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The Relationship between Energy Consumption, Carbon Emissions and Economic Growth in ASEAN-5 Countries

Kudabayeva Lyazzat[1], Aktolkin Abubakirova[2]*, Omarova Aizhan Igilikovna[3], Taskinbaikyzy Zhanargul[3], Saubetova Bibigul Suleimenovna[3]

[1]Taraz Regional University named after M. Kh. Dulaty, Taraz, Kazakhstan, [2]Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan, [3]Yessenov University, Aktau, Kazakhstan. *Email: aktolkin.abubakirova@ayu.edu.kz

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ABSTRACT

The importance of energy has made it the focus of many studies, discussions and policies. The studies carried out provide important ideas about the extent and in which direction the energy policies to be implemented affect the economic activities, and as a result, what kind of path should be followed. In terms of policy makers, determining the direction of causality is extremely important for the curriculum of the projects. In this study, the relationship between energy consumption, carbon emissions and economic growth in ASEAN-5 countries between the years 1990 and 2021 was examined. As a result of the causality analysis, it was found that there is a bilateral causality relationship between economic growth and CO_2 emissions in Singapore; it has been determined that there is a unilateral causality relationship from economic growth to CO_2 emissions in the Philippines, and from CO_2 emissions to economic growth in Indonesia and Malaysia. In addition, there is a bi-directional causality relationship between economic growth and energy consumption in Singapore; there is a unilateral causality relationship from economic growth to energy consumption in Indonesia and the Philippines.

Keywords: Economic Growth, ASEAN-5, Energy Consumption, Carbon Emissions
JEL Classifications: Q43, Q40, Q53, C33

1. INTRODUCTION

Increasing levels of industrialization, changing lifestyles, rapidly increasing population and increasing energy consumption have revealed the threat of global warming in the world. Efforts to adapt energy supply to demand, concerns about global warming are among the highlights in terms of examining the relationship between economic growth, energy consumption and carbon emissions (Cowan vd., 2014). Developing countries and markets accelerate economic development. Rapid population growth and urbanization are among the reasons for the increase in energy consumption in the world. However, increasing energy consumption has negative effects on the environment, especially with the use of fossil fuels (Zhang vd. 2017). Energy, which is used as energy in different economic activities, is among the main factors of economic growth. Understanding the relationship between energy consumption, carbon emissions and economic growth is important for governments to determine their energy policies (Payne, 2010).

In this study, the relationship between energy consumption, carbon emissions and economic growth in ASEAN-5 countries between the years 1990 and 2021 was examined. ASEAN-5 countries have an important place in the global economy. ASEAN-5's nominal GDP has exceeded 2.7 trillion USD as of 2019, making ASEAN-5 the world's seventh and Asia's fourth largest economy. ASEAN-5 is one of the fastest growing regions in the world. The average annual growth rate between 2010 and 2019 was 5.13%. Considering the strong economic growth, industrialization and a shift towards service-based economies, the energy consumption of the region has also increased (ASEAN, 2020). Growing economies often have large energy demands and energy requirements for electricity generation. Increases in energy demand cause an increase in the demand for electrical energy and environmental concerns such as carbon emissions (Salahuddin vd. 2018).

In the first part of this study, which examines the relations between economic growth, energy consumption and carbon emissions in ASEAN-5 countries, studies in the literature on the subject are examined. Then, the data set used is shown, the analysis method to be used and the inferences obtained are explained, and the empirical findings of the article are interpreted. The study ends with the conclusion part.

2. LITERATURE REVIEW

One of the theoretical dimensions of the relationship between economic growth and environmental pollution is the Environmental Kuznets Curve. The Environmental Kuznets Curve is a theory that explains the relationship between per capita gross domestic product (GDP) and environmental pollution. Accordingly, it is stated that environmental pollution increases in the previous stages of economic growth. However, as the per capita income level increases, this trend reverses after a while, and after a high income level is reached, economic growth leads to an improvement in environmental conditions. In this case, it is stated that there is an inverted U-shaped environmental impact indicator of per capita income. The logarithmic value of the indicator in question is modeled as a quadratic function of the logarithmic value of income (Stern, 2004). The Environmental Kuznets Curve is an empirical finding that shows that the emission or concentration levels of a particular polluting factor on the environment, the per capita income of a country or a city increases over time and then reaches a maximum level. After the maximum point, as per capita income continues to grow, the emission level decreases (Eugenio and Roberto, 2009). In this respect, when economic growth reaches its highest level, it affects the environmental quality positively in the long run.

