_W^X = \frac{15}{32}$ and $\bar{q}_E^X = \frac{1}{32}$. It can then be shown that $\pi^{XI} = 0.333$ (profits if integrated markets) and $\pi^{XU} = 0.336$ (maximum profits if high price in region 1 in period W). The latter case corresponds to a production level $q_{W1}^X = 0.24$, which is low enough to ensure that $p_{W1} - p_2 > 0$. In the choice between creating an import constraint on the transmission line in period 1 and letting the markets be integrated, producer X would choose to induce congestion. If we look at the possible range of production corresponding to $p_{W1} - p_2 < 0$, there is no production level resulting in profits higher than in the integrated

a corner solution before the acquisition takes place, this will constrain producer X from behaving differently after the acquisition. Furthermore, if one of the constraints are only binding on the solution after the acquisition this will limit producer X 's behaviour. In the following we shall for simplicity assume internal solutions both before and after the acquisition.

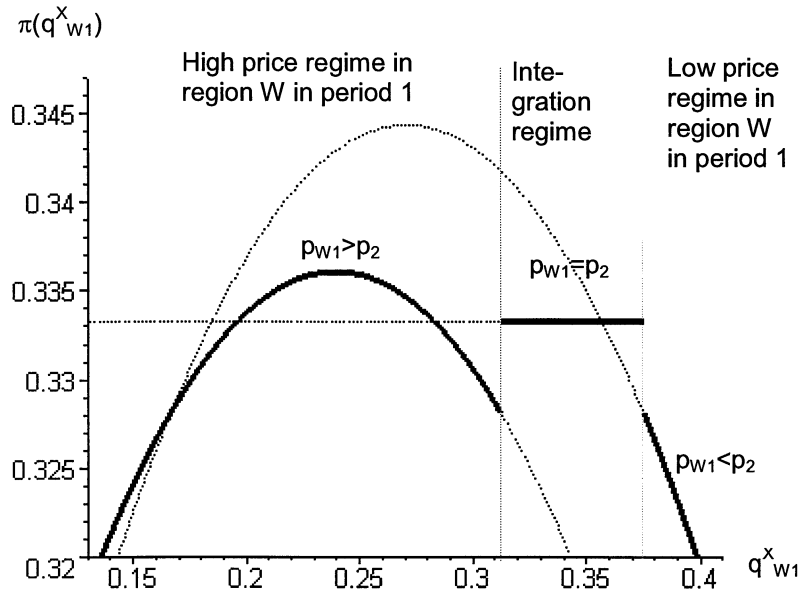


Figure 1: Profit functions for producer X under the three different price regimes ($p_{W1} > p_2$, $p_{W1} = p_2$ and $p_{W1} < p_2$). Attainable profit levels as a function of q_{W1}^X are represented by the solid line.

market case.¹⁵ After the acquisition producer X would therefore find it profitable to reduce production in sub-market $W1$ which, in turn, leads to congestion and higher prices in this market.

Our result replicates the result found in Borenstein, Bushnell and Stoft (2000). After the acquisition, the firm can find it profitable to induce a congestion on a transmission line. By reducing production in region W in period 1, producer X can act as a monopoly firm on the residual demand in that sub-market; total demand in that sub-market deducted the imports through the transmission line. Strategic behaviour has in such a case led to a temporary bottleneck on transmission.

¹⁵The maximum profit from inducing congestion and lower prices in sub-market $W1$ is even higher, $\pi^{XL} = 0.344$. This corresponds to a production level $q_{W1}^X < \frac{1}{2+2b}Q - \bar{K}_1$ implying that $p_{W1} - p_2 > 0$. This is a contradiction, so therefore not attainable.

