[*EQUILIBRIUM FORWARD PREMIUM AND OPTIMAL HEDGING IN ELECTRICITY MARKETS WITH GREEN AND BROWN PRODUCERS*]

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Overview

Forward markets play a crucial role in the liberalized electricity markets as facilitators of hedging and investment decisions by market participants. Contract prices from these markets are important tools for hedging price risk in volatile spot electricity markets and give signals for investments in infrastructure, contributing to an adequate matching of supply and demand. Successful forward markets are essential elements supporting the efforts to restructure electricity markets and therefore, research on their performance is of general interest. Electricity forward trading offers benefits to electricity producers and consumers, such as price discovery, a hedge against spot price market risk, and market power mitigation. But these benefits come at a cost when the forward price has a forward premium. If the forward premium increases (decreases) the forward price in comparison with expected spot prices during the delivery period, this cost is borne by consumers (producers).

Current literature has investigated the existence of forward premia in electricity forward markets. The importance of this topic arises for its implications about the market efficiency of power derivatives markets, which is a significant concern to financial investors, utilities, power producers, retailers, regulators, and policymakers. Economic theory (e.g. Hirshleifer, 1990, Bessembinder and Lemmon, 2002) suggests that the forward premium should compensate risk-averse market participants for bearing systematic risk. Thus, the forward premium should be related to economic risks and the willingness of different market agents to bear these risks, but neither its sign nor its size is known ex-ante. Another source of forward premium may be the market power of producers (Ito and Reguant, 2016) which materializes even when agents are risk neutral.

Bessembinder and Lemmon (2002, B&L from now on) show an equilibrium model in which risk-averse producers compete in power supply and trade with retailers who are also risk-averse. Their model shows that the forward premium decreases with the variance of spot prices but increases with the skewness of spot prices. B&L then argue that the negative impact of the variance of spot prices on the forward premium reflects the net hedge pressure from the retailers' side, as the retail price charged to the final customer by the retailers is usually fixed. The positive effect of the skewness of spot prices on the forward premium shows that the net hedge pressure comes from the producers' side, since producers may face upward spikes in marginal production cost when demand is positively skewed. Longstaff and Wang (2004) find supportive evidence to B&L model in the PJM market. Geman and Roncoroni (2006) and Douglas and Popova (2008) also report empirical evidence consistent with B&L. Other papers present mixed evidence. Bunn and Chen (2013) focus on the British market and report that the volatility of spot prices has a significant positive impact on the forward premium in peak hours only, while the skewness has a negative (instead of positive) impact. These findings suggest that the influence of power prices' distribution on the forward premium may depend on fundamental factors such as the expected demand or fuel costs, and therefore, the net hedging pressure in the forward market may switch among players because of facts other than revenue risk or cost risk. Redl et al. (2009) study the ex-post forward premium in the EEX and Nord Pool markets and report evidence of a positive effect of the variance of spot prices on the forward premium with EEX, but they do not find a significant impact of the variance or the skewness with Nord Pool. These results suggest that market-specific elements may play a role in market participants' hedge decisions.

Recently, a new challenge in the modelling of the forward premium appears because renewable power production has been growing in many countries thanks to technological development and government support. In Europe, many countries, such as Denmark, Finland, and Sweden, already produce a significant share of power using renewable sources. The 20-20-20 Climate and Energy Package (CEP2020 henceforth) is binding legislation adopted in late 2008 setting an EU-wide share of 20% of gross final energy consumption from Renewable Energy Sources (RES), although mandatory national targets vary from 10% in Malta to 49% in Sweden. Many papers in this line of research already confirm that the impact of renewable production on power prices cannot be neglected. Jonsson et al. (2013) argue that wind power generation should be considered in the forecasting model for electricity spot prices. Acemoglu et al. (2017) suggest that power producers may diversify their energy portfolio into renewable generation as a response to the price decline. Ito and Reguant (2016) identify the strategic behaviour of green producers in sequential power markets and show that spot prices are affected by factors related to renewable production.

However, there is scarce theoretically based literature studying the impact of RES on the forward premium and the change of hedging behaviour of market participants when different types of producers are competing in the market.

To fill this gap in the literature, we propose a new equilibrium model by introducing both conventional (brown) and RES (green) producers and study the consequences of this new market structure on the forward premium and on the hedging strategies of market participants. We aim to reconcile the mixed evidence found in the literature regarding the impact of the volatility and skewness of spot prices on the forward premium. In doing so, we shed light on the relationship between the forward premium and the percentage of RES production over total production. We account for the uncertainty risk in renewable production and analyse the influence of this production risk on the forward premium.

Methods

We develop an equilibrium model in the spirit of B&L by introducing green producers besides the conventional (brown) producers. Under the assumption of inelastic spot demand and the existence of market power of the conventional producers, we get the optimal production of each conventional producer as a function of both forward and spot prices by maximizing the brown producer's profit function. Then, in the forward market, the optimal forward positions of risk-averse market participants can be derived as a function of the forward premium and of the covariance between the "but-for-hedge" profit of each player and the spot prices. Applying Taylor's expansion afterwards, we derive the ex-ante forward premium as a function of several moments of the distribution of spot prices. We also study the relationship between the moments of the distribution of spot prices and the optimal forward position of all market participants.

Next, we test the model's theoretical predictions through an empirical application. We use hourly data of the Spanish electricity day-ahead and spot (real-time) markets in the year 2017. We estimate the cost parameters of brown and green producers using sophisticated econometric models and get the model-based price and forward premium. Next, we compare these estimates with realized ones.

Results

Based on the theoretical model, we posit the following hypothesis:

1. The forward premium is negatively (positively) related to the variance of spot prices, and positively (negatively) related to the skewness of spot prices when the expected demand is low (high).
2. The forward premium is negatively related to the kurtosis of spot prices at all levels of expected demand.
3. The forward premium decreases when the percentage of RES production over total production increases.
4. The forward premium increases when the uncertainty risk of RES production increases.

The empirical results largely support these theoretical predictions.

Conclusions

In this paper, we extend and generalize the implications of B&L by including a richer market setup and a more realistic structure of the generating assets. We argue that the hedging behaviour market of participants may change according to the expected spot price, or to the fundamental variables such as expected demand. The competitive pressure from the RES producers' impulses the hedge needs of brown producers when the expected demand is low and the variance of demand increases, or when the expected demand is high with potential upward spikes in demand, as the conventional production cost is convex. When there is a higher possibility of strong demand, the forward position of the conventional producers increases in order to hedge the risk of costly price spikes. These hedge behaviours impact the balance of supply and demand in the forward market, therefore changing the forward premium.

Our model implies that the conventional producers may have a net hedge pressure in the forward market when the share of renewable production increases. This is caused by the asymmetrical competition between brown and green producers. Meanwhile, since most retailers have obligations to give electricity to the final customer, higher uncertainty of the RES production risk expose the retailers to higher default risk.

Our findings help in reconciling the mixed empirical support received by earlier equilibrium models, and we give additional insights regarding the hedging behaviour of market participants. Thus, we believe that the implications of our model are useful for practitioners and policymakers alike.