ELECTRICITY FORWARD PREMIA: A HIGH-FREQUENCY EMPIRICAL ANALYSIS

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Overview

The issue of electricity pricing in spot and forward wholesale power markets has become one of the most attractive topics. During the recent years, a number of studies have realized that the electricity market is comparable to the financial market, since electricity prices have been determined through the auction mechanism. Thus, some studies employ methodologies from financial studies into the electricity market. Due to the nonstorable nature of electricity, which differs from financial assets, the electricity market is considered as limited in short-term elasticity to demand.

The purpose of this study is to explore the price dynamics in the electricity market. We study the forward premium, which is defined as the difference between the forward price and the expected spot price of electricity. Using a dataset which includes multi-transaction-lines with hour-based frequency, we first observe that the electricity forward premium exists in our data, with a large variance, and a negative skewness. Second, we test both the time-varying and cross-sectional effects in the relationship between short-term forward prices and realized spot prices. We decompose the forward price into two components: transmission congestion cost and cost of marginal losses, and we find that the forward transmission congestion cost dominates the forwad premium and consequently leads to a higher realized spot price. Third, we derive a new method to examine the significance of seasonality impact in forward premia. We find that the significant calendar effects in forward prices are different from those in spot prices. These results confirm the forward premium, and further extend the existing empirical literature by studing the properties of forward premium documenting new-risk-factor-related time variation.

We make three contributions. First, our analyses use a high-frequency intraday dataset and include over 12,000 individual transaction lines in the liberalized Pennsylvania-New Jersey-Maryland (PJM) market. Previoius studies use market-level data, which fails to tell the cross-sectional effects on price dynamics. Second, we introduce a new analytical model by including two components: transmission congestion cost and cost of marginal losses. Third, we introduce a new method to test the significance of calendar effects in forward premia.

Methods

We define the ex ante forward premium as

$$FP^{EA} = F_{t+1} - E_t[S_{t+1}]$$

Where FP is the ex ante forward premium, F_{t+1} *is the forward price observed on day t for delivery on day t+1, and* $E_t[S_{t+1}]$ *is the expected spot price on day t+1 given information available on day t.*

We defind the ex post forward premium as

$$FP^{EP} = F_{t+1} - S_{t+1}$$

First, we test the existence of the forward premium. In order to examine the forward premium, we derive the unbiased forward rate hypothesis (UFH) as below

$$S_{t+1} = a + bF_{t+1} + e_{t+1}$$

Second, we study the risk factor that affects the forward premium. We decompose the forward price into two components: transmission congestion cost and cost of marginal losses, and test their impact in the exteneded UFH as below:

$$S_{t+1} = a + b_1 Congestion_{t+1} + b_2 Marginal_{t+1} + e_{t+1}$$

Third, to evaluate the time variation of forward premium, we introduce a new method to detect the seasonality pattern of forward premia. The method has two types of hypotheses tests. The first type of hypothesis is that there are no calendar specific anomalies:

$$H_0: \xi_{(0)} = \cdots = \xi_{(m)}$$

where $\xi_{(n)}$ represents the expected return for each calendar effect.

The second type of hypothesis is that no calendar specific anomalies in standardized expected returns:

$$H_0': \rho_{(0)} = \cdots = \rho_{(m)}$$

where $\rho_{(n)}$ represents the expected standardized return for each calendar effect.

The test of these hypotheses is in the form of a χ^2 test (3):

$$T = X' \boldsymbol{B}_\perp (\boldsymbol{B}'_\perp \boldsymbol{\Omega} \boldsymbol{B}_\perp)^+ \boldsymbol{B}_\perp \boldsymbol{X}$$

where **X** is a normally distributed vector with mean λ and covariance matrix **Ω**, let **B** be a known matrix full column rank and θ a vector with proper dimension such that λ = **B**θ, $\boldsymbol{B}_\perp$ is the orthogonal matrix to B and where $(\boldsymbol{B}'_\perp \boldsymbol{\Omega} \boldsymbol{B}_\perp)^+$ is the Moore-Penrose inverse of $\boldsymbol{B}'_\perp \boldsymbol{\Omega} \boldsymbol{B}_\perp$. This χ^2 test is distributed with f = rank$(\boldsymbol{B}'_\perp \boldsymbol{\Omega} \boldsymbol{B}_\perp)$ degrees of freedom.

We apply this method into our dataset, assess the universe of calendar effects, and pick up those effects with most significant values. Thus, we confirm the existence of electricity forward premia, and find the time variation across transmission lines.

Results & Conclusions

Our preliminary results indicate that there exist significant forward premia in the electricity market. The variance of forward premia is large, and the skewness is negative. In our second step, we find that the forward transmission congestion cost dominates the forwad premium and consequently leads to a higher realized spot price. The transmission congestion cost has a 26-time larger impact on the forward premium than the cost of marginal losses. Third, we test the significance of calendar effects in different time frequencies (Day-of-the-week, Hour-of-the-day, Month-of-the-year, Day-of-the-month and season). Our results confirm the existence of calendar effects of forward premia in different time frequencies. Our test methods are able to specify those calendar effects with statistical significance, which helps electricity markets to make plans to balance the power supply and demand.

References

Bessembinder, H., Lemmon, M.L., 2002. Equilibrium pricing and optimal hedging in electricity forward markets. J. Finance 57, 1347–1382.

Botterud, A., Kristiansen, T., Ilic, M.D., 2010. The relationship between spot and futures prices in the nord pool electricity market. Energy Econ. 32, 967–978

Haugom, E., & Ullrich, C. J. (2012). Market efficiency and risk premia in short-term forward prices. *Energy Economics*, *34*(6), 1931-1941.

Longstaff, F.A., Wang, A.W., 2004. Electricity forward prices: a high-frequency empirical analysis. J. Finance 59, 1877–1900.