3.2 Asymmetry concerning location

Let us now assume that X has acquired U , and that it has led to price differences as described in Proposition 2. The next question is what will happen to this price difference when producer X acquires producer Y . Is the price difference increasing as a result of the concentration?¹⁶

After this second acquisition producer X controls the energy capacity of producer Y located in region E . Assuming positive production in both markets also after the merger, production by X in market 2 can now be expressed as follows:

$$q_2^X = \bar{q}_W^X + \bar{q}_E^X + \bar{q}_E^Y - q_{W1}^X \quad (15)$$

Producer X solves the same maximization problem as defined in equation (12) subject to the following pair of constraints;

$$q_{W1}^X \leq \bar{q}_W^X \text{ and } q_2^X \leq \bar{q}_W^X + \bar{q}_E^X + \bar{q}_E^Y \quad (16)$$

where we observe that producer X now has more energy available for production in market 2. Again, we have two possible outcomes within our framework. The producer may in equilibrium choose to produce some of the energy available in region W in period 2, thus selling electricity in market 2. As long as production in region W in period 1 also is positive, then we have an internal solution to our problem where none of the two constraints (16) above are binding. We assume this is the case and describe the solution.

As before we find the solution by solving the producer's first order condition and inserting this solution into the inverse demand functions (4 and 9). The new expression defining the price difference between the two markets then becomes:

$$\Delta \hat{p} \equiv \hat{p}_{W1} - \hat{p}_2 = \frac{1 - (K_1 + V - 1)(1 + 2b) - \bar{K}_1 + \bar{q}_E^Z}{2(1 + 2b)} \quad (17)$$

If the acquisition leads to higher price difference this implies increased welfare loss. Consumption is shifted from consumers in market $W1$ with high willingness to pay for electricity to consumers with lower willingness

¹⁶One possibility would of course be that a merger changes the incentives so significantly that the price difference disappears or turns negative. This implies that transmission changes direction. Unless otherwise stated, we shall disregard such effects and confine the analysis to whether the positive price difference becomes larger or less positive.

to pay in market 2. However, in our case we see that the price difference is reduced and thus leading to an increase in welfare.¹⁷

$$\Delta p - \Delta \hat{p} = \frac{\bar{q}_E^Y}{2(1+2b)} > 0 \quad (18)$$

The reduction in price difference follows directly from change in producer X 's incentives following the acquisition. After the acquisition producer X takes into account the price effect on energy previously controlled by producer Y . This energy is located in region E and offered for sale in market 2. A reduction in sales in market 2 would make a larger contribution to producer X 's profit through the price effect after the acquisition simply because producer X now controls more of the energy sold.

We can summarize our results as follows:

Proposition 3 *Given that X has already acquired U and resulted in $p_{W1} - p_2 > 0$, then X acquiring Y would result in a smaller price difference or have no price effects at all. If the price changes due to the acquisition of Y , then the price difference is reduced by $\frac{\bar{q}_E^Y}{2(1+2b)}$ or less.*

Note that the change in the price difference only depends on two parameter values: the relative market size (region W versus region E) and the size of the acquired producer (\bar{q}_E^Y). Both effects are quite intuitive. The larger the size of the acquired firm, the larger the price change following the acquisition; the larger the size of the integrated market, the smaller the price change following the acquisition.

More surprisingly, though, is that the size and distribution of firm's production, except for the acquired firm's total production, does not matter for the price change after the acquisition. For example, it does not matter how much production producer X has in each of the two regions, or how

¹⁷One alternative is that we have an internal solution to our problem before the acquisition but that this changes to a corner solution after the acquisition. Producer X 's incentives to transfer energy from market 2 to $W1$ may be limited by the constraint on production in region W . This would not change the conclusion. The price difference would still decrease. However, the reduction may be limited by the production constraint.

Another possibility is that we face a corner solution before the acquisition. That would be the case if one of the production constraints in equation (16) are binding. Given the assumption that $W1$ is the high price market, we know that producer X would always produce some electricity in this market. Let us therefore consider the case where $q_{W1}^X = \bar{q}_W^X$ before the acquisition, the only relevant constraint. After the acquisition we know that producer X has incentives to transfer energy to market $W1$. However, because of the binding production constraint this is not possible and the acquisition would have no effect on the price difference.

large its total production is. The intuition is that such differences in size and distribution of production is incorporated in the equilibrium price as long as we have an interior solution at the outset. Due to this, such factors do not have any effect on price changes following an acquisition.

