The Relationship Between Load and Electricity Price in Different Time Periods Based on Granger Causality Test

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Abstract. With the liberalization of the market on the selling side, the user's electricity load shows a stronger volatility, and correspondingly, the price change has a certain degree of dynamics. This paper first selects the working day load of a certain power market to realize the peak-valley period division. Secondly, with the help of Eviews software package, studying the causal relationship between load and electricity price in different time periods, the following conclusions are obtained: the peak time period electricity price has a one-way causal relationship with the peak time period load, and there is a low causal relationship between the electricity price and the electricity load during the flat time period; the valley time period electricity price has a two-way causal relationship with the electricity load.

1 Introduction

The liberalization of the electricity-selling market not only provides more choices for power users, but also the user's electricity usage will be more diversified, and the user's electricity load data volume will increase. At the same time, a variety of electricity price forms have also been formulated, providing a basis for guiding users to use electricity. Therefore, it is of great significance to study the causal relationship between user electricity load and electricity price.

.Nowadays, the research focus of the research on the relationship between the user's electricity load and the electricity price is different. Regarding the demand response of electricity prices, the literature [1] studied the tolerance of various users on electricity price, and the changes in demand for electricity price caused by fluctuations in electricity price; the literature [2] built power-saving models by studying the load characteristic of various industries, which improves user power-saving efficiency and meets user needs. For the emphasis on user behavior, the literature [3] uses power big data to study user classification and the behavior of each type of users; in [4], under the premise of user classification, the Markov model is constructed to study the range of power load adjustment for each type of user under different price levels. For the implementation of electricity price policy, the literature [5] constructs the Sigmoid function, and studies the responsiveness of the user's electricity load after the implementation of electricity price; the literature [6] studies the influence of the time-of-use electricity price policy on different types of users.

There is no research on the causality relationship between load and electricity price in the existing literature. In this paper, with the help of econometric theory, the unit root test, co-integration test and Granger causality test are applied to the load and electricity price during peak-valley period of working days respectively, and then the causality relationship between load and electricity price is studied.

2 Methodology of econometric

Eviews is a software package that runs in the Windows environment and can process time series data. Its functions include regression analysis, prediction processing and measurement statistics. The time series used in this paper mainly includes working day load and working day electricity price. To study the causal relationship between the two, it is necessary to use the unit root test, co-integration test and Granger causality test of Eviews software package.

2.1. Unit Root Test

The Unit Root Test (URT) is mainly used to check the stationary of time series. Only the stationary series can be used to perform time series analysis. In this paper, the widely used ADF test method [7] will be used to check whether the electricity load and electricity price in the peak-valley period are stable. The tests are based on the following model[8],

$$\Delta y_{\mathrm{t}} = \alpha + \beta t + \rho y_{\mathrm{t-1}} + \sum_{i=1}^{k} \zeta_i \Delta y_{\mathrm{t-i}} + u_{\mathrm{t}} \qquad (1)$$

Where, α is a constant, β is a coefficient, u_t is a residual, k is the optimal lag period, t is a time trend

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variable, representing the deterministic trend of time series with time.

2.2 Johansen Co-integration Test

The research object of this paper is the electricity load and electricity price in the peak-valley period. There are many variables. Because Johansen test method is applicable to multivariate equations, this paper will use Johansen test to test the co-integration relationship between the research objects.

2.3 Granger Causality Test

Based on the unit root test and Johansen co-integration test on the time series, Granger causality test is performed on the time series with co-integration relationship. This section will further study the relationship between electricity load and electricity price in different time periods based on the basic ideas of Granger test.

3 case study

Based on the actual load data and electricity price data of a power market in 2018, this paper analyzes the causal relationship between electricity load and electricity price. In order to make the analysis result reflect the user's production characteristics, the working day electricity load and the working day electricity price are selected as the main time series data to analyze. The specific research ideas are shown in Figure 1.
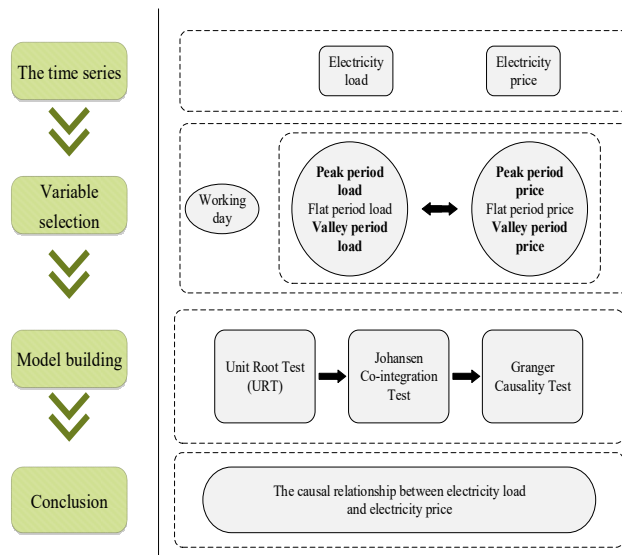

Fig. 1. The causal relationship between electricity load and electricity price.

