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The Causal Relationship between Electric Power Consumption and Economic Growth in Malaysia and Thailand: ARDL Bound Testing Approach

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Abstract: The energy-growth nexus economics is a field that attracts significant research attention because of the critical information it provides to policymakers who consider energy management measures. This paper investigated the causal relationships between per capita electric power consumption and economic growth per capita in Malaysia and Thailand. Furthermore, it suggested policymakers regarding the formulation of electricity in Malaysia and Thailand. The data used in this study was the yearly data from 1971 to 2014. The ARDL and Granger causality approaches were employed. Overall, the empirical results showed that it had established a long-run relationship between electric power consumption and economic growth. Moreover, the Granger causality approach recognized a one-way causal direction flowing from economic growth to electric power consumption in Malaysia. However, for Thailand, empirical results had no long-run relationship between electric power consumption and economic growth. Therefore, the Granger causality approach had recognized no way of causal direction flowing from electric power consumption to economic growth. Finally, the empirical results of this study provided policymakers a better understanding of the nexus to formulate energy policy in Malaysia and Thailand. In addition, the governments of Malaysia should consider the economic situation when implementing the relevant energy policies.

Keywords: electric power consumption, economic growth, autoregressive distributed lag, Granger causality approach.

馬來西亞和泰國電力消耗與經濟增長的因果關係：急性呼吸障碍邊界測試方法

摘要: 能源增長關係經濟學是一個吸引大量研究關注的領域，因為它為考慮能源管理措施的決策者提供了關鍵信息。本文研究了馬來西亞和泰國人均電力消費量與人均經濟增長之間的因果關係。此外，它就馬來西亞和泰國的電力製定向政策制定者提出了建議。本研究使用的數據為 1971 年至 2014 年的年度數據。採用了急性呼吸障碍 和格蘭傑因果關係方法。總體而言，實證結果表明，電力消費與經濟增長之間建立了長期關係。此外，格蘭傑因果關係方法認識到馬來西亞從經濟增長到電力消耗的單向因果方向。然而，對於泰國而言，實證結果與電力消費與經濟增長之間沒有長期關係。因此，格蘭傑因果關係方法沒有認識到從電力消費到經濟增長的因果方向流動的方式。最後，本研究的實證結果讓政策制定者更好地了解馬來西亞和泰國製定能源政策的關係。此外，馬來西亞政府在實施相關能源政策時應考慮經濟形勢。

关键词： 电力消耗、经济增长、自回归分布滞后、格兰杰因果关系法。

1. Introduction

Energy consumption and economic growth have become essential research topics in recent years. International Energy Agency (IEA) has predicted that energy consumption will increase 53% by 2030, and 70% of the growth will happen in developing countries such as ASEAN countries [1]. Therefore, in this study,

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we will focus on ASEAN countries such as Malaysia and Thailand.

In recent years, energy consumption in Malaysia has seen a 20.7% contribution from the residential sector [2]. The average electricity consumption for residential was 345 kWh per month based on the survey of 348 samples in Malaysia [3]. The electricity consumption for residential in Malaysia is expected to rise due to increasing appliance ownership, economic improvement, and changing lifestyle [4].

For Thailand, the residential sector consumed the electricity about 23.01% of the total electricity consumption of Thailand in 2017 [5]. It increases continuously due to a growing economy. As a result, the electricity demand growth rate was 5.20% per year, rising from 32,799.46 GWh in 2011 to 44,373.96 GWh in 2017 [6].

However, it is a fact that both countries have energy consumption at the top rank in ASEAN countries, so we want to know the relationship between electric power consumption and economic growth. Therefore, policymakers need to take action for electrical power management, which is becoming more and more critical every day and affects the economy and environmental preservation.

