Energy Consumption and Economic Growth: Evidence from Vietnam*

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Abstract

The importance of non-renewable, renewable and sustainable energy sources and energy consumption in the economic development strategy of a country is undeniable. The purpose of the paper is to investigate the impacts of energy consumption on the economic growth of Vietnam during the 1980-2014 period. By applying the Autoregressive Distributed Lag (ARDL) model of Pesaran et al. (2001), and the Granger causality test of Toda and Yamamoto (1995), the empirical results provide evidence that electricity consumption has positive impacts on Vietnam's economic growth in both the short run and long run. For public policy prescriptions, the empirical evidence suggests that an exploration of new sources of renewable and sustainable energy is essential for long run economic development.

Keywords: Energy consumption, renewable and sustainable energy, economic growth, economic development, ARDL, Granger causality.

JEL: F43, O13, O47, Q42, Q43.

1. Introduction

According to Samuelson (1948) and Rostow (1990), the prerequisites for economic development to be achieved is to be able to establish sustained economic growth in national income, namely Gross Domestic Product (GDP) or Gross National Product (GNP).. Energy, transport infrastructure, telecommunications, harbors, airports, among others, are prerequisites for the development of all production and business activities. In terms of the use of non-renewable fossil fuels, such as oil, coal and gas, as well as renewable and sustainable fuels, energy consumption plays an essential role in national development as it affects both aggregate supply and aggregate demand.

Regarding aggregate demand, energy enables consumers to enjoy numerous household utilities, such as televisions, refrigeratosr, and air conditioners, among others. In terms of aggregate supply, energy is the input of production chains: without energy, hardly any machine or chains would be able to operate. According to the International Energy Agency (IEA), the basic demand for energy of the world's population is predicted to increase consistently by 1.4% per year until 2035 in both developed and developing countries.

Kraft and Kraft (1978) is considered fundamental to the literature for discovering the empirical relationship between energy consumption and economic growth for the USA for the period 1947-1974. Over the past 40 years, this relationship has been examined in many empirical research papers internationally. However, the conclusions arising from these studies have, in general, been ambiguous, divergent and conflicting.

Generally speaking, the relationship between energy consumption and economic growth can be categorized into four testable causal hypotheses:

(i) **Consumption** hypothesis postulates that causality is uni-directional from economic growth to energy consumption;

(ii) **Growth** hypothesis assumes that energy consumption is a uni-directional factor for economic growth;

(iii) **Feedback** hypothesis emphasizes the bi-directional interdependence between energy consumption and economic growth;

(iv) **Neutrality** hypothesis assumes that there is no relationship between energy consumption and economic growth.

Given the above alternative testable hypotheses, it is obviously essential to conduct further empirical research to answer the question about the ways in which the economic growth of Vietnam might be affected by its energy consumption.

The remainder of the paper is as follows. Section 2 presents the theoretical background and a literature review, including the consumption, growth, feedback, and neutrality hypotheses. The data and research methods, including the model specification and methodology, are discussed in Section 3. The empirical results and discussion are evaluated in Section 4, including the descriptive statistics, estimated results, and causality tests. Section 5 presents some concluding comments and policy discussion.

2. Theoretical Background and Literature Review

An endogenous theory of economic growth was proposed by Romer (1990), and even earlier by Arrow (1962), to explain the economic development of a country. They argued that technology advances are a factor of economic growth. Such economic growth can be illustrated by a simple Cobb - Douglas production function, exhibiting constant returns to scale, in a general specification, as follows:

$$Y = f\,(K, L, T)$$

or in a particular specification, as follows:

$$Y = A\ K^{\alpha} L^{\beta} T^{\lambda}$$

where K denotes capital input to produce output Y, L denotes labout input, T denotes the technological level of the country for a given period, and the three exponential coefficients sum to unity.

The relationship between energy consumption and economic growth can be seen from these equations, as technology is considered to be an external factor that directly relates to energy. Almost all production and machinery chains require the provision of a particular form of energy for operatational purposes. Without energy, such as the production of electricity by renewable or non-renewable processes, or by the use of petroleum, machinery would not be able to function. Although energy might not necessarily be the deciding factor of a machine's efficiency, it is nevertheless essential for ensuring its continued usage. In this way, energy consumption contributes to the process of creating material wealth for society through economic growth.

