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Article

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Analyzing Short-run and Long-run Causality Relationship among CO_2 Emission, Energy Consumption, GDP, Square of GDP, and Foreign Direct Investment in Environmental Kuznets Curve for Thailand

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ABSTRACT

This paper analyzes the causal link between CO2 emission, energy consumption, GDP, square of GDP, and foreign direct investment in the Environmental Kuznets Curve for Thailand from 1971 to 2014. Three steps are used: bound tests to verify the presence of cointegration, autoregressive distributed lag (ARDL) model to check the effects of the dependent variables on the independent variable in the short run and long run, and finally, the vector error correction (VECM) was used the detect the causal relationships among variables. The results show no cointegration between variables, confirming the short-run relationship's existence. In addition, the Granger causality results show varied outcomes, indicating that two bidirectional causal relationships exist in the short run. The first relationship is between energy consumption and GDP, and the second is between energy consumption and GDP^2. In addition, there are seven unidirectional relationships where FDI affects CO_2 emission, energy consumption, GDP, and GDP^2, including CO_2 emission affects energy consumption, GDP, and GDP^2. The results of long-run causal relationships show three bidirectional causal relationships between GDP and CO_2 emission, GDP^2 and CO_2 emission, including GDP and GDP^2. Moreover, there are two unidirectional relationships: GDP influences energy consumption and GDP^2 affects energy consumption. Therefore, in terms of policy, the Thai government should support using more renewable energy. Including foreign direct investment, the government should issue a policy for foreign investors' investment by regulating green factories and efficient technology in reducing pollution emissions.

Keywords: CO_2 Emissions, Energy Consumption, GDP, Foreign Direct Investment, Environmental Kuznets Curve
JEL Classifications: C13, C20

1. INTRODUCTION

Environmental issues have increased interest among economists for a few decades. The environment in which we live is affected by various sorts of economic activity. For example, industry, households, governments, institutions, and the state of technology construct an economy.

Carbon dioxide emissions have been the primary source of extreme environmental pollution (Rehman et al. [2021a]). However, with the rapidly growing agriculture and farm mechanization from more food needs in the present, the agricultural sector has become a factor in speeding up the global surge in CO_2 emissions and other greenhouse gases (Rehman et al. [2021b]).

Economic, social, and environmental suitability are the three core pillars of the UN's Sustainable Development Goals (SDG) declarations (Rehman et al. [2021a]). In September 2019, Heads of State and Government gathered at the SDG Summit at the United Nations Headquarters in New York to follow up and comprehensively review progress in the implementation of the 2030 Agenda for Sustainable Development and the 17 Sustainable

Development Goals (SDGs). The summit resulted in the adoption of the Political Declaration, and its core message is to take action to respond to climate emergencies. Relevant research shows that if economic growth and climate and environmental sustainability are achieved simultaneously, emission reduction policies need to be incorporated into the economic growth policies of various countries (Murshed et al. [2021], Rehman et al. [2021a]).

During the last few decades, Thailand has experienced a significant increase in CO_2 emissions, energy consumption, and foreign direct investments. From Figure 1, CO_2 emissions were measured from liquid fuel consumption of 17330.242 kt in 1971, and the employed quantity was 115954.207 kt in 2014. The number of CO_2 emissions in Thailand increased significantly between 1971 and 2014.

It was followed by an increase in energy consumption (electric power consumption (kWh per capita)), which increased significantly from 1971 to 2014; from Figure 2, we can see that in 1971, Thailand used energy equal to 120.326 kWh per capita and has been growing until 2014, increasing to 2538.795 kWh per capita.

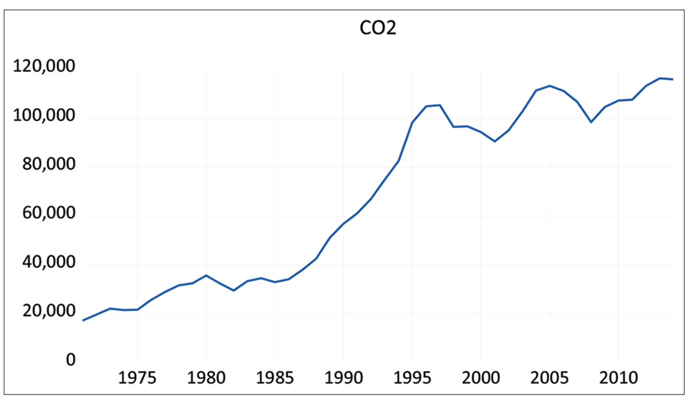
From Figure 3, the GDP per capita of Thailand has an amount of 22852.55 LCU in 1971, increasing the amount of 134895.62 LCU in 2014, which trend is rising.

The end is net inflows of foreign direct investment (FDI) for Thailand; from Figure 4, it can be seen that in 1971 the value of the foreign investment was equal to 38,865,384.6 USD, and in 2014 the value of the foreign investment was equivalent to 4,975,455,660 USD, which from the trend analysis the results showed that there were alternating up and down trends.

