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Electricity Consumption and Economic Growth in Vietnam: A Cointegration and Causality Analysis

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Abstract

Using a cointegration and causality analysis, this paper investigates the causal relationship between electricity consumption and economic growth in Vietnam during the period of 1975-2010. Empirical results show that there is no causality effect of per capita electricity consumption on per capita Gross domestic products (GDP) in both the short-run and long-run, but a causality relationship running from per capita GDP to per capita electricity consumption in the long-run. This result is helpful to understand the roles of economic growth on making energy policies in Vietnam to deal with the current electricity shortage accompanied with economic growth and to ensure national energy security.

Keywords: electricity consumption, economic growth, cointegration, causality, Vietnam.

JEL Classification: C22, Q40

1. Introduction

Over the last two decades, Vietnam has been emerging as the fast economic growth country in the Southeast Asia. Accompanied by high economic growth, its electricity demand has steadily increased. In 2010, although Vietnam had 12.0 gigawatts of installed electricity-generating capacity and produced 84.8 billion kilowatt-hours of electricity commercial capacity, per capita electricity consumption remained among the lowest levels in the Asia and domestic electricity shortages became more serious. Vietnam has had to import a significant amount of electricity from China and Laos to meet its electricity demands during the economic growing periods. A linkage between electricity consumption and economic growth, however, has not been seriously studied in Vietnam so far. One still wonders whether there is an interactive relationship between electricity consumption and economic growth in Vietnam, and how they affect each other. Proper answers to those questions would give policy makers scientific evidence and shed light on electricity development policy in Vietnam.

In energy economics literature, it is widely accepted that electricity has important roles in economic development: as an input of production and a final consumption item. Electricity has been and continues to be the fastest growing form of energy in use, and its availability is critical for developing countries to accelerate economic growth and for developed countries to sustain their economic structures. Many studies have found that an increase in productivity and living standards are accompanied by an increase in electricity consumption. The correlation between electricity consumption and GDP is strong and popular (Anderson, 1973; Morimoto and Hope, 2004). Because the correlation does not show causality, those papers did not figure out the causal relationship and whether this relationship is bidirectional or unidirectional from one to the other or vice versa.

Since the seminal work of Kraft and Kraft (1978) was published, many studies have been done to explore the causal linkage between electricity consumption and economic growth for different countries, groups of countries, and time frames. Empirical analyses of the relationship between electricity consumption and economic growth have covered both developed countries and developing countries. These analyses use standard unit root tests, cointegration tests, or error correction models to test for the unit root of electricity consumption and real GDP or wealth in the time series and vector auto-regression models to test for Granger causality as well.

Although there have been many empirical studies exploring the causality relationship between electricity consumption and economic growth, their results were elusive, and controversial. In the literature, four kinds of causality linkages between electricity consumption and economic growth were found. First, some papers find bidirectional causality between economic growth and electricity consumption such as Soytas and Sari (2003) for Argentina; Yoo (2005) for Korea during 1970-2002; Wolde-Rufael (2006) for three African countries; Yoo (2006) for Malaysia and Singapore during 1971-2002; and Bohm (2008) for the cases of Great Britain and Netherlands during 1978-2005. Second, some other studies conclude that there is a unidirectional causality relationship running from electricity consumption to economic growth. Such a relationship can be found in the work of Shiu and Lam (2004) for China during 1971-2000; Altinay and Karagol (2005) for Turkey during 1950-2000; Wolde-Rufael (2006) for three African countries; Yaun et al. (2007) for China in the period 1978-2004; Bohm (2008) for Greek, Italy, and Belgium during 1978-2005. Third, a unidirectional causality relationship running from GDP to electricity consumption is found in some other papers, for example Ghosh (2002) for India during 1950-1997; Yoo (2006) for Indonesia and Thailand; Morumder and Mazathe (2007) for Bangladesh; and Ciarreta and Zarrage (2007) for Spain in the period 1971-2005. Fourth, some papers find that there is no causality relationship between electricity consumption and economic growth such as Stern (1993) for United States in 1947-1990; Ghaderi et al. (2006) for Iran; Ciarreta and Zarrage (2008) for group of European union countries in the short-run; Bohm (2008) for Austria, Germany, Finland, France, Luxemburg, and Switzerland.

