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Inefficient and opaque price formation in the Japan Electric Power Exchange

Tadahiro Nakajima *

The Kansai Electric Power Company, Incorporated 6-16, Nakanoshima 3-chome, Kita-Ku, Osaka 530-8270, Japan

HIGHLIGHTS

- ▸ This study examines the wholesale electricity market in Japan.
- ▸ Efficient market hypothesis is rejected.
- ▸ Prices of imported fuel do not Granger-cause the prices of electricity.
- ▸ The WTI prices and the exchange rates do not Granger-cause the power prices.

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ABSTRACT

This study examines whether the spot prices in the Japan Electric Power Exchange are efficiently formed from April 3, 2006, to March 31, 2012, using the conventional and rank-based variance-ratio tests. The results seem to reject the efficient market hypothesis in the market. Moreover, by applying Granger-causality tests, this paper investigates whether the power price is determined from the information of primary energy and exchange markets that directly affect the cost of power generation. The results indicate no Granger-causality from the prices of oil and gas and the exchange rate to the price of electricity. Finally, this paper discusses the factors that lead to inefficient and mysterious price formation.

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1. Introduction

Since the end of the twentieth century, the electric power industry in Japan has undergone deregulation. However, the regional monopoly over power generation, transmission, and supply, which was under the control of 10 regional power utility companies, was legally permitted for a number of years. As liberalization policies evolved, the Japan Electric Power Exchange (JEPX) was established, and trading in wholesale electric power started in April 2005. The purpose of this endeavor was to ensure a fair competition and invigorate the business of transmitting and distributing electric power all over the nation.

In order to maximize the total utility of the whole economy, a market economy should be allowed to function effectively. Needless to discuss the cases of failure of planned economies, full advantage of the market mechanisms should be taken to optimally allocate the limited economic resources. The market economy is a system in which the action of each economic entity is optimized by transmitting the prices formed in the market to each economic entity as the integration of a variety of information. In other words, a market economy aims to reach the state where each price reflects information on the whole economy. However, in a real economy, all information cannot be instantaneously reflected in each price, and the information gaps that exist constantly lead to arbitration. As a result, the limited economic resources become optimally allocated asymptotically. It is therefore reasonable and realistic to restate the market economy as the system asymptotically aiming to optimize the allocation of limited resources. When examining the effectiveness of a certain real market economy, it is proper to discuss how early the prices reflect other information and to what extent the information impacts the prices.

Fama (1970) systematically summarized the degree of market efficiency. When prices in a certain market are formed fully reflecting an information set, the market can be understood to be efficient with respect to the information set. If a market is efficient with respect to an information set, any investment strategies based on the information set cannot consistently achieve returns in excess of the average market returns. On the contrary, unless the market prices already reflect the information set, the investors who have that information set can gain extra through the market. This concept of information efficiency has been widely accepted in general as a measure to investigate the efficiency of a market.

* Tel.: +81 6 6441 8821.
E-mail address: nakajima.tadahiro@a4.kepco.co.jp

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Granger (1969) shows that one time series C Granger-causes another time series R if the previous value of C is useful to explain the current value of R. Acceptance of the Granger-causality hypothesis does not necessarily imply acceptance of a true causality hypothesis. Conversely, true causality must certainly bring about Granger-causality. In other words, the absence of Granger-causality can be understood as the absence of true causality. Therefore, a Granger-causality test is often undertaken to examine the factor of price formation.

In a market economy, the more rapidly and widely markets process information, the better the improvement of performance of the whole economy become. Therefore, it is essential to examine the information processing ability of markets to evaluate the state of the market economy.

This study examines the information processing capability of Japan's wholesale electricity market, which may significantly affect the overall performance of the Japanese economy. More specifically, this paper analyzes the degree by which the JEPX trading prices reflect the historical prices and the market information that impacts the cost of power generation directly.

After the 2011 earthquake off the Pacific coast of Tohoku and the Fukushima Daiichi nuclear disaster, regulations on the electric power industry are being reviewed. The most important contribution of this study is the conclusion that the oil, gas, and exchange markets do not Granger-cause the JEPX, which is reached through a lag-augmented vector autoregression (LA-VAR) test after proving the inefficiency of the JEPX through a variance-ratio (VR) test to discuss how Japan's electricity market should be.

The remainder of this paper is organized as follows. Section 2 explains the methodology applied, Section 3 describes the data analyzed, Section 4 presents the empirical results, and Section 5 provides a summary and statement of conclusions.

2. Methodology

This study examines the ability of JEPX to process information, in two stages. In the first stage, the paper investigates whether the market prices are formed efficiently. This study adopts two types of VR tests to check the null hypothesis that the series is the Random Walk Hypothesis (RWH) statistics. One test is the conventional technique developed by Lo and MacKinlay (1988), and the other is the rank-based approach proposed by Wright (2000).

