



# The Causal Relationship among CO<sub>2</sub> Emission, Oil Consumption and Economic Growth in Thailand: ARDL Bound Testing Approach

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## ABSTRACT

This paper examined the causal relationships among CO<sub>2</sub> emission, oil consumption, and economic growth in 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 among CO<sub>2</sub> emission, oil consumption, and economic growth. Moreover, there is a one-way (unidirectional) short-run Granger causality between oil consumption and CO<sub>2</sub> emission. In addition, there is a one-way (unidirectional) long-run Granger causality between oil consumption and CO<sub>2</sub> emission and a one-way long-run causal route from oil consumption to economic growth and CO<sub>2</sub> emission. Finally, the empirical results of this study provided that policymakers need to improve efficiency in oil consumption not to increase CO<sub>2</sub> emissions. Furthermore, policymakers should endeavor to overcome the constraints on oil consumption to achieve economic growth.

**Keywords:** Oil Consumption, CO<sub>2</sub> Emission, Economic Growth, ARDL, Granger Causality Approaches

**JEL Classifications:** C13, C20

## 1. INTRODUCTION

In 2017, Thailand's total final energy consumption (TFEC) was 80.8 Mtoe, which increased by 1.0% accounted for 50.1% of TFEC, followed by electricity, renewable energy compared to 2016 (International Energy Agency, 2017). On the other hand, in the same year, oil and petroleum products, natural gas, and coal (20.5%, 15.7%, 7.1%, and 6.6% of TFEC, respectively) in the same year.

Oil plays an essential role in economic growth and country development. For Thailand's information, Thailand consumes 1,302,000 barrels per day (B/d) of petroleum and ranks 17<sup>th</sup> for oil consumption, accounting for about 1.3% of the world's total consumption of 97,103,871 barrels per day. In addition, Thailand consumes 0.79 gallons of oil per capita every day (based on the 2016 population of 68,971,308 people), or 289 gallons per capita per year (7 barrels) (Zoundi, 2017).

Thailand continuously requires energy to drive its economy. However, energy resources are limited, and half of the power necessary is imported (Ahmed et al., 2017). As a result, Thailand consumes enormous energy and releases many GHG emissions, especially in the energy sector (Ministry of Energy, 2017). The majority of GHG emissions in the energy sector arose from fossil fuel combustion, especially CO<sub>2</sub>. Total CO<sub>2</sub> emissions accounted for 235.8 Mt-CO<sub>2</sub>eq in 2017. Mainly the production of electricity and heat accounted for about 96.8 Mt-CO<sub>2</sub>eq (41.1%) in 2017. CO<sub>2</sub> emissions from the transportation and the manufacturing industry were 78.4 Mt-CO<sub>2</sub>eq (33.3%) and 45.2 Mt-CO<sub>2</sub>eq (19.2%), respectively. The building sector, including the residential and commercial sector, emitted 6.7 Mt-CO<sub>2</sub>eq 2.8% of total CO<sub>2</sub> emissions from the energy sector (DEDE, 2017).

The context of economic growth in the region raises the question of the environment in the EKC hypothesis. This

hypothesis stipulates that an increase in a country’s income leads to a corresponding increase in CO<sub>2</sub> emissions at the early stage of economic development. Still, in the later stage, the impact is reversed at a certain income threshold. The adoption of environmentally harmful technology in economic activities, lack of awareness of environmental problems, and the goal of higher profit in early economic development can explain the parallel pattern in per capita income and environmental degradation at this stage. However, higher per capita income, improved social indicators, and safer technology in the mature stage create a turning point in the growth-environment nexus (EPPO, 2017).

The above reasons are the source of the study; the relationship between CO<sub>2</sub> emission, oil consumption, and economic growth makes it necessary to study such issues to manage energy and the environment in parallel with economic growth.

Since 1971, there has been a growing demand for oil consumption in every sector of Thailand (Figure 1). Increasing energy consumption plays a crucial role in economic growth and CO<sub>2</sub> emissions and poses significant management and policy-making challenges. Due to environmental trends that have entered a vital role today, this study seeks to explore the existence and route of the causal relationship between CO<sub>2</sub> emission, oil consumption, and economic growth in Thailand.

The study detailed here is pursuing the following objectives:

1. To examine the existence and direction of the causal relationships among CO<sub>2</sub> emission, oil consumption, and economic growth in Thailand
2. To suggest policymakers regarding the formulation of energy policy in Thailand.