The causality linkage between electricity and economic growth is important for policy implications. It gives policy makers scientific evidence of the relationship and sheds light on making energy and economic development policies. For example, if the causality relation is bidirectional, electricity consumption and economic growth are simultaneously determined. Policies affecting electricity consumption also impact economic growth and vice versa. When a unidirectional linkage running from electricity consumption to GDP is found, restrictions in using electricity could slow down economic growth. Countries having that kind of relationship have to use "cost and benefit analysis" to choose economic growth or CO_2 emission/climate change or both. For those countries which have no causality relationship between electricity consumption and GDP, the hypothesis of neutrality exists. Policies stimulating economic growth, thus, do not affect electricity consumption, and policies applied to electricity consumption do not affect economic growth either.

This paper investigates the causality relationship between electricity consumption and economic growth in Vietnam.[1] Using data from World Development Indicators 2010, the paper did not find a granger causal relationship running from electricity consumption to economic growth in both the short-run and long-run, but it found a cointegrating relationship running from GDP to electricity consumption in Vietnam during 1975-2010. Understanding this causal relationship is useful for making energy policy that ensures electricity supply accompanied with high economic growth and guarantees national energy security for Vietnam in its development.

The remainder of this paper is organized as follows. Section 2 discusses methodology to test for the unit root, cointegration and causality. Section 3 provides some information about dataset and empirical results. Section 4 gives short explanations for the empirical findings and policy implications for Vietnam's energy policies. Section 5 concludes the paper.

2. Methodology

In the empirical studies, testing for causality relationships between electricity consumption and economic growth requires testing whether the variable series are nonstationary and cointegrated. In this paper, tests for the causality linkage of electricity consumption and economic growth will be carried out via there steps. First, the paper tests for stationary of per capita electricity consumption and per capita real GDP series, and the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kitawoski-Phillips-Schimidt-Shin (KPSS) tests are used. Second, the Johansen-Juselius approach is used to test for cointegration. This test helps to indicate the rank of cointegration. Then cointegration techniques can be used to model and estimate the long-run relationship between electricity consumption and economic growth. Third, the paper tests for causality relationships between electricity consumption and economic growth by using both standard Granger and two-step Granger tests. These tests will be more thoroughly discussed in the next sections.

2.1. Unit root tests

Economic and financial time series often exhibit trending patterns and/or non stationary in their mean. According to Newbold and Granger (1974), it would lead to the problem of spurious regression when one runs a regression among those variables. Testing for stationary, thus, is necessary for a time series analysis in empirical work. In the literature, many tests have been used to test for stationary. This paper uses some of the most popular and frequently used tests for testing unit roots of electricity consumption and economic growth. They use ADF as the main test, and two others tests including PP, and KPSS tests are also used as references.

Suppose we have a series which needs to be tested for stationary. The conventional ADF unit root test is described as follows.

$$\Delta y_t = \alpha_0 + \alpha_1 T + \alpha_2 y_{t-1} + \sum^{l} \beta_i \Delta y_{t-i} + \varepsilon_t \quad (1)$$

where α_0 is a constant; T is the time trend; l is lag length necessary to get white noise; Δ is first difference operation; and ε_t is error terms. The hypothesis is that y is non-stationary or had a unit root ($H_0^1 : \alpha_2 = 0$), and the alternative hypothesis is stationary ($H_1^1 : \alpha_2 \neq 0$). If calculated t-value is greater than ADF critical value, the null hypothesis cannot be rejected, or a unit root exists.