In the nineties, in studies examining the validity of the Environmental Kuznets Curve using econometric methods, important findings were obtained on the existence of the Environmental Kuznets Curve. These studies are expressed as Grossman and Krueger (1995), Selden and Song (1994), Shafik (1994), Holtz-Eakin and Selden (1995).

Ang (2007) examined the relationship between energy consumption and output in France during the 1960-2000 period. According to the results obtained, a causal relationship is determined from economic growth to the direction of energy use and pollution increase in the long run.

Apergis and Payne (2010) examined the relationship between carbon dioxide emissions, energy consumption and economic growth for the period 1994-2004 in eleven countries of the Commonwealth of Independent States. The findings show that there is a long-term relationship between energy consumption and carbon dioxide emissions. In addition, it is determined that there is a bidirectional causality relationship between energy consumption and economic growth.

Chang (2010) examined the relationship between carbon dioxide emissions, energy consumption and economic growth in China. The results show that economic growth increases energy consumption and carbon dioxide emissions.

Niu et al. (2011) examined the relationship between economic growth, energy consumption and emissions in the period 1971-2005 for eight Asia Pacific countries. The findings of the study, in which the panel data analysis method was used, show that there is a causal relationship between economic growth, energy consumption and carbon dioxide emissions.

El Hedi Arouri et al. (2012) examined the relationship between energy consumption, economic growth and carbon dioxide emissions in twelve Middle Eastern and North African countries for the 1981-2005 period. The cointegration test results show that there is a long-term relationship between energy consumption and carbon dioxide emissions in twelve Middle Eastern and North African countries.

Farhani and Rejeb (2012) examined the relationships between energy consumption, economic growth and carbon emissions in the countries of the Middle East and North Africa (MENA) region during the 1973-2008 period using panel cointegration and panel causality econometric test methods. According to the results of the study, there is no relationship between GDP and energy consumption, but there is a relationship between carbon emissions and energy consumption in the short run. In addition to these results, it is determined that there is a unidirectional causality relationship from GDP and carbon emission variables to energy consumption variables in the long run.

Kasperowicz (2015) examined the relationship between economic growth and carbon emissions in EU countries for the period 1995-2012. In the study, GDP and carbon emission variables were determined for econometric modeling, and panel data analysis method was used. The findings indicate that there is a relationship between GDP and carbon emissions in the EU countries in the specified period.

Issaoui et al. (2016) examined the effects of carbon emissions on economic growth in Middle Eastern countries and North African countries during the 1990-2010 period. The variables determined for the econometric model of the study were determined as carbon emissions, GDP per capita, energy consumption, urbanization and life expectancy. The results of the study, in which the authors used Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methods as econometric methods, show that per capita GDP and energy consumption are effective on carbon emissions in the short run in MENA countries. In addition, it is determined that there is a causal relationship between energy consumption and economic growth.

Obradović and Lojanica (2017) examined the relationship between energy use, carbon emissions and economic growth in South East

European countries, Greece and Bulgaria for the period 1980-2010. For the econometric model of the study, in which the Error Correction Model (ECM) method was used, the variables of GDP per capita, fixed capital formation per capita and energy use per capita were determined. The findings reveal that there is a causal relationship from energy use and carbon emissions to economic growth in the long run in both countries. On the other hand, there is no causal relationship between energy use and economic growth in the short run. Ahmed et al. (2017) findings indicate that the environmental consequences of economic growth are alarming for most of the countries in the panel, and non-renewable energy consumption is the key contributing factor towards environmental deterioration in the ASEAN region.

Dees and Auktor (2017) examined the effect of renewable energy generation capacity on economic growth in MENA countries using the Generalized Least Squares (GLS) method. In the study examining the period of 1990-2012, it is concluded that renewable electricity generation has a significant and positive effect on economic growth.

