Impact of Economic Growth, Urbanization and Electricity Consumption On Environmental Degradation: Evidence from ASEAN-5

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ABSTRACT: This study aims to reveal the impact of economic growth, urbanization, and electricity consumption on CO2 emissions. The data used is in the form of annual panel data for 30 years (1992-2021) in 5 selected ASEAN countries (Indonesia, Thailand, Malaysia, Singapore and the Philippines) which were corrected using the Panel Auto-Regressive Distribution Lags (ARDL) approach. The findings prove that in the long run economic growth and electricity consumption have a significant positive impact on CO2 emissions. Meanwhile, the urbanization variable has a negative impact on CO2 emissions. In the short term economic growth has a negative impact on CO2 emissions. Then urbanization and consumption of electrical energy have a positive impact on CO2 emissions. Therefore, this study states that the governments of the ASEAN-5 countries as policy makers must prepare environmental policies that can reduce CO2 emissions without sacrificing economic growth.

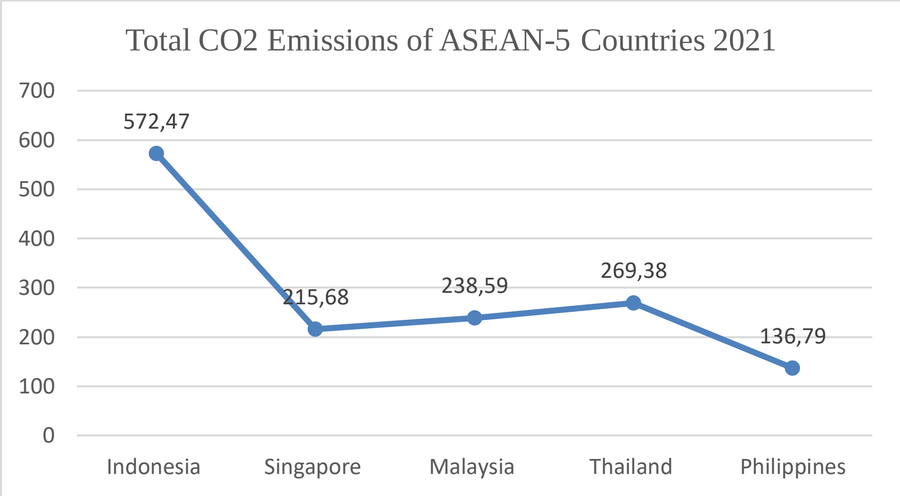
Keywords: *Environmental Degradation, CO2 Emissions, Economic Growth, Urbanization, Electrical Energy Consumption, Auto-Regressive Distribution Lags (ARDL)*

1 INTRODUCTION

In the historic year of 2015, 196 countries committed through the Paris Agreement to ambitious efforts to combat climate change, including warming to well below 2°C above pre-industrial levels and to work towards 1.5°C. In the same year, all UN member states adopted the 2030 agenda, the Sustainable Development Goals (SDGs), a comprehensive global action plan for "people, planet and prosperity" consisting of 17 SDGs and 169 targets to be achieved by 20230, including SDG 13 on addressing climate change. Climate change and its devastating impact on the environment is one of the most critical issues facing the global community. The consequences of human activities, especially CO2 emissions, have become one of the main factors causing climate change in recent decades (IPPC, 2007).

Environmental degradation is a crucial issue for policy makers to address (Saidi and Rahman, 2021; Sari *et al.*, 2023) and a major concern for countries in ASIA, especially in ASEAN (Santi and Sasana, 2021). As global warming and climate change are trending in the 21st century caused by the increasing concentration of greenhouse gases (GHG) in the atmosphere (Anam *et al.*, 2022; Hritonenko and Yatsenko, 2022). There is no doubt that CO2, which accounts for almost 60% of GHG emissions, is one of the causes of significant climate change associated with environmental degradation (Ahmed, Wang and Ali, 2019) and the largest contributor of about 81% (Bosah *et al.*, 2021; Nathaniel, Nwulu and Bekun, 2021). The main root of climate change is human activity on the earth's surface which leads to environmental damage (Zafar, Sinha, Ahmed, *et al.*, 2021). Various practices of economic activities, both leading to and based on economic growth, contribute to pollutant emissions (Ahmed *et al.*, 2020; Khan *et al.*, 2020; Odugbesan and Adebayo, 2020).

Graphics 1. Total CO2 Emissions of ASEAN-5 Countries 2021



Source: Data Processed, World Bank

The graph above shows the five ASEAN countries with the highest CO2 emissions in 2021. The first position is occupied by Indonesia, which produces 572.47 million tons of CO2 emissions. Followed by Thailand with 269.38 million tons of CO2 emissions produced. Then Malaysia occupies the third position with 238.59 million tons of CO2 emissions released. Singapore has emitted 215.68 million tons of CO2 emissions, and finally the Philippines produced CO2 emissions of 136 million tons.