The PP and KPSS unit root tests mainly differ from ADF in how they treat serial correlation in the regression. The ADF test uses a parametric autogressive structure to obtain serial correlation, and it assumes that an error term is uncorrelated with the others and constant variance of error terms. The PP and KPSS tests use non-parametric corrections based on estimates of long-run variance of Δy_t, and they allow serial correlation among error terms, so variance is inconstant.

2.2. Testing for cointegration

It is common that time series may contain a unit root, but a linear combination of two or more nonstationary series may not be non-stationary. According to Engle and Granger (1987), if such a linear combination exists, the nonstationary time series are said to be cointegrated, and the stationary linear combination can be used to specify a long-run relationship among variables. In this paper, a cointegration analysis, which is suggested by Johansen and Juselius (1990), is used to determine whether a long-run relationship between electricity consumption and economic growth and numbers of cointegrating relations exists. This test uses a maximum likelihood approach to provide two different maximum likelihood ratios; one is based on maximum engenvalues (maximum-Lambda statistics), and the other is based on trace test statistics. The test is also used to indentify the numbers of cointegrating vectors describing linkages among variables. The numbers of cointegrating relations is at most equal to the numbers of endogenous variables minus one. For example, there are two endogenous variables in this paper, so at most only one cointegrating relation could be found. Knowing the numbers of cointegration is helpful to specify a vector autoregression (VAR) and to perform causality tests.

2.3. Causality tests

One objective of this paper is to figure out whether information of electricity consumption is useful in predicting economic growth or vice versa. Theoretically, cointegration implies the presence of a linear relationship among nonstationary variables, but it does not suggest the direction of the relationship. In order to test for causality of these two variables, this paper uses a standard and two-stage Granger causality tests.

The standard Granger causality test for causality between electricity consumption and GDP is based on the bivariate regression model, which has the following forms:

$$G_t = \alpha_0 + \sum_{i=1}^{l} \beta_i G_{t-i} + \sum_{i=1}^{l} \delta_i E_{t-i} + \varepsilon_t \quad (2)$$

$$E_t = \gamma_0 + \sum_{i=1}^{l} \varphi_i E_{t-i} + \sum_{i=1}^{l} \phi_i G_{t-i} + \upsilon_t \quad (3)$$

in which and are logarithm of GDP and electricity consumption, respectively. Other variables and parameters are explained in the previous part. The null hypothesis is that electricity consumption does not granger-causal GDP ($H_0^4 : \delta_i = 0 \;\; for \; all \; i = 1, 2, ... l$), while null hypothesis of "GDP does not granger-causal electricity consumption" is $H_0^5 : \phi_i = 0$ $for \; all \; i = 1, 2, ... l$.

The two-stage Granger causality test is used to indentify whether the causality is short-run or long-run or both. The model has its form as:

$$\Delta G_t = \alpha_0 + \sum_{i=1}^{l} \beta_i \Delta G_{t-i} + \sum_{i=1}^{l} \delta_i \Delta E_{t-i} + \alpha_1 u_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta E_t = \gamma_0 + \sum_{i=1}^{l} \varphi_i \Delta E_{t-i} + \sum_{i=1}^{l} \phi_i \Delta G_{t-i} + \gamma_1 u_{t-1} + \upsilon_t \quad (5)$$

where u_{t-1} is lagged error correction terms which are obtained from the cointegrating relationship, while other variables and parameters are defined as above. If $\delta_i = 0$ for all $i = 1, 2, ...l$, electricity consumption does not affect GDP in the short-run; and if $\phi_i = 0$ for all $i = 1, 2, ...l$, GDP does not have causal effects on electricity consumption in the short-run. From coefficients δ_i and ϕ_i, temporary causality would be determined, while permanent causality would be identified by testing coefficients α_1 and γ_1.