Saudi et al. (2019) explores the role of renewable energy, non-renewable energy and technology innovation in testing the EKC hypothesis in Malaysia using annual data for the period 1980-2017. ARDL test results confirm the current long-term relationship between renewable energy, non-renewable energy, technology innovation and economic growth and carbon dioxide emissions in Malaysia. The empirical results show that renewable energy consumption and technology innovation have a significant and negative effect on carbon dioxide emissions, while non-renewable energy consumption and economic growth have a significant and positive effect on carbon dioxide emissions. Moreover, the results also confirm the existence of an inverted U-shaped curve in Malaysia.

In another study examining the Malaysian economy, Ali et al. (2020) examined the relationship between renewable and non-renewable energy consumptions and environmental degradation over the period 1997-2017. The findings confirm a bidirectional causality relationship between energy consumption and CO_2 emissions in the medium term, and a unidirectional causality running from energy consumption to CO_2 in the short run. However, no long-term evidence of any causal relationship was found. A bidirectional causality relationship was found between renewable energy consumption and CO_2 emissions in the short term, and a one-way causality relationship from renewable energy consumption to CO_2 in the medium term. However, in the long run, a unidirectional causal relationship has been identified in Malaysia, where causality runs from renewable energy consumption to environmental degradation.

Chen et al. (2019) investigates the relationships between carbon dioxide emissions, CO_2, GDP, renewable and non-renewable energy consumption and foreign trade in the Chinese economy for the period 1980-2014. ARDL limit test, VECM and Granger causality test methods were used. The findings show that there is a long-term relationship between the variables. Another important finding is that China's economic growth, non-renewable energy production and CO_2 emissions under the influence of foreign trade do not support the EKC hypothesis. However, after the addition of the renewable energy generation variable, it was found that the inverted U-shaped EKC hypothesis was supported in the long run. Long-term forecasts show that non-renewable energy and the increase in GDP increase CO_2 emissions, while renewable energy and foreign trade have a reducing effect on CO_2 emissions. Short-term Granger causality tests show that there are bidirectional causality ranging from foreign trade, CO_2 emissions and non-renewable energy to renewable energy. Furthermore, the finding shows that renewable energy consumption is an important solution in reducing CO_2 emissions over time.

Syzdykova et al. (2020) examined the relationship between energy consumption and economic growth in CIS countries. In the study, a 26-year panel data set covering the years 1992-2018 of the CIS countries was studied. According to the findings of the study, there is a bidirectional causality between energy consumption and economic growth in CIS countries. This shows that the feedback hypothesis is valid in these countries.

Erdogan et al. (2020) investigated the effects of economic growth, renewable and non-renewable energy consumption, oil prices and trade openness on CO_2 emissions in 25 OECD countries for the period 1990-2014. FMOLS and DOLS estimates show that the EKC hypothesis is valid in OECD countries. However, the AMG estimator revealed that the EKC hypothesis was invalid. Additional findings show that rising renewable energy consumption and oil prices are reducing CO_2 emissions, while non-renewable energy consumption is increasing by all estimators. However, no significant relationship was found between trade openness and CO_2 emissions.

In another study examining OECD countries, Destek and Sinha (2020) examined the validity of the EKC hypothesis for renewable and non-renewable energy use, the role of trade openness and ecological footprint in 24 OECD countries. They investigated the 1980-2014 period using second-generation panel data methodologies that allow cross-sectional dependence between countries. In the findings, group mean results determined that the inverted U-shaped EKC hypothesis is not valid in OECD countries because there is a U-shaped relationship between economic growth and ecological footprint. In addition, it was concluded that the increase in renewable energy consumption reduces the ecological footprint and the increase in non-renewable energy consumption increases environmental degradation.

Syzdykova et al. (2021) examined the relationship between renewable energy and economic growth in some developing countries (Brazil, India, China, Turkey, Mexico, South Africa, Chile, Indonesia). According to the findings, the 1% increase in the share of renewable energy use increases the GDP per capita by 0.07688% in the developing countries included in the analysis.

