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An econometric analysis of the regulation power market at the Nordic power exchange

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Abstract

Increasing shares of variable renewable energy (VRE) causes challenges related to power system balancing. The regulating power market is part of the Nordic electricity market and has as purpose to maintain the balance between total generation and consumption of power in real time. Currently, the power balance settlement is being carried on a national level, by the separate transmission operator in each Nordic country. Recent developments, in the form of a common project initiated by the system operators in Norway, Sweden and Finland, attempt to change the routinized course of the balance settlement by introducing a model for common Nordic balance and reconciliation settlement (NBS). The regulatory change will make the rules for balance settlement equal to all Nordic participants, ease market participation and possibly increase the number of smaller market actors. For power market participants it is of interest to analyze how the regulatory change will affect balancing market prices. This paper analyzes how the regulating price in different price areas in the Nord Pool region is affected by the level of the spot price and the volumes of regulating bids using historical market data. According to the estimated econometric models, the down-regulation price is more sensitive to the regulating volumes than the up-regulation price. At maximum the up-regulation price decreases by 0.14% as a result of a 1% increase in the bids' volume, while for the down-regulation price a greater than 0.2% increase is observed. Also, the results show relatively large differences in the sensitivity of spot prices and bid volumes across different areas and seasons.

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Keywords: Balancing market, market integration, regulatory changes, Nord Pool

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1. Introduction

The purpose of the Nordic regulating power market is to maintain the balance between total generation and consumption of power in real time. It is managed by the transmission system operators - TSOs (Statnett in Norway, Svenska Kraftnät in Sweden, Energinet.dk in Denmark and Fingrid in Finland). The balancing capacities traded in this market are known as tertiary reserves or regulation power reserves and are mainly manually activated [1]. Electricity retailers buy power at the wholesale market based on estimates on how much electricity their clients will consume. If the estimated figures deviate from the actual ones they should either per definition sell excess power to the system operator (in the case when customers have used less than expected) or buy power from the system operator (when customers have used more than expected).

Balancing power needs also to be settled between producers and TSOs when producers fail to produce according to the plans. The existence of a balancing market ensures that producers that have difficulties to fulfill their commitments to the spot market but have no flexibility in generation can meet those who can rapidly regulate their production. This happens through the market mechanism with up- and down-regulating prices and helps keeping the balance between supply and demand in real time. The deviating amount of electricity that is to be settled between the TSOs and the retailers/producers is called balancing power[2].

Although the market participants are making their offers to sell and bids to buy at the common Nordic power exchange, the power balance settlement is being currently carried on a national level, by the separate transmission operator in each Nordic country. Recent developments, in the form of a common project initiated by the system operators in Norway, Sweden and Finland, attempt to change the routinized course of the balance settlement by introducing a model for common Nordic balance and reconciliation settlement[1] (NBS). The model developers describe the model as one in which a common Nordic body called settlement responsible (SR) is responsible for the balance settlement, invoicing and collaterals towards the balancing responsible parties (BRP)[2]. The settlement responsible, for which decision has been taken to be established in Finland, should carry on all these activities on behalf of the transmission system operator in each country [3].

Implementing the model is expected to ease the settlement procedures as there will be only one counterpart in the face of a common Nordic settlement responsible unit, as well as reduced amount of communication between the distribution system operators and the BRP. Laws and regulations will be harmonized, the complexity for BRPs to operate in a Nordic scope reduced and the entry barriers for new participants lowered.