In the second stage, this paper analyzes whether power prices reflect current market information that directly affects generation cost. As this study's analyses are on a daily and monthly basis, one excludes fixed overheads, such as depreciation, labor, and repairs, and considers only fuel costs. The variable costs of generating hydro, nuclear, and coal-fired power are zero or much smaller than fixed cost. Therefore, their effect on the wholesale electricity market may be assumed to be limited.

Oil-fired and natural gas-fired plants are used to handle the adjustments in hourly and daily changes in demand. In other words, the marginal changes in Japan's fuel prices are only because the oil and gas prices are denominated in yen. Therefore, if the efficient market hypothesis is rejected in the JEPX, one would find that the yen-denominated prices of fuel oil and natural gas for power generation Granger-causes the prices of wholesale electricity, as with the previous studies in other countries. Moreover, in Japan, approximately 90% of power is produced from imported fuels. Nearly all imports of fuels for power generation are denominated in dollars through long-term contracts, while fuel oil is often procured through the spot market. Japan links the prices of natural gas to the crude oil benchmark. Given these factors, one would find Granger-causality from the dollar/yen exchange rates and crude oil prices denominated in dollars to power prices. This study applies the LA-VAR technique developed by Toda and Yamamoto (1995) to test the Granger-causal relationships among the variables.

2.1. The VR test

2.1.1. The conventional VR test

Assuming that a time price series p_t with sample size $T+1$ is integrated order one, the return series $y_t = \ln(p_{t+1}/p_t)$ is weakly stationary. Its mean and variance are unaffected by changes of time. The covariance $\rho_{t,s}$ between y_t and y_s is a function of $t-s$. The rate of return Y_t from t to $t+k$ can be expressed as follows:

$$Y_t = \sum_{s=t}^{t+k-1} y_s \tag{1}$$

Then, the variance of both sides of Eq. (1) is calculated.

$$\mathrm{Var}(Y_t) = k\mathrm{Var}(y_t) + 2\mathrm{Var}(y_t)\sum_{s=1}^{k-1}(T-t)\rho_{1,1+s} \tag{2}$$

where, $\mathrm{Var}(Y_t)$ and $\mathrm{Var}(y_t)$ are the variance of Y_t and y_t, respectively. If p_t is efficiently formed, the cause of the price fluctuation is the only incident that cannot be anticipated. Then, p_t follows the RWH statistics. In other words, y_t is independently and identically distributed (iid). This means that $\rho_{t,s} = 0$ (as of $t \neq s$) and Eq. (2) can be rewritten as

$$\mathrm{Var}(Y_t) = k\mathrm{Var}(Y_t) \tag{3}$$

Eq. (3) is a sufficient condition such that p_t is efficiently formed. Then, $VR(k)$ can be defined as

$$VR(k) = \frac{(1/k)Var(Y_t)}{Var(y_t)} = \frac{\frac{1}{Tk}\sum_{t=k}^{T}\left(y_t + y_{t-1} + \cdots + y_{t-k+1} - k\hat{\mu}\right)^2}{\frac{1}{T}\sum_{t=1}^{T}\left(y_t - \hat{\mu}\right)^2} \tag{4}$$

where $\hat{\mu} = \sum_{t=1}^{T} y_t/T$. When p_t is the Random Walk process, $VR(k) = 1$.

Lo and MacKinlay (1988) proposed the following two test statistics:

$$M1(k) = \{\, VR(k) - 1\}\left\{\frac{2(2k-1)(k-1)}{3kT}\right\}^{-1/2} \tag{5}$$

and

$$M2(k) = \{\, VR(k) - 1\}\left[\sum_{j=1}^{k-1}\left\{\frac{2(k-j)}{k}\right\}^2 \delta_j\right]^{-1/2} \tag{6}$$

where $\delta_j = \sum_{t=j+1}^{T}(y_t-\hat{\mu})^2(y_{t-j}-\hat{\mu})^2/\{\sum_{t=1}^{T}(y_t-\hat{\mu})^2\}^2$. They demonstrate that $M1(k)$ is asymptotically standard normal under the null hypothesis that y_t is iid if y_t does not exhibit conditional heteroscedasticity, and that $M2(k)$ is asymptotically standard normal even if y_t exhibits conditional heteroscedasticity.

2.1.2. The rank-based VR test

Assume that $r(y_t)$ is the rank of y_t among $y_1, y_2, \cdots, y_T$. Then,

$$r_{1t} = \left\{ r(y_t) - \frac{T+1}{2}\right\}\left\{\frac{(T-1)(T+1)}{12}\right\}^{-1/2} \tag{7}$$

$$r_{2t} = \Phi^{-1}\left\{\frac{r(y_t)}{T+1}\right\} \tag{8}$$

where Φ^{-1} is the inverse function of the standard normal cumulative distribution function. The series r_{1t} is a simple linear transformation of the ranks. The series r_{2t} is Van Der Waerden scores. Both r_{1t} and r_{2t} have sample mean zero and sample

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