A summary of the empirical research on the relationship between energy consumption and economic growth, according to alternative hypotheses, is as follows:

a. Consumption hypothesis

According to the Consumption hypothesis, energy consumption is affected by economic growth, so that a governmental policy limiting energy consumption has no effect on the pace of economic growth. Kraft and Kraft (1978) is considered to be the first research analysis on the relationship between energy consumption and economic growth that is favourable to this theory. Conducted for the USA during the period 1947-1974, using the Granger causality test, the authors found statistical evidence to conclude that economic growth in the USA affects energy consumption, but not the reverse.

Accordingly, the faster is economic growth, the greater will be energy consumption. In reality, the use of technical and novel machinery rather than human labour is a motivator of economic growth. Almost all kinds of machines need to be provided with a particular form of energy to operate, so that economic growth is accompanied by higher economic consumption in the following period.

Kraft and Karft's conclusion is supported by the empirical findings in Zamani (2007) for Iran; Lise and Van Montfort (2007) for Turkey; Ang (2007) for France; and Bartleet and Gounder (2010) for New Zealand, among others.

b. Growth hypothesis

It is suggested by the Growth hypothesis that economic growth is affected uni-directionally by energy consumption. As an implication, energy is a fundamental factor for any country to achieve a high and stable economic growth rate. With the vector autoregressive model, Stern (1993) examined the relationship between energy consumption and economic growth for the USA during the priod 1947-1990, and found statistical evidence to conclude that energy consumption had a positive impact on economic growth.

A similar empirical result is found in Lee and Chang (2005), using a vector error correction model, and Granger causality test for Taiwan for the period 1960-1995. The finding that energy consumption influences economic growth uni-directionally is also the conclusion of research conducted by Chandran et al. (2010) for Malaysia; Odhiambo (2009) for Tanzania; Ighodaro (2010) for Nigeria, among others.

c. Feedback hypothesis

According to the Feedback hypothesis, there is a bi-directional relationship between energy consumption and economic growth. The theory notably implies that this relationship is repetitive. It follows that energy consumption promotes economic growth, and faster economic growth will also stimulate higher energy consumption. An explanation in Apergis and Payne (2010) is that energy consumption and economic growth are dependent on the sateg of economic development in each country.

The feedback hypothesis is also supported by the empirical findings in Yu and Hwang (1984) for Taiwan; Belloumi (2009) for Tunisia; Dagher and Yacoubian (2012) for Lebanon, among others. Advocates of this theory suggest the implementation of a dual strategy, which means that economic growth should be associated with waste-of-energy limitations. Diversification of energy sources, including non-renewable fossil fuels, and energy from renewable and sustainable energy sources, and the development of new technology, are the best illustrations of effective energy cossumption and economic growth.

d. Neutrality hypothesis

The Neutrality hypothesis claims that there is no relationship between economic growth and energy consumption. This hypothesis was explained by Apergis and Payne (2009) and Shahbaz et al. (2011). Accordingly, the impacts of energy consumption on economic growth are only significant in developed and developing countries, yet are insignificant in underdeveloped countries. The reason is that, in underdeveloped countries, capital, technology, education and infrastructure, among others, are all limited. As a result, business and living conditions are mainly reliant on nature, so that the demand for energy is low.

Even if the demand for energy were high, these countries would be not be able to invest in exploration, production, operation, and large-scale distribution. Representative research focusing on this theory includes Yu and Jin (1992), Altinay and Karagol (2004), Jobert and Karanfil (2007), and Halicioglu (2007), among others.

In enalyzing the relationship between energy consumption and economic growth in Vietnam, it was concluded by Canh (2011) that economic growth stimulated electricity consumption in the long run. Using data for the period 1993-2013, by applying the Johansen cointegration technique and the Granger causality test, the conclusion in Quyet and Khanh (2014) was that electricity consumption stimulated economic growth in the short run.

To date, no research on the relationship between petroleum consumption and economic growth in Vietnam seems to have been undertaken. This gap reveals the necessity of further empirical research on the relationship between energy consumption and economic growth in Vietnam.