Although it has had some fluctuating performances, particularly during periods of crisis, foreign direct investment inflows have followed a similar path, with FDI (foreign direct investment) continuous. A glance at Thailand‘s economy reveals that it has encountered several structural changes during the last half-century. For example, in the early 1980s, Thailand started implementing liberalization policies, resulting in significant economic growth from a considerable increase in international trade, financial sector inflows, and foreign direct investments, making Thailand a critical case involving the relevant variables.

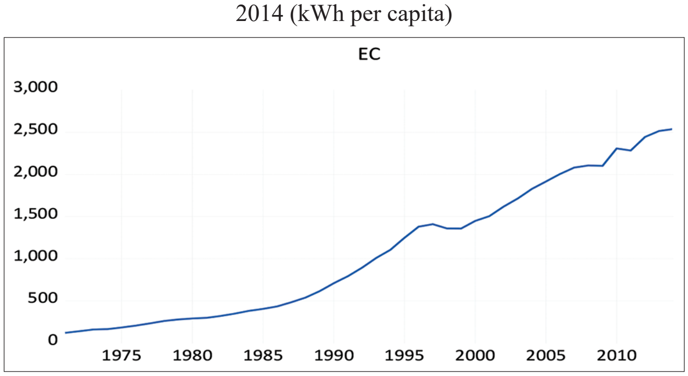
As a powerful tool for transferring technology, financial capital, and other skills, foreign direct investments (FDIs) have three impacts economic, political, and social. The political effects focus mainly on the insecurity of national independence, and the social effects are primarily concerned with the possibility of the cultural transformation of society. On the other hand, economic effects imply various outcomes regarding output, the balance of payments, and market structure (Moosa, 2002). Most studies agree that FDI contributes to economic growth by providing

Figure 1: The quantity of CO_2 emission in Thailand between 1971 and 2014 (kt)



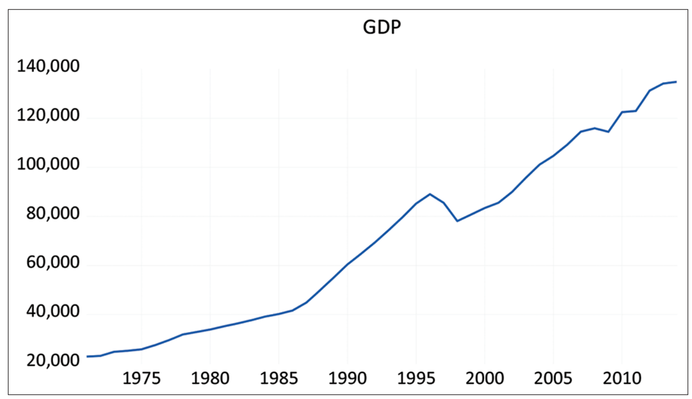
Source: The world bank, 2022

Figure 2: The energy consumption in Thailand between 1971 and 2014 (kWh per capita)



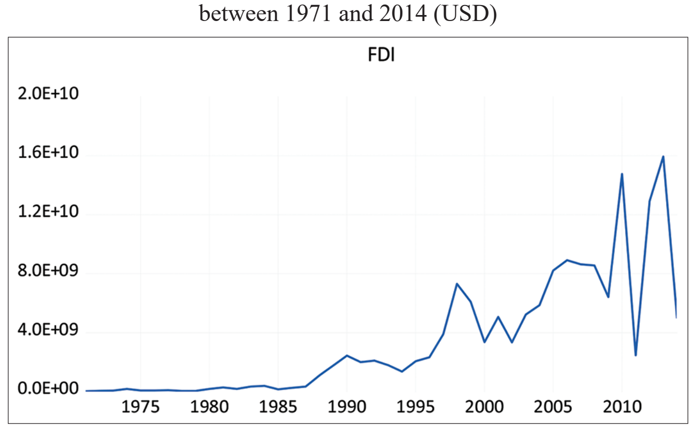
Source: The world bank, 2022

Figure 3: Shows the GDP per capita for Thailand between 1971 and 2014 (constant LCU)



Source: The world bank, 2022

Figure 4: The net inflows of foreign direct investment for Thailand between 1971 and 2014 (USD)



Source: The world bank, 2022

capital, increasing productivity, creating new job probabilities, and boosting competitiveness Choong and Lam (2010). However, some studies have explained that there is no direct impact of FDI on economic growth (Carkovic and Levine, 2002; Durham, 2004).