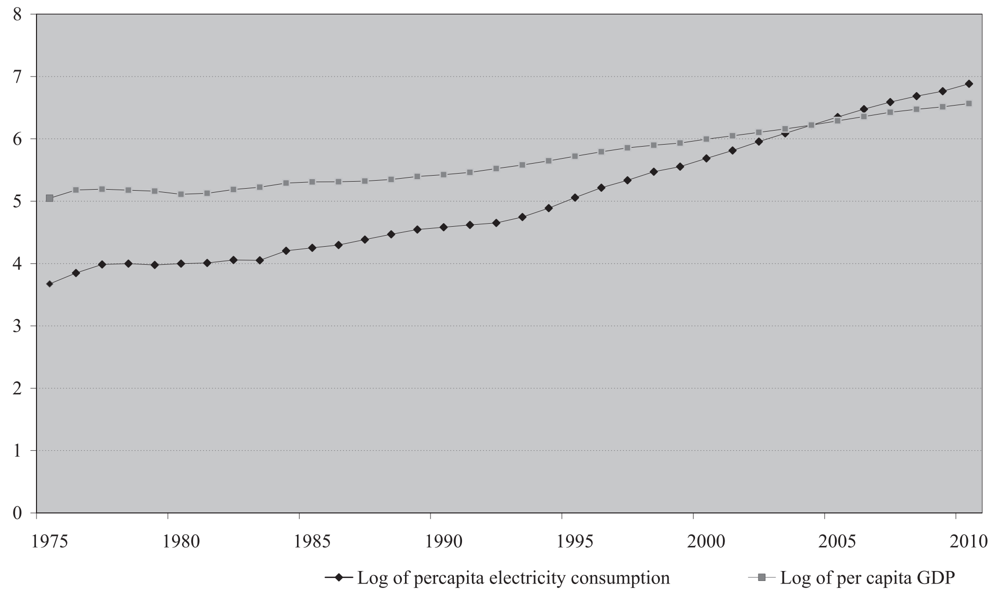
3. Data and results

This section provides some basic information about dataset and main characteristics of electricity consumption and the economic situation in Vietnam. It also gives results of unit root, cointegration, and causality tests for the relationship between electricity consumption and economic growth.

3.1. Data

Data used in this paper comes from General Statistics Office of Vietnam (1990) for GDP from 1975 to 1984 and the World Bank (2011)

Figure 1: Log of per capita GDP and electricity consumption in Vietnam, 1975-2010



for the rest[2]. Basically, there are two time series of per capita electricity consumption measured in kilowatt hours and per capita GDP measured in U.S. dollars at 2000 prices. Both series are transformed into logarithm form and shown in Figure 1.

Figure 1 shows an increasing trend in both electricity consumption and GDP, and almost all growth rates of per capita electricity consumption and per capita GDP are positive. There are exceptions for the period of 1978-1980 when per capita GDP growth decreased by 1.6% and 4.9% respectively; per capita electricity consumption had a drop-off by 2.2% in 1979. The growth rates of per capita electricity consumption were much higher than that of per capita GDP over time. For example, the average 15-year 1976-1990 growth rate of per capita electricity consumption was 6.2%, while per capita GDP growth rate was 2.6%. Those numbers for 1991-2010 were 12.0% and 5.8%, respectively. For the last 10 years, the average per capita electricity consumption growth rate doubled the average per capita economic growth rate. This rapid increase in electricity consumption has been a warning for electricity supplies in Vietnam so far.

3.2. Results

This part provides some empirical results from the unit root, cointegration, and granger causality tests to light up the relationship between electricity consumption and economic growth in Vietnam.