Ivanovski et al. (2021) examined the effect of renewable and non-renewable energy consumption on economic growth. By determining 39 countries for the period 1990-2015, OECD countries and other countries were considered as two different models. Dynamic CCEMG and non-parametric LLDVE panel data tests were used. Our estimates show that non-renewable energy consumption has a positive and significant impact on economic growth in OECD countries. Consumption of both renewable and non-renewable energy spurs economic growth in non-OECD countries, suggesting that despite constraints on technical progress, developing countries can play an important role in the transition to renewables.

3. DATA AND METHODOLOGY

3.1. Data and Model

An analysis was conducted for the ASEAN-5 (Indonesia, Malaysia, Philippines, Singapore and Thailand) countries in the study, which examined the relationship between energy consumption, CO_2 emissions and economic growth. Panel analysis was carried out in the study covering the years 1990-2021. Among the data used in the analysis, the data on energy consumption and CO_2 emissions and per capita GDP were obtained from the World Bank in the form of annual data. First, the cross-sectional dependencies of the variables were determined in the analysis. In line with the results, it was aimed to determine the relationship between the variables and the direction of this relationship. For this purpose, Kónya (2006) causality test was conducted. It is expected that the study will contribute to the literature when the subject of the study and the analyzes are up-to-date and the country group considered. The model of the study was created as follows:

$$lneconomicgrowth_{it} = \alpha_{it} + \beta_1 lnec_{it} + \beta_2 lnCO2_{it} + \varepsilon_{it}$$

The variables of the model created within the scope of the study are as stated in Table 1.

3.2. Cross-section Dependency

In panel data analysis, all tests, including unit root tests, are sensitive to cross-sectional dependency properties that can be found between variables. For this reason, cross-sectional dependency relationships that may occur between variables in panel data models should be investigated. Ignoring the cross-section dependency properties that may occur in the variables or the model may cause biased estimations. It provides interpretation of the variables in cross-section tests by comparing the time interval and the number of units. Breusch-Pegan LM, one of the cross-section tests, provides significant results in cases where the time interval is larger (T>N) in the series. Here, in case of a possible cross-section dependency, the situations that cause the varying variance can also be tested. The Bias-Adjusted test can be considered on a wider scale both when time is more than units (T>N) and when it is more than unit time (N>T). The Pesaran Scaled LM test can be considered when T>N, T~N. Pesaran CD test is considered when N>T (Pesaran et al., 2008).

3.3. Delta Test

The delta test is used to test the structures of the variables. It is also taken into account in determining the unit root and cointegration tests used during the analysis. Delta test provides convenience in expressing the variables under the assumption that the slope of the series is homogeneous. Apart from that, this test makes the extraction process easy to understand. Under the homogeneity assumption, inconsistent results can be obtained in the estimations based on panel data models, if not valid (Su and Chen, 2013). Delta test is calculated in two different ways as stated in the equations below:

$$\tilde{\Delta} = \sqrt{N}\,\frac{N^{-1}\breve{S} - k}{\sqrt{2k}}$$

$\tilde{\varnothing}_{adj}$ gives the corrected delta test statistic:

$$\tilde{\Delta}_{adj} = \sqrt{N}\,\frac{N^{-1}\bar{S} - E(\bar{Z}_{it})}{\sqrt{Var(\bar{Z}_{it})}}$$

The null hypothesis and alternative hypothesis of the test in question are expressed as follows:

H_0: $\beta_1 = \beta_2 = \cdots = \beta_n$ for all β_i

H_0: $\beta_1 = \beta_2 = \cdots \neq \beta_n$ for at least one *i*.

3.4. Kónya (2006) Causality Test

Kónya (2006) causality test is applied based on seemingly unrelated regressions (SUR) and Wald tests with country-specific bootstrap critical values. This test has two advantages. First, it

Table 1: Definitions of variables and sources

Variables	Description	Source
CO_2	CO_2 emission (metric tons)	World bank
Energy consumption	Energy use (kg of oil equivalent per capita)	
Economic growth	GDP per capita (USD)	

