DEMAND AND SUPPLY MANAGEMENT – AN ECONOMETRIC ANALYSIS OF ELECTRICITY PRICES

Ioana Neamtu, Aarhus University, +4587166098, inea@econ.au.dk

Overview

The paper investigates the potential for demand-side management for the system price in the Nordic electricity market and the price effects of introducing wind-power into the system. It departs from the standard approaches for estimating price elasticities of demand in three ways: first, it allows the estimation of hourly price elasticities of demand, which is very important for aggregated retailers, which must set the prices for households and small businesses as well as for the price regulators within the electricity markets. Second, it considers the aggregated level, for both small and large consumers, which is a plus especially for policy makers and regulators. Third, it uses a system of equations, which provides efficient and consistent estimators under the simultaneity issue which arises when estimating price elasticities of demand.

The model proposed accounts for the micro-structure of the Nordic electricity market by modeling each hour individually, while still accounting for the relationship between the hours within a day. This flexibility allows us to explore the differences between peak and shoulder demand hours.The results show potential for demand response management, as indicated by the price elasticity of demand. Our study shows that these effects are stronger during night-time and shoulder hours, compared to day-time and peak hours. Moreover, we find a small but statistically significant decrease in the price of electricity, given by the wind power penetration.

Methods

Expanding on the model proposed by Husiman et al (2013) by allowing demand to respond to price fluctuations and also allowing prices to respond to wind fluctuations, we investigate the potential for demand response at the aggregated level on the wholesale market on an hourly bases, for Nordic countries as well as the changes in hourly prices given by the increased wind power supplied to the market. We use a structural model to describe the price formation mechanism and use multiple equations GMM estimation method. This very general estimation method does not require distributional assumptions or cross-equations restrictions within the system of equations. Also, no cross-equation restrictions on the variance-covariance matrix of errors are needed. For the case of linear models, this method can be reduced to 3SLS (when the same instruments are used for all equations) and to SUR (when exogeneity of all explanatory variables is assumed) (Hayashi, 2000). Since none of these assumptions hold for the system of equations presented here, we propose the general case for estimating this model, the generalized method of moments, where we allow for contemporaneous correlations between the error terms of each equation.

Through the chosen methodology, this paper increases the support for analyzing hourly electricity prices as separate variables, which are determined simulteniously rather than sequentially. This strategy is motivated by the bidding system employed in the Nord Pool today. Bidding starts at 12:00 am every day and it covers the 24 hour period of the next day. Thus, the information available for the bidder before the bidding starts is the same for all the hours of the previous day and cannot be updated based on information from the previous hour, as it may be assumed when hourly time series are used.

The empirical model considered is based on a Marshallian demand function, where we correct for weather conditions (following Fezzi and Bunn, 2006) and the supply function is derived under the assumption of perfect competition. Although allowing for market power and strategic behavior was considered, this would not have an effect on the price elasticity of demand, which is the main concern in this study. The final form of the estimated model is:

$$log(Q_{th}) = \beta_0^D + \alpha_{0h} \cdot logp_{th} + \alpha_{1h} \cdot temp_{th} + \alpha_{2h} \cdot temp_{th}^2 + \sum \alpha_{3ih} \cdot D + \epsilon_{th}^D \quad (1)$$

$$log(p_{th}) = \beta_0^S + (c-1) \cdot log(Q_{th}) + \beta_1 w_{th} + \beta_3 r_{th} + \beta_4 p_{coal} + \beta_5 cap + \epsilon_{th}^S \quad (2)$$

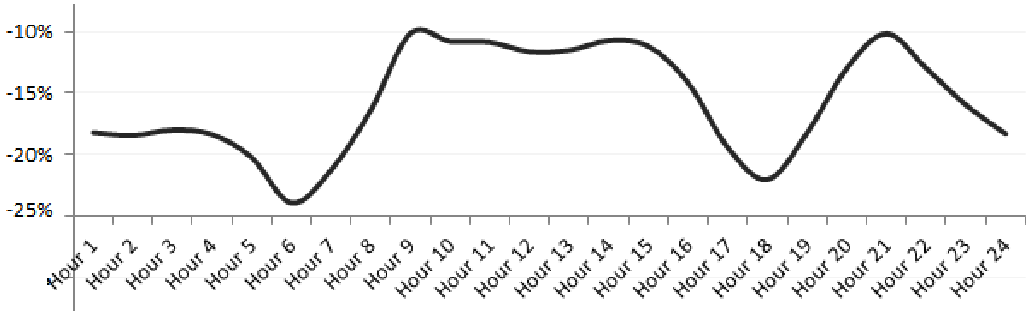
where Q represents the aggregated demand, p reperesents the system price of electricity and *temp* represents the temperature.w is the wind power produced, r represents the water reservoir, p_{coal} is the coal price, *cap* represents the available capacity.t indicates time,h represnts the hour of the day,ε represent the error term. The variable D represents a set of dummy variables for the day of the week and holidays, while the superscripts D and S stand for Demand and *S*upply equations. Totally, the system of equations has 48 equations, a demand and supply equation for each hour.

Therefore, we have a linear system of seemingly unrelated structural equations for the demand and supply of electricity,respectively, for each hour of the day. The coefficients of interest are α_{0h} (the price elasticity of demand) and β_1 (which quantifies the effect of wind power on the electricity prices).
The data used for this paper comes mainly from Nord Pool Spot, the System Operator responsible for the Nordic and Baltic countries and from the *wheaterunderground.com* website (for the wheater variables) as well as the Danish Energy Agency (for the daily coal prices). The time-span of the data is Jan-2012 to May-2014 and it covers all Nordic countries and Estonia, Lithuania and Latvia. The data has been changed as follows: the water level reservoirs have been linearly interpolated from weekly to daily observations and the temperature data used is a weighted average of temperatures in each country, where the weights correspond to the fraction of the country's consumption in the total consumption in the region.

Results

After preliminary tests of stationarity and model fit, the model presented above has been chosen as having the best fit for the data. The results show that there is a potential for demand-management, as hourly price elasticities of demand vary for each hour of the day and they are statistically different from zero at 1% and 5% significance level, depending on the hour.

Figure 1: Estimated price elasticities of demand, for the 2012-2014



Moreover, allowing for more wind integration shows a decrease in price at the aggregated level, which is statistically different from zero at a 1% significance level, although this decrease is very small and does not vary much across the hours of the day.

Conclusions

In light of the environmental-friendly aspirations of increased fossil-fuel independence, reduced greenhouse-gas emissions and increased energy efficiency in Europe by 2020 and complete independence of fossil-fuels by 2050 in Denmark, the questions of flexible demand and effects of wind integration are more pressing than ever.

This paper investigates the availability of response demand from consumers and finds that there is potential for demand response, in some hours of the day, especially during nighttime, which is to be expected, because it is the time of the day when firms and households have the option of using or not electricity, as opposed to the daytime hours when they must use it, according to the conventional work scheduales (9am-5pm). Furthermore, this paper contributes to the literature on the effects of wind-power on the wholesale market, which is a growing research field. It shows that integration of wind in the system help reduce prices for all the hours of the day, even at an aggregated level, which is benefic not only for the countries which have a high penetration of wind power, but also for the neighbouring countries, which participate in a common market.

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