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**2007:8**

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Arbeidsnotat / Working Paper 2007:8

Høgskolen i Molde / Molde University College

Molde, desember / December 2007

ISSN 1501-4592

ISBN-10 82-7962-085-0

ISBN-13 978-82-7962-085-3

# Ex Post Monitoring of Market Power in Hydro Dominated Electricity Markets*

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## Abstract

*The paper presents a proposed market monitoring procedure that takes into account the special features of an electricity market that is based largely on hydro power. Specifically, we present a method to assess water values and a set of indicators that can be used to screen the market for suspicious price formation. We then use the suggested monitoring procedure to evaluate actual price formation in the Nordic Electricity Market during the (hydrological) year 2002/2003 when precipitation failed and spot prices at the electricity exchange Nord Pool hit an all-time high.*

**Key Words**: Market Power, Wholesale Spot Prices, Market Monitoring, Strategic Hydropower Scheduling, Water Value
**JEL Classification**: C72; L13 ; L49

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*Financial support from the Norwegian Competition Authorities, the Norwegian Water Resources and Energy Directorate and the Business and Management Research Fund in Mid-Norway are gratefully acknowledged.
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## 1. Introduction

The potential abuse and adverse effects of market power in restructured electricity markets are well known and have been thoroughly analyzed and discussed in a wide range of studies the last fifteen years. Examples include, for the British market, Green and Newbery (1992), Wolfram (1999) and Bunn and Martoccia (2005); the Nordic market, Andersson and Bergman (1995), Halseth (1998) and Amundsen and Bergman (2003); the Colombian market, Garcia and Arbeláez (2002); the Spanish market, García-Díaz and Martín (2003); the Californian market, Borenstein and Bushnell (1999) and Borenstein et al. (2002); and the Australian market, Tamaschke et al. (2005). The overall conclusion to be drawn from this literature is that electricity markets are particularly vulnerable to market power abuse. However, it is very difficult to prove.

Sufficient competition on each level of the value chain should guarantee efficient pricing, at least in theory. But assessing the level of competition in the electricity industry is not a trivial task. As discussed in Borenstein et al. (1999), for example, the characteristics of electricity production, distribution and consumption make traditional market delineation and corresponding calculations of concentration measures, such as the Herfindahl-Hirshman Index (HHI), a complex task. Particularly, due to frequent and often large variations in load, transmission lines may be temporarily congested isolating generating plants behind the bottleneck, and the potential for even relatively small generators to exercise market power may rise substantially during such periods. Therefore, securing a sufficiently competitive market *ex ante* is a challenge facing authorities that are aiming at ensuring consumers get the intended benefit from a deregulated electricity industry.

As experience with electricity market reforms is gathered and the new roles of market participants are played out, it becomes evident that adequate and competent monitoring of price formation *ex post* are equally important, c.f. Decker and Keyworth (2002). However, available schemes are in short supply. Real world examples are also hard to come across; for an overview of market monitoring in practice, see Newbery et al. (2004). Moreover, the distinctiveness of deregulated electricity markets, such as technology mix, demand patterns and capacity constraints, limit the possibility of adopting indicators and monitoring procedures that have been tailored for one electricity market directly to another. Although some common principals should prevail, such principals are not well-defined in terms of markets predominated by large hydro power producers. As with the consequences on economic welfare of mergers and acquisitions in hydro dominated markets, cf. Skaar and Sørgard (2006), the ability that dominating producers have in exploiting the effects of strategic hydro scheduling distinguishes monitoring of such markets from monitoring predominantly thermal markets, see CAISO (2000) for example.

Therefore, in view of the characteristics of dominating hydro power producers and corresponding market power strategies, c.f. Bushnell (2003), we present here a monitoring scheme developed particularly for the Norwegian electricity market, which was among the first of its kind to be deregulated and where close to 100 percent of the generating capacity is hydroelectric. The purpose of the proposed procedure is to identify instances where a dominating producer may have taken advantage of its position to exercise market power. The main challenge and contribution of our analysis is the practical approach to compute the hydro power producers' marginal cost – the water value – and to use it to identify a set of indicators that can be used to screen the market for suspicious price formation.

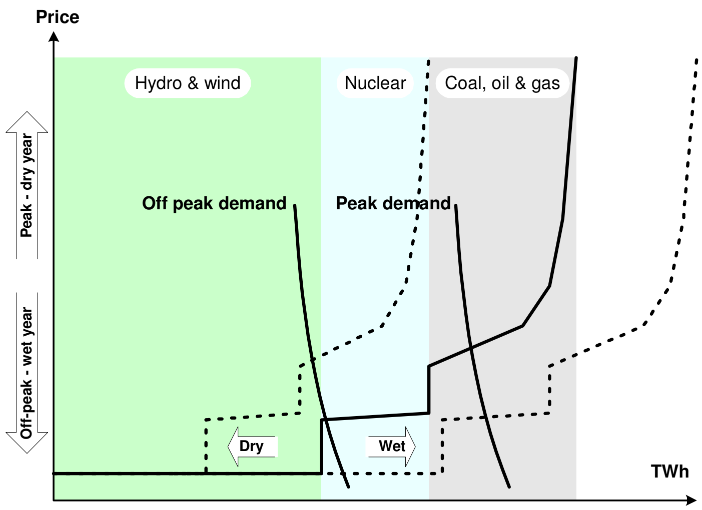
The paper is organized as follows. In the next section we present the main characteristic of the Nordic electricity market, which includes the Norwegian market in focus. A formalized model and discussion of market power strategies in hydro dominated electricity markets, and the relation to the producers' water value, are presented in Section 3. In Section 4 we introduce the indicators. In order to test the indicators empirically, we chose data from the Nordic Electricity Market during the hydrological year 2002/2003, which runs from week 13 2002 until week 12 2003. The empirical results are presented in Section 5 and Section 6 concludes the paper.