To further this research, we investigate the impact of foreign direct investments, energy consumption, and economic growth on CO_2 emissions using the autoregressive distributed lag (ARDL) modeling approach to cointegrate. The study's main aim is to explore the relationship between the environment, foreign direct investments, economic growth, and energy consumption the analysis. The study also aims to explain whether the pollution haven hypothesis is valid by investigating the impact of FDI on CO_2 emissions. This study by including the ARDL model as an exogenous variable. The following content consists of a literature review on the nexus of related variables and the primary methodologies used in the analysis and continues with the findings, and finalizes with a conclusion.

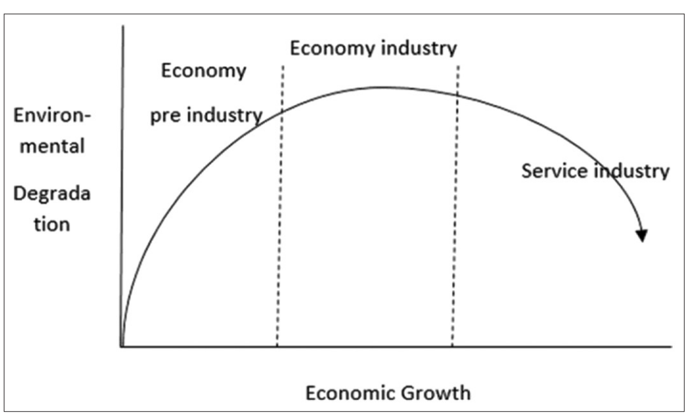
2. REVIEW OF LITERATURE

Figure 5 shows that the Environmental Kuznets Curve (EKC) model explains the relationship between changes in economic structure and economic growth. The first explanation of the Kuznets U-inverse curve relationship is the stage of economic growth through the transition from agriculture to industry and then post-industry to a service-based system. Environmental damage tends to increase due to changes in economic structure from rural to urban and from agriculture to industry as mass production and consumption growth. Then shows decreases with the second economic structure change from energy-based heavy industry to technology-based industries and services (Panayotou, 1993).

A study conducted by Suri and Chapman (1998) shows that both developed and developing countries going through a stage of industrialization will increase the demand for energy which is relatively high initially for exporting. EKC theory explains that economic growth will initially increase environmental degradation (Tenor and Beyene, 2021).

In the case of studying in each country, we can show the evidence as follows:

Figure 5: The relationship between the variables in the environmental kuznets curve



Source: Panayotou, 1993

Shahbaz et al.(2015) studied an environmental Kuznets curve (EKC) hypothesis for Portugal by applying an autoregressive distributed lag-bounds testing approach from 1971 to 2008 to capture Portugal's historical experience, demographic changes, and international trade on carbon emissions. Empirical results confirm the evidence of the EKC hypothesis in both the short-run and long run. All variables carry the expected signs except trade openness. Despite the success of Portugal in containing CO2 emissions so far, it is important to note that in recent years, carbon emissions have risen. To comply with the 1992 Kyoto Protocol on CO2 emissions, there is a need for policies that focus on the sectors responsible for CO2 emissions.

Zambrano-Monserrate et al. (2016) studied empirical evidence of a long-run environmental Kuznets curve (EKC) for Ecuador from 1971 to 2011. Using the autoregressive distributed lag-bounds testing approach, we do not just estimate the effect of economic growth on CO_2 emissions but also the impact of energy consumption on this one. The results of all variables have the expected signs. In addition, we test for Granger causality among the variables using an error correction model. Only GDP granger causes energy consumption in the short run. The results have several policy implications that are consistent with the current environmental policy of the government.

Next, Benavides et al. (2017) studied the empirical evidence of the Environmental Kuznets Curve for Austria. Using the Autoregressive Distributed Lag (ARDL) method, the relationship between methane emissions (CH4), Gross Domestic Product (GDP), electricity production from renewable energy sources (excluding hydro), and trade openness is analyzed; the variables are used per capita terms except for trade openness. In the long run, cointegration analysis indicates that the variables have a distribution inverted U-shaped, and the Granger causality test shows unidirectional causality between CH4 and the variables involved. Since CH4 is the world's second highest Greenhouse Gas (GHG) emitted, this study's political and academic implications are relevant to include in planning decisions that aim to mitigate climate change.

Layachi (2019) study is primarily motivated by testing the Environmental Kuznets Curve (EKC) framework. The results of ARDL confirm that economic growth has a positive and significant impact on carbon emissions in Algeria. On the other hand, all energy prices demonstrate a negative and significant impact on carbon emissions in Algeria, and the results of ARDL confirm the presence of a U-Shaped EKC curve in Algeria as well.

Additionally, Bunnag (2021) examined that it had established a long-run relationship between CO_2 emission, oil consumption, and economic growth in Thailand. There is a one-way (unidirectional) short-run Granger causality between oil consumption and CO_2 emission. And there is a one-way (unidirectional) long-run Granger causality between oil consumption and CO_2 emission and a one-way long-run causal route from oil consumption to economic growth and CO_2 emission. Finally, the empirical results of this study provided that policymakers need to improve efficiency in oil consumption, not increase CO_2 emissions. Furthermore, policymakers should endeavor to overcome the constraints on oil consumption to achieve economic growth.

