Dynamic Analysis of the German Day-Ahead Electricity Spot Market

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Overview

This paper deals with the empirical analysis of the dynamic effects of important variables in the European Energy Exchange (EEX) Day-Ahead Spot market for power. The main aim is to get further insights regarding the effects of a wind or solar power shock at the actual day on the Spot price at future days. Wind and solar power, domestic load and net-exports, overall conventional production as well as the EEX Spot price is included in the model over a time period of almost 3 years from July 2010 up to March 2013 and average daily data.

There is an ongoing debate about implementation of smart metering techniques such that power end users or rather private power customers are charged in line with the Spot market price for small time periods. If such techniques would be implemented and these users know the time period and magnitudes of price decreases due to a wind power increase, they could gain. They would know the periods with the cheapest Spot prices due to a wind power increase and, therefore, the demand of them would be the highest within these time periods.

The analysis of dynamic effects over time such as the effect of the Spot price due to an unforeseen shock in wind power production could shed some light on the ongoing debate regarding duration and persistence of merit order effects as stated in Würzburg et al. (2013). Moreover a theoretical analysis describing such dynamic processes is very diffcult. Therefore, this paper tries to answer these questions empirically.

So far, most of the empirical models have investigated the merit order effects by using Ordinary Least Squares (OLS). However, these models do not take into account time dependency of wind and solar power and they ignore interdependencies between the variables in the Spot market. Ignored dynamic structures and interdependencies between explanatory variables will remain to be a part of the residuals, when using OLS. But in this case explanatory variables are correlated with the residuals leading to inconsistent estimators (Baltagi (2002)).

Therefore, in this paper a Structural Vector Autoregressive (SVAR) model is estimated. A SVAR is an appropriate dynamic econometric method because the related Structural Impulse Response Functions (SIRFs) reveal the (unbiased) dynamic behaviour of the spotprice caused by shocks in wind or solar power at the actual day. A dynamic structure is needed because of the dynamic behaviour of wind and solar power. This behaviour might be transferred to the whole system.

Wind and solar power production are time dependent e.g. their actual values depend on their past values. There exist daily intertemporal dependency for both variables because of autocorrelations for several time lags (days). For example, if there is stormy weather and therefore a large amount of wind power the day before, there still may be a significant amount of wind power at the following actual day because the storm appears also significantly at this day. Such dynamic relationships are existent at the west coast of Canada. Brett and Tuller (1991) found autocorrelations of wind speeds and, therefore, of wind power.

Methods

In an SVAR every variable is depending on itself and the other variables and some stochastic shock in the same variable at different points in time. Every endogenous variable in a Vector Autoregressive (VAR) model depends linearly on itself, on a constant and each other endogenous variable at some past timelag up to the maximum lag. Any variable is assumed to be endogenous because of possible interdependencies between the variables or dynamic dependencies of the variables themselves over time. Therefore, no exogenous variable is included in the VAR. Taking into account instantanous effects between the variables leads to a SVAR. The shocks in both models are assumed vector white noise with zero mean, that is mutually independent and identical distributed.

By using a SVAR a-priori restrictions based on economic theory are imposed on the model in order to achieve identification. A perfect recursive structure of the variables with respect to a Cholesky decomposition (another option to achieve identification) does not fit to the specific relationships between the variables. However, the restrictions are similar to a Cholesky structure.

The structural shocks of the estimated SVAR are not mutually autocorrelated. Furthermore, the SVAR is exactly identified and stationary. Because of this, the estimated coefficients of the SVAR are consistent. Consistent standard errors and confidence intervals of the SIRFs are achieved by using a bootstrapping method for the residuals because the residuals are not normally distributed.

Results

By considering the related SIRFs, the Spot price is decreasing over time caused by shocks in wind and solar power. The effects can be seen as different negative merit order effects at different future days. The directions of the effects are in line with past theoretical and empirical research due to (average) negative merit order effects. The persistence of a wind power shock is longer: The Spot price permanently decreases over 2 days, double the impact caused by solar power (1 day). The development of the Spot price over time is different for wind and solar power. If there is a shock in wind power, the effects on the Spot price gradually decline over time (concave curvature) to zero. However, if there is a shock in solar power, the effects strongly and linearly decline from the 1st day over time to zero.
For comparing the magnitudes of the effects due to 1 GW wind and solar power shocks the effects are divided by the standard deviations of wind and solar power. The negative merit order effects due to a solar power shock are larger at each significant day (largest effect is at 1 future day, about -1.2 EUR/MWh) than those due to a wind power shock (largest effect is the instantanous effect, about -0.8 EUR/MWh). Moreover, by summing up the dynamic effects due to wind and solar power a total negative effect of - 2.4 EUR/MWh caused by solar power and of -1.7 EUR/MWh caused by wind power on the Spot price on average is revealed.

Conclusions

The directions of the dynamic negative merit order effects due to wind and solar power are not a surprise. The more interesting results are the dynamic merit order effects itself both as a result of a wind power and of a solar power shock found in this paper. Longer persistence of the effects on the Spot price over time due to wind power exists (2 future days for wind and 1 for solar power). The time periods in which the effects due to wind and solar power take place could be explained by their autocorrelations: Autocorrelations of wind power are significant for larger lags. Therefore, effects due to wind power are more persistent than those due to solar power. In this sense, the dynamic structures of wind and solar power are transferred to the merit order effects on the Spot price. Autocorrelations of wind and solar power are likely to autocorrelated wind speeds and solar irradiances. Merit order effects due to a solar power shock are larger at each significant day than those due to a wind power shock. Moreover, a total negative effect of - 2.4 EUR/MWh caused by solar power and of -1.7 EUR/MWh caused by wind power on the Spot price on average is revealed. The fact that solar power coincides with demand peaks and, therefore, a related steeper merit order curve might be a reason for the larger magnitudes due to solar power.
By comparing past empirical results there are differences in the range of 0.7-1.4 EUR/MWh in the total average negative merit order effects due to wind and solar power. The autocorrelation patterns of wind and solar power could explain the single negative effects for the stated days. OLS estimates might be inconsistent and overstated, if those dynamics are transferred to the merit order effects. Thus the sums of these effects, the total average effects, might have a larger magnitude. The SVAR analysis itself (with consistent estimates) may be able to reveal these different effects, especially by including dynamic relationships. The fact that the aggregated merit order effect due to solar power found in this paper is larger supports this argument. Würzburg et al. (2013) did not found this expected difference by using OLS. Taking into account also electricity simulation models the results found in this paper are in the range of merit order effects for Germany found in past research. SVAR estimates might be, therefore, more appropriate empirical findings. Previous SVAR estimates found a negative merit order effect due to wind power, but a positive effect due to solar power for Spain. The latter stands in contrast to previous theoretical as well as empirical findings. This contrary result might be driven by modelling wind and solar production as exogenous.
Private power customers could reduce their costs by purchasing a significantly high amount of power within a time period of the next 2 days due to a wind increase at the actual day, if these users may be able to apply smart metering techniques in the future.

References

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