3. Data and Research Methods

3.1 Data and model specification

According to the endogenous growth theory of Romer (1990), the Cobb-Douglas production function is illustrated as follows:

$$Y = A\ K^{\alpha} L^{\beta} T^{\lambda}$$

where Y represents the output of GDP, A is total factor productivity, K is the input of capital, L is the input of labour, T represents the input of technology, and the exponential coefficients are assumed to sum to unity to exhibit constant returns to scale. As given in the theoretical background of the model specification, energy is an external factor, directly through the use of petroleum and indirectly through the generation of electricity, that enables technology to contribute to output.

Based on the previous research of Odhiambo (2009), Shahbaz et al. (2011) and Ibrahiem (2015), among others, the following linear regression model, expressed in terms of the logarithmic transofrmations of the variables, can be specified:

$$LnGDP_t = \beta_0 + \beta_1 LnEC_t + \beta_2 .LnPC + u_t \qquad (1)$$

where LN denotes natural logarithms, EC denotes electricity consumption, PC denotes petroleum consumption, the coefficients of which are partial production elasticities, and u is a random error term.

The data sources and variables are described in Table 2. The data are collected for the period 1980-2014, when data were available for each of the variables. In equation (1), each of the variables is transformed to logarithms to reduce any possible heteroscedasticity in the errors, as well as possible functional form misspecification bias, while preserving the deterministic trend inherent in the data.

3.2 Methodology

According to Engle and Granger (1987), the inherent time series properties of the GDP data are typically persistent, which means that the economic growth rate of the current year is affected by that of previous years. Thus, lagged values of the dependent variable, GDP, have persistent explanatory effects. This issue can become problematic if the persistence is very high, and leads to spurious inferential results, whereby the asymptotic distribution is biased, if estimation is based on the Ordinary Least Squares (OLS) technique.

Consequently, the Autoregressive Distributed Lag (ARDL) technique, as developed by Pesaran et al. (2001), is used to avoid the problems of biased inferences that would arise from the use of

OLS on the basic static models given in equation (1). The dynamic ARDL time series model is given as follows:

$$\Delta LnGDP_t = \beta_0 + \beta_1.LnGDP_{t-1} + \beta_2.LnEC_{t-1} + \beta_3.LnPC_{t-1} + + \sum_{i=1}^{m} \beta_{4i}.\Delta LnGDP_{t-i} + \sum_{i=1}^{m} \beta_{5i}.\Delta LnEC_{t-i} + \sum_{i=1}^{m} \beta_{6i}.\Delta LnPC_{t-i} + \mu_t \quad (2)$$

where:

Δ denotes the first difference in *LnGDP*,
$\beta_1, \beta_2, \beta_3$ are the regression coefficients that represent the long run equilibrium impacts,
$\beta_4, \beta_5, \beta_6$ are the regression coefficients that represent the short trun dynamic impacts,
μ_t is a random error term.

When estimating equation (2), it is necessary to conduct cointegration tests to determine whether a long run relationship exists among the variables. If there is a long run cointegrated relationship among the variables, estimation of equation (2) will be examined with the error correction model (ECM) based on the following equation:

$$\Delta LnGDP_t = \beta_0 + \alpha.ECM_{t-1} + \sum_{i=1}^{p} \lambda_{1i}.\Delta LnGDP_{t-i} + \sum_{i=1}^{q} \lambda_{2i}.\Delta LnEC_{t-i} + \sum_{i=1}^{s} \lambda_{3i}.LnPC_{t-i} + \tau_t \quad (3)$$

where p, q, s are lag lengtshs corresponding to each variable, calculated for the ARDL model using the information criteria, AIC, SC, HQ, as well as the adjusted R-squared value.

In equation (3), if there exists $\alpha \neq 0$ and the estimator of α is statistically significant, α represents the speed at which *GDP* per capita adjusts to long run equilibrium after each "shock" arising in the short run. In order for the estimated results to be robust to changes in the asusmptions underlying the model, the CUSUM (that is, the Cumulative Sum of Recursive Residuals) test and the CUSUMSQ (that is, the Cumulative Sum of Squared Recursive Residuals) test are calculated to check the stability of the long and short run estimated coefficients.