Moreover, Aminata et al. (2022) analyze the relationship between economic growth, population, and policy strategies: And their effects on CO_2 emissions. They found that India and China are the countries with the most people. In addition, China and India have the highest levels of environmental degradation (CO_2 emissions) worldwide. However, the economic growth of India and China almost every year has increased. Based on tests that have been done, both in the short and long run, the population and GDP (Gross Domestic Gross) positively affect CO_2 emissions. This shows that both in the short and long run, the increase in population and GDP in both China and India in the period 1984-2014 is accompanied by the rise in CO_2 emissions from industrial activities, greenhouse gases, and activities of human activity.

3. THEORETICAL AND MODELING FRAMEWORK

The paper follows the framework of Halicioglu (2009), Jalil and Mehmud (2009), and Shahbaz et al. (2011) in estimating an environmental degradation equation. These studies evaluated the emissions-growth and energy-growth nexus in a single equation model. In addition, we include energy consumption and foreign direct investment as variables to proxy for reflecting the rapid movements from the economy's growth. In Equation 1, we suggest that CO_2 emission (CO_2) in Thailand depends on energy consumption (electric power consumption) (EC), GDP, square of GDP (GDP^2), and Foreign Direct Investment (FDI).

$$CO_2 = f(EC, GDP, GDP^2, FDI) \tag{1}$$

We convert the linear specification of the model into a log-linear specification. It is noted that log-linear specification provides more relevant and efficient results than the simple linear functional form of the model. Furthermore, a logarithmic form of variables gives direct elasticities for interpretations in Equation 2.

$$\begin{aligned} &lnCO_2 = \alpha_1 + \alpha_{EC} lnEC + \alpha_{GDP} lnGDP \\ &+\alpha_{GDP^2} lnGDP^2 + \alpha_{FDI} lnFDI + \mu \end{aligned} \tag{2}$$

Where μ is stands for residual or error term. We hypothesize that economic activity is positively stimulated by increased electric power consumption or energy use, resulting in increased environmental pollutants or carbon emissions. This leads us to expect α_{EC}>0 The EKC hypothesis suggests that α_{GDP}>0and GDP^2 <0. The sign of α_{FDI}>0 means that higher foreign direct investment drives energy consumption, resulting in increased carbon emissions.

3.1. ARDL Approach Specification

The empirical methodology that we use in this paper is the autoregressive distributive lag (ARDL) bounds test proposed by Pesaran and Pesaran (1997) and Pesaran et al. (2001). Then, the error correction model (ECM) can be easily derived from the ARDL framework, making it possible to estimate the long-run adjustment process toward equilibrium. One of the advantages of this method is that the time series regression can be carried out regardless of the nature of variables, that is, whether or not they are either I (1) or I (0). Given that most macroeconomic variables are proved to be either of those two orders, this methodology is convenient with the aim of examining long-run relationships. However, as Pesaran and Shin (1999) demonstrated, another great advantage is that serial correlation and endogeneity problems are removed when long-run and short-run components are simultaneously taken with appropriate lags.

The relationship among CO_2 per capita, energy consumption, GDP per capita, the square of GDP, and foreign direct investment (FDI) postulated in Equation 3 follows a time path before a long-term nexus is achieved. Thus, Equation 3 would be written as an unrestricted error correction representation:

$$\begin{aligned} &\Delta lnCO_{2_t} = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta \ln CO_{2_{t-i}} + \sum_{i=1}^{p} \varphi_i \Delta lnEC_{t-i} \\ &+\sum_{i=1}^{p} \gamma_i \Delta \text{üüüüüüüü}_{t-i} + \sum_{i=1}^{p} \delta_i \Delta(\quad_{t-i})^2 + \sum_{i=1}^{p} \theta_i \Delta \quad_{t-i} \\ &+\gamma_1 lnCO_{2_{t-1}} + \gamma_2 lnEC_{t-1} + \gamma_3 lnGDP_{t-1} + \gamma_4 lnFDI_{t-1} + \mu_t \end{aligned} \tag{3}$$

Where μ_t are the new serially independent errors. The estimation procedures used here involve two stages. In the first stage, we will analyze, through the ARDL bound tests, whether or not there is evidence of a cointegration relationship. With this purpose, the null hypothesis of no cointegration among the variables ($H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$) should be tested against the alternative ($H_1: \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 = 0$). Ordinary least squares report F-statistics, compared to the critical values given in Pesaran and Shin (1996) and Pesaran et al. (2001). If they go beyond the upper bound, the null hypothesis will be rejected, and there will be a cointegrating relationship among the variables.

On the contrary, if the F-statistics are below the lower bound, the null hypothesis will not be rejected. The test result should be inconclusive if the F-statistics are between the upper and lower critical values. The second stage is to estimate the long-run coefficients of the cointegrating relation and make inferences about their values.

