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Economic Growth and CO_2 Emission in ASEAN: Panel-ARDL Approach

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Abstract

This paper investigates the relationship between economic growth and CO_2 emissions from 1994 to 2018 using a panel approach from eight ASEAN countries. We found an established result using the Panel ARDL Pooled Mean Group method. First, the panel Cointegration analysis shows a significant long-term relationship between GDP and CO_2 emissions. Second, the error correction mechanism shows a stable and consistent value. Third, we found that GDP has a significant long-term effect on CO_2 emissions in ASEAN countries. Fourth, our results also show that GDP significantly impacts CO_2 emissions in the short term for four countries: Indonesia, Malaysia, Thailand, and Cambodia. Based on these empirical results, implications and policy recommendations are presented. ASEAN countries should implement green growth policies by encouraging economic development which does not suppress the environment.

Keywords: economic growth; gross domestic product; CO_2 emission; panel ARDL

JEL classifications: C52; O40; O53; Q50

1. Introduction

Mankiw (2009) argues that economic growth is one of the many proxies used in macroeconomic research to determine a country's level of welfare. Economic growth can indicate income inequality levels among countries through differences in income levels (Acemoglu 2012) and reveal the community's standard of living (Davis & Knauss 2013). Consequently, economic growth has become an important marker for gauging a country's development progress. Nevertheless, in recent years, high economic growth has brought numerous concerns in many countries. This is because environmental protection and economic growth must be balanced. (Todaro & Smith 2015). The trade-off between economic growth and the environment occurs because non-renewable natural resources are essential inputs for producing goods and services. If the use of materials in production activities is not appropriately regulated, it will result in environmental degradation (Grossman & Krueger 1995).

The trade-off between economic expansion and the environment has so far been a topic of continuing discussion in several scholarly works, especially for countries from the Global South that still concentrate on their economic growth, such as in ASEAN (Association of Southeast Asian Nations) (see. Coxhead 2003; Heidari, Katircioğlu & Saeidpour 2015; Borhan, Ahmed & Hitam 2012). Although most ASEAN countries experience declining economic growth empirically, environmental issues have increased significantly. This is evidenced by carbon dioxide (CO_2) emission levels (ASEAN Secretary 2019; Haseeb et al. 2019). According to data, the realisation of the fourth industry, innovation development, and technology use support economic progress in ASEAN countries (ASEAN Secretary 2019). ASEAN's predominantly low-income countries have their eyes on high economic growth. Hence there has been a growing concern in the region regarding increasing energy demand which poses a high risk of increasing carbon dioxide emis-

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sions (International Energy Agency [IEA] 2019), illustrated in Figure 1.

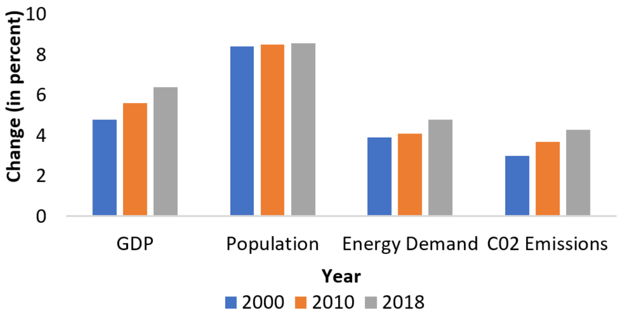

Figure 1. Shares of Selected Global Economic and Energy Indicators in Southeast Asia
Source: International Energy Agency (2019)

The International Energy Agency confirms that an increase in economic growth is compatible with an increase in energy demand in all ASEAN countries in the 2019 Southeast Asia Energy Outlook report. However, this also means a rise in carbon emissions between 2010 and 2018 in the countries in question, showing the significance of taking environmental factors—in this case, CO_2—into account as a result of economic activity. This study, therefore, intends to evaluate the link between economic growth (GDP) and CO_2 emissions from 1994 to 2018 using a panel approach from eight ASEAN countries in light of its considerable importance and relevance.