Economic growth is the main indicator in a country's development process used to see how much success in the economic field can be measured using GDP and is also a key factor that can affect environmental degradation and CO2 emissions (Pata, Korkut, 2018). Thus, the source of controversy is the causal relationship between economic growth and environmental degradation (Saidi and Rahman, 2021). Several researchers have extensively explored the causal relationship between economic growth and various indicators of environmental degradation by the Environmental Kuznets Curve (EKC) model both globally and regionally (Sarkodie and Strezov, 2018). The EKC hypothesis states that at the onset of industrialization, an increase in economic growth will increase environmental degradation and eventually decrease after a turning point (Işik, Kasımatı and Ongan, 2017; Isik, Ongan and Özdemir, 2019; Altinoz, Apergis and Aslan, 2020; Dogan *et al.*, 2020; Dogru *et al.*, 2020; Ahmad *et al.*, 2021; Alvarado *et al.*, 2021; Ongan, Isik and Ozdemir, 2021; Shahzad *et al.*, 2021). The model of the relationship between economic growth and environmental degradation can be shown in an inverted U-shape.

In various countries, especially developing countries, economic growth increases the rate of urbanization . Increasing urbanization will pose a threat to a country's sustainable development (Odugbesan and Rjoub, 2020), because it can increase energy consumption, which in turn increases CO2 emissions (Anwar, Younis and Ullah, 2020). Then (Chen, 2016) found that urbanization is a direct source of carbon emissions because it consumes about 84% of total commercial energy. Many studies have explored the relationship between urbanization and CO2 emissions. However, there is still an academic puzzle. For example, a study (Ha Minh Nguyen, 2016) revealed that urbanization has a positive effect on CO2 emissions. The study contradicts the study (Mosikari and Eita, 2020; T. S. Adebayo *et al.*, 2021) which states that urbanization has a negative effect on CO2 emissions. Meanwhile, research (Rafiq, Salim and Nielsen, 2016)states that urbanization has no impact on CO2 emissions. An empirical study (Chen, Jin and Lu, 2019) found an inverted U-shaped relationship between urbanization and CO2 emissions. While the findings of (Shahbaz *et al.*, 2016) show that the relationship between urbanization and CO2 emissions is U-shaped or no inverted U is detected.

Globally, experts state that economic expansion depends on energy because it plays an important role in increasing income and development, creating jobs and boosting productivity(T. .

Adebayo *et al.*, 2021). Economic development is inseparable from energy consumption and energy plays an important role in human survival on the earth's surface (Rehman *et al.*, 2019; Hu and Algarni, 2021). Each country to meet energy needs can be through various energy sources such as electrical energy, fossil fuels, and modern technology which depends on the environment, culture, population, resources and socio-economic factors (Gallo Cassarino, Sharp and Barrett, 2018). Some literature studies show that there are two influences that affect climate: economic growth and energy use. Studies (Adebayo and Akinsola, 2020; Rjoub *et al.*, 2021; T. S. Adebayo *et al.*, 2021) state that the main causes of environmental degradation in various countries and other regions are economic growth and energy use.

In the electricity sector in particular, in 2018, global electricity demand rose by 4%, with coal and natural gas remaining the main electricity supplies, leading to a 2.5% increase in CO2 emissions from the sector (IEA, 2019). Studies that include electrical energy consumption variables are still rarely researched, here is one study by (Ali, Razman and Awang, 2020) which investigates the relationship between population, GDP growth, electricity generation, and electricity consumption and carbon emission output which states that these variables have a positive linear relationship. Population and GDP growth can significantly result in high levels of electricity production and consumption, leading to high carbon emission expenditure.

Based on the above reasons, the purpose of this study is to examine the short-term and long-term impacts of economic growth, electrical energy consumption, urban population on environmental degradation in terms of CO2 emissions in the case study of selected ASEAN-5 countries (Indonesia, Singapore, Thailand, Malaysia and the Philippines) for the period 1992-2021. The motivation for selecting the selected countries is that according to the World Bank, among the 11 ASEAN countries, these five countries are the five largest CO2 emitters in 2021. On the other hand, according to (Centrall Intelligence Agency, 2023) shows that 100% of Singapore's population lives in urban areas. This means that no part of the population lives outside of urban areas. Therefore, there are no villages/rural areas in Singapore today.

This empirical study contributes to the existing literature. First, it reveals the impact of economic growth, urban population and electricity consumption on environmental degradation in terms of CO2 emissions in the short and long term which is new evidence from the selected ASEAN-5 countries for the period 1992-2021. Second, this study investigates whether or not the inverted U-shaped pattern of the relationship between economic growth and environmental degradation in the Environmental Kuznets Curve (EKC) hypothesis is proven in each of the selected countries. Lastly, there are few studies that include electrical energy consumption as an additional variable. Therefore, in this study, researchers try to include a new variable, namely electrical energy consumption, which is different from research in previous years that used biomass energy consumption variables (Zafar, Sinha, Ahmad, *et al.*, 2021), renewable energy consumption (Koengkan, 2018; Pata, Korkut, 2018; Kahia, Ben Jebli and Belloumi, 2019; Gao and Zhang, 2021; Zafar, Saeed, *et al.*, 2021; Raihan and Tuspekova, 2022), transportation energy consumption (Nasreen, Mbarek and Atiq-ur-Rehman, 2020). The basis for selecting these variables is the new idea that in modern times there is a transition period where people / companies tend to use electrical energy-sourced equipment more rapidly, which indicates an acceleration of CO2 emissions.