3.1 Basic Data

3.1.1 Electric Load

Based on the user's production characteristics and the electricity price policy of the region, the power load in

working days is divided into peak period L_f, flat period L_p and valley period L_g according to the time dimension. The distribution of each period is shown in Table 1.

Table 1. The peak -valley time distribution table

Period	Time Distribution
Peak period	7:00-10:00、17:00-23:00
Flat period	10:00-17:00
Valley period	23:00-7:00

3.1.2 Time Price

Based on the peak-valley period divided by the electricity load, the working day electricity price is divided into the peak period electricity price P_f, the flat period electricity price P_p, and the valley period electricity price P_g.

To eliminate the heteroscedasticity of the time series, this paper will perform logarithmic operations on the electrical load and electricity price series data in each period of the working day, which are respectively recorded as LNL_f、LNP_f、LNL_p、LNP_p、LNL_g、LNP_g. Then draw the trend of the two logarithmic sequences *LN* (load) and *LN* (price) in a day to understand whether the changes in the user's electricity load and electricity price in each time period have similarities, as shown in Figure 2 and Figure 3.
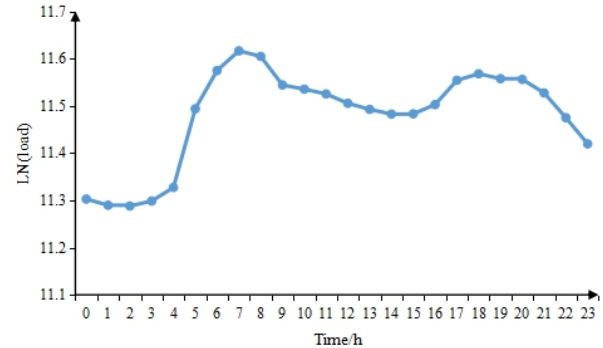

Fig. 2. The logarithmic sequence trend of electricity load.
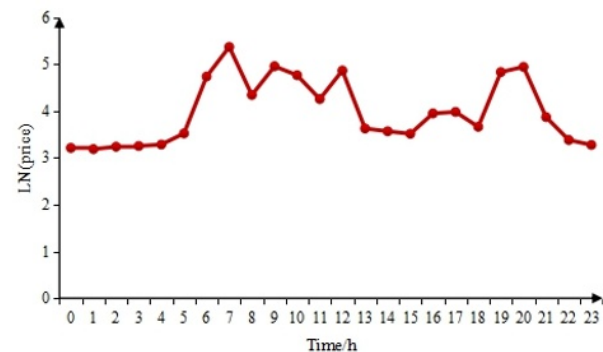

Fig. 3. The logarithmic sequence trend of electricity price.

As shown in Figure 2 and Figure 3, the trend of the electricity load in each period is almost the same as the trend of the electricity price changes, so there may be a co-integration relationship between the electricity load and the electricity price.

3.2 Unit Root Test

The purpose of the unit root test is to check whether the time series has a smoothness, that is, the fluctuation of the electricity load and the fluctuation of the electricity price are maintained at a certain level. In this paper, it is needed to test the stability of the two variables by means of the ADF test method of Eviews7.0. The test results are generally measured by the electrical load and the electricity price in each period, and the optimal lag order is based on the AIC minimum criterion. to make sure. According to the time series variables of the valley period, the first-order differences of LNL_g and LNP_g are recorded as $iLNL_g$ and $iLNP_g$ respectively. Then, the unit root test of the electric load and the electricity price during the peak-valley period is shown in Table 2.

Table 2. The unit root test results of electricity load and electricity price during peak-valley period

Period	Variables	ADF texts	Prob	Conclusion
Peak period	LNL_f	-4.1355	0.0010	stationary
	LNP_f	-6.6033	0.0000	stationary
Flat period	LNL_p	-5.0526	0.0000	stationary
	LNP_p	-10.4659	0.0000	stationary
Valley period	LNL_g	-4.5199	0.0002	stationary
	$iLNL_g$	-16.3073	0.0000	stationary
	LNP_g	-2.6223	0.0899	non-stationary

When P < 0.05, it indicates that the time series is stable. As shown in Table 2, LNL_f and LNP_f, LNL_p and LNP_p are stable at various levels, LNL_g is stable at various levels, and LNP_g is non-stationary at various levels, but LNL_g and LNP_g the first-order difference sequences are stationary, indicating that LNL_f and LNP_f, LNL_p and LNP_p are single-sequence sequences. LNL_g and LNP_g are first-order single-sequence sequences, which are I(1), that is to say, the time series variables of each time period meet the premise requirements of the co-integration test.