Instead of using the standard Granger causality test based on OLS estimation, the modified Wald (MWALD) test proposed by Toda and Yamamoto (1995) is used to examine the bivariate causal relationships between the variables. The Toda-Yamamoto procedure examines the levels of the variables based on the vector autoregressive model (VAR). For the three variables *LnGDP*, *LnEC* and *LnPC*, the VAR model is given as:

$$LnGDP_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} LnGDP_{t-i} + \sum_{j=k+1}^{d\max} \alpha_{21} LnGDP_{t-j} + \sum_{i=1}^{k} \delta_{1i} LnEC_{t-i} + \sum_{j=k+1}^{d\max} \delta_{2i} LnEC_{t-j}$$
$$+ \sum_{i=1}^{k} \theta_{1i} LnPC_{t-i} + \sum_{j=k+1}^{d\max} \theta_{2i} LnPC_{t-j} + \mu_{1t} \tag{4}$$

$$LnEC_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} LnEC_{t-i} + \sum_{j=k+1}^{d\max} \beta_{2i} LnEC_{t-j} + \sum_{i=1}^{k} \theta_{1i} LnPC_{t-i} + \sum_{j=k+1}^{d\max} \theta_{2i} LnPC_{t-j} +$$
$$+ \sum_{i=1}^{k} \alpha_{1i} LnGDP_{t-i} + \sum_{j=k+1}^{d\max} \alpha_{2i} LnGDP_{t-j} + \mu_{2t} \tag{5}$$

$$LnPC_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} LnPC_{t-i} + \sum_{j=k+1}^{d\max} \gamma_{2i} LnPC_{t-j} + \sum_{i=1}^{k} \delta_{1i} LnEC_{t-i} + \sum_{j=k+1}^{d\max} \delta_{2i} LnEC_{t-j} +$$
$$+ \sum_{i=1}^{k} \alpha_{1i} LnGDP_{t-i} + \sum_{j=k+1}^{d\max} \alpha_{2i} LnGDP_{t-j} + \mu_{3t} \tag{6}$$

where k is the lag length of the VAR model, which is chosen according to the AIC, SC, HQ criteria, and d_{max} is the maximum integrated order of the series, which is obtained from the tests of stationarity.

In equation (4), *LnEC* has a causal effect on *LnGDP* if $\delta_{1i} \neq 0 \ \forall \ i$, and similarly for equations (5) and (6). The Toda-Yamamoto method minimizes the risk of an inaccurate determination of the order of integration of each variable. The method can be applied whether the variable is stationary in levels, I(0), or in first differences, I(1), and regardless of whether or not cointegration exists (Mavrotas and Kelly, 2001).

4 Empirical Results and Discussion

4.1

4.2 Descriptive statistics

The transition in thinking and planning in terms of the underlying administration and implementation of economic policies promoting Vietnam's economic growth have significantly increased income per capita. In 2014, income per capita of Vietnam was USD 2,012.05 (in constant 2010 prices). Meanwhile, the pressure from energy consumption is also persistently high. Total electricity consumption of Vietnam in 2015 was 140.72 billion kWh. Petroleum consumption has risen from 53,808 to 825,054 barrels/day. The descriptive statistics of the variables are given in Table 3.

4.3 Empirical results

4.2.1 Stationarity tests

The stationarity property of all the variables is examined to avoid the potential problem of spurious regression. Three common methods of examining stationarity, namely the augmented Dickey and Fuller (1981) (ADF) test, the Phillips and Perron (1988) (PP) test, and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test, are used to ensure that the estimated results avoid the problem of spurious inferences. The estimated results in Table 4 reveal that, according to the ADF, PP and KPSS tests, all the variables are stationary at the I(1) level. Therefore, the conditions for using the Autoregressive Distributed Lag (ARDL) model of Pesaran et al. (2001) are satisfied.

4.2.2 Determination of optimal lag length

In the ARDL model, the determination of the optimal lag length is crucial. For this purpose, the number of previous periods in which economic growth influences current economic growth can be determined. With an initial lag length of 4, the ARDL model automatically calculates the optimal lag lengths. The results of calculating the lag lengths are shown in Table 5. According to the results in Table 5, based on all three criteria, AIC, SC and HC, the optimal lag length of the model is 1. As all the variables are stationary at I(1), according to AIC, SC and HC, the optimal ARDL model for the data is ARDL(2,0,0) such that, in equation (2), $p = 2$ and $q = s = 0$.