Finally, the empirical methodology involves the modeling of a restricted error correction representation, which takes a similar form to Equation 4 but now includes the long-run terms in the error correction variable lagged one period:

$$\begin{aligned} &\Delta lnCO_{2_t} = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta \ln CO_{2_{t-i}} + \sum_{i=1}^{p} \varphi_i \Delta lnEC_{t-i} \\ &+\sum_{i=1}^{p} \gamma_i \Delta lnGDP_{t-i} + \sum_{i=1}^{p} \delta_i \Delta (lnGDP_{t-i})^2 \\ &+\sum_{i=1}^{p} \theta_i \Delta lnFDI_{t-i} + \gamma ECT_{t-1} + \mu_t \end{aligned} \tag{4}$$

Where ECT_{t-1} is the error correction term represented by the OLS residuals series from the long-run cointegration relationship, the coefficient indicates the speed of γ adjustment towards this long-run equilibrium. Diagnostic and stability tests will reveal the soundness of the model.

3.2. Causality Analysis

ARDL cointegration method tests the existence or absence of a long-run relationship between all variables. It does not indicate the direction of causality. Once estimating the long-run model in Equation 4 obtains 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 the error correction term in the system. Therefore, the following dynamic VECM is estimated to investigate the Granger causality (Granger, 1969) between the variables in Equations 5, 6, 7, 8, and 9, respectively:

$$\Delta lnCO_{2_t} = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln CO_{2_{t-i}} + \sum_{i=1}^{p} \varphi_{1i} \Delta lnEC_{t-i} + \sum_{i=1}^{p} \gamma_{1i} \Delta lnGDP_{t-i} + \sum_{i=1}^{p} \delta_{1i} \Delta (lnGDP_{t-i})^2 + \sum_{i=1}^{p} \theta_{1i} \Delta lnFDI_{t-i} + \pi_1 ECT_{t-1} + \mu_{1t} \quad (5)$$

$$\Delta lnEC_{\text{üüüü}} = \alpha_2 + \sum_{i=1}^{p} \beta_2 \, \Delta lnEC_{-} + \sum_{i=1}^{p} \varphi_2 \, \Delta lnGDP_{-} + \sum_{i=1}^{p} \gamma_{2i} \Delta (lnGDP_{t-i})^2 + \sum_{i=1}^{p} \delta_{2i} \Delta lnFDI_{t-i} + \sum_{i=1}^{p} \theta_{2i} \Delta \ln CO_{2_{t-i}} + \pi_2 ECT_{t-2} + \mu_{2t} \quad (6)$$

$$\Delta lnGDP_t = \alpha_3 + \sum_{i=1}^{p} \beta_{3i} \Delta lnGDP_{t-i} + \sum_{i=1}^{p} \varphi_{3i} \Delta (lnGDP_{t-i})^2 + \sum_{i=1}^{p} \gamma_{3i} \Delta lnFDI_{t-i} + \sum_{i=1}^{p} \delta_{3i} \Delta lnEC_{t-i} + \sum_{i=1}^{p} \theta_{3i} \Delta \ln CO_{2_{t-i}} + \pi_3 ECT_{t-3} + \mu_{3t} \quad (7)$$

$$\Delta \text{üü}(\text{üüüüüü})^2_{\text{üüü}} = \alpha_4 + \sum_{i=1}^{p} \beta_4 \, \Delta(\quad_{-})^2 + \sum_{i=1}^{p} \varphi_4 \, \Delta \quad_{-} + \sum_{i=1}^{p} \gamma_{4\text{üüü}} \Delta lnGDP_{-} + \sum_{i=1}^{p} \delta_4 \, \Delta lnEC_{-} + \sum_{i=1}^{p} \theta_4 \, \Delta \ln CO_{2_{t-i}} + \pi_4 ECT_{t-4} + \mu_{4t} \quad (8)$$

$$\Delta \text{üüüüüüüü}_{\text{üüü}} = \alpha_5 + \sum_{i=1}^{p} \beta_5 \, \Delta \quad_{-} + \sum_{i=1}^{p} \varphi_5 \, \Delta(\quad_{-})^2 + \sum_{i=1}^{p} \gamma_{5\text{üüü}} \Delta lnGDP_{-} + \sum_{i=1}^{p} \delta_5 \, \Delta lnEC_{-} + \sum_{i=1}^{p} \theta_5 \, \Delta \ln CO_{2_{t-i}} + \pi_5 ECT_{t-5} + \mu_{5t} \quad (9)$$

Where α_1 to α_5, $\beta, \varphi, \gamma, \delta$, and θ represent the coefficients to be estimated. π_1 to π_2 is the coefficient of long-run equilibrium of the dependent variables, while ECT is the error correction term of a long run, and μ_1 to μ_5 represent the white noise term error.