Let us now extend the model by introducing more than one producer that have production in both regions. We assume that there are now n producers that have production in both regions. Then it can be shown the following result:

Proposition 4 *If there are n producers that have production in both regions and $p_{W1} - p_2 > 0$, then X_i acquiring Y would, if any effect at all, reduce the price difference by $\frac{\bar{q}_E^Y}{(n+1)(1+2b)}$ or less.*

Proof. See the Appendix A ■

We see that the result is parallel to the one obtained in the situation referred to in the last Proposition where we had just one hydropower producer with capacity in both markets. After the acquisition producer X_i takes into account price effects on energy previously controlled by producer Y , and shifts production from the integrated market in period 2 to sales in region W in period 1. Now, however, a reduction of sales in market 2 would induce the other producers that are active in both regions to increase sales in this market. The price effect of reducing sales in market 2 is therefore dampened compared to the situation where we had one supplier with flexible production. The larger the number of producers active in both regions, the more limited is the price effect of an acquisition.

3.3 Asymmetry concerning storage and location

So far we have assumed that all producers are flexible concerning storage and production, since they all can shift all its production from period 1 to period 2 or vice versa and there is no limit on production. This might not be the case in real electricity markets. With a given level of energy capacity available over the periods there are two different relevant constraints, one short run and on long run constraint. In the short run some producers may face a constraint on its production, despite energy capacity in its reservoir. This would be constraints on effect capacity. While some producers have full flexibility in the short run, other producers might be limited by the installed effect capacity. In the long run some producers are not able to shift production from one period to another, for example from one year to another. The reason is that they do not have reservoirs large enough to

store water from one season to another and they are confined to produce more or less according to the current rainfall. The ability to store water may differ a lot from one producer to another. Irrespective of whether it is a short or long run constraint, we can apply our model to analyse the effects of asymmetries concerning such constraints.

In our model above we assumed that producer Y was located with its energy capacity only in region E confined to selling electricity in market 2; the low price market. What would happen if we allowed producer Y to be located in region W instead and selling electricity in the high price market? Producer X would then have no incentives to increase production in the high price region following the acquisition, simply because producer Y 's capacity is located in that region. In contrast, we would expect increasing price differences as a result of the acquisition.

Let us now introduce asymmetries not only on location, but also on storage. We model this feature by assuming that producer Y is located with energy capacity in region W and that the producer is lacking sufficient storage capacity. To highlight the effect of asymmetries on storage, we consider the extreme case where producer Y has no storage capacity at all. This means that producer Y 's production is determined by the amount available in each period¹⁸. Using this assumption we can rewrite the two equilibrium conditions as follows:

$$S_{W1} = q_{W1}^X + \bar{q}_{W1}^Y + \bar{K}_1, \quad S_2 = \bar{q}_E^X + q_{W2}^X + \bar{q}_{W2}^Y + \bar{q}_E^Z - \bar{K}_1 \quad (19)$$

We solve to find the expressions representing the price differences before and after the acquisition in the same manner as above. Doing so we can write the difference between the two price differences as follows:

$$\Delta p - \Delta \hat{p} = \frac{1}{2} \frac{\bar{q}_{W2}^Y - (1 + 2b)\bar{q}_{W1}^Y}{1 + 2b} \quad (20)$$

For a given value of the parameter b in the equation above we observe that the price difference will be reduced if Y 's energy capacity in market 2 (in period 2, region W) is sufficiently large compared to the capacity in region W in period 1. If \bar{q}_{W2}^Y is sufficiently low compared to \bar{q}_{W1}^Y the price difference will increase following the acquisition. Thus the changes in the price difference is dependent upon whether X earns the most by reducing production in market $W1$ or market 2. This again is directly linked to where

¹⁸Alternatively we could have assumed that producer Y 's production was effectively constrained on effect capacity in both periods both before and after the acquisition.

producer Y has its production capacity distributed; between periods. Then we have shown the following result:

Proposition 5 *Let us assume that Y is located in region W , and $p_{W1} - p_2 > 0$. Then X acquiring Y would lead to a lower price difference if $\bar{q}_{W2}^Y > (1 + 2b)\bar{q}_{W1}^Y$.*

3.4 Introducing thermal production

In most markets where hydropower is present we also have a significant share of thermal based electricity production. This is also the case within the Nordic electricity market. A natural extension of our model is to include thermal production in one of the two markets central to the analysis.