The rest of the paper, section 2, presents the literature review. Section 3 outlines the methodology related to data description, empirical model and estimation technique. Section 4 presents the estimation results. Finally, section 5 contains conclusions and outlines the policy implications of this research article for practitioners or academics.

2 LITERATUR REVIEW

2.1 *The Impact of Economic Growth on CO2 Emission*

The Environmental Kuznets Curve (EKC) developed by (Kuznets, 1955) illustrates the relationship between economic growth and environmental degradation, which shows that environmental degradation increases with increasing income levels until a certain turning point, then increasing income will result in a decrease in environmental degradation. However, it contributes to the final stage that leads to environmental improvement as long as the threshold level of GDP is exceeded (A. Omojolaibi and P. Nathaniel, 2020; Murshed and Dao, 2020; Nathaniel *et al.*, 2021). In other words, there is an inverted U-shaped relationship between economic growth and environmental degradation.

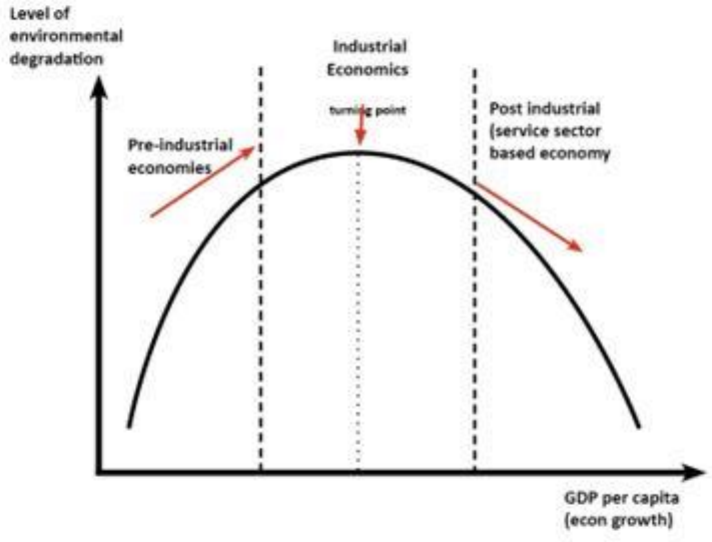


Figure 1. Environmental Cuznet *Curve (EKC)*

Research (Zhang, Zhang and Yuan, 2019) investigated the relationship between carbon emissions and five influencing variables in a representative set of 50 developing countries from 1995-2017. They used the Fully Modified OLS (FMOLS) Panel approach. The findings showed the validation of the inverted U-curve of the Environmental Kuznets Curve (EKC) theory that appears in some countries such as Mexico, Croatia, Kazakhstan, Iran, Algeria, Indonesia and Thailand, in addition to these countries, it is proven that the curve is U-shaped or rejects the Environmental Kuznets Curve (EKC) hypothesis.

(Mosikari and Eita, 2020)investigated the relationship between CO2 emissions, urban population, energy consumption and economic growth in 29 selected African countries from 2005-2019. To achieve its goal, it used the Panel Smooth Transition Regression (PSTR) model approach. The findings proved the existence of an Environmental Kuznets Curve (EKC) or validated inverted U-shaped curve in all 29 selected African countries. (Bouznit and Pablo-romero, 2016) examined using the ARDL model showed the validation of the EKC hypothesis and the increase in economic growth in Algeria has increased CO2 emissions.

(Pata, Korkut, 2018) analyzed the relationship of renewable energy consumption, urbanization, financial development, economic growth (GDP per capita), CO2 emissions and tested the EKC hypothesis in the country of Turkey in 1974-2014 using the ARDL approach. The findings show that support the EKC hypothesis which establishes an inverted U/N-shaped relationship between economic growth and CO2 emissions. The study was corroborated (Ozatac, Gokmenoglu and Taspinar, 2017) investigating the EKC hypothesis in the Turkish case study by considering several selected indicators. The data used annual data covering 1960-2013 with ARDL approach. The results found by researchers support the EKC hypothesis or an inverted U-shaped relationship.

(Raza and Shah, 2018) examined the relationship of trade, economic growth, and renewable energy to environmental degradation in terms of CO2 emissions in G7 countries. Using panel data of seven G7 countries for the period 1991-2016. Assessment with panel unit root test approach and cointegration test. The results show that the three independent variables are cointegrated in the long run and have a significant effect on CO2 emissions. In addition, it also supports the EKC curve hypothesis or the validation of an inverted U-shaped relationship in the G7 countries. A strengthened study (Nathaniel *et al.*, 2021) examines the impact of nuclear energy use, renewable energy and economic growth with respect to mitigating CO2 emissions. The study used annual panel data for the period 1990-2017 in six of the seven G7 countries with panel data regression econometric techniques. The findings prove the validity of the EKC hypothesis for Canada, the United Kingdom, France and the United States, other than these countries, the EKC hypothesis does not apply.