Numerous academics have been researching the connection between environmental factors and economic growth for some time. However, the subject of study on this topic is not merely developed countries but also includes Southeast Asian countries. By demonstrating a non-linear link between CO_2 emissions and economic growth in Singapore and Thailand using the ARDL time series method, Saboori & Sulaiman (2013b) support the use of the Environmental Kuznets Curve (EKC). There are no long-term associations between related variables in the Philippines and Thailand, according to a different study by Vo, Vo & Le (2019) using the same methodology, namely the ARDL time series. However, there are relationships in Indonesia, Myanmar, and Malaysia. In addition, the EKC phenomenon is found in Myanmar but not in Indonesia and Malaysia. However, at the same time, there are other contradictory findings. Using the generalized method of moments (GMM) technique, Chen et al. (2016) demonstrated a negative correlation between global GDP and carbon emissions or energy consumption, particularly in emerging countries. Thus far, the impact of economic growth on the environment as proxied by CO_2 emissions is still up for debate. This debate creates confusion and raises crucial questions about the actual nature of the relationship between those two parameters in the ASEAN region.

This paper seeks to contribute to these discussions empirically. Using panel ARDL with eight ASEAN countries (including Indonesia, Philippines, Singapore, Thailand, Malaysia, Brunei Darussalam, Vietnam, and Cambodia) as a sample from 1994 to 2018, this paper attempts to establish a relationship between economic growth and CO_2 emission. The main contribution of the present study is threefold. *First*, this study attempts to clarify several confusions that were the results of previous findings. For example, it was still unclear how to establish a link between environmental issues and economic growth, which was the initial puzzle. *Second*, the Panel ARDL method becomes relevant compared to other dynamic panel methods because this panel ARDL produces a more consistent estimate and comprehensive results explicitly. *Third*, studying environmental factors is crucial because the environment's role and existence are closely related to economic activities.

The use of natural resources in the production process is primarily determined by environmental factors so that directly or indirectly, the role of the environment will affect economic growth (Grossman & Krueger 1995).

In addition to the three issues mentioned above, environmental aspects in the long term are irreversible, which means they cannot be changed, repaired, or returned to their original state (Prieur 2006). Therefore, investment in environmental pol-

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lution control is a form of investment in maintaining the natural environment (Fisher & Hanemann 1986). Based on these facts, this study offers empirical evidence to evaluate economic expansion's long- and short-term impacts on the environment, particularly CO_2 emissions. This study hypothesizes that there is a positive link between economic growth as measured by GDP and environmental quality as measured by CO_2 emissions. As a result, environmental quality degradation is expected to continue along with the acceleration of economic expansion in its current form. The results of our research support the hypothesis that long-term economic growth has a positive relationship with CO_2 emissions in ASEAN countries. In addition, our results also indicate that the effect of GDP on CO_2 emissions has a significant positive value in the short run, particularly in Indonesia, Malaysia, Thailand, and Cambodia.

In the next section, we briefly discuss several existing research on the subject. Subsequently, we describe our methodology and the sources of our data. Section IV presents and discusses the empirical findings. The final part will discuss the conclusion of our study by summarizing the main findings.

2. Literature Review

There is still disagreement regarding how economic activity and environmental variables interact. According to a large body of literature, economic growth and CO_2 emissions correlate positively. However, several other studies demonstrate a non-linear relationship between environmental and economic growth, demonstrating that economic growth will gradually lower CO_2 after crossing a specific threshold. According to research by Shan et al. (2021), economic expansion harms the environment, while fiscal decentralization has a nonlinear impact on CO_2 emissions reduction. These results imply that improving the region's economic growth and wisely harnessing nature resources can improve the environment's quality.

