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The forward premium in electricity futures

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ABSTRACT

Understanding the nature of the forward premium is particularly crucial, but rather elusive, for a non-storable commodity such as wholesale electricity. Whilst forward prices emerge as the expectation of spot plus, or minus, an ex ante premium for risk, the manifestation and empirical analysis must focus upon realised ex post premiums. This presents modelling requirements to control for shocks to the spot expectation as well as the endogeneity of ex post premia with spot price outcomes. In addition, because electricity is a derived commodity in the sense that market prices are often set by technologies that convert gas or coal into power, it is an open question whether much of the premia in power may actually be a pass-through of the premia in gas (or coal). Using a four dimensional VAR model we are able to distinguish fundamental and behavioural aspects of price formation in both the daily and monthly forward premia from the British market. We present new evidence on daily and seasonal sign reversals, associated with demand cycles, the greater importance of behavioural adaptations in the risk premia than fundamental or spot market risk measures, and the substantial fuel risk pass-through. We also show the value of a nonlinear specification in this context.

1. Introduction

Futures markets and forward trading for electricity have grown to become significant financial activities in the energy commodity sector, motivated by the remarkably high spot volatility and consequent risk in wholesale power prices. Thus, in the most liquid of European power markets, Germany and the Nordic, churn ratios approaching 8 have been reported for the volume of forward trading to physical delivery whilst, in Britain, over 90% of the power delivered has been *via* forward contracts with maturities of between a month and two years (Ofgem, 2009). However, in this context, the pricing of risk in forward trading remains a complex issue, confounded by the non-storability of the commodity, a convolution of economic and technical fundamentals, agents' asymmetries in terms of information and risk exposures, the exercise of market power by some generators, and constraints posed by the infrastructure, regulators and market design. The non-storability in particular means that agents cannot link spot and forward prices through storage costs, but must choose instead to conceive forward prices in terms of expected spot plus risk premia, with the revealed market premia emerging as the net hedging costs from the different risk aversions of generators and retailers, as sellers and buyers, in the wholesale market (Bessembinder and Lemmon, 2002).

However, from this perspective of forward price formation, with the premium being set ex ante and therefore unobservable, empirical analysis looks instead at an ex post (realised) premium, $F_{t,T} - S_T$, where $F_{t,T}$ is the forward price quoted at time t, for delivery at time T, when the spot price turns out to be S_T. Thus,

$$F_{t,T} - S_T = F_{t,T} - E_t(S_T) + E_t(S_T) - S_T = FP_{t,T} + \varepsilon_{t,T} \quad (1)$$

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with the ex post forward premium being the ex ante premium $FP_{t,T}$ plus a random error $\varepsilon_{t,T}$ in the (rational) spot price expectation due to price relevant shocks, occurring between t and T. To the extent that the random error distribution has zero mean, the realised premium is a consistent estimator of the ex ante premium, but this does raise an important concern in empirical analysis of how much of each ex post value reflects the price of risk and how much is forecast error in the rational expectation of the spot price.

Care needs to be taken with the terminology in published research related to the forward premium. For example, several authors including Benth et al. (2008) and Ronn and Wimschulte (2009) analyse the same effects in terms of a market risk premium which is the negative of the forward premium as defined above (Weron, 2008, provides a discussion of this). Furthermore, some authors (e.g. Benth et al., 2008 and Weron, 2008) seek to avoid the ex post estimation (sometimes defined as realised premia) by formulating an expectation of the spot price to produce an ex ante estimate. This is conceptually attractive as the true forward premium, but highly dependent upon the subjective choice of a model for the spot price expectation, and therefore tends to be less commonly applied.

Previous empirical research on the sign of the electricity forward risk premium has shown diverse findings without clear economic interpretations. Some studies document the existence of a positive (ex post) premium, which means that forward electricity prices are higher than their actual realised spot prices, e.g., Botterud et al. (2010) and Shawky et al. (2004) for various maturities in the Nordic and the California–Oregon markets respectively; and Saravia (2003) for the day-ahead premium on New York data. In contrast, negative premia also arise, depending on the season of the year, trading period of the day, or price model assumed. Lucia and Schwartz (2002) conclude that both the sign and size of the premium in the Nordic market are ambiguous, whilst a detailed high-frequency analysis of the PJM market (Pennsylvania-New Jersey-Maryland) by Longstaff and Wang (2004) suggests that the sign of the day-ahead premium is time-varying across the day without an obvious pattern, occasionally reaching as much as 50%. Borenstein et al. (2001) also document large disparities between day-ahead and real-time prices in the California market, which they attribute to trading inefficiencies and market power.