Some research contradicts the above research. For example, the South Korean case study (Koc and Bulus, 2020) investigates the relationship between CO2 emissions, energy use and economic growth using annual data for the period 1971-2017. Utilizing the ARDL approach with the results of the researchers did not find any support / validity of the EKC hypothesis, while energy use and economic growth resulted in environmental degradation. (Demissew Beyene and Kotosz, 2020) in his research found that there is a correlation between CO2 emissions and economic growth in 12 countries in East Africa for 1990-2013 using the Pull Mean Group (PMG) approach. The results show a U-shape which means that it rejects the EKC hypothesis in the form of an inverted U.

Recently (Erdogan, Okumus and Guzel, 2020) also confirmed that for 25 OECD countries for the period 1990-2014 using the Augmented Mean Group (AMG) estimation method, the EKC hypothesis does not hold. Another corresponding study (Miranda *et al.*, 2020) involving Mexico, the United States and Canada in the period 1990-2016. Using OLS, VAR, and Granger causality tests. Researchers found that the EKC hypothesis was confirmed for Mexico and the United States. While the EKC hypothesis is not valid in Canada. The Granger causality test shows a unidirectional causality relationship between CO2 emissions and economic growth. With some of the statements that have been expressed, four hypotheses can be formulated, namely H0: economic growth has a negative impact on CO2 emissions and H1: economic growth has a positive impact on CO2 emissions. H0: the relationship between economic growth and CO2 emissions does not support the EKC hypothesis in selected ASEAN-5 countries and H1: the relationship between economic growth and CO2 emissions does not support the EKC hypothesis in selected ASEAN-5 countries.

2.2 *Impact of Urbanization on CO2 Emissions*

The environmental transition theory developed by (McGranahan and Satterthwaite, 2002) talks about how environmental aspects are related to development at the urban level. It states that urban environmental problems will evolve following the development of its economic development stage. In some countries, especially developing countries, economic growth increases the rate of urbanization (Odugbesan and Rjoub, 2020). It has been proven in several studies that urbanization and energy consumption and environmental degradation are significantly related (Zi, Jie and Hong-Bo, 2016; Behera and Dash, 2017). These studies also argue that globally approximately 75% of energy consumption and 60% of carbon emissions are also accounted for by urban spaces. In addition, some researchers claim that urbanization is an important determinant of CO2 emissions (Ali, Law and Zannah, 2016; Kirikkaleli and Kalmaz, 2020).

(Abbasi *et al.*, 2020) investigated the impact of urbanization and energy consumption on carbon emissions in selected ASEAN-8 countries (Sri Lanka, Malaysia, Nepal, Bangladesh, Pakistan, China, India and Indonesia). Using panel data over a 35-year period from 1982-2017. To achieve their goal they used granger causality and panel cointegration approaches. The results of the panel cointegration test show that in the long run there is a relationship between urbanization, energy consumption and carbon emissions. It further confirms that energy consumption, and urbanization have a positive and significant effect on carbon emissions and shows that energy consumption and urban development cause environmental degradation.

(Anwar, Younis and Ullah, 2020) examined the impact of urbanization and economic growth on CO2 emissions case studies of countries in East Asia. The data used is annual panel data for the period 1980-2017. To achieve the goal, researchers adopted a panel data fixed effects model. The study results show that urbanization, economic growth and trade openness have a significant positive effect on CO2 emissions in East Asian countries. (Ali, Bakhsh and Yasin, 2019) tried to explore the impact of urbanization on CO2 emissions in Pakistan. The study used time series data from 1972-2014. Testing with Auto Regressive Distributed Lag (ARDL) and VECM approaches. The ARDL model was used to determine the impact in the long run and short run, while the VECM model was used for causal analysis. Researchers found that urbanization can increase CO2 emissions in both the long and short term.

(Mosikari and Eita, 2020) investigated the non-linear impact of urban population, energy consumption, and economic growth on CO_2 emissions in 29 selected African countries. Using annual data for the period 2005-2019, the Panel Smooth Transition Regression (PSTR) estimation method was used. The empirical study results show that urban population has a negative impact on CO_2 emissions, while energy consumption has a positive impact on CO_2 emissions. (Bosah *et al.*, 2021) investigated the impact of energy consumption, economic growth, urbanization on CO_2 emissions. The data are annual panel data for the period 1980-2017 using panel cointegration and PMG-ARDL tests. The researchers found that urbanization has no significant effect on environmental degradation in the long or short term, while energy consumption has a significant negative effect on environmental degradation in both the short and long term, as well as economic growth that can cause environmental distortions.
Empirical analysis (Ali, Abdul-Rahim and Ribadu, 2017) examines the impact of urbanization on CO_2 emissions in the Singapore case study for the 1970-2015 time period. The analysis used the Autoregressive Distribution Lags (ARDL) estimation method. The findings revealed that urbanization has a negative impact on CO_2 emissions in Singapore, which means that urban development in Singapore is not an obstacle to improving environmental quality. And economic growth has a significant positive impact on CO_2 emissions, which means that economic growth can reduce environmental quality in the country.