Environmentally harmful economic activities worsen the state of the economy and welfare while also wreaking irreparable environmental damage (Prieur 2006). Research in the Middle East and North Africa (MENA) region supports this finding, demonstrating that economic activities, including industrial opening, international trade, energy consumption, and urbanization, trigger environmental degradation over the long term (Al-Mulali & Ozturk 2015). Nevertheless, Shaw et al. (2010) found different results where the effect of income on the environment can principally bring about environmental improvements. Higher incomes translate into more significant investments in research and development (R&D), providing ways of controlling pollution with more sophisticated technologies. The BRICS (Brazil, Russia, India, China, and South Africa) study by Wang & Zhang (2020), which confirms that there is a positive correlation between increasing R&D expenditure and the decoupling of economic growth from environmental harm, provides further support for this finding. Further, lower carbon emissions often accompany enhanced R&D spending.

However, Yang et al. (2018) offer conflicting findings that demonstrate that while China's economic growth does have a significant positive impact on technological advancement, the latter's contribution to reducing industrial smoke and dust emissions is insignificant. This indicates that the emissions in China's prefecture-level cities are above the capacity of existing technology advancements. In addition to technology, environmental regulation may be able to limit emissions to some level, but it cannot decrease the industrialization process' positive stimulative effect. One method to mitigate carbon dioxide emissions is to reduce the usage of fossil fuels. However, reducing fossil fuel use will ultimately slow down the economy (Saboori & Sulaiman 2013b). So, pollution will not disappear along with economic progress in low-income nations where fossil fuels fuel it. Furthermore, the use of renewable energy and carbon dioxide emissions have a negative correlation, according to a recent study by Namahoro et al. (2021) in East Africa.

Additionally, there is a strong correlation between renewable energy development and economic growth. This indicates that the adverse effects of energy growth on the environment and carbon dioxide emissions can be reduced if a nation uses a significant amount of renewable energy. This is in line with research by Radmehr, Rastegari & Shayanmehr (2021) in the European Union, which claims that a 1% increase in renewable energy consumption per person will result in a 0.05% reduction in carbon emissions.

ASEAN, as an association for southeast Asian countries, has several objectives, one of which is accelerating the economic growth of its members, mainly low-income countries. As a result, ASEAN's economic growth rate is the fastest among other economic regions in the world, with an average growth rate of 6.5% for the 2000–2008 period (Saboori & Sulaiman 2013a). Nevertheless, the high economic growth in ASEAN is still supported by the activity of using high fossil energy consumption inputs. Most of ASEAN's energy consumption—90% of it—comes from fossil fuels like coal, oil, and gas (Saboori & Sulaiman 2013a). Assuming that the population growth rate and GDP development continue, ASEAN's energy consumption will rise by an average of 4.4% through 2030 (Saboori & Sulaiman 2013a).

Heidari, Katircioğlu & Saeidpour (2015) argued that there is a non-linear link between economic growth, carbon emissions, and energy consumption using data from five ASEAN nations (Malaysia, Indonesia, Philippines, Singapore, and Thailand). According to their regression analysis, an increase in GDP per capita can temporarily boost carbon emissions; however, once it reaches its maximum level, carbon emissions start to decline. The ASEAN Secretariat (2019) data showed that ASEAN countries' average real GDP growth in 2018 was above 5%. ARDL panels were utilized in earlier research by Saboori & Sulaiman (2013b) to examine the connection between energy use, economic growth, and CO_2 emissions. However, only five ASEAN nations, namely Indonesia, Malaysia, the Philippines, Singapore, and Thailand, are the subject of this research. Therefore, further research is required to determine the extent to which the impact of economic growth on CO_2 emissions in ASEAN countries has increased due to the region's economic expansion. For analyzing the relationship between economic growth and CO_2 emissions, this study uses data from eight ASEAN countries between 1994 and 2018 to add to the existing scholarship. To confirm the immediate and long-term effects of the factors under investigation, we use the ARDL panel approach.

3. Method

3.1. Data

Indonesia, Philippines, Singapore, Thailand, Malaysia, Brunei Darussalam, Vietnam, and Cambodia are the eight ASEAN nations included in the study's empirical research, which spans the years 1994 to 2018. Unfortunately, a lack of data limits the scope of this study. Nevertheless, a sample of eight countries was used in this study after excluding Lao PDR and Myanmar due to the sufficiency of the country data. We concentrate on three factors: trade openness, GDP per capita (measured in constant 2010 US dollars), and CO_2 emissions (measured in metric tons per capita). The World Development Indicators (WDI) of the World Bank is the data source of these variables.

Table 1 summarizes the standard descriptive statistics as a whole and the countries in the sample. We can deduce from the sample that an average CO_2 value (metric ton per capita) is 0.005, with a minimum value of 0.0001 found in Cambodia and a maximum value of 0.024 found in Brunei Darussalam. The value of CO_2 (metric ton per capita) listed from above average to average respectively comprises Brunei Darussalam, Singapore, Philippines, and Malaysia, while the rest are below the average from the lowest were Cambodia, Vietnam, Indonesia, and Thailand respectively.

We can infer from Table 1 that there is a correla-

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Table 1. Descriptive Statistics of the CO_2 Metric Ton per Capita and the GDP per Capita

	CO_2 (metric ton per capita)				GDP per capita			
	Mean	Max	Min	Std. Dev.	Mean	Max	Min	Std. Dev.
Full sample	0.0050	0.0240	0.0001	0.005	12142.00	59074.0	321.28	16011.00
By countries:								
Indonesia	0.0010	0.0027	0.0010	0.0004	2865.70	4284.6	2071.50	712.02
Philippines	0.0090	0.0013	0.0007	0.0001	2089.20	3190.7	1530.60	494.89
Singapore	0.0100	0.0180	0.0043	0.0032	41845.00	59074.0	28341.00	9841.80
Thailand	0.0030	0.0042	0.0023	0.0005	4544.70	6370.0	3236.30	992.01
Malaysia	0.0060	0.0081	0.0047	0.0011	8478.20	12120.0	5861.70	1831.20
Brunei Darussalam	0.0170	0.0246	0.0119	0.0039	35504.00	37843.0	31436.00	1885.70
Vietnam	0.0010	0.0022	0.0003	0.0005	1131.00	1964.4	541.61	424.97
Cambodia	0.0003	0.0008	0.0001	0.0001	675.87	1202.6	321.28	276.30

tion between GDP per capita and CO_2 per capita. Therefore, it can be implied that countries with the highest average value of CO_2 per capita, such as Singapore, Brunei Darussalam, and Malaysia, are the top three countries with the highest GDP per capita in ASEAN. Meanwhile, countries with low GDP per capita, such as Cambodia, Vietnam, and Indonesia, have low average CO_2 values despite the fact it is not the case in the Philippines. Regardless, the data is consistent with the basic theory that a country's economic activity, as measured by its GDP per capita, will negatively affect the environment, measured by its CO_2 per capita.

3.2. Estimation Strategy

We used the Panel-ARDL model method developed by Pesaran & Smith (1995) and Pesaran, Shin & Smith (1999) to analyze the effects of economic activity on CO_2 emissions. This approach gains appeal when compared to other dynamic panel models, such as IV (Instrument Variable), GMM (Generalized Method of Moments), and FEM (Fixed Effect Model) (see Anderson & Hsiao 1982; Arellano 1989; Arrelano & Bover 1995), since it can generate a more stable average value of estimate by simulating PMG (Pooled Mean Group) or MG (Mean Group) and then testing it. The model used in this research was adopted from Asongu, El Montasser & Toumi (2016) and Da Silva, Cerqueira & Ogbe (2018). We specifically estimate the following model:

$$\begin{aligned}\Delta \mathrm{CO_{2it}} &= \alpha_i + \sum_{j=1}^{p-1} \beta_{ij} \Delta \mathrm{CO_{2i,t-j}} + \sum_{k=o}^{q-1} \delta_{ik} \Delta \mathrm{GDP_{i,t-k}} + \sum_{l=1}^{r-1} \varphi_{it}{}' \Delta \mathrm{X_{i,t-1}} + \gamma_1 \mathrm{CO_{2i,t-1}} + \gamma_2 \mathrm{GDP_{i,t-1}} \\ &+ \gamma_3{}' \mathrm{X_{it-1}} + \varepsilon_{i,t}\end{aligned} \quad (1)$$

Where CO_2, GDP and X_i are, respectively, the logarithm of CO_2 (metric ton per capita) and the logarithms of GDP per capita and TO (Trade Openness). Δ and $\varepsilon_{i,t}$ are the first difference operators and a white noise term. Also, α_i is an intercept of a specific country. Meanwhile, subscript i shows a cross-section that varies from 1 to N, whereas we use the minimum SIC (Schwarz Information Criterion) approach to select each variable's optimal lag.

In this study, we apply the Pedroni (2004) cointegration test. The Pedroni cointegration test has been utilized extensively in earlier research since a panel of unit root tests may not yield the same results. These findings support the unit root null hypothesis in various empirical situations. The Pedroni cointegration test's null and alternate hypotheses are then established. There will not be a long-term link between the variables if the null hypothesis of no cointegration is not proven incorrect. On the other hand, there is proof of a long-term association between the variables if the alternative hypothesis is not disproved. We estimate the long-term relationship model for equation (1) as follows:

$$CO_{2it} = \mu_i + \sum_{j=1}^{p-1} \rho_{1j} CO_{2i,t-j} + \sum_{k=o}^{q-1} \rho_{2j} GDP_{i,t-k} + \sum_{l=1}^{r-1} \rho_{3j}{}' \Delta X_{i,t-l} + v_{1i,t} \quad (2)$$

Additionally, the following describes the error correction model, which is used to take into account the short-term relationship between variables:

$$\begin{aligned} \Delta CO_{2it} \quad = \quad & \alpha_i + \sum_{j-1}^{p-1} \beta_{ij} \Delta CO_{2i,t-j} \\ & + \sum_{k=o}^{q-1} \delta_{ik} \Delta GDP_{i,t-1} + \sum_{l=1}^{r-1} \varphi_{it}{}' \Delta X_{i,t-l} \\ & + \sigma ECT_{t-1} + e_{i,t} \end{aligned} \quad (3)$$

Where the residual $e_{i,t}$ is independent and normally distributed with zero mean and constant variances, and ECT_{t-1} is the error correction term defined from the long-term equilibrium relationship. The parameter σ shows the speed of adjustment to the equilibrium level. Where ECT_{t-1} is the error correction term derived from the long-term equilibrium relationship, the residual $e_{i,t}$ is independent, normally distributed, has zero mean, and constant variances. The parameter displays how quickly the equilibrium level is reached after adjustment.

4. Results and Analysis

4.1. Unit Root Test

We employ two different sorts of tests to check stationarity. Im, Pesaran & Shin (2003), also known as IPS, and Levin, Lin & Chu (2002), also known as LLC, are the two tests used. The LLC unit root testing method, which is restricted to the hypothesis, has flaws made up for by the IPS unit root testing method, especially the homogenous character of the autoregressive root under the alternative hypothesis.

According to Table 2, all data except for TO exhibit non-stationary conditions at the level utilizing the LLC approach at a significance level of 10%. Furthermore, the results show that all variables are stationary for both the LLC and IPS approaches, with a significance level of 1%, proving that the variables included in the model are a combination of I(1) and I(0), matching the criteria in ARDL panel estimation.

4.2. Cointegration Results

The Pedroni (2001) Cointegration test, which established seven statistical tests to evaluate the null hypothesis that there is no cointegration in a nonstationary panel, is summarized in Table 3. The seven statistics allow for panel variation, including the run's slope, intercept coefficients, and short-term dynamics. The seven test statistics are divided into two categories: the panel statistic, which includes data from several within-dimension nonparametric (rho and t) and parametric (adf) test statistics, and the group mean statistic, which averages the test statistic findings for each country.

Because all test statistics are typically distributed to N, statistical inference is reasonably straightforward (0.1). Overall, the results demonstrated a cointegration link between the three variables, in the least, as evidenced by the group-t statistic at the 10% level, even though the majority cointegration test results were not significant. Therefore, we can still conclude that CO_2, GDP, and TO have a long-term association among eight ASEAN nations.

4.3. ARDL Results Panel

The short- and long-term coefficients affecting CO_2 emissions in the ASEAN nations are shown in Table 4. We then estimate the link between GDP per capita and CO_2 using two methods, employing the panel ARDL estimation technique, which allows us to run many models. In the beginning, we calculate the static panel model using the Pooled Least

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Table 2. The Results of the Variable Stationarity Test At the Level and First Difference

		Level		First Difference	
		Intercept	Intercept and Trend	Intercept	Intercept and Trend
CO2	LLC	0.0916	-0.9631	-6.4373***	-5.6243***
	IPS	28.082	0.3690	-6.8329***	-6.0122***
GDP	LLC	0.8458	-25.636	-6.6784***	-6.2677***
	IPS	55.283	-0.5787	-6.5549***	-6.1330***
TO	LLC	-0.6186	-1.5354*	-6.4138***	-5.7109***
	IPS	0.1407	-0.9045	-7.3118***	-6.5105***

Notes: The stationarity test in the table uses CO_2 data in the form of the logarithm of metric tons per capita, GDP in the logarithm of GDP per capita and TO in exports minus imports divided by GDP.
Asterisks, *, **, *** symbolizes statistical significance at the 10%, 5%, and 1%.

Table 3. The Results of the Pedroni Cointegration Test

Test Stats	Panel	Probabilities	Group	Probabilities
V	-0.453	0.674	.	
Rho	0.234	0.407	1.366*	0.085
T	-0.925	0.822	-0.179	0.571
Adf	0.555	0.289	0.902	0.183

Notes: All statistics are distributed N (0,1), under a null of no cointegration, and diverge to negative infinity (save for panel v).
Asterisks, *, **, *** symbolizes statistical significance at the 10%, 5%, and 1%.

Square (PLS), Fixed Effect (FEM), and Random Effect (REM). Then, using Mean Group (MG), Pooled Mean Group (PMG), and Dynamic Fixed Effect, we estimate panel ARDL (DFE).

Using the Hausman test, we decided that PMG is the best model compared to MG and DFE. Hausman test results suggest no rejection of the null hypothesis. This clearly shows that PMG is a more consistent and efficient as well as a more precise estimation when compared to MG and DFE. While the MG estimator permits heterogeneity in both the short-term and long-term estimators, the PMG estimator imposes homogeneity in the long term but not the short term. These techniques are suitable when the study variables have varying orders of integration. Thus, the short-term effects appear to vary among the eight ASEAN countries.

As a comparison, we also estimate the coefficients of GDP per capita against CO_2 using a static panel model. Long-term coefficient in static panel model indicates overestimate values (OLS = 0.925, FEM = 0.855, and REM = 0.822) compared to PMG. We cannot currently determine the short-run association between variables in the static panel model. However, we can use PMG to estimate the short-run association between variables fully or individually.

According to the results in Table 4, the PMG estimate demonstrates that the GDP per capita in the long-run model is statistically significant at the 1% real level. The panel elasticity of GDP per capita for ASEAN nations is 0.6173, which means that every 1% rise in GDP per capita would result in a 0.6173% increase in CO_2 emissions. These results are consistent with those obtained through empirical research by Jalil & Feridun (2011), Shahbaz et al. (2013), Begum et al. (2015), Salahuddin et al. (2017), Sapkota & Bastola (2017), Borhan, Ahmed & Hitam (2018). Their findings demonstrate that economic activity in ASEAN nations still negatively impacts the environment, particularly CO_2 emissions. In the long-term model, the impact of the Trade Openness control variable on CO_2 emissions is not statistically significant.

The PMG estimation procedure provides short-term estimates for each country. Table 5 offers a negative error correction term coefficient for all countries except Cambodia. These findings suggest that the factors in these nations have a long-term link. The speed of long-term balance adjustment from fastest to slowest respectively is Malaysia at -0.4854, Thailand at -0.4661, Brunei Darussalam at -0.3422, Indonesia at -0.3076, Singapore at -0.1906 and Vietnam at -0.0779. These outcomes resemble those of Prawoto & Basuki (2020), which prove that Indonesia has a balance value of 37.25% adjusted

Table 4. ARDL Long-Run and Short-Run PMG Estimation Panel for the Entire Sample

Dependent variable: CO_2						
	PMG	MG	DFE	PLS	FEM	REM
	Coeff. (p-value)	Coeff. (p-value)	Coeff. (p-value)	Coeff. (p-value)	Coeff. (p-value)	Coeff. (p-value)
Long-run estimation for the entire sample						
GDP	0.617***	2.0352	0.882***	0.925***	0.885***	0.882***
	(0.000)	(0.119)	(0.000)	(0.000)	(0.000)	(0.000)
TO	0.0001	-0.009	0.002	-0.001***	0.0006	0.0003
	(0.869)	(0.206)	(0.242)	(0.000)	(0.361)	(0.561)
Short-run estimation for the entire sample						
ECT	-0.250***	-0.321***	-0.167***			
	(0.000)	(0.000)	(0.000)			
△GDP	0.163	-0.198	0.194			
	(0.733)	(0.776)	(0.525)			
△TO	-0.0004	0.0001	-0.001**			
	(0.661)	(0.896)	(0.046)			
cons.	-2.729***	-6.006*	-2.303***	-13.55***	-13.55***	-13.48***
	(0.000)	(0.055)	(0.000)	(0.000)	(0.000)	(0.000)
	$N = 8$					
Hausman	2.80					
	(0.247)					

Notes: This table reports Panel ARDL estimation results.
The dependent variables are noted in bar 1, while the independent variables are noted in column 1.
The data sample covers eight countries in ASEAN over the period 1994–2018.
Asterisks, *, **, *** symbolizes statistical significance at the 10%, 5%, and 1% levels.

for one year.

For illustration, Malaysia has a fast pace towards the long-term, where 48.5 per cent of the adjustment occurs in each period, and the time it takes to reach long-term equilibrium is around two years. This conclusion is consistent with Aslam et al. (2022), which demonstrates that Malaysia experiences speedy adjustment from disequilibrium to equilibrium each year. Meanwhile, Vietnam has a slow pace towards the long-term, where 7.7 per cent of the adjustment occurred in each period, and the time it took to reach a long-term equilibrium was around 13 years. Sultana et al. (2021) explain that the speed of adjustment for ASEAN countries is approximately 31% or comparable to 3 years, which validates this finding. This means there is a span between 7.7% to 48.5% to return to equilibrium.

The short-run coefficient for PMG in each country shows different results. However, in the short term, the effect of GDP per capita on CO_2 emissions shows significant results for four countries: Indonesia, Malaysia, Thailand, and Cambodia. These results conclude that for the cases in Indonesia, Malaysia, Thailand and Cambodia, the effect of GDP per capita on CO_2 emissions has a significant relationship in the short and long term. This result is consistent with other research from Adebayo (2021), Tang & Tan (2016) in Cambodia, and Kim (2019), which finds a close association between economic growth and environmental issues in the majority of low-income nations.

In the short run, the elasticity of GDP per capita to CO_2 emissions from the largest to the smallest, respectively, is given by Indonesia at 1.085 per cent, Cambodia at 0.950 per cent, Malaysia at 0.722 per cent, and Thailand at 0.558 per cent. With a coefficient of 1.08 per cent for the case of Indonesia, this study demonstrates a substantial relationship between the first difference in GDP growth per capita and the first difference in CO_2 emission increase. This suggests that compared to other ASEAN nations, Indonesia's economic activity contributes the most to CO_2 emissions in the short term, as measured by GDP per capita.