2. Literature Review

For this section, there are four types of causal relationships between electric power consumption and economic growth that various authors have revealed:

(1) Unidirectional causality runs from electric power consumption to economic growth

(2) Unidirectional causality runs from economic growth to electric power consumption

(3) Bi-directional causality exists between electric power consumption to economic growth

(4) No causality exists between electric power consumption to economic growth

Table 1-3 summarizes the literature on the various hypotheses or relationships established between electric power consumption and economic growth in the present study. The authors have used several methodologies such as Co-integration, Vector Error Correction (VECM), Vector Autoregressive (VAR), the ARDL approach, and Granger causality.

Table 1 offers a sequential view of an empirical study that declares way causal route from electric power consumption to economic growth. Table 2 summarizes literature that proved way causal route from electric power consumption to economic growth. Finally, Table 3 presents the bi-directional causality between electric power consumption to economic growth.

Table 1 Empirical literature that declares one-way causal route from electric power consumption to economic growth

Countries	**Authors**	**Methodology**
Fuji Island (1971-2002)	[7]	Co-integration, Granger causality approach
Malaysia (1972-2003)	[8]	ARDL bound test
Ghana (1971-2008)	[9]	Granger causality test and ARDL approach
Russia (1990-2017)	[10]	Co-integration, VECM, and Granger causality test
Indonesia and Thailand (1971-2014)	[11]	Co-integration and VECM

Table 2 Empirical literature that declares one-way causal route from economic growth to electric power consumption

Countries	**Authors**	**Methodology**
Nepal (1980-2006)	[12]	Co-integration and Granger causality approach
Turkey (1945-2006)	[13]	VAR and Granger causality approach
India (1974-2014)	[14]	Co-integration and Granger causality approach

Table 3 Empirical literature that declares bi-directional causality among electric power consumption to economic growth

Countries	**Authors**	**Methodology**
Portugal (1971-2009)	[15]	VECM and ARDL bound test
Mauritius (1970-2009)	[16]	ARDL approach and VECM
Portugal (1970-2005)	[17]	VECM and co-integration
Nigeria (1970-2012)	[18]	ECM approach
South Africa (1983-2016)	[19]	Co-integration and Granger causality test

3. Rationale and Scope of the Study

Since 1971, there has been a growth in electricity demand in Malaysia and Thailand (as shown in Figure 1 and Figure 2). An increase in electricity consumption indicates an expansion of production activities and improvement in the living standard of citizens, which may reflect the advancement of an economy. However, it is not clear that the growth in electricity consumption is the critical factor for economic development in Malaysia and Thailand. The former paper has not been studied enough to testify the causality between these two variables in the evidence of Malaysia and Thailand. Therefore, this study explores the existence and route of the causal relationship between electric power consumption and economic growth in Malaysia and Thailand. Identification of the existence and direction of the causal relation between electric power consumption and economic growth may support policymakers in determining the steps to be taken towards the beginning and implementation of various electricity policies in Malaysia and Thailand.

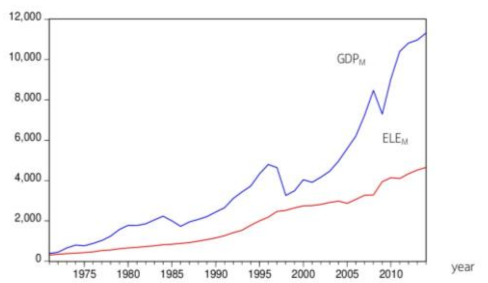

Fig. 1 Relationship between per capita electric power consumption and per capita GDP of Malaysia

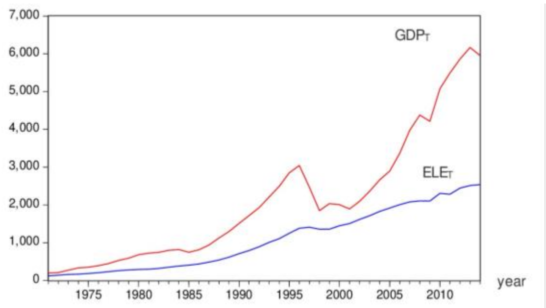

Fig. 2 Relationship between per capita electricity consumption and per capita GDP of Thailand

4. Objectives

The study detailed here is pursuing the following objectives:

1. To examine the existence and direction of the causal relationships between per capita electric power consumption and "per capita" economic growth in Malaysia and Thailand.