Empirically (Khoshnevis Yazdi and Dariani, 2019) examined the dynamic causality relationship of CO_2 emissions, energy consumption, economic growth, trade openness and urbanization in a case study of Asian countries in the interval 1980-2014. Researchers used the PMG approach and Granger causality test with the results showing that between variables there is a relationship in the long run, urbanization can increase energy consumption and CO_2 emissions. While the Granger causality test, there is a two-way causality relationship between economic growth, urbanization and CO_2 emissions. With some of the statements that have been expressed, the hypothesis can be formulated, namely H0: Urbanization has a negative impact on CO_2 emissions and H1: Urbanization has a positive impact on CO_2 emissions

2.3 *Impact of Electric Energy Consumption on CO2 Emissions*

The study (Ali, Razman and Awang, 2020) examines the relationship between population, GDP growth, electricity generation, electricity consumption and CO_2 emissions in Malaysia for the period 1970-2014. The data used time series using time series approach, correlation and multiple linear regression analysis. The results showed an increasing trend of GDP, population, electricity generation, consumption and emission output in Malaysia. Correlation analysis presents a positive linear relationship between GDP, population, electricity generation, electricity consumption and emission output. Population and GDP growth tend to significantly result in high levels of electricity generation and consumption leading to greater carbon emissions in Malaysia.

Empirical study (Bah and Azam, 2017) used ARDL test and Granger causality test to investigate the causal relationship of electricity consumption, economic growth, financial development and CO_2 emissions with a case study of South Africa for the period 1971-2012. The researcher found that in the Granger causality test there was no causality between electricity consumption and economic growth. (Rehman *et al.*, 2019) using ARDL approach, Dickey-Fuller unit root test, and Phillips-Perron unit root test investigated the long-run and short-run causality relationship of electric energy consumption, renewable energy consumption, fossil fuel energy consumption, energy use, CO_2 emissions, and GDP per capita of Pakistan case study for the period 1990-2017. The study results show that in the long run, CO_2 emissions, electric power consumption, and renewable electricity output have a positive and significant relationship with GDP per capita, while the relationship of renewable energy consumption, energy use, and fossil fuel energy consumption with GDP per capita has a negative effect.

Another relevant study (Asumadu-Sarkodie and Owusu, 2017) analyzed multivariate CO_2 emissions, electricity consumption, economic growth, financial development, industrialization and urbanization for the period 1980-2011 in the case study of Senegal. They used non-linear regression analysis literative partial least square (NIPALS) method. The results prove that there is a linear relationship between the variables. And showed that the variables of financial development, electricity consumption and industrialization have a positive effect on CO_2 emissions, while the variables of urbanization and economic growth have a negative effect on CO2 emissions. From several statements that have been disclosed, the hypothesis can be formulated, namely H0: Electric energy consumption has a negative impact on CO2 emissions and H1: Electric energy consumption has a positive impact on CO2 emissions.

3 METHODS

This study investigates the impact of economic growth, urbanization and electricity consumption on environmental degradation in terms of CO2 emissions in the short and long term in selected ASEAN-5 countries. The data used are annual panel data for the period 1992-2021. The variables used are CO2 emissions as the dependent variable (Y) and for the independent variables include economic growth (X1), urbanization (X2) and electrical energy consumption (X3). Carbon emission variable (CO2) is measured in MTCO2 (million tons) available at bp energy, economic growth denoted (GDP) measured in Per Capita (Current US$) available at World Development Indicators (WDI), urbanization denoted (URB) measured in million people available at World Development Indicators (WDI) and electrical energy consumption denoted (ELC) measured in billion kWh available at International Energy Administration (IEA).

Tabel 1. Description and Data Source.

Variable	Symbol	Unit	Source
Carbon Emission	CO2	Metric Per Ton	bp energy
GDP per capita	GDP	Per Capita (Current US$)	WDI
Urbanization	URB	Millions People	WDI
Electricity Consumption	ELC	Kwh	IEA

Source:Data Processed

In revealing the impact of economic growth, urbanization and electrical energy consumption on environmental degradation in the case study of selected ASEAN-5 countries, the approach used is the Panel Auto-Regressive Distribution Lags (ARDL) approach used to analyze the impact in the short and long term. The general equation represented in this study is as follows:

$$CO2_t = f(GDP_t, URB_t, ELC_t) \quad (1)$$

To avoid violation of basic econometric assumptions, all variables are transformed into natural logarithms. The Log version of the equation model from the transformation of equation 1 is as follows:

$$LnCO2_t = \beta_0 + \beta_1 LnGDP_t + \beta_2 LnURB_t + \beta_3 LnELC_t + e_t \quad (2)$$

Where, CO2 represents carbon emissions, GDP represents economic growth, URB represents urbanization, ELC represents electrical energy consumption, Ln represents the natural logarithm and et is the error term.

Panel Auto-Regressive Distribution Lags (ARDL) approach developed by (Pesaran, Shin and Smith, 2001). The advantages of this ARDL model are 1) ARDL ignores the stationary level of the data, which is different from the VECM method that requires stationary at the same order level. However, ARDL cannot be used if the data is stationary at the second 2nd difference. 2) ARDL is not concerned with the small number of samples/observations. From equation 2, it can be represented into equation 3, namely the ARDL estimation model which consists of the estimation of long-term and short-term equations as follows:

$$LnCO2_t = \alpha_0 + \alpha_{1i} \sum_{i=1}^{n} \Delta LnCO2_{t-1} + \alpha_{2i} \sum_{i=1}^{n} \Delta LnGDP_{t-1} + \alpha_{3i} \sum_{i=1}^{n} \Delta LnURB_{t-1} + \alpha_{4i} \sum_{i=1}^{n} \Delta LnELC_{t-1} + \beta_1 LnGDP_t + \beta_2 LnURB_t + \beta_3 LnELC_t + e_t \quad (3)$$

Where Ln represents the natural logarithm, CO2 represents carbon emissions, GDP represents economic growth, URB represents urbanization, ELC represents electrical energy consumption, Δ represents inertia, and $\alpha_{1i} - \alpha_{4i}$ represents the short run, while $\beta_1 - \beta_1$ represents the long run.

4 RESULT AND DISCUSSION

4.1 *Descriptive Statistics of Variables*

Table 2 presents descriptive statistics of variables related to the selected ASEAN-5 countries. The average CO2 emission is 5.127 and the range is between 3.86 and 6.42 which indicates that the variation is not large. Similarly, the average GDP is 8.47 with a range between (6.13-11.20), urbanization (1700.94) is in the range between (1499-1887) and electric energy consumption is 4.258 with a range between (2.77-5.64). In general, the range between the dependent and independent variables in this study shows low variation.

Table 2 also shows that the variables of CO2 emissions (LnCO2), urbanization (LnURB), and electrical energy consumption (LnELC) have negative skweness. While the economic growth variable (LnGDP) has positive skweness. In addition, all variables have positive kurtosis with values below 3. Then on the standard deviation which shows the deviation of the variables from their average value presents that the small growth rate (fluctuation) of these variables during the study period.

Tabel 2. Descriptive Statistics of Variables.

	LnX1	LnX2	LnX3	LnY
Mean	8.474133	1700.940	4.258267	5.127733
Median	8.245000	1709.000	4.240000	5.225000
Maximum	11.20000	1887.000	5.640000	6.420000
Minimum	6.130000	1449.000	2.770000	3.860000
Std.Dev.	1.239188	106.8256	0.675192	0.594453
Skewness	0.538641	-0.228716	-0.003633	-0.032712
Kurtosis	2.486539	2.243822	2.192347	2.361691
Jarque-Bera	8.901126	4.881551	4.077223	2.573245
Probability	0.011672	0.087093	0.130209	0.276202
Sum	127.1120	255141.0	638.7400	769.1600
Sum Sq. Dev	228.8024	1700344	67.92675	52.65283
Observation	150	150	150	150

Sources: Data Processed 2023, Eviews 12

4.2 *Stationary Test*

There are several diagnostic tests that must be performed before estimating the ARDL model so that the estimated model is free from violations of basic econometric assumptions. The first step of the empirical study is the stationarity test. Recently, the method often used by econometricians for stationarity testing is the unit root test (Widarjono, 2018).

The unit root test was first developed by (Dickey and Fuller, 1979) and is now known as the Dickey-Fuller unit root test. The panel data unit root test is presented in table 3 which contains several approaches including LCC (Levin, Lin and Chu, 2002), IPS (Im, Pesaran and Shin, 2003), ADF Fisher and PP Fisher (Pedroni, 2004). Since this study uses the ARDL method, all variables must be stationary at the level (I(0)) or first order (I(1)). If this condition is not met, or there are variables that are stationary at second order (I(2)), the ARDL method will be invalid.

Table 3 presents the panel unit root stationary test results. We apply the Levin, Lin and Chu (LCC), Im, Pesaran and Shin (IPS), Phillip Perron (PP) and Augmented Dickey Fuller (ADF) tests for the variables in levels and first differences. The results of the stationarity tests show that none of the series are stationary in I(2). Evidence from LCC, IPS, PP, and ADF shows that there are variables that are stationary in levels and stationary in first differences.

Tabel 3. Unit Root Test.

