Energy Economics 34 (2012) 1931–1941

Contents lists available at SciVerse ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Market efficiency and risk premia in short-term forward prices

Erik Haugom [a,*,1], Carl J. Ullrich [b]

[a] Lillehammer University College, NO-2624 Lillehammer, Norway, and the Norwegian University of Science and Technology, NO-7491 Trondheim, Norway
[b] Virginia Tech, Pamplin College of Business, Department of Finance, Insurance, and Business Law, Blacksburg, VA 24061, USA

ARTICLE INFO

Article history:
Received 2 January 2012
Received in revised form 10 July 2012
Accepted 9 August 2012
Available online 24 August 2012

JEL classification:
G14
G13
Q47
L94

Keywords:
Market efficiency
Unbiased forward rate hypothesis
Joint hypothesis problem
Forward prices
Electricity markets

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.
© 2012 Elsevier B.V. All rights reserved.

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,[2] 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 price 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.

* Corresponding author.
E-mail addresses: erik.haugom@hil.no (E. Haugom), cullr@vt.edu (C.J. Ullrich).
[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.

0140-9883/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.eneco.2012.08.003

The rest of this paper is organized as follows. Section 2 reviews risk premia in forward markets with a focus on electricity markets. Section 3 describes the data and presents preliminary analyses. Section 4 updates tests of the Bessembinder and Lemmon (2002) model using recent data. Section 5 provides empirical evidence on the relationship between spot and forward prices by using static, rolling, and recursive estimations. Section 6 summarizes and concludes.

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,

$$RP^{ea} = F_{i,t,t+1} - E_t\left[S_{i,t+1}\right], \tag{1}$$

where

RP^{ea} is the *ex ante* risk premium,
$F_{i,t,t+1}$ is the forward price observed on day t for delivery in period i on day $t+1$, and,
$E_t[S_{i,t+1}]$ is the expected period i day $t+1$ spot price given information available at time t.[3]

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.[4]

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

$$RP^{ep} = F_{i,t,t+1} - S_{i,t+1}, \tag{2}$$

where

RP^{ep} is the *ex post* risk premium, and,
$S_{i,t+1}$ 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,

$$\begin{aligned} RP^{ep} &\equiv F_{i,t,t+1} - S_{i,t+1} \\ &= \left(F_{i,t,t+1} - E_t\left[S_{i,t+1}\right]\right) + \left(E_t\left[S_{i,t+1}\right] - S_{i,t+1}\right) \\ &= RP^{ea} + FE_{i,t,t+1}, \end{aligned} \tag{3}$$

where $FE_{i,t,t+1} \equiv (E_t[S_{i,t+1}] - S_{i,t+1})$ 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.[5]

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.[6] 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.[7]

Define the log ex post risk premium (LRP^{ep}) to be[8]

$$LRP^{ep} = lnF_{i,t,t+1} - lnS_{i,t+1}. \tag{4}$$

Table 1 presents the first four moments of the ex post risk premia for the whole sample and by each season.[9] The raw ex post risk premia 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

[3] In anticipation of the empirical work which follows, we include the subscript i to refer to the (sub)period of the day in question. i can refer to hour of the day, peak hours (12 noon–6 pm), off-peak hours (7 pm–11 am), or the whole day. The industry standard for peak hours is from 7 am–10 pm. However, all the sample moments of both the spot and day-ahead forward prices at PJM take their highest values from 12 noon–6 pm. To ensure that the price generation process is as close to uniform as possible we choose to use these peak hours (12 noon–6 am) in the analyses. We are grateful to an anonymous referee for clearly articulating this issue.

[4] For example, owners of generation utilize cost-based commitment and dispatch software to simulate the operation of the system the next day.

[5] The theory of storage explains the difference between spot and futures/forward prices as function of the storage costs per unit, interest forgone, and a convenience yield. This theory dates back to Kaldor (1939); Working (1949); Brennan (1958), and Telser (1958). See Hull (2009) for a theoretical elaboration, Fama and French (1987) for empirical investigation of both the theory of storage and the alternative view (i.e., risk premia) for traditional commodities, and Botterud et al. (2010) for the specific case of electricity markets.

[6] Shorter samples from the same market have also been used by Bessembinder and Lemmon (2002); Longstaff and Wang (2004), and Douglas and Popova (2008).

[7] All the analyses also are carried out for individual hours. Overall conclusions are unchanged though the erratic behavior for individual hours makes it more difficult to make statistical inferences. We also consider intra-weekly patterns by fitting a second and third order polynomial for ex post risk premia sorted by weekday but are unable to document any economical meaningful intra-weekly relationships.

[8] Notice that the **log** ex post risk premium is not the log of the risk premium. It is the difference between the log forward price and the log spot price.

[9] Due to the non-symmetric and leptokurtic distribution of the raw ex post risk premia, we avoid attaching a significance level to the raw numbers.

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات