

Energy Consumption and Economic Growth in Vietnam: Threshold Cointegration and Causality Analysis

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ABSTRACT: This study investigates the energy consumption-growth nexus in Vietnam. The causal relationship between the logarithm of per capita energy consumption (LPCEC) and the logarithm of per capita GDP (LPCGDP) during the 1976-2010 period is examined using the threshold cointegration and vector error correction models for Granger causality tests. The estimation results indicate that the LPCEC and LPCGDP for Vietnam are cointegrated and that there is a strong uni-directional causality running from LPCGDP to LPCEC, but not vice versa. It is also found that the effect of LPCGDP on LPCEC in Vietnam is time-varying (i.e. significantly different between before and after the structural breakpoint, 1992). The research results strongly support the neoclassical perspective that energy consumption is not a limiting factor to economic growth in Vietnam. Accordingly, an important policy implication resulting from this analysis is that government can pursue the conservation energy policies that aim at curtailing energy use for environmental friendly development purposes without creating severe effects on economic growth. The energy should be efficiently allocated into more productive sectors of the economy.

JEL classification: Q4

Key words: Energy consumption, Economic growth, Cointegration, Granger causality, Vietnam

1. Introduction

The high volatility of energy prices and increased greenhouse gas emissions have recently attracted attention from academics and policy-makers in terms of designing the energy conservation policy. This kind of policy can, however, not be arbitrarily enacted without considering the causal relationship between energy consumption and economic growth. In certain context, policy-makers must understand whether economic growth boosts energy consumption or whether energy consumption causes economic growth. And this issue has not been reached to a consensus among energy economists.

The causal relationship between energy consumption and economic growth has been extensively investigated since the seminal paper of Kraft and Draft in 1978. Different studies have done in different countries, time periods, and proxy variables using different econometric methodologies (Ozturk, 2010). However, evidences from empirical researches are still mixed and controversial in terms of the direction of causality and the intensity of impact on energy policy. Understanding the linkage between these two variables is extremely significant because energy policy implications mostly depend upon what kind of causal relationship exists. Bartleet and Gounder (2010) state that it's more important to know whether energy consumption causes economic growth than the case where either economic growth promotes energy consumption or no causal relationship exists between them. The underlying reason of this justification is that it's really difficult for policy-makers to enact energy conservation policies if a country is known as energy-dependent. In the presence of such a relationship, any structural policies that aim at reducing energy consumption might possibly slow economic growth (Tsani, 2010).

Theoretically, an appropriate energy policy choice depends on the actual direction of the causal relationship between energy consumption and economic growth. Ozturk (2010) and Ozturk & Acaravci (2010) sum up four possible hypotheses about energy-growth nexus. Firstly, no causality between these variables is referred to as 'neutrality hypothesis'. In other words, energy is assumed to be neutral to growth. If this is not a case, conservative or expansive policies on energy consumption could adversely affect economic growth. Supporters of this view emphasize the role of substitution

and technological progress. According to Belloumi (2009), the main reason for the neutral impact of energy on economic growth is that the cost of energy is negligible, so it is not likely to have a significant impact on economic growth. It has also been argued that the possible impact of energy consumption on growth will depend on the structure of the economy and the level of economic growth of the country concerned. As the economy grows, its production structure is likely to shift towards service sectors, which are not much dependent on energy (Solow, 1974; and Cheng, 1995). Secondly, uni-directional causality from economic growth to energy consumption supports the ‘conservation hypothesis’. This implies that a country might implement the energy conservation policy without having any adverse effect on economic growth. Thirdly, uni-directional causality from energy consumption to economic growth is commonly considered as ‘energy-led growth hypothesis’. Within this situation, policy makers should pay special attention on restrictions of energy use because this action may, to which extent, impede economic growth. Proponents of this hypothesis believe that energy is a critical input of production and plays as a complement to the basic factors of land, labour and capital. If this is a case, energy is said to be a limiting factor of economic growth (Stern, 1993; and Cleveland *et al.*, 2000). Finally, bi-directional causality between energy consumption and economic growth is known as ‘feedback hypothesis’. This provides an insight that energy consumption and economic growth are jointly determined and affected together.

Chen *et al.* (2007) explains the mixed findings from previous studies are due to differences in not only data set, econometric approaches, but also countries’ characteristics. For this reason, it’s very dangerous to design future energy policy of one country based on experiences of others. Accordingly, a country-specific causality study between energy consumption and economic growth must be done to provide deep insights into design of energy policies. Therefore, is it correct to believe in the statement of ‘energy for economic development’ stated by the Vietnam energy industry? What is the evidence for the national energy development strategy that still provides special favour for energy sectors?

A great number of causality studies have been conducted for many countries around the world; however, none have focused on the causal relationship between energy consumption and economic growth for Vietnam. Hence, it’s now necessary to examine this causal relationship in Vietnam. This research aims at answering the following questions: (1) Does long-term equilibrium exist between energy consumption and economic growth in Vietnam? (2) Is the energy consumption quickly adjusted to reach the long-run equilibrium if an instantaneous shock to its consumption occurs? (3) Which of the above hypotheses is acceptable for the case of Vietnam?

The remainder of this paper is organized as follows: Section 2 briefly reviews the literature on the energy-growth nexus. Section 3 presents the data and methodology used. Section 4 discusses the empirical results. We’ll then provide the policy implications and give conclusions in Section 5.

2. Literature Review

The relationship between energy consumption and economic growth has been theoretically investigated through two main different approaches. In the neoclassical growth models, energy is simply considered as an intermediate input of production (Tsani, 2010). According to Bartleet and Gounder (2010), proponents of this view think that there are some mechanisms by which economic growth could remain in spite of a limited source of energy resources. The underlying explanation for this is built upon the possibility of technological change and substitution of other physical inputs for energy to use existing energy resources efficiently, and to generate renewable energy resources that are not subject to binding supply constraints (Solow, 1974, 1997; Stiglitz, 1997). Accordingly, energy is merely one of the non-essential inputs in production process. In other words, the advocates of this theory support the ‘neutrality hypothesis’ and ‘conservation hypothesis’. These hypotheses imply that energy supply restrictions might not have any harmful effect on economic growth. Thus, the government can simultaneously adopt the energy conservation and economic growth policies (Bartleet and Gounder, 2010).

On the other hand, the ecological economic theory states that energy consumption is a limiting factor to economic growth, especially in modern economies. Ecological economists judge that technological progress and other physical inputs could not possibly substitute the vital role of energy in production process (Stern, 1993, 2000). They even consider energy as the prime source of value because other factors of production such as labour and capital cannot perform without energy (Belloumi, 2009). The promoters of this perspective protect the so-called ‘growth hypothesis’, and

hence, advise that any shock to energy supply will ultimately have a negative impact on economic growth. As a result, they are against the energy conservation policies.

Lots of empirical studies on energy consumption and economic growth nexus using different data set from different countries have so far provided various and contradictive results. The idea of causality between energy consumption and economic growth was first introduced in the seminal paper of [Kraft and Kraft \(1978\)](#) with the application of a standard version of Granger causality (standard Granger) test, which provided proof to support a uni-directional long-run relationship running from gross domestic product (GDP) to energy consumption for the USA over the 1947-74 period. This study suggests that government could pursue the energy conservation policies. On the other hand, by employing the Sims causality technique, [Akarca and Long \(1980\)](#) showed no evidence of causality between energy consumption and GDP, so they criticized drastically the [Kraft and Kraft's](#) result in terms of the temporal sample instability. Since then, many academics have zealously joined the debate, but they have never reached the consensus ([Belloumi, 2009](#)). In the same manner, [Yu and Hwang \(1984\)](#) took up the Sims causality test with annual data and found no causality between energy consumption and GDP in the USA for the 1947-79 period. When using quarterly data with the same testing method, conversely, these authors discovered a uni-directional causality running from gross national product (GNP) to energy consumption in the USA for the 1973-81 period ([Belloumi, 2009](#)).

[Yu and Choi \(1985\)](#) employed the standard Granger causality test for the 1954-1976 period to explore the causal linkages between GNP and various types of energy consumption for a set of countries. Their empirical studies indicated that uni-directional causality running from economic growth to energy consumption for Korea, uni-directional causality running from energy consumption to income for the Philippines, while no causality existed in the USA, Poland and UK. [Erol and Yu \(1987\)](#) employed both Sims and Granger causality tests and found unidirectional causality from energy consumption to income for West Germany while bi-directional causality for Italy, and no evidence of causality for UK, Canada and France. Besides, they also uncovered the uni-directional causality running from energy consumption to economic growth for Japan over the 1950-1982 period. On the contrary, when the sample was restricted to the 1950-1973 period, this causal relationship was no longer significant. [Hwang and Gum \(1992\)](#) used the cointegration and error correction model, and the bi-directional causal relationship between energy consumption and economic growth was observed in Taiwan for the period 1955-1993.

By using the cointegration and error-correction version of Granger causality test (ECM), [Cheng \(1995\)](#) realized the presence of uni-directional causality running from economic growth to energy consumption in India. In addition, [Masih and Masih \(1996, 1997\)](#) found the existence of cointegration between energy and GDP in India, Pakistan and Indonesia, but non-cointegration in Malaysia, Singapore and the Philippines. With the same data set, these authors applied the vector error correction model (VECM), and recognised a uni-directional causality running from energy consumption to income in India, a uni-directional causality running from economic growth to energy consumption in Indonesia, and bi-directional causality in Pakistan. This study also made use of the standard Granger causality test for the non-cointegrated countries (including Malaysia, Singapore and the Philippines), but did not find any Granger causality.

[Glasure and Lee \(1997\)](#) examined the causality between energy consumption and GDP for South Korea and Singapore and reported different results from different methodologies used. The standard Granger causality tests revealed no causal relationship for South Korea and a uni-directional causal relationship running from energy consumption to GDP for Singapore, while the ECM model gave signal of bi-directional causality for both countries. [Cheng and Lai \(1997\)](#) applied Hsiao's version of Granger causality to investigate the link between energy consumption and GDP for Taiwan for 1955–1993 period. This study showed that causality runs from GDP to energy consumption without feedback in Taiwan. [Yang \(2000\)](#) re-examined the causality between energy consumption and GDP for Taiwan using updated data for the 1954–1997 period. The finding of this paper totally denies the findings of [Cheng and Lai \(1997\)](#) of unidirectional causality from GDP to energy consumption. They found evidences of bi-directional causality between energy consumption and GDP.

[Asafu-Adjaye \(2000\)](#) tested the causal relationship between energy use and income in four Asian countries (including India, Indonesia, Thailand and the Philippines) using the ECM models. The test results indicated a uni-directional causality running from energy to income in India and Indonesia, and a bi-directional causality in Thailand and the Philippines. [Aqeel and Butt \(2001\)](#) used the ECM models

to investigate the causal relationship between energy consumption and economic growth as well as between energy consumption and employment for Pakistan. The results inferred that economic growth caused total energy consumption. [Soytas and Sari \(2003\)](#) studied causality between energy consumption and GDP for the G7 countries and for the top 10 emerging economies. Their research results found a bi-directional causality for Argentina, uni-directional causality running from GDP to energy consumption in Italy and Korea, and uni-directional causality running from energy consumption to GDP in Turkey, France, Germany and Japan.

[Paul and Bhattacharya \(2004\)](#) re-examined the direction of causality between energy consumption and economic growth in India by employing the ECM model for the 1950–96 period. As a result, they realized that a bi-directional causality existed between energy consumption and economic growth. Besides, they also applied the Johansen cointegration testing approach and figured out the same direction of causality between energy consumption and economic growth. [Altinaya and Karagol \(2004\)](#) detected causality between the GDP and energy consumption in Turkey employing the Hsiao's version of Granger causality for the 1950–2000 period, characterized by structural break. The main conclusion of this study is that there is no evidence of causality between energy consumption and GDP in Turkey based on the detrended series.

[Lee \(2005\)](#) investigated the cointegration and the causality relationship between energy consumption and GDP in 18 developing countries, using data for the 1975–2001 period and employing panel unit root tests, heterogeneous panel cointegration and panel ECM models. The empirical results supported a long-run cointegration relationship between energy consumption and GDP after allowing for the heterogeneous country effects. The evidence illustrated that there were only long-run and short-run causalities running from energy consumption to GDP. This result suggested that energy conservation policies might, to which extent, harm economic growth in developing countries. [Wolde-Rufael \(2005\)](#) ran a cointegration and a modified version of the Granger causality test to investigate the long-run and causal relationship between per capita GDP and per capita energy use for 19 African countries for the 1971–2001 period. Their results offered further evidence of the long-run relationship for eight out of the nineteen countries and causality for twelve out of nineteen countries.

[Mehrra \(2007\)](#) examined the causal relationship between the per capita energy consumption and the per capita GDP in a group of eleven oil-exporting countries (including Iran, Kuwait, Saudi Arabia, United Arab Emirates, Bahrain, Oman, Algeria, Nigeria, Mexico, Venezuela and Ecuador) by using panel unit root tests and panel cointegration tests. The test results found a uni-directional causality running from economic growth to energy consumption for these oil-exporting countries. Interestingly, the results recommended that energy conservation policies through reforming energy prices could not have any adverse effect on economic growth.

[Chiou-Wei et al. \(2008\)](#) conducted both linear and nonlinear Granger causality tests to examine the causal relationship between energy consumption and economic growth for a panel of Asian newly industrialized countries as well as the USA for the 1954–2006 period. Their study again supported a neutrality hypothesis for the USA, Thailand, and South Korea. Moreover, they unearthed the existence of a uni-directional causality running from economic growth to energy consumption for Philippines and Singapore while energy consumption might have negative effects on economic growth for Taiwan, Hong Kong, Malaysia and Indonesia. [Chontanawat et al. \(2008\)](#) tested for causality between energy and GDP using a consistent data set and Granger test for thirty OECD countries and seventy non-OECD countries. They discovered that causality running from energy to GDP appeared to be more prevalent in the developed OECD countries.

[Tsani \(2010\)](#) studied the causal relationship between aggregated and disaggregated levels of energy consumption and economic growth in Greece for the 1960–2006 period by using the methodology proposed by [Toda and Yamamoto \(1995\)](#). At the aggregated levels of energy consumption, the empirical findings suggested the presence of a uni-directional causality running from total energy consumption to real GDP. At the disaggregated levels, the results indicated a bi-directional causal relationship between industrial and residential energy consumption to real GDP, and no causality between transport energy consumption and real GDP. The energy policy implication from these findings focused on the demand side and energy efficiency improvements in order to put less impact on economic growth.

Esso (2010) investigated the cointegration and causal relationship between energy consumption and economic growth in seven Sub-Saharan countries over the 1970–2007 period. This study used the Gregory and Hansen (1996b) threshold cointegration approach and the Toda and Yamamoto (1995) version of Granger causality test. The test results revealed that energy consumption was cointegrated with economic growth in Cameroon, Cote d'Ivoire, Ghana, Nigeria and South Africa in the presence of a structural break. Moreover, threshold cointegration test and ECM models suggested that economic growth had a significant positive long-run impact on energy consumption in these countries before 1988 while this effect was negative after the breakpoint, 1988, for Ghana and South Africa. Furthermore, Granger-causality tests suggested a bi-directional causality between energy consumption and real GDP in Cote d'Ivoire and a uni-directional causality running from real GDP to energy consumption in the case of Congo and Ghana.

By using the recently developed autoregressive distributed lag (ARDL) bounds testing approach of cointegration and dynamic vector error correction (VECM) model for four Eastern European countries, Ozturk and Acaravci (2010) figured out that there is weak evidence about the long-run and causal relationships between energy consumption (or electric power consumption) and economic growth. Specifically, they found that evidence of cointegration and bi-directional strong Granger causality between these variables is only found in Hungary for the 1980-2006 period. This study contributes not only the proof of causality, but the methodology used. The authors explained clearly the ARDL bounds testing approach used in the energy-growth linkage. In addition, Ozturk *et al.* (2010) employed the panel cointegration and causality analysis to investigate the differences in energy consumption and economic growth relationship among three groups of 51 countries classified as low income countries, lower middle income countries, and upper middle income countries for the 1971-2005 period. The test results indicate that there exists cointegration between energy consumption and real GDP for all three income groups. From the panel causality tests, they conclude that there is a long-run Granger causality running from GDP to energy consumption for low income countries and bi-directional Granger causality between these variables for the other groups. Furthermore, these authors also provide evidence that there is no strong relation between energy consumption and economic growth in these countries.

In summary, a general judgment is that the results are still mixed: that is, while some studies find causality running from economic growth to energy consumption, others figure out causality running from energy consumption to economic growth and even some studies suggest no causality and/or bi-directional causality between these two variables. The differences among these studies lie on the specific country characteristics, sample periods, research methodologies, and proxy variables.

3. Data and Methodology

3.1 Data Collection and Unit Root Tests

This paper uses the time series data of per capita GDP (PCGDP) and per capita energy consumption (PCEC) for the 1976-2010 period in Vietnam. Data are obtained from three sources: (i) the World Development Indicators (2011); (ii) International Financial Statistics (2011); and the Vietnam's General Statistics Office. In this study, per capita energy consumption is expressed in terms of kg oil equivalent and per capita GDP is expressed in constant 2000 US\$. The choice of the starting period was constrained by the availability of data and the historical milestone as well. The Vietnam War ended in 1975, and the country was united in 1976. The trends of PCGDP and PCEC for Vietnam are graphically depicted in Figure 1. It's noted that all variables are transformed into natural logarithms in order to reduce heteroskedasticity and obtain the growth rate of the relevant variables by their differenced logarithms (Ozturk and Acaravci, 2010).

It seems that there might be a structural break in these series around the year 1991. By using the Quandt-Andrews breakpoint test, we recognize that the PCGDP is broken at the year 1992, while the PCEC at the year 1993. These breakpoints are depicted in Figure 2 and 3. This fact might, to which extent, imply that PCGDP causes PCEC. The final answer will, however, be clear after performing Granger causality tests presented in the empirical results. These figures also indicate that both series have increasingly grown since these breakpoints.

Figure 1: Vietnam's per capita energy consumption and per capita GDP

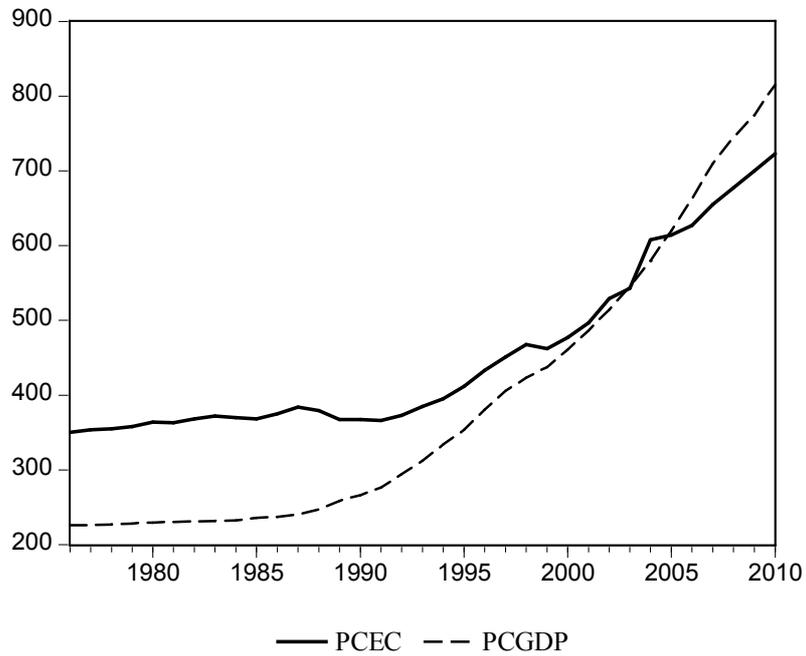


Figure 2: Fitted trend of per capita energy consumption

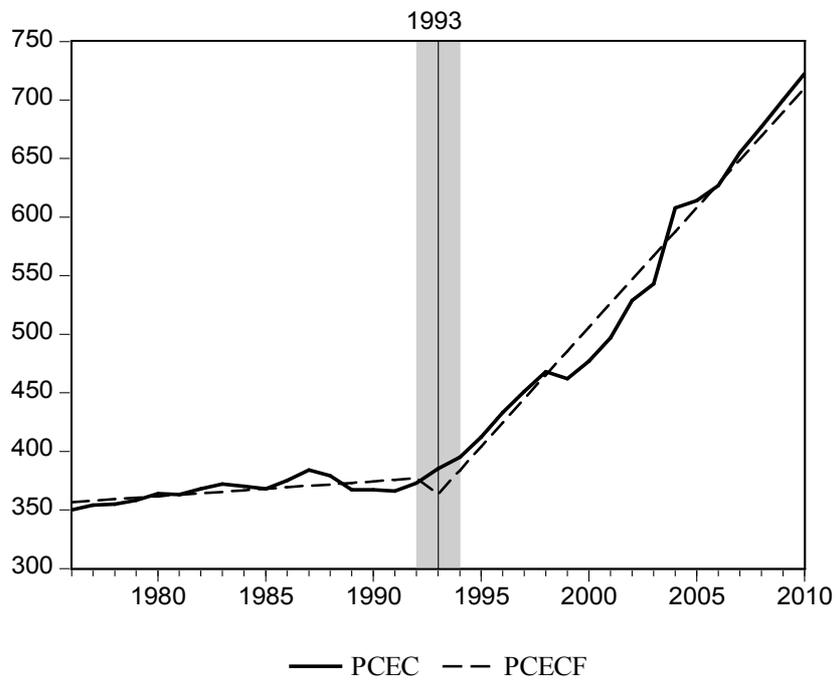
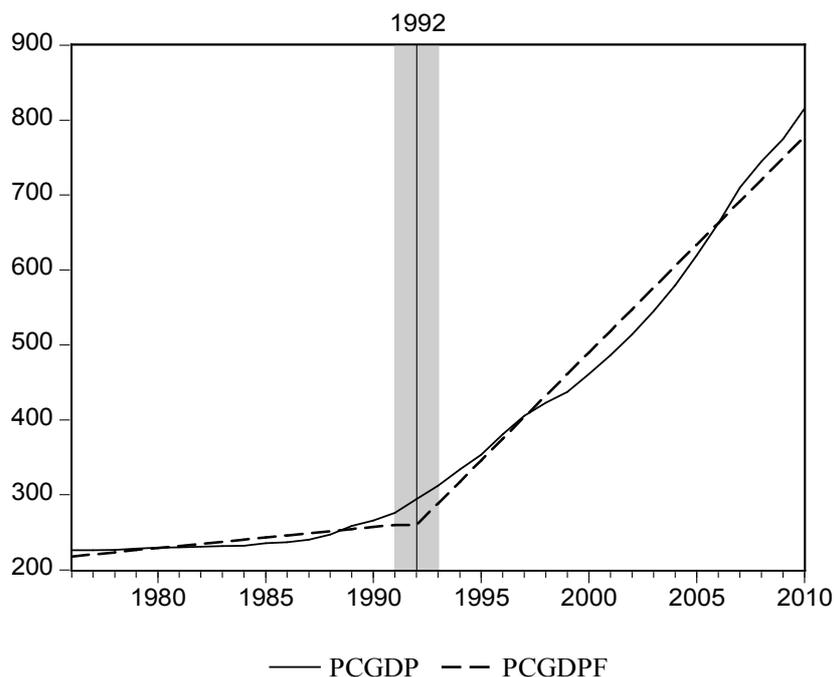


Figure 3: Fitted trend of per capita GDP



In order to establish the order of integration of the variables concerned, this study first employs the conventional unit root tests widely known as the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Generally, a variable is said to be integrated of order d , written by $I(d)$, if it turns out to be stationary after differencing d times. The variable is integrated of order greater than or equal to 1 is non-stationary. According to Asteriou and Hall (2007), most economic variables are cointegrated of order 1.

In testing for the existence of a unit root of the time series Y_t ($H_0: \delta = 0$), we can select one out of the following three possible forms of the ADF test (Y_t can be either $LPCEC_t$ or $LPCGDP_t$):

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \quad (1)$$

$$\Delta Y_t = \alpha_0 + \delta Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \quad (2)$$

$$\Delta Y_t = \alpha_0 + \alpha_1 T + \delta Y_{t-1} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + u_t \quad (3)$$

The difference between the three regressions concerns the presence of the deterministic elements α_0 and $\alpha_1 T$. For choosing the best one among the three equations, we will first plot the data (of each series) and then observe the graph because it can, to which extent, indicate the presence or not of the deterministic trend regressors.

Esso (2010) states a break in the deterministic trend affects the outcome of unit root tests because many previous studies have found that the conventional unit root tests fail to reject the unit root hypothesis for series that are actually trend stationary with a structural break. Perron (1989) showed that a Dickey and Fuller (1979) type test for unit root is not consistent if the alternative is that of a stationary noise component with a break in the slope of the deterministic trend. His main point is that the existence of exogenous shock which has a permanent effect will lead to a non-rejection of the unit root hypothesis even though it is true. Perron (1989) proposed a unit root test allowing for a structural break with three alternative models: crash model (i.e., shift in the intercept), changing growth model (i.e., change in the slope) and the change both in the intercept and the slope. Several studies have found that the conventional unit root tests fail to reject the unit root hypothesis for the series that are actually trend stationary with a structural break. On the other hand, the Perron (1989) test has been

generally criticized for treating the time of break as exogenous (i.e., the time of break is known a priori). (Christiano, 1992; and Altinay and Karagol, 2004).

Zivot and Andrews (1992) further developed the Perron unit root tests that consider the breakpoint (τ_b) as endogenous. To test for a unit root against the alternative of trend stationarity process with a structural break both in slope and intercept, the following regressions are used:

$$Y_t = \mu + \theta DU_t(\tau_b) + \beta T + \alpha Y_{t-1} + \sum_{i=1}^p \phi_i \Delta Y_{t-i} + u_t \quad (4)$$

$$Y_t = \mu + \gamma DT_t(\tau_b) + \beta T + \alpha Y_{t-1} + \sum_{i=1}^p \phi_i \Delta Y_{t-i} + u_t \quad (5)$$

$$Y_t = \mu + \theta DU_t(\tau_b) + \beta T + \gamma DT_t(\tau_b) + \alpha Y_{t-1} + \sum_{i=1}^p \phi_i \Delta Y_{t-i} + u_t \quad (6)$$

where DU_t and DT_t are dummy variables for a mean shift and a trend shift respectively; $DU_t(\tau_b) = 1$ if $t > \tau_b$ and 0 otherwise, and $DT_t(\tau_b) = t - \tau_b$ if $t > \tau_b$ and 0 otherwise. In other words, DU_t is a sustained dummy variable that captures a shift in the intercept, and DT_t represents a shift in the trend occurring at time τ_b . The breakpoint τ_b can be found by using the Quandt-Andrews breakpoint test. The optimal lag length p is also determined by using the general to specific approach so as to minimize the AIC or SIC. The Zivot and Andrews (1992) unit root test suggests that we reject the null hypothesis of a unit root if computed $t_{\hat{\alpha}}$ is less than the left-tail critical t value.