4. OBJECTIVES OF THIS STUDY

For this research work to be complete, therefore we have to mention in objectives as follows:

1. To examine the existence and direction of the causal relationship among CO_2 emission, energy consumption, GDP, square of GDP, and foreign direct investment in the Environmental Kuznets Curve for Thailand
2. To suggest policymakers regarding pollution reduction in Thailand by consideration of causal relationship among variables of the Environmental Kuznets Curve.

5. DATA COLLECTION AND VARIABLES

We have used yearly data on CO_2 emissions, energy consumption (electric power consumption), GDP per capita, and foreign direct investment in Thailand from 1971-2014. The World Bank Indicator has been the data source for all variables, such as CO_2 emission was measured in kt, energy consumption per capita was measured in kWh, gross domestic product per capita data was measured in the constant LCU, and inflows of foreign direct investment were estimated in current USD. The movement of CO_2 emission, energy consumption, GDP, and foreign direct investment can show in Figures 1-4, respectively.

6. EMPIRICAL ANALYSIS AND RESULTS

In this part of this study, we try to analyze the different relationships between variables, but generally, in time series analysis, the primary stage is to investigate the integrated order of the study variables. ADF (Dickey and Fuller, 1981) and PP (Phillips and Perron, 1988) approaches have been used in this study to check the order of integration. We want to test the hypothesis of the existence of a unit root. The null and alternative hypotheses can be formulated as follows:

H_0: $\alpha = 1$ (unit root)
H_1: $\alpha < 1$ (Integrated of order zero)

These two tests are based on the null of non-stationarity, which indicates the presence of a unit root, and the alternative hypothesis of the non-existence of a unit root, which means that the variable examined is stationary.

6.1. Results of the Unit Root Test

All data for variables of CO_2 emissions, energy consumption, GDP, GDP^2, and foreign direct investment have been converted into a log form and shown in Table 1. The different results of the stationarity test are indicated in Table 1. The results show that all variables are stationary in the first difference, meaning that there are integrated into order one I (1). In this case, we can reject the null hypothesis of the presence of unit root, and we can accept the alternative hypothesis. After determining the order of integration, we will verify the existence of cointegration between variables using the bound test.

6.2. Results of the ARDL Model

We now estimate $(p+1)^k$, the number of regressions, where p is the maximum number of lags and k is the number of variables in the model, to determine the model lag selection. To select the optimum lag order for the model, we focus on the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion

Table 1: Unit root test for lnCO2, lnEC, lnGDP, lnGDP2 and lnFDI

Variables	ADF test statistic				PP test statistic			
	intercept		Intercept and trend		intercept		Intercept and trend	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
lnCO2	−1.436	−4.200***	−1.414	−4.329 ***	−1.896	−4.239***	−1.198	−4.329***
lnEC	−2.030	−3.532***	−0.325	−4.171***	−3.0173**	−3.504***	−0.458	−4.151***
lnGDP	−1.459	−3.871***	−1.629	−4.037***	−1.168	−3.871***	−1.285	−4.076***
lnGDP2	−1.252	−3.958***	−1.791	−4.043***	−0.939	−3.958***	−1.488	−4.075***
lnFDI	−2.275	−0.882	−0.638	−2.001	−1.719	−9.007***	−3.478	−9.089***

** = 5% significant level, ***=1% significant level

Table 2: Optimum lag order for model selection

Order for ARDL model selection	AIC	SBC
	(1.1.1.1,1)	(1.1.0,0,1)
Standard error of the regression	0.047	0.049

Table 3: Cointegration results and estimation of the ARDL (1,1,1,1,1) model

Variables	Coefficient	t-statistics
C	−1.446	−0.240
lnCO2 (−1)	0.916***	10.623
lnEC	1.184***	3.246
lnEC (−1)	−1.140***	−3.834
lnGDP	13.420***	2.266
lnGDP (−1)	−13.115***	−2.211
lnGDP2	−0.598***	−2.261
lnGDP2 (−1)	0.591***	2.222
lnFDI	0.008	0.595
lnFDI (−1)	−0.035	−2.293

F-bounds test	Value	Significant	I (0)	I (1)
F-statistic (4,43)	2.020	10%	2.45	3.52
		5%	2.86	4.01
		2.5%	3.25	4.49
		1%	3.74	5.06