We assume that transmission capacity is fully utilized in period 1. In period 2 we have an integrated market. We assume that electricity flows from market 2 to market $W1$, making $W1$ the high price market. The linear inverse demand function in market $W1$ is exactly the same as before. We let the thermal producer be located in region E with just one production site. Now, the price in market 2 will depend on how much is produced (q_E^T) by the thermal producer.

$$p_2 = V - \frac{1}{1 + 2b}(\bar{q}_E^X + \bar{q}_W^X - q_{W1}^X + \bar{q}_2^Y + \bar{q}_E^Z + q_E^T - \bar{K}_1) \quad (21)$$

We make two simplifications, $\bar{q}_E^X + \bar{q}_W^X = \bar{q}^X$ and $1 + 2b = h$. We assume that thermal production is based on one or more fossil fuel technologies (coal, oil or gas). We let the thermal producer's cost be represented by the following linear function:

$$C(q_E^T) = cq_E^T \quad (22)$$

Thus, we have constant marginal cost (c) in thermal production of electricity. Now we let both producer X and producer T act strategically. Producer X chooses how to allocate water between the two markets given thermal production. The thermal producer chooses q_E^T given distribution of available water by producer X ($\bar{q}_E^X + \bar{q}_W^X - q_{W1}^X$ and q_{W1}^X). Hydro producer X has the same maximization problem as before with the change that production in market 2 now also include thermal production. The thermal producer maximizes:

$$\max_{q_E^T} p_2 q_E^T - cq_E^T \quad (23)$$

We solve the system of first order conditions to find equilibrium quantities in the two markets. We can then solve for the difference in equilibrium prices between the two markets. The price difference prior to the acquisition is:

$$\Delta p \equiv p_{W1} - p_2 = -\frac{(-2h^2 - 2h + 2\bar{K}_1 h^2 + \bar{q}^X h - Vh^2 - \bar{q}_2^Y h - q_E^Z h + 3Kh + ch^2 + Vh - \bar{q}_2^Y - \bar{q}_E^Z + \bar{K}_1 + ch)}{h(4h + 3)} \quad (24)$$

In the same way as before this expression will be positive if there is enough capacity in region E relative to region W . The partial derivative of the expression above with respect to reservoir levels in region E (\bar{q}_2^Y , \bar{q}_E^Z , \bar{q}_E^X) are all positive. We assume these levels are high enough making the expression positive both before and after the acquisition.

We look at what will happen if producer X acquires producer Y 's energy capacity, given that Y is located in region E . Through the same operations as described above we find the equilibrium values of q_{W1}^X and q_E^T . We then use these values to find the price difference after producer X has acquired control over producer Y 's resources.

$$\Delta \hat{p} \equiv \hat{p}_{W1} - \hat{p}_2 = -\frac{(-2h^2 - 2h + 2\bar{K}_1 h^2 + \bar{q}^X h - Vh^2 + \bar{q}_2^Y h - q_E^Z h + 3Kh + ch^2 + Vh - \bar{q}_E^Z + \bar{K}_1 + ch)}{h(4h + 3)}$$

Assuming this price difference is still positive with electricity flowing from region E to W in period 1 equal to the capacity \bar{K}_1 , we can solve for the change in price difference before and after the acquisition.

$$\Delta p - \Delta \hat{p} = \frac{\bar{q}_E^Y (2h + 1)}{h(4h + 3)} > 0 \quad (25)$$

We see that the existence of a thermal producer in market 2 does not alter the direction of the price change. We still have that the price difference becomes smaller due to a positive expression in equation (25). The intuition is identical to the one we provided in the previous analysis.