3.3 Johansen Co-integration Test

Johansen co-integration test is used to test whether the electricity load and electricity prices have co-integration relationship in each period. OLS should be used to establish the regression model. The co-integration relationship between the electricity load and the electricity price in the peak period is as shown in formula (2); The co-integration relationship between the electricity load and the electricity price in the flat period is as shown in equation (3); the co-integration relationship between the electricity load and the electricity price in the valley period is as shown in equation (4).

$$el_f = LNL_f + 4.4517 \times LNP_f \qquad (2)$$

$$el_p = LNL_p - 0.2699 \times LNP_p \qquad (3)$$

$$el_g = LNL_g + 2.4193 \times LNP_g \qquad (4)$$

Determine the co-integration relationship between the electricity load and the electricity price for each period, and then verify the correctness of the co-integration relationship. In this paper, the unit root test will be used to verify the stationary of sequence el_f、el_p、el_g, respectively. The verification results are shown in Table 3.

Table 3. The unit root test results of the co-integration relationship between electricity load and electricity price in the period of peak-valley Period

Period	Variables	ADF texts	Prob	Conclusion
Peak period	el$_f$	-6.6207	0.0000	stationary
Flat period	el$_p$	-7.3778	0.0000	stationary
Valley period	el$_g$	-13.8738	0.0000	stationary

When P < 0.05, it indicates that the time series is stable. As shown in Table 3, the above Johansen co-integration test results show that the long-term stable equilibrium relationship between the electricity load and the electricity price in each period.

3.4 Test of Causality Between User's Electricity Load and Electricity Price

This section will use the Granger model to estimate the causal relationship between LNL_f and LNP_f, LNL_p and LNP_p, and LNL_g and LNP_g. The optimal lag period p is tested by the VAR model. First, the VAR(1), VAR(2), VAR(3), and VAR(4) models are established respectively. Secondly, the values of AIC and SC are compared, respectively. At that time, the optimal lag period p value is obtained. Then, the results of the causal relationship test between the electrical load and the electricity price for each time period are shown in Table 4.

Table 4. The Granger causality test results of electricity load and electricity price during peak period

Period	Null Hypothesis	lags	F-Statistic	Prob
Peak period	Lnl_f does not Granger Cause lnp_f	2	0.0453	0.8316
	Lnp_f does not Granger Cause lnl_f	2	4.7128	0.0310
Flat period	Lnl_p does not Granger Cause lnp_p	3	0.1592	0.6903
	Lnp_p does not Granger Cause lnl_p	3	1.0759	0.3008
Valley period	Lnl_g does not Granger Cause lnp_g	2	3.9591	0.0479
	Lnp_g does not Granger Cause lnl_g	2	2.7405	0.0493

As shown in Table 4, the change of electricity price affects the change of electricity load during the peak period, while the change of electricity load has little effect on the change of electricity price during the peak period, that is to say, the relationship between electricity

load and electricity price during the peak period is a one-way causal relationship between the change of electricity price and electricity load during the peak period; the change of load has little effect on electricity price during the flat period, and at the same time, it has little effect on electricity price during the flat period. The change of electricity load affects the change of electricity price during the valley period. At the same time, the change of electricity price will affect the change of electricity load during the valley period, that is to say, there is a two-way causal relationship between electricity load and electricity price during the valley period.

4 Conclusion

With the help of Eviews, this paper studies the causal relationship between electricity load and electricity price during the peak-valley period, and obtains the following conclusions:

(1) There is a long-term equilibrium relationship between the electricity load and the electricity price in each period, and the electricity load is negatively correlated with the electricity price during the peak period and the valley period. For every 1% increase in electricity price, the peak load will be reduced by 4.4517%. The electricity load will be reduced by 2.4193%; the electricity load in the flat period is positively correlated with the electricity price. For every 1% increase in electricity price, the electricity load during the flat period will increase by 0.2699%.

(2) The electricity load has different relationship with the electricity price in each period: the electricity price has a one-way causal relationship with the load during the peak period; the electricity price and load have a two-way causal relationship during the valley period; the load and electricity price have a low causal relationship during the flat period.

Acknowledgment

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