The literature on balancing market has so far been focusing primarily on its operational side. The works of Vandezande et al. [4] and Sorknæs et al. [5] focus on the effects of wind power generation on the balancing market, while Van der Veen and De Vries [6] analyze the possible impact of an increasing share of household and small business microgeneration technologies on the Dutch balancing power market. Scientific work has also been devoted to the enhancement of a larger regulating power market in Northern Europe. Such an example is the research carried out by Farahmand and Doorman [7] and Jaehnert and Doorman [8]. The work of Skytte [9] focuses on the pattern of the prices on the regulating market and as such stands closest to the research presented here. Skytte investigates the regulating power market considering the costs associated with the inability of market actors to comply with the commitments made at the spot market. Clearly generators with fluctuating production participate in the power exchange on the same conditions as those producers that can regulate their generation and always comply with the offers made. This fact questions the strategy that producers with fluctuating generation may have under the bidding process as they will have to take into account the cost for up- or down-regulation they have to carry. Skytte defines the cost associated with using regulating power as a quadratic function of the amount of regulation and indicates the possibility for aggressive bidding strategy on the spot market as a consequence of this asymmetric cost.

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[1] With reconciliation settlement is meant the settlement method that takes into account the differences between consumption that has been preliminary profiled for the purposes of balance settlement and finally profiled consumption.

[2] Balancing responsible parties are considered those power market players that have agreements with the system operator to buy or sell market power in order to neutralize grid imbalances.

Despite the fact that various aspects of the balancing market have been examined in the literature so far, no one has analyzed the regulating power market in the Nordic countries, to our knowledge. As noted by Skytte [9], the relationship between the prices in the spot and regulating power market is of particular importance for agents in the market that has unpredictable, fluctuating supply and demand, like e.g. variable renewable energy (VRE). And a Nordic study is of particular interest with the prospects of a common balance settlement model in the Nordic region. The objective of this paper is to analyze how the spot price and bid volumes affect the regulating power prices, i.e. the costs of being unable to fulfil the commitments made on the spot market in the different Nordic countries. For the purpose will be used historical data available from the Nord Pool Spot database. Considering the new developments in the regulating market as defined in the NBS model, the possible effect of an increase in the volume of regulating bids on the balancing market prices will then be investigated. Also, the differences between estimation results with respect to generation mix in the separate country and seasonal variations are discussed.

2. Econometric model and data

Following the study of Skytte, [9], the following functional form will be investigated:

$$P_r = \sigma_0 + 1_{V>0}(\alpha P_s + \beta V + \eta) + 1_{V<0}(\gamma P_s + \delta V + \mu) \qquad (1)$$

In the equation (1) P_r presents the regulating price, P_s is the spot price, and V is the volume of regulating bids. In the case where V is positive the equation will be estimated for up-regulation and P_r will actually represent the up-regulating price, and V is the volume of up-regulating bids. Respectively, when V is negative the equation will be estimated for down regulation with P_r then being the down-regulating price and V – the volume of down-regulating bids. The multiplicator of 1 serves as an indicator and equals zero if the statements about the value of V are false, and σ_0 is the constant term.

The coefficients α and γ represent the relation between regulating and spot prices, while β and δ define the dependence of regulating prices on the up- or down-regulating volumes of bids. In his work Skytte [9] analyzes an equation of a similar functional form and describes these coefficients as the “marginal regulating power prices per unit of regulated power”. However, in his study the independent variables used are the spot price and the total amount of regulating power activated, and not the volume of bids. In this case β and δ will be the marginal prices per unit of regulating bid, thus providing a different application of Skytte’s functional form. To complete the econometric model the error terms η and μ are added to respectively the equation parts for down and up regulation.

The data used in the model represents time-series for the six-month period: 1 January 2012 to 30 June 2012. The time series comprise hourly data taken from Nord Pool Spot database and includes all the price areas in the Nordic countries Sweden, Finland and Norway. This corresponds to a total number of 4368 hourly observations for each variable in the model. The analysis is based on three main groups of variables: regulating prices, elspot prices and volumes of regulating bids. Here by “groups” is meant the division in bidding areas within each variable (five bidding areas in Norway, four in Sweden and one in Finland).

The functional form (1) could intuitively raise questions of endogeneity. However, since the market spot price is being decided prior to the clearing in the regulating market, it seems reasonable to assume that the spot price is determined independently of the regulating price. Second, the volume variable in the equation consists of the total volumes bid at the market, not the market clearing volumes, and is thus also assumed to be independent from the regulating prices. Hence, in similarity to the approach of Skytte [9], we assume that the two right-hand side variables are determined independently of the regulating price.

3. Estimation results and discussion

To conduct the econometric analysis the program Stata is used. Before the estimation work starts stationarity of the time series is being confirmed using the Dickey-Fuller test. At a next step equation (1) is estimated for each of the price zones, the variables being transformed in logarithmic form to find elasticity values. A summary of the results is presented in the table below; all the coefficient estimates (except the ones in brackets in Table 1) are statistically significant at 5% significance level.

Table 1 – Constant term and estimated coefficients on equation (1)

Constant term/Coeff.	NO1	NO2	NO3	NO4	NO5	SE1	SE2	SE3	SE4	FI
$\sigma_0\ (up)$	0.3894	0.2997	-0.1134	0.4292	-0.3013	0.5080	0.1221	0.0555	-0.0557	0.8382
$\alpha\ (P_s)$	1.0093	1.0103	1.0857	1.0025	1.1020	0.9698	1.0415	1.0855	1.0984	1.0887
$\beta\ (V_{up})$	-0.0502	-0.0359	-0.0177	-0.0569	(0.0014)	-0.0548	-0.0357	-0.0393	-0.0333	-0.1412
$R^2\ (up)$	0.8287	0.7864	0.7701	0.7673	0.8151	0.7780	0.7464	0.7662	0.7347	0.6334
$\sigma_0(down)$	-0.7598	-1.6043	-1.7193	-1.2625	-1.9352	-0.6023	-1.1637	-0.3706	0.8073	-0.2930
$\gamma\ (P_s)$	1.0185	0.8414	0.9848	0.9003	0.9737	1.1153	1.0369	0.9783	0.6638	1.0496
$\delta\ (V_{down})$	0.0790	0.2409	0.2267	0.2146	0.2590	(0.0039)	0.1330	0.0561	0.0791	(-0.0108)
$R^2\ (down)$	0.6407	0.6260	0.6276	0.6464	0.6350	0.6067	0.6345	0.6205	0.5707	0.6003

3.1. The impact of changes in the spot price and in the volumes of regulating bids on the balancing price

All significant coefficient estimates on β (negative elasticity values) indicate a slight decrease in the price for up-regulation as a result of an increase in the volumes of up-regulating bids. The highest value for percentage decrease in the up-regulating price is for Finland (-0.14%), followed by NO2, NO4 and SE1.

To examine the elasticity of down-regulating prices with respect to regulating bids, the estimation values of δ are to be analysed. For price areas NO2, NO3, NO4 and NO5 the coefficient estimates indicate greater than 0.2% increase in down-regulating price as a result of a 1% increase in the volume of bids for down-regulation.

It seems like the sensitivity of the down-regulating price with respect to an increase in the regulating bids' volume is higher than that of the up-regulating price. The observed trends are different from the ones provided by Skytte [9], who concludes that the amount of balancing power affects the up-regulating price more strongly than it does for the down-regulating price. However, as previously mentioned, Skytte [9]considers the total amount of regulation, while this article focuses on the specific volumes of up and down regulation bids. In this respect, the different results are not contradicting, but rather complementing each other.

The option for easing accessibility to the balancing market in the form of a common balance settlement could be a key motivating factor for increasing the volumes of the bids. Making the rules for balancing settlement equal to all Nordic participants might be particularly important for the smaller actors that so far have been prevented from participation due to the complexity in the settlement procedures, and one could expect larger volumes from these actors in a common Nordic market. Yet, it is important to notice that the estimated elasticity values are only valid for the regulating bids (V) data selected for the model. Big changes in the volume of bids could alter the effects, but our aim here is to detect the regulating price trends associated with a potential increase in V.