This is not the whole story. We assumed that all available water is used to produce energy, implying that total production based on hydro power is fixed through the analysis. Thermal production, on the other hand, can

change. In order to see how the acquisition effects thermal production we simply compare equilibrium thermal production values before (q_E^T) and after (\widehat{q}_E^T) the acquisition takes place.

$$\Delta q_E^T = \widehat{q}_E^T - q_E^T = \frac{\bar{q}_E^Y}{4h + 3} \quad (26)$$

The expression above is positive, so we have that thermal production is increased following X 's acquisition of producer Y . With a thermal producer located in region E we then have that total production in the two markets are increasing following an acquisition. All else equal, this is welfare improving. In addition, the acquisition leads to a reduction in the price difference between the two markets. With a reduction in the price difference and increased total production we can safely state that welfare is increased.

Proposition 6 *Let us assume there is a thermal producer in region E , and and $p_{W1} - p_2 > 0$. If X acquires Y , which is located in region E , then the price difference becomes smaller and the thermal producer's production increases, and total welfare improves.*

This is an example where an acquisition leads to counter-intuitive results: higher total production and reduction in price differences. It is straight forward to see that those results can be reversed. There can be instances where an acquisition leads to a reduction in the price difference and a lower total production, increase in price differences and higher production, and finally larger price differences and lower production.

4 Some concluding remarks

Hydropower producers are more flexible than any other energy producers. Is this a virtue or a problem seen from society's point of view? In the existing literature it has been shown that we should be concerned about a hydropower producer that is the marginal producer, since it has flexibility to withheld capacity in the period where other producers are constrained.

Our main point is that in an situation where such a producer does not have total dominance, the competitive effects of higher concentration is less clear-cut. The important feature in a hydropower system is that the producers must allocate their production between different sub-markets. If one producer withdraws production in one period, it must offer the withdrawn quantity at a later time period or export it to another region. In contrast to other producers, its total production is fixed unless it is able to spill water. Then the price effect of an increase in concentration depends on the location and flexibility of the hydropower producers. Asymmetries in location as well as asymmetries in the ability to store water (for example from one year to another) is decisive for whether an increase in concentration leads to larger or smaller price differences.

Our study has important implications of the evaluation of the competitive effect of an acquisition or merger in a hydropower system. Obviously, the comparison is between the market outcome before and after the merger (or acquisition).¹⁹ As earlier studies have shown, it is of importance to check whether the merged firm becomes a marginal producer more often than what was the case before the merger. Given that this is not a very severe problem, our study suggests that it is important to evaluate any possible asymmetries between the merging parties. Are they located in different regions? Is one located in several regions, and another in only one region? Do they have the same flexibility concerning storage of water, or could it be that one of them has the ability to store water from one year to another and the other does not have such an option? How are the price differences before the merger or acquisition? Is the producer that a large firm acquires primarily active in a low price market, which can be regarded as a dumping market? These and similar questions must be answered in order to evaluate whether a merger or acquisition will increase or reduce existing price differences.

¹⁹See for example Willig (1992), where such a comparison is recommended for merger analysis. For more recent examples, see Froeb and Werden (2002) and Epstein and Rubinfeld (2001).

A n producers in both regions

In addition to producers Y and Z we now assume there are n other producers X_i (where $i = 1..n$) with energy capacity in both regions W and E . In the following we shall analyze the price difference between our two markets $W1$ and 2 before an acquisition by producer X_i . The analysis is analogous to the one in section 2, now with n flexible hydropower producer present in both regions.