## 2. REVIEW OF LITERATURE

For this section, there are causal relationships among CO<sub>2</sub> emission, oil consumption, and economic growth have revealed by various authors.

**Figure 1:** Relationship among CO<sub>2</sub> emission (logCO), oil consumption (logOC), and per capita GDP (logGDP) of Thailand in log-form

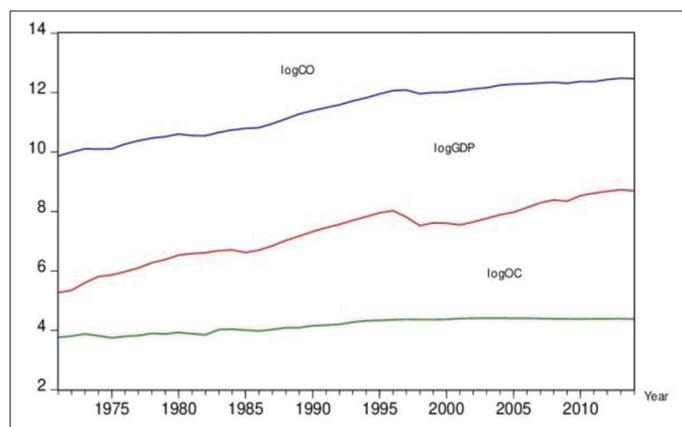


Table 1 summarizes the literature on the multiple hypotheses or relationships established among CO<sub>2</sub> emission, oil consumption, and economic growth in the present study. The authors have used several methodologies such as cointegration, vector error correction (VECM), vector autoregressive (VAR), the ARDL approach, and Granger causality.

Table 1 offers a sequential view of an empirical study that declares causality tests’ results on CO<sub>2</sub> emission, oil consumption, and economic growth, with the short-run and long-run relationships in differentiation for each country.

## 3. DATA AND RESEARCH METHODOLOGY

### 3.1. Data Collection and Variables

We have used yearly data of CO, OC, and GDP of Thailand from 1971 to 2014. The data are graphically represented in Figure 1. The World Bank Indicator has been the source of data for three study variables. Data on CO<sub>2</sub> emission is measured in kt, oil consumption is measured in gallons per capita, and the gross domestic product (GDP) per capita is estimated in the current U.S. dollar. Thus, CO has been used as a variable of CO<sub>2</sub> emission, OC has been used as a variable of oil consumption, and GDP has been used as a variable of economic growth.

### 3.2. Research Methodology

#### 3.2.1. Model specification

For testing whether CO<sub>2</sub> emission causes oil consumption and economic growth or not, the following simple model was used:

$$Y_t = \alpha + \beta_1 X + \beta_2 Z + \mu_t$$

**Table 1: Empirical literature that declares the results of causality tests among CO<sub>2</sub> emission, oil consumption, and economic growth**

Countries	Authors	Methodology	Causality Relationship
Malaysia (1971-1999)	Ang (2008)	Cointegrating analysis, Granger causality approach	Y→E (short-run) C, E→Y Y, C→E (long-run)
China (1960-2007)	Zhang and Cheng (2009)	Granger causality approach	E→C (long-run)
China (1981-2006)	Chang (2010)	Cointegration, Granger causality test	Y→C, E C→E E→Y, C (long-run)
Turkey (1968-2005)	Ozturk and Acaravci (2010)	ARDL approach	C, E→Y (long-run)
Iran (1967-2007)	Lotfalipour et al. (2010)	Granger causality approach	Y→C, E
South Africa (1965-2006)	Menyah and Wolde-Rufael (2010)	Granger causality approach	C→Y E→Y, C
Saudi Arabia (1990-2017)	Algarini (2020)	VAR and VECM	Y→E E→Y Y→C C→Y

Note: Y, E, and C indicate GDP, energy consumption, and CO<sub>2</sub> emissions, respectively

However, in this study, we rely on Thailand. So we can write this model again as follows:

$$CO_T = \alpha_T + \beta_1 OC_T + \beta_2 GDP_T + \mu_{iT} \tag{1}$$

Where  $CO_T = CO_2$  emission (kt) of Thailand  
 $OC_T =$  Oil consumption (Gallons Per Capita) of Thailand  
 $GDP_T =$  GDP per capita (Current US\$) of Thailand  
 $\alpha_T =$  Constant  
 $\mu_{iT} =$  error term  
 $t =$  time trend

We assume that the CO<sub>2</sub> emission, oil consumption, and economic growth have a relationship and cause to each other. Therefore, it will perform two steps on the long-run and causal relationships between CO<sub>2</sub> emission, oil consumption, and economic growth. Firstly, we will test the long-run relationships among the variables by using the ARDL bounds testing approach of cointegration. Secondly, we will try causal relationships by using the error correction based on causality models.