## 2. Characteristics of the Nordic Electricity Market

The Nordic electricity market is a highly integrated system with a common spot market exchange for electricity, Nord Pool. Historically, since the deregulation of the Norwegian market in the early 1990s, the market has been subsequently expanded with Sweden, Finland, and Denmark joining in turn. The highly flexible hydropower capacity is concentrated in Norway and Sweden, whereas Denmark and Finland are dominated by thermal capacity and to a lesser extent wind power.

The main characteristics of electric power as a commodity – simultaneous balancing supply and demand along with large variations in load within the course of 24 hours – imply that the market situation in practice changes every hour and, consequently, also capacity utilization and flows on the transmission lines. Hydropower generation varies with load which means that Norway is normally exporting during daytime and importing during the night. Also, ice and snow in the mountains start melting around week 13 and inflows to the reservoirs are typically higher than consumption (and generation). Despite low demand in summer, generators need to keep producing as heavy rain is expected during the fall. The goal is to build up reservoirs until winter starts and precipitation mostly comes as snow. Then inflow is very low and at the same time consumption is at its highest level. Electricity is the main source for space heating in Norway and to a lesser extent in Sweden. An illustration of how the Nordic market is cleared each hour at Nord Pool as a function of the time of day in normal years, dry years and wet years is presented in Figure 1. The effects of limited transmission capacities between market areas are not captured in the figure.

*Figure 1 Supply (marginal costs) and demand in the Nordic electricity market*




Due to limited transmission capacity within and between the Nordic countries, having a joint market place does not imply that a common Nordic price always prevails. Moreover, the inherited pre-deregulation market structure means that market concentration is high in submarkets, e.g., Norwegian Statkraft has an overall market share of about 35 percent of Norwegian generation capacity and Swedish Vattenfall controls about 50 percent of Swedish generation capacity. However, following deregulation and throughout the 1990s the Nordic market was largely successful in producing a competitive price level – reflecting varying precipitation and, hence, production potential in the Norwegian and Swedish systems (see Hjalmarsson, 2000 for example). During this period there was excess generation capacity in the Nordic electricity market. Since then a general increase in electricity demand has caught up with supply capacity and there has been a growing dependency on electricity import into the Nordic market, resulting in increased exchange between market areas. Unless transmission capacity is appropriately adjusted, the rate of periods where lines are congested will rise and, consequently, opportunities for dominant generation owners to exercise market power might rise significantly, c.f. the cases where the Danish Competition Authority found that Elsam had abused its dominant position by exploiting the limited transmission capacity in Western Denmark during 2 384 hours between July 2003 and January 2007 (Nordic competition authorities, 2007).

## 3. Incentives to exercise market power

To find the appropriate indicators that can identify anomalous behavior and circumstances that require further investigation, one need to have a clear idea of the kind of strategies that are available to potentially abuse market power. We define market power as the ability of an electricity generator to profitably raise the price in a particular hour or on average. In the context of electricity market manipulations one usually distinguish between physical and economical withholding, c.f. the references in the introduction. Physical withholding implies derating capacity from the market, whereas economical withholding implies rising bids so as not to produce or to raise the clearing price in the spot market. In addition, strategic conduct may also involve changing the flows in the transmission network.[1]

Generally speaking, the extent to which a player in the electricity market has the ability and incentives to exercise market power depends on its relative size, its cost structure, and market response. The market response, or competitive environment, facing a single player can be

[1] In the presence of loop flows generators may even have incentives to *lower* the price in order to congest transmission lines, c.f., Hogan (1997).

represented by the elasticity of his individual residual demand curve. The responses from the consumers are captured in the elasticity of the market demand curve, which is highly inelastic on short terms. The response from other generation owners is represented by the elasticity of the individual residual demand curve, which is influenced by *their* abilities and incentives to exercise market power. This in turn is influenced by the level of capacity utilization (when demand is high fewer producers have spare capacity), temporary congested transmission lines which limit the number of competitors, the frequency of market interaction which may spur learning and tacit collusion (c.f. Borenstein et al., 2000), and barriers to entry.

### 3. 1 Hydro scheduling and market power – a multi-period Cournot Equilibrium

Hydropower generators with reservoirs have different strategies than thermal generators when it comes to abusing market power. This is mainly because a thermal generator has a flexible (at least deterministic) energy capacity as more or less fuel can be bought in the market, whereas a hydropower generator's energy capacity is given – although it varies with inflow (stochastic). Moreover, any water withheld for the purpose of lifting prices in one period must be produced in a later period, as spilling water is not allowed. Therefore, to hydro power producers exercising market power involves dynamic considerations, c.f. Bushnell (2003).

Formally, consider a fixed and final set $I$ of oligopolistic producers acting in a Cournot-manner, who control hydro generation resources with storage possibilities. Then, let $q_{it}$ denote the hydro output level of firm $i \in I$ at time $t \in T$. We assume that any producer $i \in I$ has a reservoir of $\overline{q}_i$ units of available water and that total production is limited over the $T$ periods, such that $\sum_{t \in T} q_{it} = \overline{q}_i$ . Spilling of water is not permitted. For simplicity, we ignore the stochastic nature of inflow.