GDP: Gross domestic product

Table 2: Cross-section dependency results

Variables	Statistics value	Probability value
Economic growth		
Breusch, pagan 1980	78.713	0.0000***
Pesaran 2004 CDlm	11.815	0.0000***
Pesaran 2004 CD	−2.687	0.0003***
Bias-adjusted CD test	23.383	0.0000***
CO_2		
Breusch, pagan 1980	67.776	0.0000***
Pesaran 2004 CDlm	8.636	0.0000***
Pesaran 2004 CD	−3.150	0.0001***
Bias-adjusted CD test	22.160	0.0000***
Energy consumption		
Breusch, pagan 1980	97.823	0.0000***
Pesaran 2004 CDlm	15.121	0.0000***
Pesaran 2004 CD	−3.235	0.0000***
Bias-adjusted CD test	23.864	0.0000***

***It is significant at the 1% level. CD: CrossSectionally dependency

Table 3: Delta test results

Delta test	Statistics value	Probability value
Δ	15.791	0.0000***
Δadj	16.693	0.0000***

***It is significant at the 1% level

Table 4: Causal relationship between gross domestic product per capita and CO_2 emissions

Hypotheses	Countries	Wald statistics	Probability value	Critical values (%)			Panel Fisher statistics
				1	5	10	
H_0: Economic growth is not the cause of CO_2 emissions	Indonesia	0.388	0.841	12.248	8.302	6.553	24.515 (0.0190)**
	Malaysia	0.230	0.868	12.444	8.424	6.805	
	Philippines	16.486**	0.035	18.168	14.354	12.258	
	Singapore	33.331**	0.024	34.848	26.834	23.086	
	Thailand	0.118	0.428	1.863	1.085	0.582	
H_0: CO_2 emissions are not the cause of economic growth	Indonesia	34.840**	0.018	44.062	34.880	30.162	28.630 (0.0201)**
	Malaysia	34.885**	0.028	44.638	34.658	28.888	
	Philippines	0.805	0.841	10.502	5.488	6.086	
	Singapore	24.833**	0.014	25.054	18.868	16.534	
	Thailand	0.841	0.108	1.886	1.258	0.885	

**It is significant at the 5% level

Table 5: Causality relationship between gross domestic product per capita and energy consumption

Hypotheses	Countries	Wald statistics	Probability value	Critical values (%)			Panel Fisher statistics
				1	5	10	
H_0: Economic growth is not the cause of per capita energy consumption	Indonesia	20.264**	0.019	25.433	19.417	15.453	20.567 (0.0120)**
	Malaysia	0.471	0.997	25.229	19.503	15.534	
	Philippines	12.019*	0.007	10.301	7.373	5.175	
	Singapore	34.721**	0.032	37.030	27.255	23.005	
	Thailand	0.047	0.954	5.707	4.505	3.521	
H_0: Energy consumption per capita is not the cause of economic growth	Indonesia	0.215	1.000	42.790	33.329	27.931	5.307 (0.9501)
	Malaysia	0.230	1.000	42.252	32.755	27.414	
	Philippines	1.271	0.977	10.957	7.440	7.379	
	Singapore	24.573**	0.029	34.077	25.000	22.577	
	Thailand	2.557	0.172	5.511	3.754	3.159	

Note: * and ** indicate 1% and 5% significance levels, respectively

is assumed that the panel is not homogeneous. Thus, Granger causality can be tested separately for each country included in the panel. Second, since simultaneous correlation is allowed between countries, it makes it possible to take advantage of the additional information provided by the panel data. This test does not require a common hypothesis for all panel units and does not require any prior knowledge other than determining the number of lags (Kónya, 2006). The SUR structure to be considered for this test is as follows:

$$Y_{1,t} = \alpha_{1,1} + \sum_{l=1}^{mly_1} \beta_{1,1,l} Y_{1,t-l} + \sum_{l=1}^{mlx_1} \varphi_{1,1,l} X_{1,t-l} + \varepsilon_{1,1,t}$$

$$Y_{2,t} = \alpha_{1,2} + \sum_{l=1}^{mly_1} \beta_{1,2,l} Y_{2,t-l} + \sum_{l=1}^{mlx_1} \varphi_{1,2,l} X_{2,t-l} + \varepsilon_{1,2,t}$$