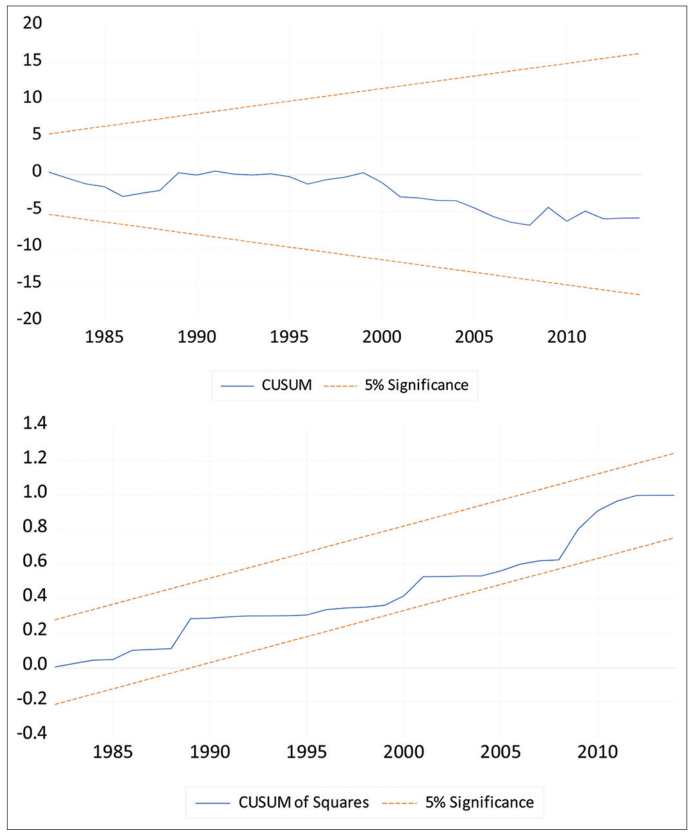
LM test	Value	
F-statistic	1.823	
Heteroskedasticity test: Breusch-Pagan-Godfrey (HT)		Value
F-statistic (9,33)		0.909

***=1% significant level

(SBC). We use a high enough order to ensure that the optimal one is not exceeded. As we can see in Table 2, the optimum lag order is (1, 1, 1, 1, 1) according to the AIC, but it is (1, 1, 0, 0, 1) according to the SBC. Therefore, based on the minimum value of the standard error of the regression, we finally choose the order selected by the AIC.

Once the properties of the time series have been analyzed, the optimum lag order is determined, and we have to check whether or not a cointegrating relationship (long-run nexus) exists in the ARDL model and estimate the long-run coefficients. Therefore, a bounds test is carried out. As we can see in Table 3, the computed F-statistics (4.43) equal to 2.020 indicate that there is no cointegrating relationship among $lnCO_2$, lnEC, lnGDP, $lnGDP^2$, and lnFDI at a 1% level. It means that there are short-run relationships among these variables. Moreover, Table 3 presents the estimated ARDL model that has passed several diagnostic tests that indicate no serial correlation and heteroscedasticity.

Figure 6: The plot of CUSUM and CUSUMSQ test statistics for Thailand from 1971 to 2014



F–bounds test 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 y^2 distribution with two degrees of freedom. HT is the Heteroskedasticity test with a y^2 distribution

In addition, due to the structural changes in the economies of Thailand, the 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 6 presents the plot of Thailand's CUSUM and CUSUMSQ test statistics that fall within the critical bounds of 5% significance. This result implies that the estimated parameters are stable from 1971 to 2014.

Based on our consideration of the F-bound test, we confirmed that the relationship between the independent and dependent

Table 4: Long run estimates of the ARDL model

Variable	Coefficient	t-statistic	P-value
lnEC	0.520	0.285	0.776
lnGDP	3.640	0.285	0.776
lnGDP2	−0.076	−0.158	0.874
lnFDI	−0.314	−0.788	0.436

Table 5: Error correction representation for the selected model

Variable	Coefficient	t-statistic	P-value
Constant	−1.446	−3.448	0.001
ΔlnEC	1.184	4.460	0.000
ΔlnGDP	13.420	2.839	0.007
ΔlnGDP2	−0.598	−2.825	0.008
ΔlnFDI	0.008	0.792	0.433
ECT(−1)	−0.083	−3.365	0.002

Table 6: Granger causality tests among variables in the environmental kuznets curve model for Thailand