4.2.3 Bounds test

According to the examination of the cointegration property for time series data developed in Engle and Granger (1987), there may be long run cointegration among the variables. The technique to examine cointegration in the ARDL model of Pesaran et al. (2001) is called the Bounsd test. Table 6 shows that the F statistic of 10.62 exceeds the upper bound for I(1) = 5 at the 1% significance level. The results of the bounds test show that there exists long run cointegration for the three variables, *LnGDP, LnEC* and *LnPC*. Therefore, equation (2) should be estimated using the error correction model.

4.2.4 Error Correction model

There is long run cointegration among the variables in the model, so that equation (2) is estimated with the error correction model to determine the impact coefficients in the short run. The estimated results of the short run impacts of energy consumption on economic growth are shown in Table 7.

The estimated results show that $\alpha = -0.3656$ at the 1% significance level, which implies that *GDP* per capita is able to adjust to the long run equilibrium after each short run shock that is created by energy consumption, with the time needed for adjustment being approximately 3 years ($= 1/|\alpha|$). The coefficients of *LnEC* are positive at a significance level of 1%, implying that, in the short run, promoting electricity consumption has positive impacts on economic growth. *LnPC* also has a positive effect, though it is not statistically significant. Therefore, there is insufficient evidence to determine that petroleum consumption contributes to promoting *GDP* per capita in the short run.

4.2.5 Stability test

The stability of equation (2) can be deteremined on the basis of the Cumulative Sum of Recursive Residuals (CUSUM) and the Cumulative Sum of Squared Recursive Residuals (CUSUMSQ) tests. Figure 1 shows that both the CUSUM and CUSUMSQ lines (solid lines) for equation (2) are within the critical bounds at a significance level of 5% (dashed lines). Therefore, it can be concluded that equation (2) is stable, and that the estimated results are reliable for further analysis and prediction.

4.2.6 Estimated results of long run impacts

In order to identify the "*direction of impacts*" and the "*level of impacts*" of energy consumption on the economic growth of Vietnam during the period 1980-2014, the long run impacts are calculated. The estimated results in Table 8 show that *LnEC* has a positive impact, at a significance level of 1%, on economic growth. If the other conditions remain unchanged, a 1% increase in electricity energy consumption would lead to a 0.667% increase in economic growth, on average. *LnPC* has a positive effect, though it is statistically insignificant, on average. Therefore, there is not sufficient evidence to deteremine the impact of petroleum consumption on economic growth.

The paper also examines the bivariate causal relationships between the variables using the Toda-Yamamoto method, with the null hypothesis being no Granger causality. According to the test results in Table 9, *LnEC* does not Granger cause *LnGDP*, with p-value = 0.0197 < 0.05, and *LnGDP* does not Granger cause *LnEC*, with p-value = 0.0963 > 0.05. Therefore, the null hypothesis is rejected in each case *LnEC* has a one-way (uni-directional) Granger causal relationship with *LnGDP*. With the same reasoning applied to the other variables, the results of the Granger causality tests between pairs of *LnGDP, LnEC* and *LnPC* are illustrated in Table 2 and Figure 2.

The empirical results of these relationships are in general agreement with the conclusions of other research for countries and regions with similar starting points and conditions as for Vietnam (see, for example, Tang (2009) for Malaysia for the period 1970-2005, Abdullah (2013) for India for the period 1975-2008, Odhiambo (2009) for Tanzania for the period 1971-2006, and Ibrahiem (2015) for Egypt, among others.

These estimated results are consistent with what is observed in the real worldy. According to the International Energy Agency (IEA), energy consumption is expected to increase consistently over time for developing countries with large population, such as China, India, Brazil and Vietnam. The research of Long et al. (2018), in which gross national income (GNI) was used as the variable representing economic growth, leads to a similar conclusion. Accordingly, electricity energy consumption has, in general, a positive influence in improving GNI per capita in both the long and short run.

However, the results of the present paper are different from the conclusions in Canh (2011), and Quyet and Khanh (2014). In order to explain this discrepancy, the paper gives the following two reasons:

(i) The first explanation is due to the choice of variables. In the pesent paper, energy consumption is represented by both electricity and petroleum consumption while, in the research of Canh (2011) and Quyet and Khanh (2014), only electricity consumption was used to capture the effects of energy inputs to explain economic growth.