For the coefficient estimates on the spot price it can be seen from table 1 that a 1% increase in the spot price increased the price for up regulation with more than one percent in all cases except for SE1 in our data. On the contrary, such a generalized conclusion cannot be derived for the elasticity of the down-regulating prices with respect to spot prices. Here the increase in spot price by 1% leads to an increase in the price for down-regulation with a bit less than 1% in most cases, but with more than 1% for NO1 and SE2. Yet, on average, the sensitivity of the regulating prices due to change in the spot price was found higher for the up-regulating prices than for the down-regulating ones.

With technological advances in the smart grid field, it will become easier for market actors to utilize flexibility in consumption as a balancing power resource. Active electricity suppliers or actors of the type "energy system company" that choose to take the role of an aggregator could make profit by bidding their customers' aggregated flexible loads on the regulating power market. Despite the existing requirements for activation time and size of the bid, innovative techniques for communication and measuring, combined with the integration in the settlement procedures, will make possible the participation of new market actors in the balancing power market. In addition, the estimated elasticities may experience significant changes in the future as more end-user flexibility enabled by smart meters is added to the power system. As a result the need for balancing power can be reduced: a fact that will influence both bidding volumes and balancing prices.

3.2. Differences between countries

From table 1, it can be seen that the regulation price in Finland is most sensitive to changes in the volumes of bids for up-regulation. When it comes to the down-regulating price elasticities, it is the Norwegian price areas NO2, NO3, NO4 and NO5 that exhibit highest values (Figure 1). However, these are not the price areas where the greatest volumes of regulating power are being traded. Instead the areas SE1, SE2 and NO2 are the most dependent on up- and down- regulation (Figure 2). Thus there could be other factors that determine how strongly the regulating prices depend on the volumes of regulating bids in a given area - such as bottlenecks in transmission, or availability of longer-term contracts for delivery of balancing power (such as options or bilateral contracts).

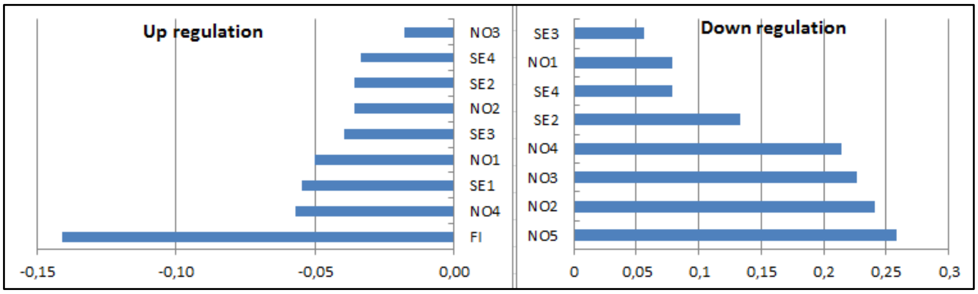

Figure 1 – Elasticity of regulating prices with respect to regulating bids' volumes in the different price areas.