Variabel	LLC	IPS	ADF	PP
Level				
LnCO2	0.0001	0.1355	0.0722	0.0001
LnGDP	0.5482	0.9844	0.9982	0.9957
LnURB	0.0000	0.0003	0.0000	0.0000
LnELC	0.0000	0.0009	0.0003	0.0000
First Difference				
LnCO2	0.0002	0.0000	0.0000	0.0000
LnGDP	0.0000	0.0000	0.0000	0.0000
LnURB	0.6345	0.2372	0.1453	0.0014
LnELC	0.0000	0.0000	0.0000	0.0000

Source: Data Processed 2023, Eviews 12

4.3 *Optimum Lag Testing*

Next is the optimum lag test, in the ARDL model the lag function is to show the effect of the time interval on the observation. The importance of the ARDL method is to identify the optimal lag length criteria. This makes it possible to determine the maximum number of lags of the model by applying the Vector Autoregressive (VAR) selection criteria. Table 4 presents the lag model selection criteria. The majority of frequently used criteria are the Akaike Information Criteria (AIC) and the Schwarz Information Criteria (SIC).

In this study, we use the AIC lag selection test to identify the lags that fit the model. We can see, in table 4, that the sign (*) at lag 2 has been selected as the value for all variables set on the AIC criteria. Previous research by (Farhani and Ozturk, 2015) has implemented in identifying ADF lag length using AIC criteria. Figure 2 shows the top sixteen models according to the ARDL method. We use the AIC criterion to determine the appropriate ARDL lag order model for this study which is (2,2,2,2) because it has a smaller error than other ARDL models.

Tabel 4. Optimum Lag Testing.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-8475983	NA	6230863	15.48361	15.58181	15.52344
1	378.6250	2340.972	1.73e-08	-6.520455	-6.029458*	-6.321304
2	408.4875	54.83845	1.35e-08*	**-6.772501***	-5.888707	-6.414029*
3	413.0288	8.009078	1.66e-08	-6.564159	-5.287569	-6.046367
4	436.1531	39.10120*	1.47e-08	-6.693693	-5.024305	-6.016581
5	447.2916	14.52994	1.62e-08	-6.605302	-4.543116	-5.768868
6	456.6933	19.40658	1.85e-08	-6.485333	-4.030351	-5.489579
7	469.8706	19.40658	1.99e-08	-6.434011	-3.586232	-5.278937
8	480.1807	14.43412	2.26e-08	-6.330558	-3.089982	-5.016163

Source: Data Processed 2023, Eviews 12

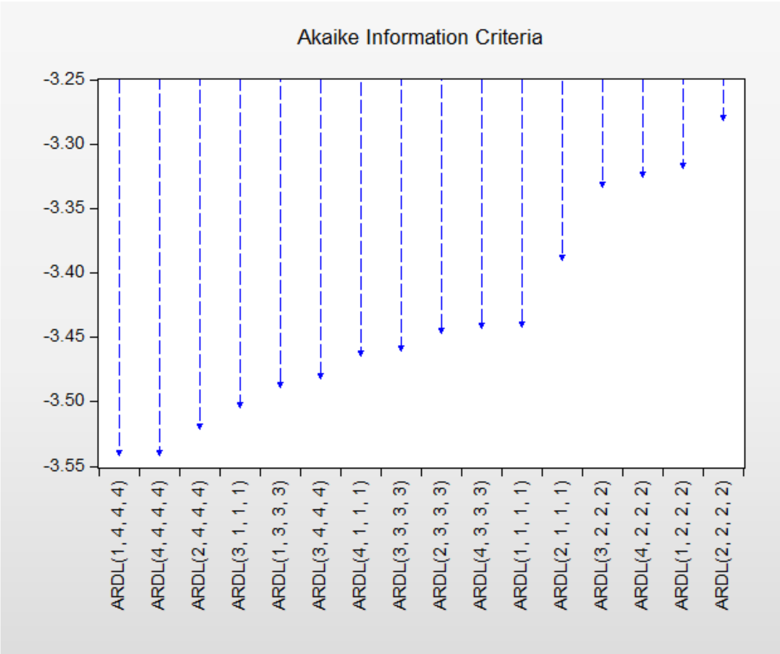


Figure 2. Optimum Lag Testing

4.4 *Cointegration Test*

In this section, the cointegration test is conducted to test whether there is a relationship between the dependent variable and the independent variable. This study uses the residual cointegration cointegration test proposed by (Pedroni, 2004).

In the Pedroni cointegration test presented in table 5, it proves that using the Panel ADF-Statistic method together all variables are cointegrated. Because the probability is at 0.0016 which is smaller than 0.05. This means that each independent variable has a relationship with the dependent variable in the long run and short run.

Tabel 5. Cointegration Test.

Pedroni test				
	Statistic	Prob.	W. Statistic	Prob.
Panel v-Statistic	-0.779040	0.7820	-1483791	0.9311
Panel rho-Statistic	1.699629	0.9554	1296072	0.9025
Panel PP-Statistic	1.923774	0.9728	-0.117347	0.4533
Panel ADF-Statistic	1.325022	0.9057	-2.95779	**0.0016**

Source: Data Processed 2023, Eviews 12

4.5 *Long-Term Estimation Results*

Table 6. shows the results of the long-term estimation, where the economic growth variable measured by GDP per capita has a significant positive impact on CO2 emissions. This means that the concentration of CO2 emissions will increase along with the increase in economic growth (GDP per capita). A 1% increase in GDP will increase CO2 emissions by 65.76% in the long run.