(ii) The second explanation is due to the outcome of the Granger causality test. The present paper uses the robust method of Toda and Yamamoto (1995), while Canh (2011) and Quyet and Khanh (2014) used the method of Engle and Granger (1987). The advantages of the Toda-Yamamoto method have already been discussed in previous sections.

5 Concluding Remarks and Policy Implications

The primary purpose of the paper was to examine the effects of energy consumption, namely the use of non-renewable fossil fuels such as oil, coal and gas, as well as renewable and sustainable fuels, on economic growth. Using data for Vietnam for the period 1980-2014, and based on the estimated Autoregressive Distributed Lag model of Pesaran et al. (2001), and the robust Granger causality test of Toda and Yamamoto (1995), the empirical results in the paper demonstrated the following major points:

(i) There is significant statistical evidence that electricity consumption has positive impacts on the GDP per capita in both the short run and long run.

(ii) There is not sufficient evidence to conclude that economic growth is affected by petroleum and other fossil fuel consumption.

(iii) There is a one-way (uni-directional) Granger causal relationship between energy consumption (that is, electricity and petroleum) and GDP, thereby supporting the Growth hypothesis.

The empirical results also suggest the following public policy implications:

(iv) The national energy development strategy should be completed quickly, and include a pre-specified rate of energy increase that corresponds to the economic growth rate in Vietnam.

(v) A deficiency in energy development will result in a reduction in economic growth, thereby having a negative impact in attracting foreign direct investment to Vietnam.

(vi) Electricity consumption significantly bolsters economic growth in Vietnam, but this does not necessarily mean that there should be an increase in the construction of power plants.

(vii) In addition to investing in new sources of renewable and sustainable energy, Vietnam should focus on raising the awareness of individuals and companies on energy saving.

(viii) Switching to renewable and sustainable energy efficient appliances, as well as intelligent equipment (such as automatic on/off processes), is also a method for improving renewable and sustainable national energy production in Vietnam.

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Table 1

Empirical Research on the Relationship between Energy Consumption (EC) and Economic Growth (Y)

No.	Authors	Countries	Methodology	Conclusions			
				EC→Y	Y→EC	EC↔Y	EC ≠ Y
1	(Ramcharran, 1990)	Jamaica	Granger causality	x			
2	(Altinay, Karagol, 2004)	Turkey	Granger causality	x			
3	(Ho, Siu, 2007)	HongKong	Cointegration, ECM Granger causality	x			
4	(Wang, Wang, Zhou, Zhu, Lu, 2011)	China	Johansen cointegration, VECM	x			
5	(Lee, Chang, 2005)	Taiwan	Granger causality, VECM	x			
6	(Bowden, Payne, 2009)	USA	Toda- Yamamoto causality test	x			
7	(Wang et al., 2011)	China	Cointegration, ARDL	x			
8	(Odhiambo, 2009)	Tanzania	ARDL, Granger causality, VECM	x			
9	(Akinlo, 2009)	Nigeria	Johansen, VECM	x			
10	(Salahuddin, Alam, Ozturk, Sohag, 2018)	Banglades h	Johansen, VECM	x			
11	(Abosedra, Dah, Ghosh, 2009)	USA	Cointegration, Granger causality		x		
12	(Cheng, Lai, 1997)	Taiwan	Granger causality		x		
13	(Zamani, 2007)	Iran	Granger causality, VECM		x		
14	(Yoo, Kim, 2006)	Indonesia	Granger causality, VAR		x		
15	(Narayan, Smyth, 2005)	Autralia	Granger causality		x		