3.2 Cointegration Analysis

Once the order of integration of each variable is established, we then evaluate whether the variables under consideration is cointegrated. According to Engle and Granger (1987), a linear combination of two or more nonstationary series (with the same order of integration) may be stationary. If such a stationary linear combination exists, the series are considered to be cointegrated and long-run equilibrium relationships exist. Thanks to the existence of cointegration, although the series are individually nonstationary, they cannot drift farther away from each other arbitrarily. Cointegration implies that causality exists between the two variables, but it does not indicate the direction of the causal relationship. The presence of cointegration among the variables rules out the possibility of ‘spurious’ regression (Belloumi, 2010). There are various approaches to test for cointegration, say, Engle and Granger approach, Johansen approach, ARDL bounds testing approach (by Pesaran *et al.*, 2001), and Gregory and Hansen approach.

According to Belloumi (2010), the bivariate approach of Engle and Granger is very restrictive because it can be applied only if there is one cointegrating relation. And the most commonly used method is the Johansen cointegration test based on the autoregressive representation discussed by Johansen (1988) and Johansen and Juselius (1990). This test determines the number of cointegrating equations for any normalization used. It provides two different likelihood ratio tests; one is based on the trace statistic and the other on the maximum eigenvalue.

Esso (2010) states that the cointegration framework of Engle and Granger (1987), and Johansen (1988) has its limitations especially when dealing with economic data containing the structural breaks. In this case, we tend to reject the hypothesis of cointegration, albeit one with stable cointegrating parameters. The reason is that the residuals from cointegrating regressions capture unaccounted breaks and thus typically exhibit nonstationary behaviour. Therefore, it’s necessarily to employ the non-linear techniques for testing cointegration if the economic data has structural breaks. One of the widely used methods is the Gregory and Hansen (1996a,b) threshold cointegration test. And the test equation is expressed as below:

$$Y_t = \mu_1 + \mu_2 DU_t(\tau_b) + \beta_1 T + \beta_2 T \cdot DU_t(\tau_b) + \alpha_1 X_t + \alpha_2 X_t \cdot DU_t(\tau_b) + u_t \quad (7)$$

$$X_t = \mu_1 + \mu_2 DU_t(\tau_b) + \beta_1 T + \beta_2 T \cdot DU_t(\tau_b) + \alpha_1 Y_t + \alpha_2 Y_t \cdot DU_t(\tau_b) + u_t \quad (8)$$

where μ_1 and μ_2 represent the intercept before the shift and the change in the intercept at the time of the shift; β_1 and β_2 are respectively the trend slope before the shift, the change in the trend slope at the time of the shift; α_1 is the cointegrating slope coefficient before the regime shift, α_2 denotes the change in the cointegrating slope coefficient at the time of the regime shift; Y_t and X_t denote LPCEC_{*t*} and LPCGDP_{*t*}. The standard methods to test the null hypothesis of no cointegration are residual-based.

The equations (7) and (8) are estimated by OLS method, and the unit root tests are applied to the regression errors (Gregory and Hansen, 1996a).

3.3 Granger Causality Analysis

Let's denote $LPCEC_t$ and $LPCGDP_t$ for the natural logarithms of the corresponding energy consumption and real GDP per capita respectively; and suppose that $LPCEC_t$ and $LPCGDP_t$ are both integrated of order 1, the VAR model developed by Granger (1969) can be defined as:

$$\Delta LPCEC_t = \alpha + \sum_{i=1}^p \beta_i \Delta LPCEC_{t-i} + \sum_{j=1}^q \gamma_j \Delta LPCGDP_{t-j} + u_{1t} \quad (9)$$

$$\Delta LPCGDP_t = \varphi + \sum_{i=1}^p \theta_i \Delta LPCGDP_{t-i} + \sum_{j=1}^q \delta_j \Delta LPCEC_{t-j} + u_{2t} \quad (10)$$

This study use the Akaike's information criterion (AIC) and Schwarz's Bayesian criterion (SBC) to determine the optimal lag length of $\Delta LPCEC_t$ and $\Delta LPCGDP_t$. The equations (9) and (10) are first estimated by OLS method, and then we apply the normal F Wald test for the joint significance of the coefficients on the lagged terms in the unrestricted models. Specifically, the following null hypotheses are necessarily tested:

$$(A) H_0 : \sum_{j=1}^q \gamma_j = 0 \text{ or economic growth does not Granger cause energy consumption}$$

$$(B) H_0 : \sum_{j=1}^q \delta_j = 0 \text{ or energy consumption does not Granger cause economic growth}$$

It is possible to have that (a) energy consumption causes economic growth (reject B, but do not reject A), (b) economic growth causes energy consumption (reject A, but do not reject B), (c) there is a bi-directional feedback between energy consumption and economic growth (reject A and B), and (c) energy consumption and economic growth are independent (do not reject A and B).

According to Mehrara (2007), the most popular method for Granger causality tests, is based on the VECM if variables are cointegrated. The VECM can avoid shortcomings of the VAR based models in distinguishing between a long- and a short-run relationship among the variables. Theoretically, cointegration implies the existence of causality between variables, but it does not indicate the direction of the causal relationship. The VECM is estimated by using the following VAR model:

$$\Delta LPCEC_t = \alpha + \pi_1 ECT_{1,t-1} + \sum_{i=1}^p \beta_i \Delta LPCEC_{t-i} + \sum_{j=1}^q \gamma_j \Delta LPCGDP_{t-j} + u_{1t} \quad (11)$$

$$\Delta LPCGDP_t = \varphi + \pi_2 ECT_{2,t-1} + \sum_{i=1}^p \theta_i \Delta LPCGDP_{t-i} + \sum_{j=1}^q \delta_j \Delta LPCEC_{t-j} + u_{2t} \quad (12)$$

where the error correction term (ECT_{t-1}) is derived from the long-run cointegration relationship and measures the magnitude of the past disequilibrium. The coefficients, π of the ECT_{t-1} represent the deviation of the dependent variables from the long-run equilibrium.

Within this VECM model, we can examine whether the relationship between energy consumption and economic growth is weak Granger causality, long-run Granger causality, or strong Granger causality. The weak Granger causality exists if we can find the short-run relationship between energy consumption and economic growth which is based on the normal F Wald test for the joint significance of the coefficients on the lagged terms in the unrestricted models (equation (11) and (12)) in the same manner as the null hypotheses (A) and (B). The long-run causality can be tested by looking at the significance of the speed of adjustment, which is the coefficient of the error correction term. This is easily based on the t statistic. Specifically, we must test the following null hypotheses:

$$(C) H_0 : \pi_1 = 0 \text{ or Granger non - causality in the long - run}$$

$$(D) H_0 : \pi_2 = 0 \text{ or Granger non - causality in the long - run}$$

According to Belloumi (2010), the significance of ' π ' indicates that the long-run equilibrium relationship is directly driving the dependent variable. If π , say, in equation (11) is zero, then it can be implied that the change in energy consumption does not respond to deviation in the long-run equilibrium for the $t-1$ period.

The strong Granger causality between energy consumption and economic growth, which is based on the normal F Wald test for joint significance of both the coefficient associated with the ECT_{t-1} and the coefficients on the lagged terms in the unrestricted models (equation (11) and (12)) as follows:

(C) $H_0 : \pi_1 = \sum_{j=1}^q \gamma_j = 0$ or economic growth does not strongly cause energy consumption

(D) $H_0 : \pi_2 = \sum_{j=1}^q \delta_j = 0$ or energy consumption does not strongly causes economic growth

Above models could include dummy variables in order to take into account the existence of the possible structural breaks during the study sample. In addition, we sometimes include the trend variable if there is the existence of deterministic trend in the relationship between energy consumption and economic growth. These inclusions depend on the actual data property.

4. Empirical Results

4.1 Unit Root Tests

The high coefficient of correlation between two variables (0.98) does not imply cointegration. According to Granger (1988), the condition for cointegration is that each of the variables should be integrated of the same order (more than zero) or that both series should contain a deterministic trend (Belloumi, 2010). Table 1 reports the results of the standard unit root tests (ADF and PP) on the integration properties of the LPCEC and LPCGDP variables for Vietnam. Because the actual values of these series exhibit trends, so all unit root test regressions include constant and trend terms. The test results suggest that none of the series are stationary at any levels and only the LPCEC series is stationary in its first difference. On the other hand, the test results seem not much different between LPCGDP and its first difference. The reason for this situation is that because the series are basically characterized by structural breaks, so the ADF and PP tests may be suspect. Therefore, we have to employ the Zivot and Andrews (1992) unit root tests.

Table 1: Unit root test results using ADF and PP

Variable	ADF		PP	
	Level	First difference	Level	First difference
LPCEC	-0.58	-5.25*	-0.60	-5.25*
LPCGDP	-2.48	-1.98	-2.51	-2.04
1% Critical value	-4.26	-4.26	-4.25	-4.25
5% Critical value	-3.55	-3.55	-3.55	-3.55
10% Critical value	-3.20	-3.20	-3.20	-3.20

Note: * indicates significance at 1% level.

The null hypothesis of the Zivot and Andrews (1992) is $\alpha = 1$, i.e., a unit root, against the alternative that the series are trend stationary process with a structural break. The estimated regressions that yield the minimum $t_{\hat{\alpha}}$ statistic with the optimum number of k regressors are presented in Table 2. As can be seen from this table, there is sufficient evidence against the unit root hypothesis for the first differenced series. In other words, the LPCEC and LPCGDP variables are now said to be individually $I(1)$.

Table 2: Unit root test results using Zivot and Andrews (1992)

Variable	ZA (1992)	
	Level	First difference
LPCEC	-3.13 (0)	-6.29*** (0)
LPCGDP	-3.01 (1)	-3.95* (0)

Note: The numbers in parentheses are the lag order. The lag parameters are selected based on the AIC. *** and * indicate significance at the 1% and 10% levels respectively.

4.2 Cointegration Tests

Applying the Engle and Granger cointegration approach discussed in Section 3.2, we obtain the results as shown in Table 3. Residuals obtained from OLS regressions between LPCEC and LPCGDP is then tested by using the ADF and PP tests. The test results indicate that there seems to be no

cointegrating relationship between the two variables. This approach, however, is very restrictive because it cannot deal properly with economic data containing the structural breaks. Therefore, it's hard to have any conclusion about the cointegration between these variables from this simplified test.

Table 3: Unit root tests for residuals (Engle and Granger) using ADF and PP

from equation	ADF	PP
LPCEC = f(LPCGDP)	-1.15	-1.31
1% Critical value	-2.63	-2.63
5% Critical value	-1.95	-1.95
10% Critical value	-1.61	-1.61

We then employ the Johansen approach for testing cointegration between LPCEC and LPCGDP. Before performing the Johansen cointegration tests, this study uses the AIC to determine the optimum lag length. As a result, the optimum lag length is 6. In these tests, we denote the number of cointegrating vectors by r_0 ; the trace test is calculated under the null hypothesis $H_0: r_0 \leq r$, and the alternate hypothesis $H_1: r_0 > r$; and the maximum eigenvalue test is calculated under the null hypothesis $H_0: r_0 = r$, and the alternate hypothesis $H_1: r_0 > r$. The test results are presented in Table 4 and Table 5. If the test statistic is greater than the critical value at a given level of significance, we reject the null hypothesis, and vice versa.

Table 4: Johansen cointegration estimation results between PCEC and PCGDP

Rank test (trace)			
<i>Model 2 (intercept (no trend) in CE, no intercept or trend in VAR)</i>			
Number of cointegration	Eigenvalue	Trace statistic	5% Critical value
None	0.554	27.13	20.27
At most 1	0.149	4.54	9.16
<i>Model 3 (intercept in CE and VAR, no trend in CE and VAR)</i>			
None	0.542	21.89	15.87
At most 1	0.000	0.017	3.84
<i>Model 4 (intercept in CE and VAR, linear trend in CE, no trend in VAR)</i>			
None	0.554	36.35	25.87
At most 1	0.388	13.73	12.52

These tests indicate clearly that all null hypotheses ($r_0 \leq 0$ for trace statistic, and $r_0 = 0$ for maximum eigenvalue statistic) are rejected at the 5% level of significance. Thus, we can reject the hypothesis of no cointegrating equation between energy consumption and economic growth at the 5% significance level. However, under the null hypothesis ($r_0 \leq 1$ for trace statistic, and $r_0 = 1$ for maximum eigenvalue statistic), both maximum eigenvalue statistic and trace statistic are below the 5% level of significance. Accordingly, energy consumption and economic growth are said to be cointegrated at 5% level of significance. As a result, there must be a long-run relationship between per capita energy consumption and economic growth for Vietnam in the sample period.