Let $P_t(Q_t)$ denote the inverse market demand function at time $t$, where $Q_t = \sum_{i\in I} q_{it}$ represents total industry output. This function is assumed to be non-increasing and twice differential in $Q_t$ with first and second derivatives $P_t`$ and $P_t`` \leq 0$. Now each producer wishes to choose $q_{it} \geq 0$ so as to maximize its (spot market) profit, this being its single-period objective

$$\pi_{it}(q_{it}, Q_t) = P_t(Q_t) q_{it} \tag{1}$$

**Definition 1** *An output profile* $q_t^* = (q_{it}^*)_{i\in I} \geq 0$ *is said to constitute a Cournot-Nash equilibrium if each* $q_{it}^*$ *is an optimal solution to the problem*

$$\begin{aligned} &\max_{q_{it}\geq 0} \pi_{it}(q_{it}, Q_t) \quad \text{subject to} \\ &\sum_{t\in T} q_{it} = \overline{q}_i \,, \ \forall i \end{aligned} \tag{2}$$

Equilibrium will exist under weak assumptions not explored here.

To characterize the optimal solution consider the following Kuhn-Tucker conditions, where $\sigma_i$ is the Lagrange multiplier corresponding to the individual total reservoir constraint:

$$\begin{aligned} &P_t(Q_t) + P_t'(Q_t) q_{it} - \sigma_i = 0 \,, \ \forall i,t \\ &\sigma_i \left( \sum_t q_{it} - \overline{q}_i \right) = 0 \,, \ \forall i \\ &\sum\nolimits_t q_{it} \leq \overline{q}_i \,, \ \forall i \\ &q_{it}, \sigma_i \geq 0 \,, \ \forall i,t \end{aligned} \tag{3}$$

The first equation of (3) states the traditional optimality condition that strategic producers choose output levels such that marginal revenue equals marginal cost. Moreover, they will allocate water such that marginal revenue is constant across time periods. This behaviour contrasts the competitive strategy that tends to smooth prices across time periods. Note that the term $\sigma_i$ coincides with the so-called *marginal water value*.

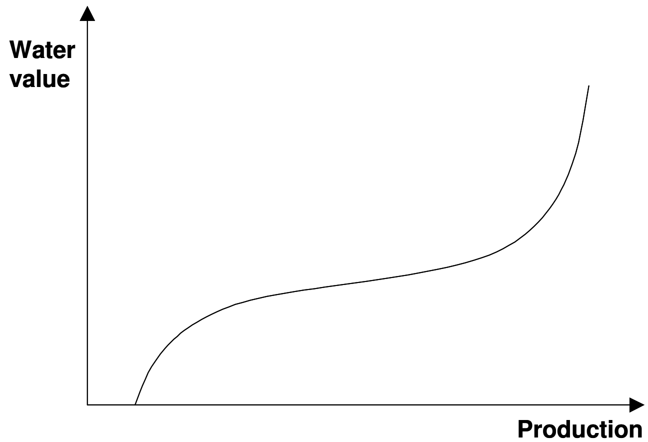
Then letting $|I|$ be the number of producers and $\varepsilon < 0$ denote the elasticity of market demand $\frac{\partial Q}{\partial p}\frac{P(Q)}{Q}$, we can add individual profit maximizing equations and rearrange, to get

$$P_t(Q_t)\left(1+\frac{1}{|I|\varepsilon}\right)=\frac{\sum_{i\in I}\sigma_i}{|I|}. \tag{4}$$

Here we observe that producers acting in a Cournot manner have incentives to exercise market power, implying that the less elastic demand or the smaller the number of competitors, the greater the markup of price over marginal cost. However, if fringe-players are included in the model, the strategic firms cannot enforce a complete Cournot regime on the market, c.f. Bushnell (2003) who also includes thermal production capacity in the model.

It is important to note that in practice the water value may change over time due to expectations about future market prices, and, consequently, also prospects of market power abuse. The water value is also a subjective value that varies between firms and generation plants. Therefore, the characteristic of a production facility determines a firm specific water value. A generator with little ability to regulate its production, for example, will typically have a lower water value than a generator with high flexibility. Flexibility depends on the size of the reservoir (ability to wait longer for prices to increase) and the power capacity (ability to produce more during hours with high prices). In fact, each generator (plant) will have a water value *curve*, showing the alternative value of water for different production levels. The individual water value curve, as well as the aggregated water value curve, which represents the market supply curve, may have a shape as depicted in Figure 2 below.

*Figure 2  Water value curve*




It shows that the water value falls to zero if the production levels fall below a certain level (spilling) and is high for high production levels. Depending on the time of year, reservoir level and power capacity, individual water value curves may lack both the low and the high end of the curve.

In case a hydropower generator exercise market power one would expect prices to vary more across the day than in a competitive situation, and, that prices would be higher than the water value in periods with high demand (peak load). Price levels during the night will not be affected to the same extent, although strategic withholding of water will increase the probability of spilling and/or low load prices below the (day-time) water value. Moreover, we would expect the production plan over time to be changed by strategic behavior: For example, total production may be lower in a wet period than with perfect competition. However, if future precipitation is above the expected level, the effect of withholding may also be to reduce the (future) water value. Hence, the longer withheld water has to be stored in order to limit losses, the more risky is the withholding.