16	(Hu, Lin, 2008)	Taiwan	Threshold cointegration, VECM		x		
17	(Shahbaz, Feridun, 2012)	Pakistan	ARDL bound test		x		
18	(Lise, Van Montfort, 2007)	Turkey	Cointegration		x		
19	(Yang, 2000)	Taiwan	Hsiao's Granger causality			x	
20	(Jumbe, 2004)	Malawi	Granger causality, ECM			x	
21	(Yoo, 2005)	Korea	ECM			x	
22	(Zachariadis, Pashourtidou, 2007)	Cyprus	Cointegration, VECM			x	
23	(Shahbaz et al., 2011)	Portugal	ARDL, Granger causality			x	
24	(Lorde, Waithe, Francis, 2010)	Barbados	VAR, Granger causality			x	
25	(Shahbaz, Lean, 2012)	Pakistan	Conintegration, Granger causality			x	
26	(Oh, Lee, 2004)	Korea	Conintegration, Granger causality			x	
27	(Erdal et al., 2008)	Turkey	Johansen cointegration, Granger causality			x	
28	(Belloumi, 2009)	Tunisia	Granger causality, VECM			x	
29	(Yu, Hwang, 1984)	USA	Sim's technique				x
30	(Yu, Jin, 1992)	USA	Conintegration, Granger causality				x
31	(Cheng, Lai, 1997)	Taiwan	Granger causality				x
32	(Altinay, Karagol, 2004)	Turkey	ECM				x
33	(Jobert, Karanfil, 2007)	Turkey	Granger causality				x
34	(Payne, 2009)	USA	Toda- Yamamoto causality test				x
35	(Soytas, Sari, 2009)	Turkey	Toda- Yamamoto causality test				x

Table 2

Data Sources and Variables

Variable	Meaning	Units	Expected impact	Data source
LnGDP	Gross Domestic Product per capita (at constant 2010 prices).	USD/person	Dependent variable	UNCTAD
LnEC	Total electricity consumption	Billion kWh	+	IEA
LnPC	Total petroleum consumption	Thousand barrels/day	+	IEA

Table 3

Descriptive Statistics

Variables	Mean	Max	Min	Std Error
LnGDP	5.63	7.61	3.52	1.22
LnEC	2.80	4.81	1.19	1.21
LnPC	12.38	13.78	10.89	0.99

Table 4

Stationarity Test Results

Variables	ADF	PP	KPSS
LnGDP	-4.001**	-2.927	0.047
ΔLnGDP	-4.369***	-5.035***	0.221***
LnEC	-0.537	-3.140	0.173**
ΔLnEC	-2.757*	-2.703*	0.189**
LnPC	-0.496	-0.977	0.145*
ΔLnEC	-5.028***	-5.046***	0.167**

Note: ***, ** and * denote significance at 1%, 5% and 10%, respectively.

Table 5

Determining the Optimal Lag Length

Lags	AIC	SC	HQ
0	1.6272	1.7646	1.6727
1	-8.0543*	-7.5046*	-7.8721*
2	-7.9071	-6.9452	-7.5883

Note: AIC is the Akaike Information Criteriosn, SC is the Schwartz Bayesial Information Criterion, and HQ is the Hannan-Quinn Information Criterion. # denotes the lowest values of the respective criteria.

Table 6

Results of Cointegration Test

F bounds test for equation (2)		Null Hypothesis: No levels relationship		
Test Statistic	**Value**	**%**	**I(0)**	**I(1)**
F statistic	10.62459	10%	2.63	3.35
k	1	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

Table 7

Estimation of Error Correction Model (ECM)

Variables	Coefficient	Std Error	t-statistic	P-value
Intercept	-0.1252	0.8167	-0.1533	0.8793
ECM(-1)	-0.3656	0.0533	-6.8594	0.0000
ΔLnGDP(-1)	0.4751	0.0851	5.5842	0.0000
LnEC	0.2441	0.0828	2.9464	0.0064
LnPC	0.1239	0.0877	1.4131	0.1687

Table 8

Estimated Long Run Impacts

Variables	Coefficient	Std Error	t-statistic	P-value
LnEC	0.6676	0.1747	3.8201***	0.0007
LnPC	0.3391	0.2171	1.5621	0.1295
Intercept	-0.3424	2.2201	-0.1542	0.8786

Note: *EC* = *LnGDP* - (0.6676**LnEC* + 0.3391**LnPC* – 0.3424).
*** denotes significance at the 1% level.