Bessembinder and Lemmon (2002) provided some insights into the variable sign of the forward premium from an equilibrium hedging model, with risk averse agents. Forward price should be below their realised spot price if expected demand is low and demand risk is moderate, with the reverse arising when expected demand is high or very volatile. The intuition is that in high demand, high price periods, the risk aversion of retailers to high prices dominates, whereas in low demand periods, generators' concerns about maintaining output creates more competitive pricing. To obtain analytical solutions, the assumed economy involves identical generators and no speculators, but, despite these simple assumptions, evidence from the PJM market is consistent. Elsewhere, Anderson and Hu (2008) introduce a gaming element between generators and retailers, concluding that high positive forward premia may be substantially induced by the retailers' fear of generator market power in the spot market. In an alternative framework, Pirrong and Jermakyan (2000) emphasise the fundamentally non-linear supply function, which maps demand into prices, and derive seasonality in both the size and sign of the premium.

In terms of empirical specifications, following a Taylor expansion of the expected utility functions, Bessembinder and Lemmon (2002) express the forward premium as a linear combination of the variance and the skewness of expected spot price; the former postulated as having a negative impact whilst the latter is conjectured to have a positive effect. Whilst Douglas and Popova (2008) confirm these signs for the PJM day-ahead forward market, others including Lucia and Torro (2008), Botterud et al. (2010) for weekly contracts at the Nord Pool, Redl et al. (2009) for monthly contracts at the EEX and Nord Pool, and Furio and Meneu (2010) for monthly contracts in the Spanish electricity market, find at best only partial support. Longstaff and Wang (2004) define three ex-ante measures of risk which are likely to influence the day-ahead premium, namely the conditional volatility of unexpected changes in demand, price and revenues. These three effects vary substantially across the day but their statistical significance occurs in only a few of the 24 intra-day trading periods in their empirical analysis. Elsewhere, in general, descriptive research on forward premia shows significant values, although signs vary by time of day and season. Hadsell and Shawky (2006), Diko et al. (2006), and Gjolberg and Johnsen (2001), Weron (2008) as well as Daskalakis and Markellos (2009) find significant premia in the NYISO, APX, Powernext and Nord Pool long-term electricity markets respectively, whilst Bierbauer et al. (2007), Kolos and Ronn (2008), Benth et al. (2008), Daskalakis and Markellos (2009) and Redl et al. (2009) and Kolos and Ronn (2008) find a negative forward premium for monthly, quarterly and yearly contracts at the EEX (German) market. Regarding the latter, Benth et al. (2008) relate the term structure of the forward premium to the net hedging demand of consumers and producers, producing a model that yields decreasing absolute values of forward premia (eventually getting negative) when time to maturity or delivery period length increases.

Whilst some of these empirical results are contradictory to various theoretical implications, these could reflect methodological limitations. The endogeneity of spot prices is usually disregarded in the empirical reduced form models of forward prices. Furthermore, most of the reported models are underspecified in terms of omitted variables both with respect to those driving the ex ante premia and those controlling for shocks affecting the expected spot prices occurring between contracting and delivery times. Redl and Bunn (2013) seek to address this latter problem by including a change in the reserve margin between the contracting and delivery periods, in a monthly regression model of German data, and this inclusion appears to be useful.

A further complicating aspect of interpreting the forward premia is that electricity, as a commodity, is a derived commodity, insofar as in most electricity markets a substantial amount of the technologies use the conversion of gas, coal or oil, and furthermore these technologies tend to set the market price. With this in mind, Huisman and Kilic (2012) have noted that the storability of underlying fuels provides a fundamental link in the forward prices of power, which is itself, nonstorable. Forecasts of electricity prices are therefore strongly dependent upon those of the marginal fuels (mainly gas) and so an important, and as yet