On the other hand, a hydropower generator may exercise market power by producing *too much*: Draining reservoirs excessively in periods with highly elastic residual demand (i.e., responsive thermal production) increases the likelihood of a higher water value in subsequent periods. This kind of strategic behavior may be more difficult to detect: The production pattern may be in accordance with short-term water values in all periods, but the development in water values over time will not be in accordance with price taking behavior.

## 4. Indicators of short-term market power abuse

The above discussion of water values and market power strategies in hydro dominated electricity markets reveal the complexity of monitoring firm behavior ex post. Therefore, our greatest challenge when developing a monitoring scheme is to create a system that is easy to implement and, once installed, requires little resources.

As a first screening of the market – to pick up suspicious price formation – we choose a modified Learner index. The traditional Lerner index measures the share of the market price which is not explained by marginal costs

$$L = \frac{p - mc}{p},$$

where $p$ is the market price and $mc$ is the marginal cost, i.e. $L \in [0,1]$. Price equal to marginal cost implies the Lerner index is zero. Withholding production in high load (low elasticity) periods may thus be detected using this index.[2] However, it should be noted that the Lerner index may be greater than zero for other reasons than market power, most notably if there is capacity scarcity. Varying load (and generation availability) implies that there will be a positive shadow price on capacity in some situations. We do, however, believe that a

[2] The Learner index can either be calculated using historical data – to assess whether or not there *has* been any exercise of market power – or using model simulations of a future market situation, see e.g. Wolfram (1999), Borenstein et al. (2002), and Joskow and Kahn (2002) for analyses related to electricity markets.

monitoring system *should* pick up such instances as suspicious: even if production is at the capacity limit, prices may have been set too high.

In order to assess price formation in the market using the Lerner index we need a measure of the water value. A hydro power generator may choose either to produce this period or to save the water to future periods when prices are (at least) as favorable. Therefore, prices in the underlying financial market could work well as proxies for the water value in later periods. However, which forward price, or mix of forward prices, that is most adequate will vary between generators and across seasons. Generators with large reservoir capacity will be able to store water for longer periods than generators with little reservoir capacity, and individual power capacities will also influence production decisions differently. Moreover, in periods of great uncertainty prices tend to fluctuate more, which may result in a substantial fall in turn-over in the underlying financial market. Consequently, we reject forward prices as estimates of water values for monitoring purposes.

The most important information for agents in a hydropower system is the weather forecast. As water values change with expectations, and expectations are updated and adjusted as new information is revealed, the water value assessments may change from day to day.[3] Following theory we know that in equilibrium all generators will have the same marginal water value. Moreover, we know that there is a high degree of flexibility in Norwegian hydropower, meaning that most generators can allocate water between day and night in order to maximize profits. We may also assume that, apart from periods with heavy precipitation and high reservoirs fillings, generators will probably not produce below the water value during the night when load is low. Even if they exercise market power, we may assume that production

[3] In principle the water value may be updated hourly. However, in the Nordic market suppliers submit bids for the next 24 hour cycle and it is reasonable to assume that the same water value curve is the basis of all 24 bids.

during the night will not be increased to an extent that will make prices fall significantly below the water value. This is because it will be possible to store water for later periods when the residual demand is more elastic. Given the above assessment, it is reasonable to assume that prices in the low load periods are a good measure of the short-term expectations. This measure internalizes the individual assessment of the alternative value of water on the margin.

Yet in wet periods, notably during wet summers, some of the water inflow cannot be stored (unregulated inflows), and the price in low load periods will fall below the marginal water value. This means that using the low load price as a proxy for the daily marginal water value will result in values that are too low in these periods, and the corresponding Lerner index will erroneously indicate possible strategic pricing. The correct value should be the value of water that can be stored. Therefore, in order to correct for errors stemming from excess water, we replace the marginal cost assessment based on low load prices in these periods with the marginal cost of base load, which in the Nordic market is the cost factor of a reasonably efficient Danish coal fired plant. The coal power cost factor takes into account the fuel cost (time series), efficiency and other variable production costs in the said power plant.

Based on the above discussion we propose calculating a *daily* (24h) Lerner index, $L_d$, having the following form:

$$L_d = \sum_{t=7}^{24} \frac{p_t - mc_d}{p_t}. \tag{5}$$

Marginal cost of day $d$, $mc_d$, is here the average of the 6 lowest price hours and the sum is taken over the remaining 18 hours, $t$ = 7 to $t$ = 24, of that day. However, if the estimated marginal cost is lower than the coal power cost level, it is replaced by that value in the calculation. Recall that for most production levels, the water value curve is slightly increasing, c.f. Figure 2, which means that for many hours during the day prices will be (slightly) above the calculated water value. This is also in accordance with market observations: even in periods when we have no reason to suspect market power, there are some price differences between night and day. Therefore, we set a critical value of the $L_d$ index at 1.8, implying that prices in the hours $t$ = 7…24 are allowed to be 10 percent above the calculated water value (on average) without alarms being raised.

Moreover, to be sure to pick up days when prices peak for just one or a few hours, we supplement the daily index with a *peak price* index, $L_d^{PP}$, defined as

$$L_d^{PP} = \frac{p_d^{\max} - mc_d}{p_{dx}^{\max}}, \tag{6}$$

where $mc_d$ is the water value and $p_d^{\max}$ the maximum price of day $d$. This is simply the Lerner index for the hour with the highest observed price per day. We suggest the critical level of the $L_d^{PP}$ index to be set at 0.15, implying that days with maximum prices less than 15 percent above the water value will not be singled out.