2. To suggest policymakers regarding the formulation of electricity in Malaysia and Thailand.

5. Data and Research methodology

5.1. Data Collection and Variables

We have used yearly data of ELE and GDP of two ASEAN countries from 1971-2014, such as Malaysia and Thailand. The data are graphically represented in Figure 1 and Figure 2. The World Bank Indicator has been the source of data for both study variables. Data on the gross domestic product (GDP) per capita is measured in the current US dollar, and electric power consumption per capita is measured in kWh. Thus, GDP and ELE have been used as a variable of economic growth and used as a variable of electric power consumption.

5.2. Research Methodology

5.2.1. Model Specification

For testing whether economic growth causes electric power consumption or not, the following simple model was used:

$$Y_t = \alpha + \beta X + \mu_t$$

However, in this study, we rely upon two ASEAN countries such as Malaysia and Thailand. Therefore, we can write this model again as follows:

$$GDP\_M=\alpha\_M+\beta ELE\_M+\mu\_tM \quad (1)$$

$$GDP\_T=\alpha\_T+\beta ELE\_T+\mu\_tT \quad (2)$$

where GDPM - GDP per capita (Current US$) of Malaysia

ELEM - Per capita electric power consumption (kWh) of Malaysia

GDPT - GDP per capita (Current US$) of Thailand

ELET - Per capita electric power consumption (kWh) of Thailand

αM and αT - constant

µtM and µtT - error term

t - time trend

We assume that electric power consumption and economic growth have a relationship and cause to each other. The long run and causal relationships between the electric power consumption per capita and GDP per capita will be performed in two steps.

Firstly, we will test the long-run relationships among the variables by using the ARDL bounds testing approach of co-integration.

Secondly, we will try causal relationships by using the error-correction-based causality models.

5.2.2 Autoregressive Distributed Lag (ARDL) Co-Integration Analysis

The ARDL approach to co-integration was developed by [20, 21]. The ARDL co-integration approach has more advantages in comparison with co-integration methods such as [22] and procedures [23]:

1. The ARDL approach can be applied whether the regressors are I(1) or I(0), while Johansen co-integration techniques require that all the variables be of equal order of integration. This means that the ARDL can be applied, and no need for unit root testing.

2. While the Johansen co-integration techniques require large data samples for validity, the ARDL approach is a statistically more significant approach to determine the co-integration relation in small samples.

3. The ARDL approach allows the variables to have different optimal lags, while it is impossible with co-integration approaches.

4. The ARDL approach employs only a single reduction from the equation, while the co-integration approaches estimate the long-run relationships within system equations.

The ARDL model for log-linear functional specification of the long-run relationship between per capita electric power consumption and GDP per capita may follow as:

$$\Delta \ln GDP_t = \alpha + \sum_{i=1}^{k} \emptyset_i \Delta \ln GDP_{t-i} + \sum_{j=0}^{t} \beta_j \Delta \ln ELE_{t-j} + \delta_1 \ln GDP_{t-1} + \ln ELE_{t-1} + \vartheta_t \quad (3)$$

where ϑ_t and Δ are the white noise term and the first difference operator, respectively. An appropriate lag selection is based on a criterion such as the Akaike information criterion (AIC). The bounds testing procedure based on the joint F-statistic that is tested the null of no co-integration:

H0: $\delta_r = 0$

H1: $\delta_r \neq 0$, r = 1, 2,….