### 3.2.2. Autoregressive distributed lag (ARDL) cointegration analysis

The ARDL approach to cointegration is developed by Pesaran and Shin (1998) and Pesaran et al. (2001). The ARDL cointegration approach has more advantages in comparison with cointegration methods such as Johansen and Juselius (1990) and Johansen (1991) procedures:

1. The ARDL approach can be applied whether the regressors are I(1) or I(0), while Johansen cointegration 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 cointegration techniques require large data samples for validity, the ARDL approach is a statistically more significant approach to determine the cointegration relation in small samples
3. The ARDL approach allows the variables to have different optimal lags, while it is impossible with cointegration approaches
4. The ARDL approach employs only a single reduction from the equation, while the cointegration approaches estimate the long-run relationships within system equations.

The ARDL model for log-linear functional specification of the long-run relationship between CO<sub>2</sub> emission, oil consumption, and GDP per capita may follow as:

$$\Delta \log CO_t = \alpha + \sum_{i=1}^k \varnothing_i \Delta \log CO_{t-i} + \sum_{j=0}^t \beta_j \Delta \log OC_{t-j} + \sum_{j=0}^t \gamma_j \Delta \log GDP_{t-j} + \delta_1 \log CO_{t-1} + \delta_2 \log OC_{t-1} + \delta_3 \log GDP_{t-1} + \vartheta_t \tag{2}$$

Where  $\vartheta_t$  and  $\Delta$  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 cointegration,

$$H_0: = 0$$

$$H_1: \neq 0, r=1, 2, \dots$$

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 (cointegration). On the other hand, if the calculated F-statistic is below the critical value, we cannot reject the null hypothesis of no cointegration, indicating there are no long-run relationships that exist.

If there is cointegration between the variables, Equation 3 presents the long-run models, and Equation 4 shows the short-run models:

$$\log CO_t = \alpha + \sum_{i=1}^m \varnothing_i \log CO_{t-i} + \sum_{j=0}^n \beta_j \log OC_{t-j} + \sum_{j=0}^n \gamma_j \log GDP_{t-j} + \mu_t \tag{3}$$

$$\Delta \log CO_t = \alpha + \sum_{i=1}^k \varnothing_i \Delta \log CO_{t-i} + \sum_{j=0}^t \beta_j \Delta \log OC_{t-j} + \sum_{j=0}^t \gamma_j \Delta \log GDP_{t-j} + \sigma ECT_{t-1} + \varepsilon_t \tag{4}$$

Where  $\sigma$  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.

### 3.2.3. Causality analysis

ARDL cointegration method tests whether the existence or absence of a long-run relationship between CO<sub>2</sub> emission, oil consumption, and GDP per capita. However, it does not indicate the direction of causality. Once the estimating the long-run model in Equation 3 to obtain the estimated residuals, the next step is to evaluate 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:

$$\Delta \log CO_t = \alpha_1 + \sum_{i=1}^k \varnothing_i \Delta \log CO_{t-i} + \sum_{j=1}^t \beta_j \Delta \log OC_{t-j} + \sum_{j=1}^t \gamma_j \Delta \log GDP_{t-j} + \sigma_1 ECT_{t-1} + \varepsilon_{1t} \tag{5}$$

$$\Delta \log OC_t = \alpha_2 + \sum_{i=1}^k \varphi_i \Delta \log OC_{t-i} + \sum_{j=0}^t \delta_j \Delta \log GDP_{t-j} + \sum_{j=0}^t \pi_j \Delta \log CO_{t-j} + \sigma_2 ECT_{t-1} + \varepsilon_{2t} \tag{6}$$

$$\Delta \log GDP_t = \alpha_3 + \sum_{i=1}^k \omega_i \Delta \log GDP_{t-i} + \sum_{j=0}^t \tau_j \Delta \log CO_{t-j} + \sum_{j=0}^t \theta_j \Delta \log OC_{t-j} + \sigma_3 ECT_{t-1} + \varepsilon_{3t} \tag{7}$$

Residual terms,  $\varepsilon_{1t}$ ,  $\varepsilon_{2t}$ , and  $\varepsilon_{3t}$ , 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 logCO does Granger cause logOC and/or logGDP; logOC does Granger cause logGDP and/ or logCO, and logGDP does Granger cause logCO and/or logOC, respectively.