Finally, since high prices in periods with low production levels are "worse" than high prices in periods with production close to the capacity limit, we need an indicator that evaluates the capacity dimension of the system. This can be done in various ways, for example by calculating a capacity adjusted daily Lerner index, $L_K$, as follows:

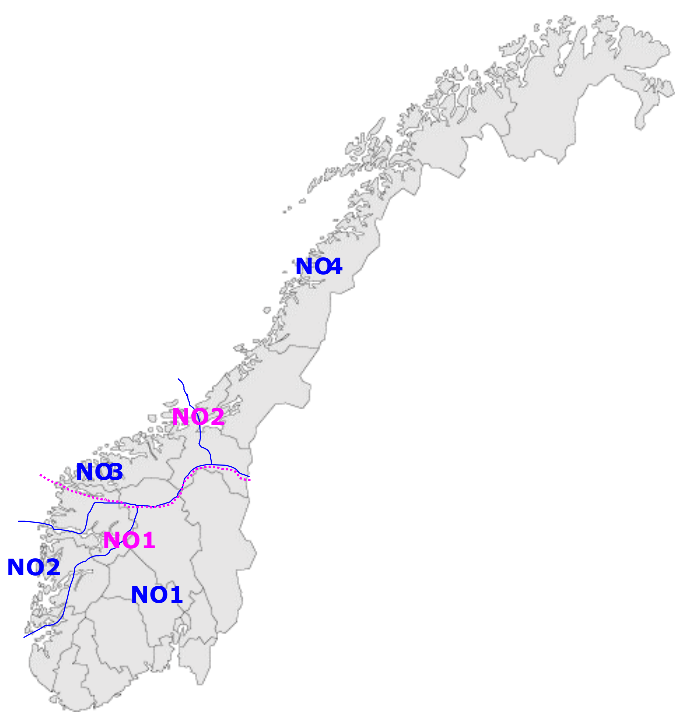
$$L_K = L_d\left(\frac{2K - k}{K}\right). \tag{7}$$

Here $L_d$ is multiplied with a capacity term, where $K$ is maximum available capacity and $k$ is capacity utilization (in one particular hour or the average of several hours). The capacity term (in brackets) will be 1 if capacity is fully utilized and 2 if all capacity is idle. Adjusting the indicator in this fashion means that for a given markup the value increases with lower capacity utilization. Due to lack of accurate data for available capacities on a daily or hourly basis, we have so far not developed this idea any further.

## 5. Empirical results - testing the indicators

The empirical basis for testing the indicators presented above is the hydrological year 2002/2003, i.e. from week 13 (2002) to week 12 (2003). Normally Norway is divided into two price areas NO1 and NO2. In situations with extensive bottlenecks the Norwegian transmission system operator (TSO) Statnett, sometimes find in appropriate to establish more price areas. Therefore, during the winter 2002/2003 Norway had four price areas, starting week 51 (2002) and lasting until week 23 (2003), see the illustration in Figure 3.

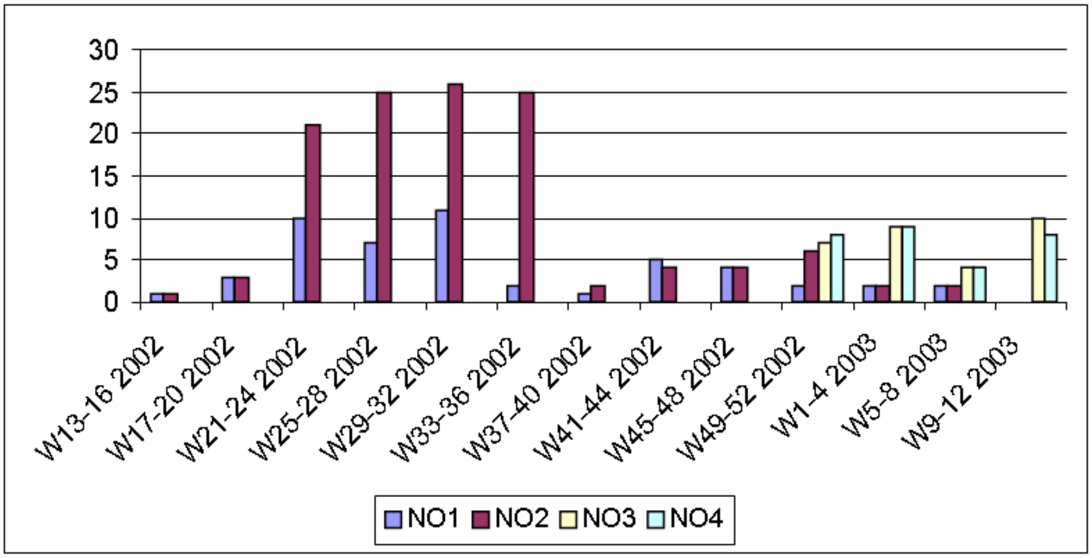
*Figure 3 Price areas in Norway*




Source: Statnett

First, we calculate the daily Lerner index $L_d$ for the whole period in question. Then we collect the observations that had values above the suggested critical value of 1.8, see Figure 4.