Unit root test

Since Vietnam implemented the *Doi moi* (renovation) package in 1986, it was possible to have structural breaks in the data. To test for structural breaks/changes, a Chow test for both per capita variables in the logarithm form has been used. Results of the Chow tests showed that there was no evidence of structural breaks

Table 1: Unit root test results of per capita GDP and par capita electricity consumption

	ADF		PP		KPSS	
	Level	First difference	Level	First difference	Level	First difference
Log of per capita electricity consumption	-3.102	-4.310	-0.918	-5.677	0.184	0.129
Log of per capita GDP	-2.886	-3.698	-1.217	-4.389	0.204	0.064
Critical values at 5%	-3.568	-3.568	-3.564	-3.564	0.146	0.146

Table 2: Johansen-Juselius cointegration rank test

No. of cointegrations	Max-Eigen Statistics	Critical values at 5%	Trace Statistics	Critical values at 5%
None	16.46	14.07	17.08	15.49
At most 1	3.28	3.84	3.28	3.84

Table 3: Results of the standard and two-step Granger causality tests

	Granger causality Wald tests	Two-step Granger causality tests	
		Short-run	Long-run
Per capita electricity consumption granger causal GDP	4.83 (0.089)*	2.70 (0.111)	1.01 (0.322)
Per capita GDP granger causal electricity consumption	10.25 (0.006)***	0.05 (0. 826)	4.44 (0. 043)**

**** is statistically significant at 1% level, ** is for 5% level, and * is for 10% level.*

in both intercept and trend of logarithm of electricity consumption and GDP in Vietnam during 1975-2010. Without any structural change in the variables during the period, the regular ADF and other tests for unit root testing are used. Results of unit root tests are presented in Table 1.

The calculated values of ADF, PP, and KPSS test statistics on level of logarithm of per capita GDP and per capita electricity consumption are larger than the critical values at 5%, so the null hypothesis cannot be rejected. It means that logarithm of per capita electricity consumption and per capita GDP are nonstationary series at their levels. Applying those tests for the first difference of two series, the null hypotheses of nonstationary are rejected at 5%. The rejections imply that the first difference of two variables is stationary. All test statistics give the same rejection/non-rejection decisions; therefore, per capita electricity consumption and per capita GDP in Vietnam during 1975-2010 are integrated at the same order of degree one.

Results of cointegration test

Because of an integration degree one between electricity consumption and GDP, the paper needs to test whether a long-run relationship between two series exists. As mentioned in the earlier section, cointegration tests are used to determine if a long-run relationship between two series exists. To get cointegration test results, the Johansen-Juselius test requires obtaining optimal lag length in the model. Using the Akaike's information criterion (AIC), the optimal lag length is two[3]. Results of Johansen cointegration rank test are presented in Table 2.

Results from Johansen-Juselius cointegration rank test are for testing two null hypotheses of no cointegration and cointegration at most one. The maximum Eigen statistic of 16.46 exceeds its critical values at 5%, which leads to a rejection of the null hypothesis. Similarly, the trace test statistic of 17.08 is also greater than its critical value of 15.49, so the hypothesis of no integration is also significantly rejected. Both Max-eigen and Trace statistics give the same rejection conclusion. These results imply that there is a cointegrating relationship between GDP and electricity consumption. We next test the hypothesis that rank of cointegration between per capita electricity consumption and per capita GDP is one. The maximum-eigen test statistic of 3.18 is smaller than its critical value at 5% of 3.84, so the null hypothesis cannot be rejected. The trace test statistic gives the same non-rejection conclusion. Thus, the hypothesis of one cointegration is statistically significantly rejected regardless which test statistic is used. A combination of test results implies that there is a cointegrating relationship between per capita GDP and per capita electricity consumption in Vietnam during 1975-2010.

Results of granger causality tests

Results of the cointegration test concluded that there was a cointegrating relationship between per capita electricity consumption and per capita GDP, so performing causality tests are necessary to figure out the relationship between the two variables. Table 3 presents results of the standard Ganger and two-step Granger causality tests to indentify which direction are presented for per capita electricity consumption and per capita GDP in Vietnam.

Numbers in the parentheses are p-values.