Granger causality can be examined in two ways using Equation 5, 6, and 7 as follows:

1. Short-run Granger causalities are detected by testing  $H_0: \beta_j = \gamma_j = 0$ ,  $H_0: \delta_j = \pi_j = 0$  and  $H_0: \tau_j = \theta_j = 0$  for all  $j$  in Equation 5, 6, and 7, respectively
2. 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  $H_0: \sigma_1 = 0$ ,  $H_0: \sigma_2 = 0$ , and  $H_0: \sigma_3 = 0$  for Equation 5, 6, and 7, respectively.

#### 4. EMPIRICAL ANALYSIS AND RESULTS

This study investigates the long-run and causal relationships between CO<sub>2</sub> emission, oil consumption, and economic growth in Thailand from 1971 to 2014 by employing CO<sub>2</sub> emission, oil consumption, 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 cointegration approach
2. We employ the VECM to test causal relationships between variables. According to Pesaran and Shin (1998), this study used the AIC to select an appropriate lag for the ARDL model.

Table 2 presents the estimated ARDL model that has passed several diagnostic tests that indicate no serial correlation and heteroscedasticity.

In addition, due to the structural changes in the economies of Thailand, 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). Figure 2 present the plot of CUSUM and CUSUMSQ test statistics for Thailand that fall inside the critical bounds of 5% significance. This result implies that the estimated parameters are stable from 1971 to 2014.

The ARDL bound test results show a unique long-run relationship among CO<sub>2</sub> emission, oil consumption, and GDP per capita in Thailand at a 10% significance level. In other words, there is cointegration between CO<sub>2</sub> emission, oil consumption, and GDP per capita in Thailand (Table 2). Therefore, the econometric analysis suggests that can estimate any causal relationships within VECM for Thailand.

Figure 2: Stability tests for Thailand

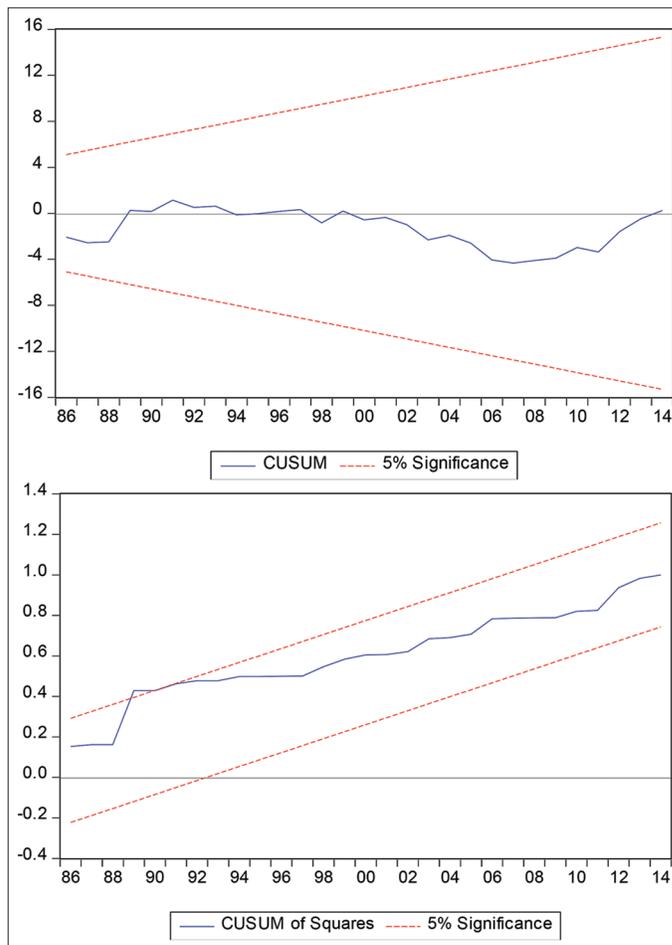


Table 2: Estimated ARDL models and bound F-test for cointegration

Countries	Models	F	LM	HT
Thailand	ARDL(3,4,1)	6.3665	0.2063 (0.9020)	10.0788 (0.4336)
Critical values		I(0)	I(1)	
Critical values at 1%		4.13	5.00	
Critical values at 2.5%		3.55	4.38	
Critical values at 5%		3.10	3.87	
Critical values at 10%		2.63	3.35	