*Figure 4* *Number of daily indices above the critical value of 1.8 in different market areas during 4-week periods between W13 2002 – W12 2003*



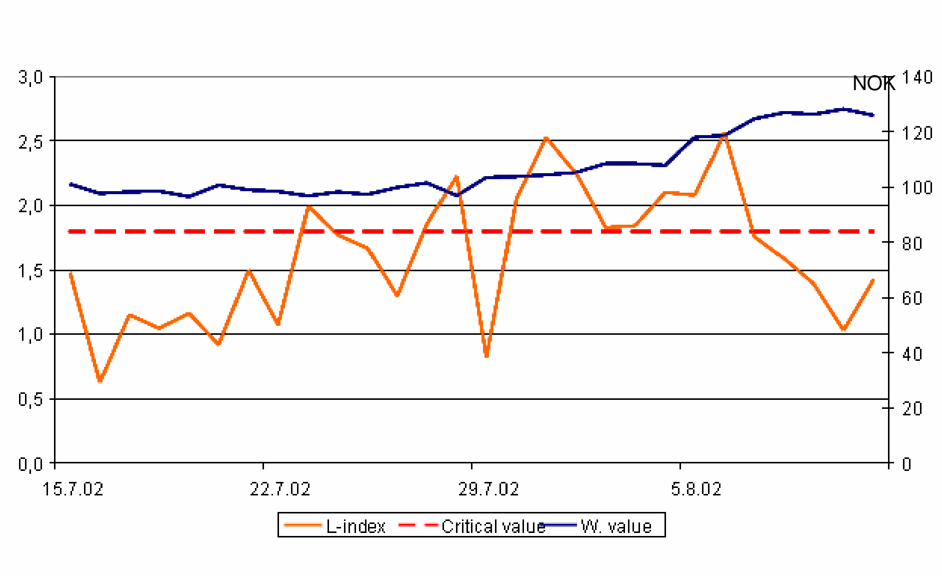

From Figure 4 we see that there were many occasions of daily index values above the critical value during this (hydrological) year. But we can not confer to this illustration as evidence of market manipulations. However, "hits" above the critical value is a basis for analyzing the behavior during these days more closely.

Here we choose to look more closely at the data and corresponding indicators from two distinct periods, first weeks 29-32 (2002) for the market area of Southern Norway (NO1), and then weeks 3-3 (2003) for the two market areas constituting Northern Norway (NO3 and NO4).

### 5.1 Weeks 29-32 (2002) Southern Norway (NO1)

This four-week period is the middle of summer (July-August) after an unusually wet spring and summer with high reservoir fillings. Figure 5 below displays the calculated water values, the daily Lerner indices and the suggested critical value.

*Figure 5 Indicator values, calculated water values and critical value, NOK/MWh, weeks 29-32 2002, Southern Norway (NO1)*




The price level in this period is very low, resulting in water values at around 100-120 NOK/MWh (about 12 –15 EUR/MWh). We also observe index values well above the critical value in some periods.

Therefore, we investigate further the index values of period 29.7.02-4.8.02 (Week 31), displayed in Table 1

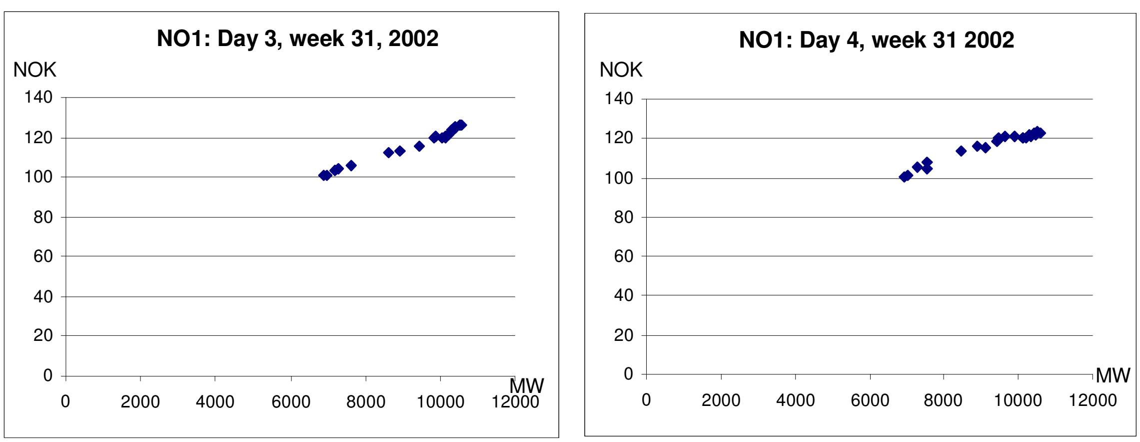
*Table 1 "Hits" on different indicators, Southern Norway (NO1), week 31 2002.*

| ***Week 31*** | ***d*** | ***$L_d$>1.8*** | ***$L_d$>Variable*** | $L_d^{PP}$ ***.15*** | $L_d^{PP}$ ***.20*** | ***SUM1*** | ***SUM2*** |
|---|---|---|---|---|---|---|---|
| | ***1*** | 0 | 0 | 0 | 0 | 0 | 0 |
| | ***2*** | 1 | 0 | 0 | 0 | 1 | 0 |
| | ***3*** | 1 | 0 | 1 | 1 | 2 | 1 |
| | ***4*** | 1 | 0 | 1 | 0 | 2 | 1 |
| | ***5*** | 1 | 0 | 0 | 0 | 1 | 0 |
| | ***6*** | 1 | 0 | 1 | 0 | 2 | 1 |
| | ***7*** | 1 | 0 | 1 | 0 | 2 | 1 |
| *Number of hits* | | 6 | 0 | 4 | 1 | 6 | 4 |