The results from the standard Granger causality test show Wald test statistic of 10.25 with p-value of 0.006. It implies that the null hypothesis of no causality running from per capita GDP to per capita electricity consumption is rejected at 5%. In other words, per capita GDP does affect per capita electricity consumption in Vietnam. When considering the causality running from per capital electricity consumption to per capita GDP, however, the Wald test statistic of 4.83 and p-value of 0.089 implies a non-rejection of no causality running from per capita electricity consumption to per capita GDP, or causality relationship running from electricity consumption to per capita GDP does not exists in Vietnam, at 5 percent level. The result implies that electricity consumption does not affect economic growth during the period.

Additionally, the short-run causality was performed by an F-test for the lagged independent variables, while the long-run causality was obtained by a t-test for the lagged error terms in (4) and (5). Using the AIC criteria, the optimal lag length for this exercise was two, and results of above tests were also provided in Table 3. In the short-run, no granger causality between per capita electricity consumption and per capita GDP in any directions was found. This result implies that there is neutrality between electricity consumption and GDP in the short-run. The results also show that, in the long-run there is no causality running from per capita electricity consumption to per capita GDP, but a long-run causality relationship running from per capita GDP to per capita electricity consumption in Vietnam during 1975-2010 exists.

This Granger causality test results mean that GDP has its effects on electricity consumption in Vietnam, but no inverse direction, and this is a long-run relationship. The result would have its policy implications, which are mentioned in the next section.

4. Explanations and policy implications

This section provides some explanations for the causality relationship running from GDP to electricity consumption in Vietnam. In general, an increase in GDP may increase electricity consumption via some channels. First, when household income increases, the household would spend its income on electricity-intensive goods such as air conditioners, food processors, refrigerators, washing machines, televisions and computers… if the above goods are normal. Second, an increase in income would expand electricity-intensive production since electricity is one of the most important and effective inputs for the industrial sector of a country, especially for countries whose electricity price is artificially set at a low level.

In the Vietnamese context, electricity generation, transmission, and distribution belong to a state owned corporation, Vietnam Electricity (EVN). It is a monopsonist of electricity supplied, and a monopolist of commercial electricity. It has responsibility for electricity supply, transmission, and distribution to meet the demand of firms and households as requirement of the Prime Minister. With a low electricity price policy artificially set by the government to meet its inflation target, households and firms have enjoyed low prices for electricity. This policy would lead Vietnamese consumers to use much more electricity than needed and ineffectively, the percentage of inefficient electricity use was about 12.8% in 2010, and it was extremely high in administrative agencies.[4] In addition, the infrastructure of the power sector has been in bad condition. Because of old electricity transmission networks, for example, electricity losses were up to 40% in some mountainous and rural areas and around 10% in large cities. Therefore, it is hard for electricity consumption to be translated into economic growth in both the short-run and long-run in Vietnam.

Another reason would be that Vietnam has been in its early period of development, and most people have had relatively low income. Annual per capita GDP in 2010 (at constant price) was USD 712; the percentage of poor was 9.5%, and many people were just above the national poverty line; nearly 68.1% of the population were located in rural areas (General Statistics Office, 2011). So when income increases, individuals or households try to secure their basic needs rather than electricity-intensive goods at least in the short-run. Moreover, rural economy is based on agricultural production, so expansions of this production due to an increase in income would not have significant effects on electricity consumption, at least in the short-run. These characteristics would explain that economic growth does not statistically affect electricity consumption in the short-run in Vietnam.

In the long-run, however, economic growth helps to increase real income of individuals and households enough to create demand for electricity-intensive goods, including both final and intermediate consumption goods. With such increases in income, firms would have extra investment in electricity-intensive production, and households would consume electricity-intensive products. Such behavior of households and firms increase demand for electricity and electricity consumption. In fact, economic growth has put pressure on electricity supplies, and indeed, electricity shortages have become more serious in Vietnam recently.