Notes: F is the ARDL cointegration test. The critical values for the lower I(0) and upper I(1) bounds are taken from Narayan (2005). LM is the Lagrange multiplier test for serial correlation with a  $\chi^2$  distribution with two degrees of freedom. HT is the Heteroskedasticity test with a  $\chi^2$  distribution

The existence of a cointegration relationship among CO<sub>2</sub> emission, oil consumption, and GDP per capita in Thailand suggests that there must be Granger causality in at least one direction. This study found evidence of a one-way (unidirectional) short-run and long-run Granger causality between oil consumption and CO<sub>2</sub> emission in Thailand (Table 3). Moreover, there is a one-way (unidirectional) long-run Granger causality run from oil consumption to GDP per capita and CO<sub>2</sub> emission.

**Table 3: Granger causality tests for Thailand**

The null hypotheses	Chi-square (P-value)
Short-run Granger causality	
$\Delta \log \text{CO} \rightarrow \Delta \log \text{GDP}$	0.006 (0.9355)
$\Delta \log \text{CO} \rightarrow \Delta \log \text{OC}$	0.407 (0.5234)
$\Delta \log \text{GDP} \rightarrow \Delta \log \text{CO}$	0.527 (0.4675)
$\Delta \log \text{GDP} \rightarrow \Delta \log \text{OC}$	1.851 (0.1736)
$\Delta \log \text{OC} \rightarrow \Delta \log \text{CO}$	2.968 (0.0849)*
$\Delta \log \text{OC} \rightarrow \Delta \log \text{GDP}$	2.068 (0.1504)
Long-run Granger causality	
$\log \text{CO} \rightarrow \log \text{GDP}$	0.117 (0.7317)
$\log \text{CO} \rightarrow \log \text{OC}$	0.025 (0.8730)
$\log \text{GDP} \rightarrow \log \text{CO}$	1.746 (0.1864)
$\log \text{GDP} \rightarrow \log \text{OC}$	1.637 (0.2007)
$\log \text{OC} \rightarrow \log \text{CO}$	3.795 (0.0514)*
$\log \text{OC} \rightarrow \log \text{GDP}$	0.925 (0.3361)
$\log \text{OC} \rightarrow \log \text{GDP}, \log \text{CO}$	5.568 (0.0618)*

Note: \* is significant at 10% level

## 5. CONCLUSION

The paper investigates the nexus among CO<sub>2</sub> emission, oil consumption, and economic growth for Thailand from 1971-2014. To examine this linkage, we use the two-step procedure from the Engle and Granger model (Engle and Granger, 1987).

Firstly, we explore the long-run relationship among three variables using the ARDL bounds testing approach of cointegration. Secondly, we employ VECM to test the causal relationships among the variables.

Overall, the empirical results showed that it had established a long-run relationship among CO<sub>2</sub> emission, oil consumption, and economic growth. Thus, there is a long-run relationship (cointegration) between CO<sub>2</sub> emission, oil consumption, and economic growth. There is a one-way (unidirectional) short-run Granger causality between oil consumption and CO<sub>2</sub> emission. In addition, there is a one-way (unidirectional) long-run Granger causality between oil consumption and CO<sub>2</sub> emission. The findings align with Zhang and Cheng's (2009) study from China, which found a causal relationship between energy consumption and carbon emission.

Moreover, there is a one-way long-run causal route from oil consumption to economic growth and CO<sub>2</sub> emission. The results are consistent with those of Menyah and Wolde-Rufael (2010); in South Africa, a causal relationship was found, running from energy consumption to economic growth and carbon emission.

The empirical results of this study provided that policymakers need to improve efficiency in oil consumption not to increase CO<sub>2</sub> emissions. Furthermore, policymakers should endeavor to overcome the constraints on oil consumption to achieve economic growth.

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