Even though we have used the coal power cost factor to reduce the number of hits, because we otherwise calculate a too low water value, we get many hits in week 31. Moreover, in order to avoid this – only about 1.25 to 1.50 EUR/MWh can not be explained by the water value – we also allow an average price difference ($p - mc$) of 20 NOK/MWh over the 18 hours that is included in the index calculation, meaning that the critical value will vary and be higher than 1.8 for water values below 200 NOK/MWh. This procedure removes in fact all the hits of the daily indicator this week, see column $L_d$ *>Variable* of Table 1. However, the $L_d^{PP}$ index picks up a few days, depending on the chosen critical value. The two last columns on the right merely sums up the number of hits; SUM1 being the sum of column $L_d$ *>1.8* and column $L_d^{PP}$ *.15*, and SUM2 being the sum of column $L_d$ *>Variable* and column $L_d^{PP}$ *.15*.

Figure 6 below depicts the combinations of prices and production levels for the days $d$ = 3 and $d$ = 4 in Table 1.

*Figure 6 Scatter diagram price/production, days 3 and 4, week 31(2002) Southern Norway, NOK/MWh vs. MW*




We observe that the water value curves seem to have the expected slightly upward sloping shape, and that the difference between the two days is that there seems to be a slight peak in prices in day 3. However, production is far from the capacity limit of 19,100 MW that particular day, c.f. Table 2.

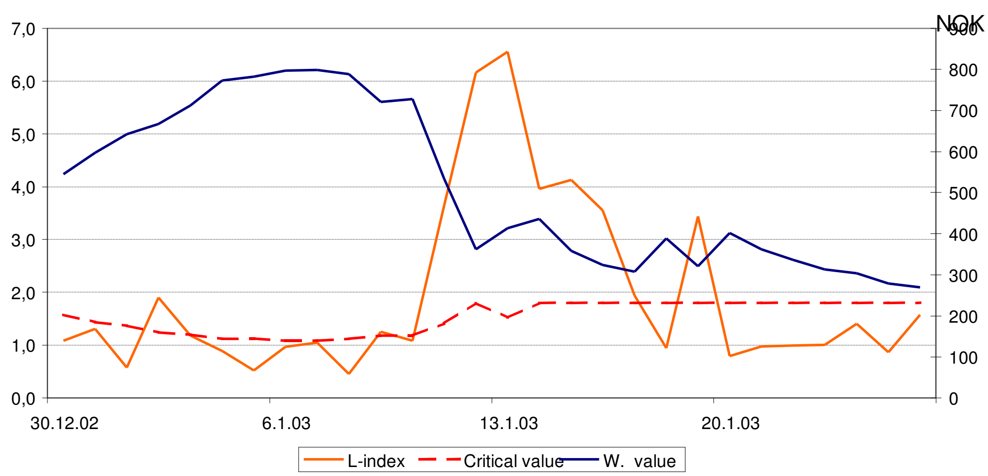
*Tabel 2 Key values for the behavior of day 3 week 31, 2002.*

| ***Day 3, week 31*** | $\boldsymbol{L_d = 2.53}$ | $\boldsymbol{L_d^{PP} = 0.21}$ |
|---|---|---|
| | *Water value/price (NOK/MWh)* | *Capacity/Production (MW)* |
| | 104.5 | 19,100 |
| Maximum | 126.4 | 10,575 |
| Minimum | 100.8 | 6,895 |

**5.2 Weeks 1-4 (2003) Northern Norway (NO3 and NO4)**

This period covers mid-winter when spot prices were peaking after the market had experienced a historic inflow shortage throughout the Nordic exchange area the previous fall. During these four weeks there were close to no price differences between the market areas NO3 and NO4, therefore Figure 7 displays the calculated water values, the daily Lerner indices and the *variable* critical value for NO4.

*Figure 7 Indicator values, calculated water values and variable critical value, NOK/MWh, W1-W4 2003, Northern Norway (NO4)*



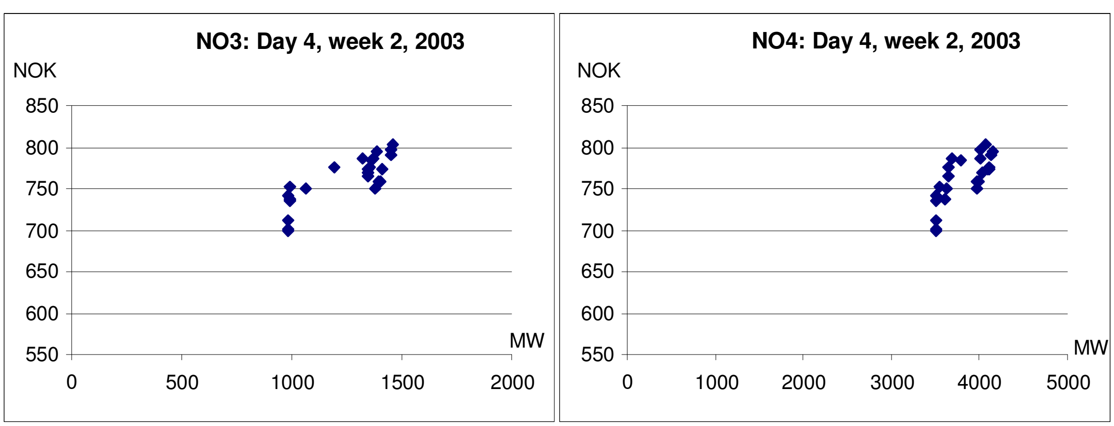
As we see from Figure 7, water values reached 800 NOK/MWh (about 100 EUR/MWh) during the first week of January. Later prices went down to 270 NOK/MWh (about 34 EUR/MWh). We also see that there are many index values above the critical value, particularly in weeks 2 and 3. We choose to investigate further the index values of week 2, displayed in Table 3.