$$Y_{N,t} = \alpha_{1,N} + \sum_{l=1}^{mly_1} \beta_{1,N,l} Y_{N,t-l} + \sum_{l=1}^{mlx_1} \varphi_{1,N,l} X_{N,t-l} + \varepsilon_{1,N,t}$$

$$X_{2,t} = \alpha_{2,2} + \sum_{l=1}^{mly_1} \beta_{2,2,l} Y_{2,t-l} + \sum_{l=1}^{mlx_2} \varphi_{2,2,l} X_{2,t-l} + \varepsilon_{2,2,t}$$

$$X_{1,t} = \alpha_{2,1} + \sum_{l=1}^{mly_2} \beta_{2,1,l} Y_{1,t-l} + \sum_{l=1}^{mlx_2} \varphi_{2,1,l} X_{1,t-l} + \varepsilon_{2,1,t}$$

$$X_{N,t} = \alpha_{2,N} + \sum_{l=1}^{mly_1} \beta_{2,N,l} Y_{N,t-l} + \sum_{l=1}^{mlx_2} \varphi_{2,N,l} X_{N,t-l} + \varepsilon_{2,N,t}$$

Here l denotes the lag length. Granger causality is tested in the SUR system structure. Each equation relates to a different country and is determined by a different sample. The same variables with different observations are the same in all equations. The possible connection between individual regressions is tested through cross-sectional dependence.

4. ANALYSIS FINDINGS

The results of the cross-section dependency test are as stated in Table 2. According to the results of the analyzed analysis, it was determined that there was a cross-section dependence in the series.

The findings regarding the Delta test, which was considered for the homogeneity test, are presented in Table 3.

According to the test results examined, it is seen that the examined variables have a heterogeneous structure. After cross-section dependency test and Delta test, Kónya causality test was applied. In this test, a common hypothesis is needed for all panel units and testing is done without the need for prior knowledge such as unit root and cointegration. The findings obtained as a result of the Kónya causality analysis are presented in Table 4.

According to the results obtained, it is seen that there is a bilateral causality relationship between GDP per capita and CO_2 emissions. When examined individually, there is a bilateral causality relationship between GDP per capita and CO_2 emissions in Singapore; it is seen that there is a one-way causality relationship from GDP per capita to CO_2 emissions in Philippines, and from CO_2 emissions to GDP per capita in Indonesia and Malaysia (Table 5).

5. CONCLUSION

In many developed and developing countries, the effects of economic activities on the environment are constantly discussed. The increase in economic activities causes environmental pollution and social costs increase significantly. In this respect, economic approaches that center sustainable economic growth are becoming more important today. Today, the effective and efficient use of energy resources has an impact on economic development. The realization of sustainable economic growth, which is based on minimizing the negative effects of this development on the environment, is becoming increasingly important.

The aim of this research is to investigate the effect of energy consumption and CO_2 emissions on economic growth for emerging market economies such as Indonesia, Malaysia, Philippines, Singapore and Thailand. For this purpose, an analysis covering the years 1990-2021 was made in the study. In the study, in which panel analysis was carried out, the horizontal cross-sections of the variables were initially examined. Kónya (2006) causality test was conducted to determine the causality relationship between the variables in line with the results. As a result of the causality analysis, it was found that there is a bilateral causality relationship between economic growth and CO_2 emissions in Singapore; it has been determined that there is a unilateral causality relationship from economic growth to CO_2 emissions in the Philippines, and from CO_2 emissions to economic growth in Indonesia and Malaysia. In addition, it has been determined that there is a bilateral causality relationship between economic growth and energy consumption per capita in Singapore, and a unilateral causality relationship from economic growth to energy consumption per capita in Indonesia and the Philippines.

Along with economic development, the effects of high energy use on environmental quality will continue to be discussed. In this context, sustainable economic development and growth approaches that take into account environmental sensitivities along with economic development and growth are becoming increasingly important. Therefore, in addition to realizing economic growth, it is important to minimize the negative effects of growth on environmental pollution, reduce social costs and leave a more livable healthy environment to future generations. In this context, it is necessary for the state to make the necessary regulations, to minimize the damage to the environment with financial and legal sanctions, and therefore to reduce the social costs that arise.

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