Two sets of critical values are generated; the upper bound critical values refer to the I(1) series and the lower bound critical values to the I(0) series. If the calculated F-statistic lies above the upper level of the band, the null hypothesis is rejected, indicating there are long-run relationships that exist (co-integration). On the other hand, if the calculated F-statistic is below the critical value, we cannot reject the null hypothesis of no co-integration, indicating no long-run relationships exist.

If there is co-integration between the variables, Equation 4 presents the long-run models, and Equation 5 shows the short-run models:

$$\mathrm{lnGDP_t} = \alpha + \sum_{i=1}^{m} \emptyset_i \mathrm{lnGDP_{t-i}} + \sum_{j=0}^{n} \beta_j \mathrm{lnELE_{t-j}} + \mu_t \quad (4)$$

$$\Delta\mathrm{lnGDP_t} = \alpha + \sum_{i=1}^{k} \emptyset_i \Delta\mathrm{lnGDP_{t-i}} + \sum_{j=0}^{t} \beta_j \Delta\mathrm{lnELE_{t-j}} + \sigma \mathrm{ECT_{t-1}} + \varepsilon_t \quad (5)$$

where σ is the coefficient of error correction term, it shows how quickly variables coverage to equilibrium, and it should have a statistically significant coefficient with a negative sign.

5.2.3 Causality Analysis

ARDL co-integration method tests whether the existence or absence of a long-run relationship between the electric power consumption per capita and GDP per capita. However, it does not indicate the direction of causality. Once the estimating the long-run model in Equation 4 to obtain the estimated residuals, the next step is to estimate a Vector Error Correction Model (VECM), with the variables in first differences and including the long-run relationships as error correction term in the system. Therefore, the following VECM is estimated to investigate the Granger causality between the variables:

$$\Delta\mathrm{lnGDP_t} = \alpha_1 + \sum_{i=1}^{k} \emptyset_i \Delta\mathrm{lnGDP_{t-i}} + \sum_{j=0}^{t} \beta_j \Delta\mathrm{lnELE_{t-j}} + \sigma_1 \mathrm{ECT_{t-1}} + \varepsilon_{1t} \quad (6)$$

$$\Delta\mathrm{lnELE_t} = \alpha_2 + \sum_{i=1}^{k} \gamma_i \Delta\mathrm{lnGDP_{t-i}} + \sum_{j=0}^{t} \delta_j \Delta\mathrm{lnELE_{t-j}} + \sigma_2 \mathrm{ECT_{t-1}} + \varepsilon_{2t} \quad (7)$$

Residual terms ε_{1t} and ε_{2t} are independently and normally distributed with zero mean and constant variance. Thus, an appropriate lag is based on a criterion such as AIC. Rejecting the null hypotheses indicates that lnELE does Granger cause lnGDP, and lnGDP does Granger cause lnELE, respectively.

For Equation 6 and 7, Granger causality can be examined in two ways:

First, short-run Granger causalities are detected by testing H0: $\beta_j = 0$ and H0: $\gamma_j = 0$ for all j in Equation 6 and 7, respectively.

Second, another possible source of causation is the ECT's in equations. The coefficients on the ECT's represent how fast deviations from the long-run equilibrium are eliminated following changes in each variable. Therefore, long-run causalities are examined by testing H0: $\sigma_1 = 0$ and H0: $\sigma_2 = 0$ for Equations 6 and 7, respectively.

6. Empirical Analysis and Results

This study investigates the long run and causal relationships between per capita electric power consumption and GDP per capita in Malaysia and Thailand from 1971 to 2014 by employing electric power consumption per capita and GDP per capita variables. To examine this linkage, we use the two-step procedure from the Engle and Granger model:

(1) We explore the long-run relationships between the variables using the recently developed ARDL bounds testing co-integration approach.

(2) We employ the VECM to test causal relationships between variables.

According to Pesaran and Shin, this the study used the AIC to select an appropriate lag for the ARDL model. Table 4 presents the estimated ARDL model that has passed several diagnostic tests that indicate no serial correlation and heteroscedasticity.