*Table 3 "Hits" on different indicators, Northern Norway (NO4), week 2 2003.*

| ***Week 2*** | ***d*** | $L_d$***>1.8*** | $L_d$***>Variable*** | $L_d^{PP}$***.15*** | $L_d^{PP}$***.20*** | ***SUM1*** | ***SUM2*** |
|---|---|---|---|---|---|---|---|
| | ***1*** | 0 | 0 | 0 | 0 | 0 | 0 |
| | ***2*** | 0 | 0 | 0 | 0 | 0 | 0 |
| | ***3*** | 0 | 0 | 0 | 0 | 0 | 0 |
| | ***4*** | 0 | 1 | 0 | 0 | 0 | 1 |
| | ***5*** | 0 | 0 | 0 | 0 | 0 | 0 |
| | ***6*** | 0 | 1 | 1 | 1 | 1 | 2 |
| | ***7*** | 1 | 1 | 1 | 1 | 2 | 2 |
| *Number of hits* | | 0 | 3 | 2 | 2 | 3 | 5 |

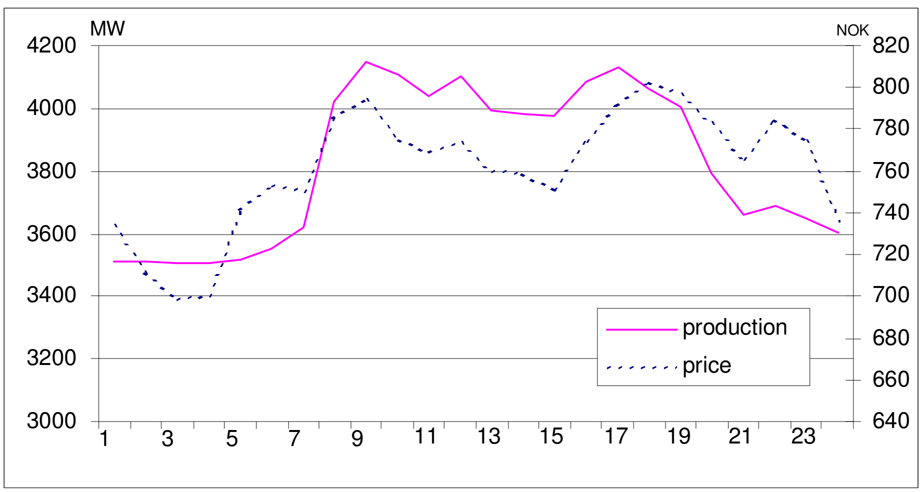
Figure 8 below depicts the combinations of prices and production levels for $d = 4$ in Table 3 for the two price areas constituting Northern Norway, NO3 and NO4.

*Figure 8 Scatter diagram price/production, day 4, week 2(2003) Northern Norway, NO3 and NO4, NOK/MWh vs. MW*




Compared to the "nice" water value curves depicted in Figure 6, we observe here a quite different pattern of price/production combinations. First, production is close to the capacity limit of 1,935 MW in NO3 and 4,800 MW in NO4. Second, there are hours with relatively large difference in production levels that have a significant price difference which goes the "wrong" way. If we study the course of price and production during day 4, week 2 in NO4, see Figure 9, we observe that the muddled water value pattern of Figure 8 is due to prices being almost as high during the night as during the day – although production was much lower.

*Figure 9 The course of price and production, day 4 (24h), week 2, 2003, Northern Norway, NO4, NOK/MWh and MW*




Due to the relative strain of the resource situation in the Nordic electricity market this particular winter, authorities made explicit appeals to hydro power producers to be economical with their hydro resources, which may explain the above observations. However, there are many ways of economizing water. One alternative is to decide the total volume to be produced during a 24 hour course, and then portion it out in the most profitable manner. If a generator has market power in some hours, it is possible to withhold production during these hours and produce more in the others. This may also be an explanation to the above results.

## 6. Conclusions

The system of indices) presented here makes it possible in a relatively simple way – based on publicly available data – to screen the market for days of suspicious price formation. Competition authorities or regulators may use it without having access to actual individual market bids. When the monitoring system identifies instances where price formation cannot be explained by general market data, including data on transmission flows and bottlenecks not discussed here, the next step is to ask the Nord Pool exchange to work out a report based on the actual bidding on that day (probably a period).

The system is not meant to be "fool-proof" in the sense that market power can be proved. But it may be sufficiently precise so as to identify possible strategic behavior, and to form a basis on which generators may be asked to produce explanations for irregular bidding.

Studying data we see instances where capacity is clearly held back; e.g. during the winter of 2003 there are days when prices during the night are higher than prices during the day. The explanation is said to be that generators bid in capacity in accordance with a production plan; if they do not expect to produce to full capacity during the night, they simply do not bid in all available capacity. This is withholding, although it may not be strategic. The market would perform better if such behavior were mitigated.

The type of market power that involves shifting total production between seasons can not be detected without simulations of production plans on longer-terms.

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