In addition, the urbanization variable has a significant negative impact on CO2 emissions. This means that the concentration of CO2 emissions will decrease as urbanization increases. A

1% increase in urbanization will reduce CO_2 emissions by 1.18%. This is in line with research (Ali, Abdul-Rahim and Ribadu, 2017; Mosikari and Eita, 2020) which shows that urbanization has a negative impact so that it will reduce CO_2 emissions.

Meanwhile, electrical energy consumption has a significant positive impact on CO_2 emissions. This means that every 1% increase in electrical energy consumption will increase CO_2 emissions by 73.12%. The study is in line with research (Asumadu-Sarkodie and Owusu, 2017) with results showing that in the long run electrical energy consumption will increase CO_2 emissions.

4.6 *Short-term Estimation Results*

The results of the short-term estimation are presented in Table 6. The short-term estimation proves that economic growth (GDP) has a negative and insignificant impact on CO_2 emissions. This means that if there is a 1% increase in economic growth, CO_2 emissions will decrease by 1.66% in the short term. Then, urbanization has a positive and insignificant impact on CO_2 emissions. This means that every 1% increase in urbanization rate will increase CO_2 emissions by 0.0561% in the short term. Meanwhile, electrical energy consumption has a positive and insignificant impact on CO_2 emissions. This means that every 1% increase in electrical energy consumption will increase CO_2 emissions by 1.18% in the short term.

Tabel 6. Long-term and Short-term Estimation Results.

Long Run Equation		
Variable	Coefficient	Prob
LnX1	0.657617	0.0000
LnX2	-0.011815	0.0048
LnX3	0.731215	0.0002
Short Run Equation		
Variable	Coefficient	Prob
COINTEQ01	-0.326198	0.0007
D(LnX1)	-0.016587	0.8304
D(LnX1(-1))	-0.109530	0.0468
D(LnX1(-2))	-0.048940	0.3571
D(LnX1(-3))	-0.124212	0.0790
D(LnX2)	0.000651	0.9565
D(LnX2(-1))	-0.000464	0.9564
D(LnX2(-2))	0.017840	0.1904
D(LnX2(-3))	0.006912	0.2868
D(LnX3)	0.011804	0.9515
D(LnX3(-1))	-0.069953	0.6838
D(LnX3(-2))	-0.229371	0.4526
D(LnX3(-3))	-0.020609	0.8860
C	5075559	0.0001

Source: Data Processed 2023, Eviews 12

5 CONCLUSION AND POLICY IMPLICATIONS

Environmental degradation is a crucial issue for policy makers to address (Saidi and Rahman, 2021; Sari et al., 2023) and a major concern for countries in ASIA especially in ASEAN (Santi and Sasana, 2021). This study investigates the impact of economic growth, urbanization and consumption on environmental degradation in terms of CO_2 emissions as evidenced by the selected 5-ASEAN countries of Indonesia, Singapore, Malaysia, Thailand and the Philippines. Using annual panel data for the time period 1992-2021, the Panel Auto-Regressive Distribution Lags (ARDL) method is used to reveal the impact in the long run and short run.

The results show that in the long run economic growth and electrical energy consumption have a positive impact on CO2 emissions. This means that any increase in economic growth and high electrical energy consumption will lead to environmental degradation. Urbanization itself has a negative impact on CO2 emissions. This means that any increase in the level of urbanization will reduce CO2 emissions. In the short term, it is the opposite where economic growth has a negative impact. Meanwhile, urbanization and electrical energy consumption have a positive impact.

Based on these results, which show that in the long run economic growth has a positive impact on CO2 emissions, the government as a policy maker in selected ASEAN-5 countries must prepare environmental policies that can reduce CO2 emissions without having to sacrifice economic growth. In this case, the government can impose a carbon tax on economic activities that produce CO2 emissions above the standard limit to reduce CO2 emissions and encourage polluters to reduce their waste output without sacrificing their economic expansion. It is also recommended that policymakers implement a carbon pricing mechanism to intensify modernized technologies and reduce energy pollution.

In addition, the results reported that in the long run urbanization has a negative impact on CO2 emissions, while in the short run urbanization has a positive impact on CO2 emissions. Therefore, it is important for policy makers to create public awareness about the adverse/dangerous effects of excessive CO2 emissions through social awareness programs. And it is expected that urbanization is associated with increased economic activity resulting in higher income and more demand for energy-intensive products, which will increase CO2 emissions. However, on the other hand, a wealthy and highly educated population is aware of the benefits of a sustainable environment.

Finally, studies have shown that in both the long and short term, electrical energy consumption has a positive impact on CO2 emissions. This means that electrical energy consumption will increase CO2 emissions, which leads to environmental degradation. This finding is expected because the largest source of electrical energy comes from fossil energy, including coal. Therefore, policy makers gradually need to reduce their dependence on fossil fuels and can replace them with alternative renewable energy sources to restructure electrical energy consumption in an environmentally friendly and sustainable way.

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