Table 4 Estimated ARDL models and bound F-test for co-integration

Countries	**Models**	**F**	**LM**	**HT**
Malaysia	ARDL (1,0)	9.7460	1.3050 (0.2511)	0.0998 (0.8987)
Thailand	ARDL (4,2)	2.1309	1.0237 (0.2786)	1.7625 (0.1330)
Critical values		I(0)		I(1)
Critical values at 1%		4.94		5.58
Critical values at 2.5%		4.18		4.79
Critical values at 5%		3.62		4.16
Critical values at 10%		3.02		3.51

Notes: F is the ARDL co-integration test. The critical values for the lower I(0) and upper I(1) bounds are taken from Narayan [24].
LM is the Lagrange multiplier test for serial correlation with a γ^2 distribution with two degrees of freedom.
HT is the Heteroskedasticity test with a γ^2 distribution.

In addition, due to the structural changes in the economies of these countries, macroeconomic series may likely be subject to one or multiple structural breaks. For this purpose, the stability of the short-run and long-run coefficients is checked through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) test proposed by Brown et al. (1975) [25]. Figures 3 and 4 present the CUSUM and CUSUMSQ test statistics for Malaysia and Thailand that fall inside the critical bounds of 5% significance. This implies that the estimated parameters are stable throughout 1971-2014.