Each producer X_i has $\bar{q}_W^{X_i}$ available for production in region W and $\bar{q}_E^{X_i}$ for production in region E . Production in market 2 by producer X_i can be expressed as; $q_2^{X_i} = \bar{q}_W^{X_i} + \bar{q}_E^{X_i} - q_{W1}^{X_i}$. In order to simplify we shall assume that all producers X_i have the same energy capacity available in both regions; $\bar{q}_W^{X_i} = \bar{q}_W^X$ and $\bar{q}_E^{X_i} = \bar{q}_E^X$. Thus, in the absents of any production costs these producers can be treated symmetrically.

The transmission line between regions W and E is only constrained in period 1, and electricity flows from region E to W with market $W1$ being the high price market. We can now write our two new inverse linear demand functions:

$$p_{W1} = 1 - \sum_i q_{W1}^{X_i} - \bar{K}_1 \quad (27)$$

$$p_2 = V - \frac{1}{1+2b} (n(\bar{q}_W^X + \bar{q}_E^X) - \sum_i q_{W1}^{X_i} + \bar{q}_E^Y + \bar{q}_E^Z - \bar{K}_1) \quad (28)$$

Producers Y and Z are only located with capacity in region E . The producers X_i , however, can choose how to distribute available capacity between the two markets. We assume that these suppliers act strategically according to a one shot Nash-Cournot strategy where they simultaneously determine the level of production in market $W1$. The maximization problem of producer X_i can be expressed as:

$$\max_{q_{W1}^{X_i}} = p_{W1}(q_{W1}^{X_i}) + p_2(q_2^{X_i})$$

subject to the constraints that apply for production in one region; $q_{W1}^{X_i} \leq \bar{q}_W^{X_i}$ and $q_2^{X_i} \leq \bar{q}_W^{X_i} + \bar{q}_E^{X_i}$.²⁰ In order to find the equilibrium before the

²⁰With at least some production in both markets none of these constraints bind and we have an interior solution to the problem. As mentioned before the second constraint is irrelevant here because with higher prices in market $W1$ the producer will always have some production in this market. We discuss here the equilibrium price difference assuming an interior solution.

acquisition we solve the n producers first order conditions simultaneously to find the optimal values of production in market $W1$. Since the producers are symmetric, we have that $\sum_i q_{W1}^{X_i} = nq_{W1}^{X_i}$. We then use these values to calculate the pre-acquisition price difference:

$$\Delta p \equiv p_{W1} - p_2 = \frac{-(\bar{K}_1 + V - 1)(1 + 2b) - \bar{K}_1 + \bar{q}_E^Y + \bar{q}_E^Z}{(1 + n)(1 + 2b)} \quad (29)$$

Let producer X_i acquire control over producer Y 's energy capacity in region E . Because producer X_i now controls the production capacity of producer Y , X_i can no longer be treated symmetrically with the other producers X_j (where $j = 1..n, j \neq i$) having capacity in both markets. Now we have to solve for optimal production by producer X_i and one of the other $(n - 1)$ symmetric producers. Now we use the fact that $\sum_j q_{W1}^{X_j} = (n - 1)q_{W1}^{X_j}$ and solve for the optimal values of production in market $W1$. By substitution we can then write the new price difference as follows:

$$\Delta \hat{p} \equiv \hat{p}_{W1} - \hat{p}_2 = \frac{-(\bar{K}_1 + V - 1)(1 + 2b) - \bar{K}_1 + \bar{q}_E^Z}{(1 + n)(1 + 2b)} \quad (30)$$

We assume this price difference to be positive also after the acquisition, meaning that electricity flows from region E to W in period 1. We look at how the acquisition effects the price difference; whether this difference becomes less or more positive. The change in price difference can be expressed by:

$$\Delta p - \Delta \hat{p} = \frac{\bar{q}_E^Y}{(1 + n)(1 + 2b)} > 0 \quad (31)$$

This is the condition shown in proposition 4.²¹

²¹Producer X_i 's incentives to increase production in market $W1$ may be limited by constraints on production in region W . If producer X_i before the acquisition have used all the available capacity in region W , then the acquisition would not have any effect on the price difference. Similarly, the production constraint could constrain producer X_i from increasing production as much as wanted after the acquisition. In this case, the effect on the price difference would be lowered.

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