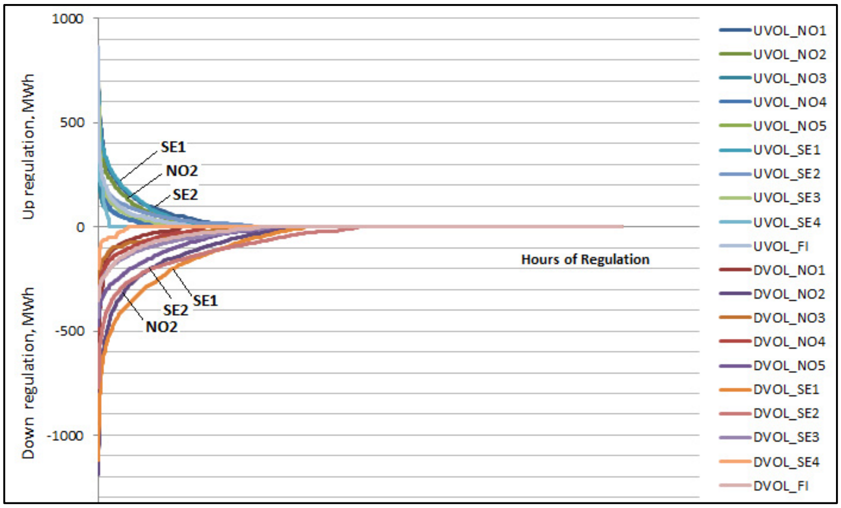

Figure 2 – Up and down regulation during the six month period - sorted by volume for each hour

Further we aim to investigate if the differences in the production mix between countries can be related to the elasticity values obtained from the model. In general, the electricity production in Norway is based on hydro power and in Sweden it is dominated by hydro and nuclear power. Finland gets almost one-third of its electricity generated from nuclear power while the rest of the production is a combination of hydro power, natural gas, hard coal, wood fuels and peat. Considering these country-specific production mixes, we could find some parallels to the estimation results presented in Table 1.

The impact of increase in the volumes of down-regulating bids on the down-regulating price, as measured by the coefficient δ (V_{down}) in Table 1, is highest for Norway (Price areas NO2 to NO5). This finding is probably caused by periods with extraordinary high water flow levels (typically during snow melt), where the unregulated hydro production is very high and rather unpredictable. These circumstances will typically cause quite low down regulation prices. The elasticity of up-regulating prices with respect to the volumes of up-regulating bids is highest ($\beta(V_{up}) = -0.14$) for Finland where there is least amount of hydro power in the generation mix and a wide range of other generation technologies are being used.

Regarding the relation between the spot and the regulating prices in each country, no clear trend that parallels the production mix can be discovered. The dependences at this point are rather related to the separate price areas, and not to the countries. The price area NO5 is the one for which an increase in the spot price will cause a highest increase in the up-regulating prices ($\alpha\,(P_s) = 1.1$). This region (the Bergen area) was established in 2011 as a consequence of an extraordinary tight supply-demand situation. The high α parameter is as such not surprising.

Among the spot price elasticity values for down-regulation, the lowest is that for the price area SE4 ($\gamma\,(P_s) = 0.66$). SE4 is the Northern Sweden having a large share of run-of-river hydro power and relatively limited demand.

The importance of the NBS model is expected to increase as more VRE (e.g. wind) is added to the power system. Currently all the participating countries have plans to increase this type of electricity production in nearest future. A common model for balance settlement and reduced prices for up-regulation can benefit power plants that run on intermittent renewable resources and motivate for further investments.

3.3. Seasonal variation

To capture the impact of seasonal variation we run the regression model with data for the second and sixth month in 2012. The following results are obtained for the different price areas:

Table 2 – Estimation results per price area, averaged data for February and June 2012. Estimation coefficients that are not significant at the 5% significance level are presented in brackets.

	Coefficient	NO1	NO2	NO3	NO4	NO5	SE1	SE2	SE3	SE4	FI
February 2012	$\alpha\,(P_s)$	0.9913	0.9950	1.1424	1.0625	1.150871	0.8910	1.1265	1.1382	1.0211	1.0251
	$\beta\,(V_{up})$	-0.1251	-0.0974	-0.0598	-0.0936	(-0.0465)	-0.1041	-0.0299	0.2234	0.3886	-0.3833
	$\gamma\,(P_s)$	0.7218	0.6317	0.7462	0.7567	0.6585	0.8339	0.7451	0.7819	0.6403	0.7285
	$\delta\,(V_{down})$	0.0959	0.1851	0.2314	0.1225	0.5013	-0.0198	0.1914	(0.0286)	0.0955	0.0757
June 2012	$\alpha\,(P_s)$	1.0405	1.0571	1.1947	1.1724	1.0067	0.9286	0.9967	1.0756	1.0260	1.1463
	$\beta\,(V_{up})$	-0.0320	(-0.0115)	0.0892	0.0479	(0.0028)	-0.0801	-0.0304	-0.1757	-0.1359	(0.0049)
	$\gamma\,(P_s)$	2.0519	1.9587	1.2169	1.6348	2.2123	1.4763	1.2924	1.0911	0.6903	1.2715
	$\delta\,(V_{down})$	(-0.0020)	(0.0172)	0.3615	(-0.0653)	-0.2590	-0.0714	0.2745	(0.0390)	0.1007	(-0.1096)