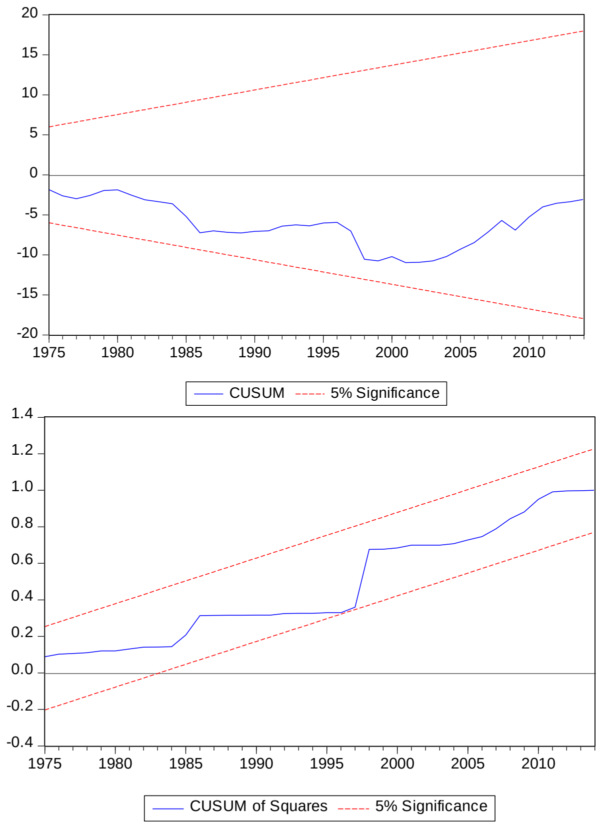

Fig. 3 Stability tests for Malaysia

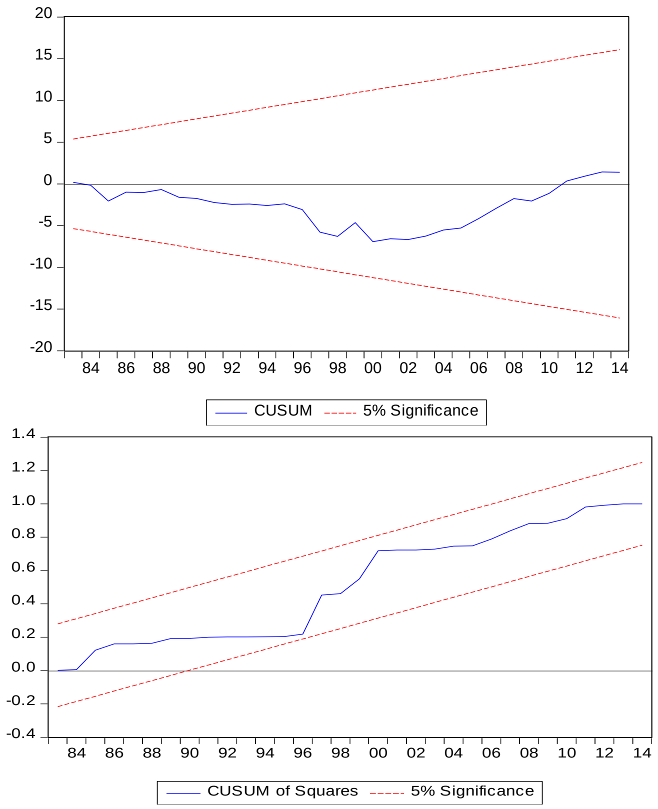

Fig. 4 Stability tests for Thailand

The ARDL bound test results show a unique long-run relationship between electric power consumption per capita and GDP per capita in Malaysia at a 10% significance level. In other words, there is a co-integration between electric power consumption per capita and GDP per capita in Malaysia. On the other hand, there is no unique long-run relationship between electric power consumption per capita and GDP per capita in Thailand at a 10% significance level. In other words, there is no co-integration between electric power consumption per capita and GDP per capita in Thailand (see Table 4). Therefore, the econometric analysis suggests that any causal relationships within VECM for Malaysia can be estimated.

The existence of a co-integration relationship among electric power consumption per capita and GDP per capita in Malaysia suggests that there must be Granger causality in at least one direction. This study found evidence of a one-way (unidirectional) long-run Granger causality between GDP per capita and electric power consumption per capita only in Malaysia (see Table 5). However, there is no short-run Granger causality in Malaysia. Moreover, for Thailand (see Table 6), we found no short-run and long run Granger causality between these variables.

Table 5 Granger causality tests for Malaysia

The null hypotheses	**Chi-square (p-value)**
Short-run Granger causality	
ΔlnELEM → ΔlnGDPM	0.4766(0.4900)
ΔlnGDPM →ΔlnELEM	2.2644(0.1324)
Long-run Granger causality	
lnELEM → lnGDPM	1.6584(0.1978)
lnGDPM → lnELEM	2.9984(0.0833)*

Note: * is significant at 10% level.

Table 6 Granger causality tests for Thailand

The null hypotheses	**Chi-square (p-value)**
Short-run Granger causality	
ΔlnELET → ΔlnGDPT	0.1522(0.9267)
ΔlnGDPT →ΔlnELET	0.4289(0.8070)
Long-run Granger causality	
lnELET → lnGDPT	0.1348(0.9348)
lnGDPT → lnELET	3.6909(0.1580)

7. Conclusion

The energy-growth nexus economics is a field that attracts significant research attention because of the critical information it provides to policymakers who consider energy management measures.

The paper searches the nexus between electricity consumption and economic growth for Malaysia and Thailand from 1971-2014. We use the Engle and Granger model [25] to examine this linkage: Firstly, we explore the long-run relationship between two variables using the co-integration ARDL bounds testing approach. Secondly, we employ VECM to test the causal relationships between the variables.

All results suggest that there is long-run Granger causality between electricity consumption and economic growth:

(1) There is a long-run relationship (co-integration) between economic growth and electric power consumption. However, evidence of one-way (unidirectional) long run Granger causality between these variables is found only in Malaysia.

(2) There is no unique long-run relationship between electric power consumption and economic growth in Thailand.

(3) Any causal relationships within VECM for Thailand cannot be estimated.

The empirical results of this study provide policymakers a better understanding of energy consumption and economic growth nexus to formulate energy policy in Malaysia and Thailand. In addition, the governments of Malaysia should consider the economic situation when implementing the relevant energy policies.

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