The null hypotheses	Chi-square (P-value)
Short-run granger causality	
ΔlnEC → ΔlnCO2	0.812 (0.367)
ΔlnGDP →ΔlnCO2	0.426 (0.513)
ΔlnGDP2 → ΔlnCO2	0.505 (0.443)
ΔlnFDI →ΔlnCO2	3.031 (0.081)*
ΔlnCO2 → ΔlnEC	14.690 (0.000)***
ΔlnGDP →ΔlnEC	6.457 (0.011)**
ΔlnGDP2 →ΔlnEC	7.027 (0.008)***
ΔlnFDI →ΔlnEC	16.552 (0.000)***
ΔlnCO2 →ΔlnGDP	6.474 (0.011)**
ΔlnEC →ΔlnGDP	4.076 (0.043)**
ΔlnGDP2 →ΔlnGDP	1.178 (0.277)
ΔlnFDI →ΔlnGDP	5.758 (0.016)**
ΔlnCO2 →ΔlnGDP2	6.658 (0.009)***
ΔlnEC →ΔlnGDP2	4.563 (0.032)**
ΔlnGDP →ΔlnGDP2	1.060 (0.303)
ΔlnFDI →ΔlnGDP2	5.952 (0.014)**
ΔlnCO2 →ΔlnFDI	1.658 (0.197)
ΔlnEC →ΔlnFDI	0.152 (0.696)
ΔlnGDP →ΔlnFDI	2.514 (0.112)
ΔlnGDP2→ΔlnFDI	2.514 (0.105)
Long-run granger causality	
lnEC→lnCO2	1.046 (0.306)
lnGDP→lnCO2	5.849 (0.015)**
lnGDP2→lnCO2	5.014 (0.025)**
lnFDI→lnCO2	1.723 (0.189)
lnCO2→lnEC	1.856 (0.173)
lnGDP→lnEC	11.918 (0.000)***
lnGDP2→lnEC	10.445 (0.001)***
lnFDI→lnEC	0.024 (0.875)
lnCO2→lnGDP	5.673 (0.017)**
lnEC→lnGDP	0.209 (0.647)
lnGDP2→lnGDP	5.576 (0.018)**
lnFDI→lnGDP	0.001 (0.974)
lnCO2→lnGDP2	5.498 (0.019)**
lnEC→lnGDP2	0.175 (0.675)
lnGDP→lnGDP2	4.745 (0.029)**
lnFDI→lnGDP2	0.004 (0.947)
lnCO2→lnFDI	0.039 (0.842)
lnEC→lnFDI	0.017 (0.896)
lnGDP→lnFDI	1.218 (0.269)
lnGDP2→lnFDI	1.170 (0.279)

* is significant at the 10% level, ** is significant at the 5% level, and *** is significant at the 1% level

variables was short-run. However, we can prove from the long-run estimation from Table 4 that the long-run coefficients of all variables are insignificant.

Therefore, we look at the relationship between the independent and dependent variables in a short-run relationship. From Table 5, we found that the coefficients of almost all variables were significant at the 5% level except FDI. Energy consumption and GDP positively impact CO_2 emissions, while GDP^2 has a negative effect. We can interpret this as follows: A 1% increase in energy consumption would result in a 1.184% increase in CO_2 emissions, and a 1% increase in GDP would result in a 13.420% increase in CO_2 emissions. 0.598% and a 1% increase in GDP would result in a 0.598% decrease in CO_2 emissions. Finally, the FDI variable must be verified in Granger causality analysis for the other relationship with CO_2 emissions.

6.2.1. Statistics

$R^2 = 0.661$, Adjusted $R^2 = 0.615$, S.E. of regression = 0.045 and F-statistic = 14.435.

6.3. Empirical Findings from the Granger Causality Test

The different results are reported in Table 6. In the case of Thailand, the results indicate that two bidirectional causal relationships exist in the short run. The first relationship is between energy consumption and GDP, and the second is between energy consumption and GDP^2. In addition, there are seven unidirectional relationships where FDI affects CO_2 emission, energy consumption, GDP, and GDP^2, including CO_2 emission affects energy consumption, GDP, and GDP^2.

The results of long-run causal relationships show three bidirectional causal relationships between GDP and CO_2 emission, GDP^2 and CO_2 emission, including GDP and GDP^2. Moreover, there are two unidirectional relationships: GDP influences energy consumption, and GDP^2 influences energy consumption.

7. CONCLUSION

This study uses data collected from the World Bank indicator to examine the causal link between CO_2 emission, energy consumption, GDP, square of GDP, and foreign direct investment in the Environmental Kuznets Curve for Thailand from 1971 to 2014. Three steps are used: bound tests to verify the presence of cointegration, autoregressive distributed lag (ARDL) model to check the effects of the dependent variables on the independent variable in the short run and long run, and finally, the vector error correction (VECM) was used the detect the causal relationships among variables. From ARDL analysis, in the short run, we found that the coefficients of almost all variables were significant at the 5% level except FDI. Energy consumption and GDP positively impact CO_2 emissions, while GDP^2 has a negative effect. And from causality analysis, the results indicate that two bidirectional causal relationships exist in the short run. In addition, there are seven unidirectional relationships in which we found the relationships between FDI and CO_2 emission. Finally, the results of long-run causal relationships show three bidirectional causal relationships, with two unidirectional relationships.

Therefore, from the results of both short-run and long-run studies of the relationship of variables in the EKC model, it was found that energy consumption, economic growth, and foreign direct investment affect increasing carbon emissions. Therefore, in terms of policy, the Thai government should support using more renewable energy. Including foreign direct investment, the government should issue a policy for foreign investors' investment by regulating green factories. Frankel and Rose (2005) stated that foreign investors are equipped with advanced technology and management skills. Innovation from their native country for the host country's benefit will likely lead to adopting energy-saving and emission-reducing methods.

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