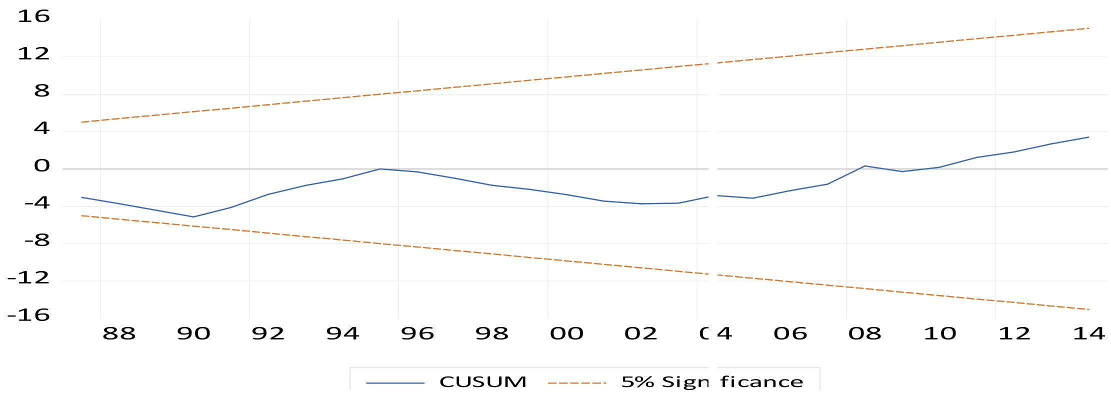
Table 9

Granger Bivariate Causality Test using the Toda-Yamamoto Method

Null hypothesis	Chi-square	P-value
LnEC does not have a causal effect on *LnGDP*	13.42032	0.0197
LnGDP does not have a causal effect on *LnEC*	9.338375	0.0963
LnPC does not have a causal effect on *LnGDP*	16.71394	0.0051
LnGDP does not have a causal effect on *LnPC*	6.963048	0.2234
LnPC does not have a causal effect on *LnEC*	10.13231	0.0716
LnEC does not have a causal effect on *LnPC*	2.933227	0.7103

Figure 1

Results of CUSUM and CUSUMSQ Stability Tests



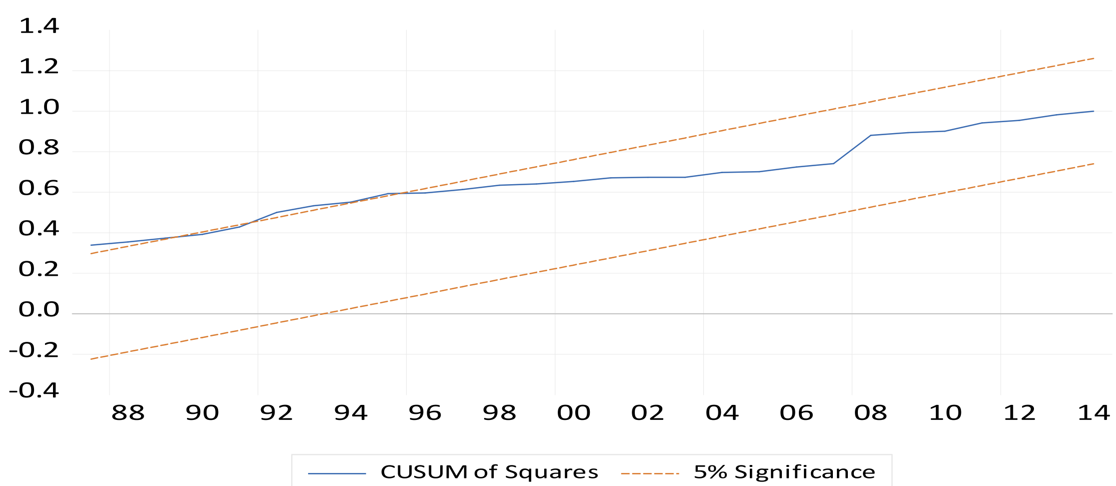
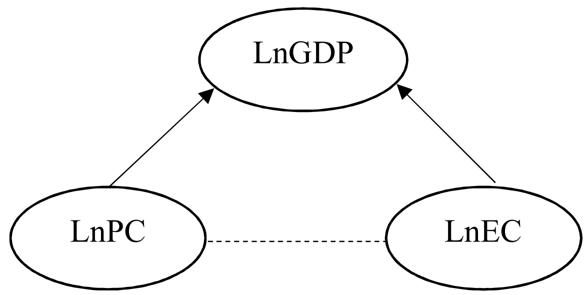


Figure 2

Granger Causal Relationships using the Toda-Yamamoto Method



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