Although the differences in the estimation coefficients are small, some seasonal patterns can be observed. The elasticity values presented by $\alpha\,(P_s)$ indicate that the impact of spot prices on the up-regulating prices varies between months and price areas. However, the results do not show any clear trends of differentiation between the seasons – for some price areas the February price elasticity values are lower than the June values, while for other they are higher. It should be noted that the 2012 winter had somewhat higher temperatures than the normal, and that the hydro power balance (hydro storage) was above normal levels.

The case is different when the model is run for down-regulation. The summer spot price elasticity values $\gamma\,(P_s)$ are significantly higher for all price areas. Thus an increase in the spot price during the summer months will cause greater percentage increase in the down-regulating price than it will during the winter time. One explanation could be that in the summer months balancing parties have more free capacity, and would rather trade in the spot market than reduce production to make profit in the balancing market.

Regarding the volume of bids, no specific patterns in the seasonal elasticity values can be discovered. The differences are rather concerning the different price areas, and not the monthly variations as a whole. For example, the NO5 volume of down-regulating bids coefficient ($\delta\,(V_{down})$) is positive for February and negative for June. Yet, the estimated NO5 coefficient for the whole period is positive (($\delta\,(V_{down}) = 0.2590$ in Table 1). For price areas with typically higher amount of down regulation needed (total regulation amount for the period: 161,804 MW/h for NO5 versus 51,886 MW/h for NO1), the increase in the volume of down-regulating bids could actually decrease the down-regulating prices during the summer periods when more free capacity is available.

4. Conclusions

Regulative changes directed towards increased power market integration in the Nordic region will also affect the balancing market. The TSOs in Norway, Finland and Sweden are cooperating on the development of a model for common Nordic balance settlement that is to be operational from 2015. One of the main benefits associated with this model will be lower entry barriers for market actors willing to offer balancing power. Using the tools of regression analysis the possibility for increase in the volume of bids for up and down regulation and their impact on the balancing prices have been examined in this study. The estimation results indicate a slight decrease in the price for up-regulation as a result of an increase in the volumes of up-regulating bids (at maximum 0.14% as a result of a 1% increase in the bids' volume); and greater than 0.2% increase in down-regulating price. The sensitivity of the down-regulating price with respect to an increase in the regulating bids' volume has been proven higher. The establishment of a common Nordic balance settlement regime could strengthen the significance of this fact. Making the rules for balance settlement equal to all Nordic participants might be particularly important for the smaller actors that have been so far prevented from participation due to the complexity in the settlement procedures. Possibly the increase will be significant for the smaller in size up- and down-regulating bids, thus contributing for lower up-regulating and higher down-regulating prices.

In the regression model both the spot price and the volume of regulating bids have been used to determine the changes in the regulating price. The estimation results indicate that the impact of the spot price can vary between price areas and seasons. One example is that an increase in the spot price during summer months has proven to cause greater percentage increase in the down-regulating price, than it will during winter time. Thus the actual regulating prices and the associated elasticity values in the future will be dependent on the amount of VRE in each area, the season, the level of flexible demand, and also (as suggested by Skytte [9]) the BRPs' market strategies. Yet the results in this work can be considered indicative for the expected adjustments in the balancing price associated with a NBS regime.

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