The unidirectional causality running from GDP to electricity consumption of this empirical analysis would have important policy implications on Vietnam's economic policies. Although electricity consumption does not affect economic growth in both the short-run and long-run, electricity management should be concerned. Because of inefficient electricity consumption, electricity losses, and artificial low electricity prices, it is hard for electricity consumption to translate into economic growth. The Vietnamese government should gradually privatize the electricity sector, and eventually create a competitive electricity market. These activities would create a more competitive electricity market, in which electricity prices would be determined by market forces, and electricity would be consumed more efficiently. It would lead to significant reductions in ineffective electricity use and eventually electricity shortages. The Vietnamese government should restructure power supplies to meet increasing demands for electricity. According to the economic development strategy 2011-2020, annual economic growth is 7-8%, so it creates a higher demand for electricity, which is estimated to increase by 17% yearly. This figure would be higher if domestic electricity supplies do not increase sufficiently.

Since electricity-generated capacity has not met the high electricity demand led by high economic growth, Vietnam has imported electricity from China since 2005 to meet the high domestic demand for electricity. Initially, this purchase was about 200 million KWh a year to mainly supply to Ha Giang and Yen Bai provinces. In 2007, Vietnam bought 2.6 billions KWh, and since 2008, electricity imported from China was around 4.5 billion KWh per year. Currently, EVN has had to import 5.1 billions kilowatt-hours from China and Laos to cover the domestic electricity shortage. To meet this increasing demand, EVN has to call for investment on developing new electricity generation plans, which are environmentally friendly and protect energy conservation such as oil, natural gas, coal, and reproduced energy, by appropriately increasing electricity prices and gradually developing a more competitive electricity market.

5. Conclusions

This paper investigates a causality relationship between electricity consumption and economic growth in Vietnam during 1975-2010. Using cointegration and causality analysis, the paper found that there was no causality running from electricity consumption to GDP in both the short-run and long-run, but it found a causality running from GDP to electricity consumption in the long-run. This granger causal relationship is helpful to understand how important the roles of economic growth on energy policies are. Electricity has not been a driver of economic growth in Vietnam yet, but economic growth increases demand for electricity and then puts stress on electricity supplies. This empirical finding implies any policies accelerating economic growth would lead to an increase in electricity consumption and the needs to increase electricity supplies. The electricity shortage in Vietnam so far is vivid evidence that the electricity supply is far behind economic growth. Vietnam should have a national energy policy that can solve the electricity shortage problem with a focus on adjusting electricity prices and developing a more competitive electricity market. Its national energy policy has to be accompanied by high economic growth and assure national energy security if Vietnam does not want to be a net energy importer in the near future when its economy will grow more rapidly.

Note:

1 Electricity consumption is not a perfect proxy for electricity demand. In the practice, demand for electricity is hard to estimate, so it seems to be impossible to get demand for electricity for running granger causality between the two variables. To solve this issue, the academic assumes that electricity consumption is one of the most possible proxies for electricity demand, and electricity consumption is used for this purpose.

2 GDP adapted from General Statistic Office of Vietnam (1990) were measured in USD million 1990 constant prices. From these data, we calculated the growth rates of GDP, and based on these growth rates and GDP of 1985 at 2000 constant prices (come from World Bank, 2010) we calculated GDP at 2000 constant prices for the year from 1975 to 1984. Since we did not have CPI index for the years before 1983, we could not use CPI index to convert from 1990 constant price GDP to 2000 constant prices GDP for the

year before 1983. Compared the 2000 constant prices GDPs of 1983 and 1984 of the two methods; however, we got similar results. It implies that GDP data used in this paper would be homogenous and compatible.

[3] Results showed that the optimal lag length should be 1 if we used Schwarz's Bayesian information criterion (SBIC). However, SBIC often gives a shorter lag length than AIC does. Two lags are also supported by using the final prediction error (FPE) and Hannan and Quinn information criterion (HQIC). We also estimated model using 1 optimal lag length, the conclusions were similar as the case of two-optimal lag length.

[4] According to the Ho Chi Minh City Department of Power in 2010, 80% of administrative agencies in the city use electricity wastedly and none of them saved 10% of power spending as the government instructed, while the figure for Hanoi city was 71.2%.

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