Table 5: Johansen cointegration estimation results between PCEC and PCGDP

Rank test (maximum eigenvalue)			
<i>Model 2 (intercept (no trend) in CE, no intercept or trend in VAR)</i>			
Number of cointegration	Eigenvalue	Max-Eigen statistic	5% Critical value
None	0.554	22.88	15.89
At most 1	0.149	4.54	9.16
<i>Model 3 (intercept in CE and VAR, no trend in CE and VAR)</i>			
None	0.542	21.88	14.26
At most 1	0.000	0.017	3.84
<i>Model 4 (intercept in CE and VAR, linear trend in CE, no trend in VAR)</i>			
None	0.554	22.62	19.38
At most 1	0.387	13.73	12.52

As we believe that the sample series contain structural breaks, we apply the threshold cointegration approach proposed by [Gregory and Hansen \(1996a,b\)](#) to make sure the above Johansen cointegration tests. We first estimate the regression equations (7) and (8), then obtain the residuals. We

also plot line graph and correlogram of the residuals in a priori to recognize the stationarity of the series. The results of the residual-based unit root tests presented in Table 6 indicate that there really exists a cointegrating equation between energy consumption and economic growth.

Table 6: Unit root tests for residuals (threshold cointegration) using ADF and PP

from equation	ADF	PP
LPCEC = f(DU _t , T, LPCGDP, LPCGDP*DU _t)	-4.24	-4.36
LPCGDP = f(DU _t , T, T*DU _t , LPCEC, LPCEC*DU _t)	-4.50	-3.47
1% Critical value	-2.63	-2.63
5% Critical value	-1.95	-1.95
10% Critical value	-1.61	-1.61

4.3 Granger Causality Tests

It's already known that cointegration implies the existence of Granger causality, but it does not indicate the direction of the causality relationship. According to Altinay and Karagol (2004), taking the first differences of the series with structural breaks to achieve stationarity may lead to spurious results. In this case, they suggest that stationary series can be obtained by detrending the series taking the estimated breakpoints into consideration through the following regression:

$$LPCEC_t = \mu + \delta DU_t(\tau_b) + \beta T + \alpha DT_t + \tilde{LPCEC}_t \tag{13}$$

$$LPCGDP_t = \mu + \delta DU_t(\tau_b) + \beta T + \alpha DT_t + \tilde{LPCGDP}_t \tag{14}$$

where \tilde{LPCEC}_t and \tilde{LPCGDP}_t are detrended stationary series. This alternative could be appropriate if we just consider the short-run relationship between two variables of interest. Therefore, this might not be the best choice of this empirical study. In order to investigate the direction of causality between energy consumption and economic growth for Vietnam, this section employs the VECM models because the properties of these series are completely satisfactory.

In order to specify the proper VECM models, we should now consider two important things. First, it's necessary to understand whether the first differences of the two series exhibit deterministic trend. In doing so, we simply have a look at the line graphs depicted in Figure 4. And the result is quite straightforward. Accordingly, the most specified VECM models can be written as follows:

$$\Delta LPCEC_t = \alpha_0 + \alpha_1 T + \pi_1 ECT_{1,t-1} + \sum_{i=1}^p \beta_i \Delta LPCEC_{t-i} + \sum_{j=1}^q \gamma_j \Delta LPCGDP_{t-j} + u_{1t} \tag{15}$$

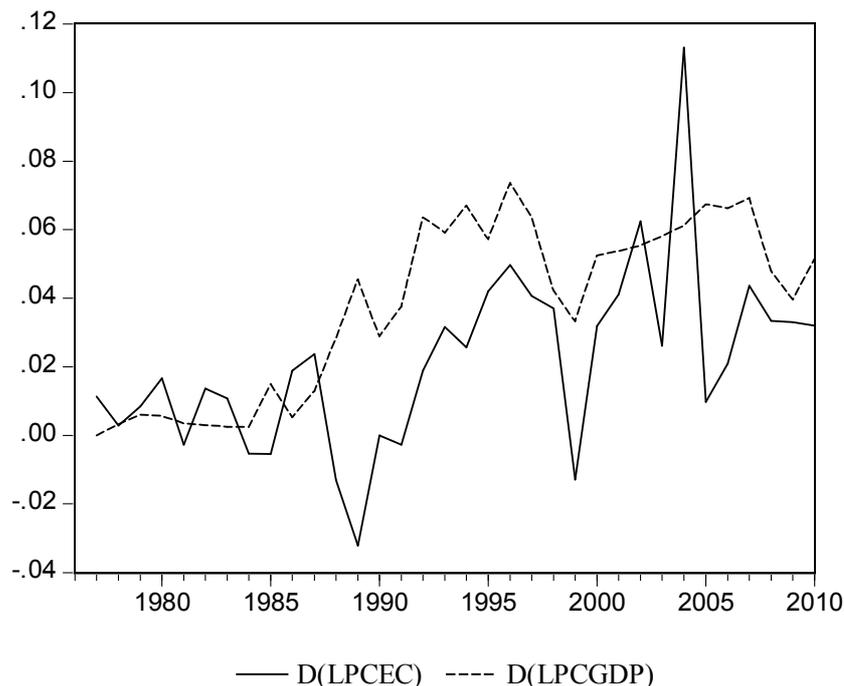
$$\Delta LPCGDP_t = \varphi_0 + \varphi_1 T + \pi_2 ECT_{2,t-1} + \sum_{i=1}^p \theta_i \Delta LPCGDP_{t-i} + \sum_{j=1}^q \delta_j \Delta LPCEC_{t-j} + u_{2t} \tag{16}$$

where $ECT_{1,t-1}$ and $ECT_{2,t-1}$ are the equilibrium error lagged one period, obtained from the threshold cointegrating equations. Since all variables are stationary, so the OLS method is reliable for estimating equations (15) and (16). The long-run effects of economic growth on energy consumption and vice versa are provided by Table 7 (cointegrating equations), and estimates for the dynamic relationship between these two variables are represented in Table 8 (VECM equations). Second, we have to specify the optimum lag length of the VAR model based on the minimum Akaike information criterion. The test result indicates that the optimum lag length of the VAR model is 1.

Table 7: Threshold cointegrating equations

Independent variable: LPCEC _t						
Variable	Intercept	DU _t	T	T·DU _t	LPCGDP	LPCGDP·DU _t
Coef.	7.624	-4.957	0.008		-0.334	0.871
t-Stat.	(12.57)	(-9.96)	(4.50)		(-2.92)	(9.75)
	R ² = 0.99		F-Stat. = 1563.64		DW = 1.41	
Independent variable: LPCGDP _t						
Variable	Intercept	DU _t	T	T·DU _t	LPCEC	LPCEC·DU _t
Coef.	13.996	-11.005	0.017	0.028	-1.482	1.770
t-Stat.	(11.56)	(-7.82)	(15.78)	(5.20)	(-7.17)	(7.06)
	R ² = 0.99		F-Stat. = 6874.53		DW = 1.20	

Figure 4: First differences of LPCEC and LPCGDP series



The estimation results of the error correction models in Table 8 indicate that the lagged error correction terms have the negative signs as expected. While the coefficient of the lagged error correction term in the LPCGDP equation is zero and insignificant, this is relatively high (-0.898, or 89.8%) and significant at the 1% level in the LPCEC equation. This significance implies that the change in logarithm of per capita energy consumption (growth rate) does rapidly respond to any deviation in the long-run equilibrium (or short-run disequilibrium) for the $t-1$ period. In other words, the effect of an instantaneous shock to per capita energy consumption will be completely adjusted in the long-run. In addition, the effect of economic growth on energy consumption seems to be time-varying. The long-run effect on energy of growth is -0.334 before the date break, 1993, while it is (-0.334+0.871) after the breakpoint. This means that economic growth has positively influenced energy consumption after 1993. This provides further evidence to believe that economic liberalization and reforms in 1989 which have helped Vietnam to achieve relatively rapid growth rates have resulted in a corresponding rapid increase in demand for energy.

