Market efficiency and risk premia in short-term forward prices

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Abstract

Using recursive estimation and rolling windows over extended sample periods we examine the time-varying relationship between spot and short-term forward prices in the Pennsylvania–New Jersey–Maryland (PJM) wholesale electricity market. We examine theoretical models of forward risk premia in electricity markets and show that recent data do not provide support for existing models. The results indicate that short-term forward prices have converged towards unbiased predictors of the subsequent spot prices.

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1. Introduction

In forward markets the risk premium, defined to be the difference between the forward price and the expected spot price, plays a central role in understanding market dynamics. Since the introduction of financial electricity markets, the relationship between electricity spot and forward prices has been subject to growing interest among researchers and practitioners. The well-documented properties of electricity prices, such as strong seasonality and price spikes, have led researchers to develop equilibrium models to account for the stylized features of the underlying price process and to determine specific conditions that would induce a risk premium in forward prices. The seminal example of such a model is presented in Bessembinder and Lemmon (2002).

For more than a decade, agents in the liberalized Pennsylvania–New Jersey–Maryland (PJM) market have had the opportunity to hedge against real time price fluctuations by taking positions in the short-term, day-ahead forward market. Longstaff and Wang (2004) use these short-term forward prices and the subsequent realizations of spot prices to test the model of Bessembinder and Lemmon (2002). Their results indicate that there exist significant risk premia in forward prices at PJM.

As liberalized electricity markets have developed only recently, it is possible that risk premia have changed. We repeat the tests of Longstaff and Wang (2004) using the most recent data from PJM. We present results based on rolling windows and recursively extended samples. To our knowledge, this is the first such attempt in the literature. These analyses enable us to test for time variation in the relationship between short-term forward prices and realized spot prices, and thus indirectly allow us to examine potential market learning as well as time variation in market efficiency and/or risk premia.

We make three contributions. First, our analyses show that the simple reduced form models of higher order moments of the spot price or by demand characteristics as in Bessembinder and Lemmon (2002) are not supported by the recent data. Second, in contradiction to previous studies, we find a striking lack of evidence for significantly biased predictions in recent short-term electricity forward prices at PJM. Third, we provide evidence that including other information known to market participants does not significantly improve forecasts of future spot prices compared to forecasts based on the forward price alone. We conclude that either (1) market efficiency has increased, (2) risk premia are reduced, or (3) both, as agents have gained experience.

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1 Part of this work was completed while Haugom was a Visiting Scholar at Virginia Tech.

2 This arises from very inelastic short-term demand and the fact that electricity cannot be directly stored. Even though hydro-power can be indirectly stored in reservoirs and thermal power can be stored as coal or oil, these forms of storage are not available to speculators and consumers.
2. Forward prices and risk premia

If the forward price market participants willingly pay today for delivery tomorrow is different than today's expectation of tomorrow's spot price, then the forward price is said to contain a risk premium. Accordingly we define the ex ante risk premium to be the difference between (1) the forward price observed on day \( t \) for delivery on day \( t+1 \), and, (2) the expected day \( t+1 \) spot price, given information available on day \( t \).

\[
R_{\text{P}a}^t = F_{t,t+1} - E_t[S_{t+1}]
\]

where

- \( R_{\text{P}a}^t \) is the ex ante risk premium,
- \( F_{t,t+1} \) is the forward price observed on day \( t \) for delivery in period \( i \) on day \( t+1 \), and,
- \( E_t[S_{t+1}] \) is the expected period \( i \) day \( t+1 \) spot price given information available at time \( t \).

In general today's expectation of tomorrow's spot price is unavailable. In order to examine the risk premium researchers can either develop a model to generate expected spot prices for tomorrow (using only that information which is available today), or proxy for the expected spot price using the observed spot price.

The former approach is subject to the joint hypothesis problem. Any test for a risk premium using expected spot prices derived from such a model is also a test of the model itself. Timmermann and Granger (2004) point out that agents have a huge, possibly infinite-dimensional, space of potential forecasting models, and imposing one of these as the true model is inappropriate if the aim is to examine whether risk premia are present, particularly if the model is assumed to be time invariant. This problem is particularly acute in electricity markets as agents have access to an unknown amount of private, or professional, information that is not available to researchers.

To avoid unrealistic assumptions about the correct spot price model researchers often use the latter approach and focus on the ex post, or realized risk premium

\[
R_{\text{P}p} = F_{t,t+1} - S_{t+1}\]

where

- \( R_{\text{P}p} \) is the ex post risk premium, and,
- \( S_{t+1} \) is the observed, or actual, period \( i \) day \( t+1 \) spot price.

The ex post risk premium can be decomposed into the sum of the ex ante risk premium plus a forecast error,

\[
R_{\text{P}p} = F_{t,t+1} - S_{t+1} = (F_{t,t+1} - E_t[S_{t+1}]) + (E_t[S_{t+1}] - S_{t+1})
\]

where \( F_{t,t+1} = E_t[S_{t+1}] - S_{t+1} \) is the forecast error.

Common practice in the literature is to assume the forecast error is random noise and therefore the ex post risk premium is a good proxy for the ex ante risk premium. It follows that evidence of a nonzero ex post risk premium is also evidence of a nonzero ex ante risk premium.

Wholesale electricity markets are a recent phenomenon. In such newly formed markets, agents have little experience about the functioning of the market. Under these circumstances it may be that a nonzero ex post risk premium arises from a nonzero forecast error and therefore may be an indication of market inefficiency. As agents gain experience, any nonzero forecast error should diminish and possibly disappear completely.

3. Data description and preliminary analyses

The sample data consist of more than a decade of hourly spot and day-ahead forward prices for the eastern hub of the Pennsylvania–New Jersey–Maryland (PJM) wholesale electricity market. The sample period extends from June 1, 2000 to December 31, 2010, for a total of 92,784 hourly observations. As electricity markets are strongly seasonal we consider intra-yearly and intra-daily patterns separately. In the intra-daily case, we focus on prices averaged across the entire day, and across peak- and off-peak periods within the day.

Define the log ex post risk premium (LRP\(_{\text{P}p}\)) to be

\[
L R P_{\text{P}p} = \ln F_{t,t+1} - \ln S_{t+1}
\]

Table 1 presents the first four moments of the ex post risk premia for the whole sample and by each season. The raw ex post risk premium exhibit extreme left skewness and excess kurtosis, while the log ex post risk premia are more symmetric and less leptokurtic. For the entire sample, the average daily ex post risk premium is $0.29/MWh. Longstaff and Wang (2004) report a mean ex post risk premium of $0.59/MWh for the June 1, 2000 through November 30, 2002 time period, hence the mean ex post risk premium has decreased in magnitude as the market has matured.

The log transformed data reveals positive ex post risk premia significant at the 1% level when compared to the critical values of the Student’s t distribution with six, seven, and four degrees of freedom.
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