Table 8: Estimation results of the error correction models

Dependent variable: $\Delta LPCEC_t$					
Variable	Intercept	T	$ECT_{1,t-1}$	$\Delta LPCEC_{t-1}$	$\Delta LPCGDP_{t-1}$
Coef.			-0.898	0.372	0.396
t-Stat.			(-3.955)	(2.254)	(3.471)
$R^2 = 0.55$			$DW = 2.05$		
Dependent variable: $\Delta LPCGDP_t$					
Variable	Intercept	T	$ECT_{2,t-1}$	$\Delta PCGDP_{t-1}$	$\Delta PCEC_{t-1}$
Coef.			-0.081	0.991	0.000
t-Stat.			(-0.056)	(14.708)	(0.000)
$R^2 = 0.793$			$DW = 2.13$		

From the above estimations, we can derive the following equations that express the long-run relationship between energy consumption and economic growth (all coefficients are statistically significant at 1% level):

$$\Delta LPCEC_t = -0.898ECT_{t-1} + 0.372\Delta LPCEC_{t-1} + 0.396\Delta LPCGDP_{t-1} + u_t \quad (17)$$

$$ECT_{t-1} = LPCEC_{t-1} - 7.624 + 4.957DU_t - 0.008T + 0.334LPCGDP_{t-1} - 0.871LPCGDP_{t-1} \cdot DU_t \quad (18)$$

$$LPCEC_t = -7.624 + 4.957DU_t + 0.0072T + 0.096LPCGDP_{t-1} + 0.782LPCGDP_{t-1} \cdot DU_t - 0.396LPCGDP_{t-2} + 0.474LPCEC_{t-1} - 0.372LPCEC_{t-2} + u_t \quad (19)$$

For 1976-1993 period:

$$LPCEC_t = -7.624 + 0.0072T + 0.096LPCGDP_{t-1} - 0.396LPCGDP_{t-2} + 0.474LPCEC_{t-1} - 0.372LPCEC_{t-2} + u_t \quad (19a)$$

For 1994-2010 period:

$$LPCEC_t = -2.667 + 0.0072T + 0.878LPCGDP_{t-1} - 0.396LPCGDP_{t-2} + 0.474LPCEC_{t-1} - 0.372LPCEC_{t-2} + u_t \quad (19b)$$

Two important observations can be made from equation (17). First, there is a short-run (week) exogeneity as shown by the significant estimate of $\Delta LPCEC_{t-1}$. Second, there is a long-run (strong) exogeneity as shown by the significant estimate of the error correction term.

From the above equations we can also realize that the per capita energy consumption in a specific year in the second period is strongly influenced by the per capita GDP and per capita energy consumption of the previous year (positive sign). It seems that per capita GDP of the previous year has a moderate effect on per capita energy consumption in the first period. The estimation results also indicate that both per capita GDP and per capita energy consumption of two years ago have a negative influence on the specific year energy consumption.

Table 9 presents the results for Granger causality tests from economic growth to energy consumption, and vice versa. It is shown that the null hypothesis that energy consumption does not Granger-cause economic growth in the short-run cannot be rejected. This frankly refuses justifications of energy-led growth hypothesis in Vietnam. Incorporating with the cointegration analysis, we can conclude that there is a strong Granger causality running from economic growth to energy consumption. This fact shows that energy consumption is determined by the economic growth in Vietnam. In other words, the conservation hypothesis is acceptable. Thus, energy conservation policy will have little effect on economic growth.

Table 9: Granger causality tests

Dependent variable		$\Delta LPCEC_t$		$\Delta LPCGDP_t$	
Causality type		Weak	Strong	Weak	Strong
Test statistic	F-Stat.	12.05 (0.0016)	21.59 (0.000)	0.000 (0.999)	0.129 (0.879)
	χ^2 -Stat.	12.05 (0.0005)	43.19 (0.000)	0.000 (0.999)	0.258 (0.878)
Excluded variables		$\Delta LPCGDP_{t-1}$	$ECT_{1,t-1}, \Delta LPCGDP_{t-1}$	$\Delta LPCEC_{t-1}$	$ECT_{2,t-1}, \Delta LPCEC_{t-1}$
Conclusion		LPCGDP causes LPCEC		LPCEC does not cause LPCGDP	

Note: Numbers in (.) are p-values.

This research finding is consistent with the empirical study of [Ozturk et al. \(2010\)](#). We approve with the way [Ozturk et al. \(2010\)](#) explain for this causality process. First, like other low income countries, the recent economic growth in Vietnam has resulted in an expansion in commercial and industrial sectors where energy is a fundamental input. Second, higher disposable income increases demand for electronic devices for entertainment and comfort for households. This is also consistent with the previous findings by [Khanh Toan, P. \(2009\)](#)¹. He stated that energy might be

¹ Khanh Toan, P., et al., (2009)

mostly allocated into the residential uses (i.e. 39% residential, 36% industry, 20% transport in 2007; and 60.3% residential, 27.3% industry, and 8.7% transport in 1990).

5. Conclusion

This article investigates the causal relationship between per capita energy consumption and per capita GDP for Vietnam during the 1976-2010 period. In doing so, various cointegration testing approaches are employed before estimating the vector error correction models. The empirical findings suggest the existence of a uni-directional causality running from per capita GDP to per capita energy consumption. In addition, it is also found that economic growth has a significant positive long-run impact on energy consumption after the pointbreak, 1992. The research results strongly support the neoclassical view that energy consumption is not a limiting factor for the Vietnam's economic growth. This in turn implies that the rise in energy prices can be a good opportunity for the economy to promote substitution and technological innovation.

From a policy perspective, the results in this study are consistent with the conservation hypothesis. Since a high level of economic growth leads to a high level of energy demand, but not vice versa, the government can pursue the conservation energy policies that aim at curtailing energy use for environmental friendly development purposes. We should gradually establish a competitive energy market in order to allocate these resources into the most productive uses in the economy.

This study just focuses on the bivariate causality tests for the aggregated energy consumption and economic growth, so it contains space for criticism. Further studies can be done by using either multivariate models for total energy use or bivariate models for disaggregated energy consumption in industrial, residential, and transport sectors.

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