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Table 5. Panel ARDL Long-Run And Short-Run PMG Estimation For Each Country

Dependent variable: CO2								
Long-run estimation								
	Coef.	Std. Error	Z	p-value				
GDP	0.6173***	0.0660	9.35	0.000				
TO	0.0001	0.0007	0.16	0.869				
Hausman	2.80 (0.247)							
Short-run estimation for each country								
	Indonesia Coef. (p-value)	Philippines Coef. (p-value)	Singapore Coef. (p-value)	Thailand Coef. (p-value)	Malaysia Coef. (p-value)	Brunei Darussalam Coef. (p-value)	Vietnam Coef. (p-value)	Cambodia Coef. (p-value)
ECT	-0.3076*	-0.1908	-0.1906*	-0.4661***	-0.4854***	-0.3422**	-0.0779*	0.0588
	(0.065)	(0.107)	(0.090)	(0.002)	(0.002)	(0.016)	(0.050)	(0.194)
ΔGDP	1.0850*	0.3422	-1.911	0.5581**	0.7228**	-1.9868	1.5466	0.9506*
	(0.064)	(0.586)	(0.144)	(0.015)	(0.033)	(0.223)	(0.183)	(0.078)
ΔTO	-0.0015	0.003**	0.0001	-0.0012*	-0.0010	0.0025	0.0025	-0.0065***
	(0.475)	(0.029)	(0.983)	(0.052)	(0.367)	(0.576)	(0.576)	(0.000)
cons.	-3.4973*	-2.224	-2.1315*	-5.072***	-5.1560***	-3.6283	-3.6283**	0.7587
	(0.068)	(0.106)	(0.092)	(0.005)	(0.003)	(0.017)	(0.017)	(0.174)
N = 8								
Obs. = 192								
Log likelihood = 238.59								

Notes: This table reports Panel ARDL estimation results.
The dependent variables are noted in bar 1, while the independent variables are noted in column 1.
The data sample covers eight countries in ASEAN over the period 1994–2018.
Asterisks, *, **, *** symbolizes statistical significance at the 10%, 5%, and 1% levels.

5. Conclusion

This paper proposes and attempts to examine the impact of economic activity, as measured by GDP per person in ASEAN nations, on CO_2 emissions. Our paper further evaluates a vital question related to environmental issues in the ASEAN region, especially in specific countries, whether economic activities still produce high carbon emissions. Comparatively, Shaari, Abdul Karim & Zainol Abidin (2020) discovered that the effect of GDP on CO_2 emissions in the OIC (Organization of Islamic Cooperation) group has an elasticity value of 0.214. Asongu, El Montasser & Toumi (2016) discovered that the effect of GDP on CO_2 emissions in African countries has an elasticity value of 0.257; Al-Mulali & Ozturk (2015) found that the impact of GDP on CO_2 emissions in European countries has an average elasticity value.

Our findings demonstrate that the ASEAN countries' GDP effects on CO_2 emissions have a high elasticity value of 0.6173 per cent. This suggests that a 0.617 per cent increase in CO_2 emissions results from an increase in GDP of one per cent. These findings imply that CO_2 emissions from economic activity in the ASEAN group of nations are still relatively high when compared to the results of earlier works by Asongu, El Montasser & Toumi (2016), Al-Mulali & Ozturk (2015), and Shaari, Abdul Karim & Zainol Abidin (2020). Additionally, our findings indicate that in Indonesia, Malaysia, Thailand, and Cambodia, the impact of GDP on CO_2 emissions is significantly favourable over the short and long terms. These findings suggest that the effect of high-emission economic activity is permanent.

With high carbon emissions from economic activity in ASEAN countries, policymakers in specific member countries or all ASEAN committees should agree to implement green growth policies. By ensuring that natural resources and environmental services that are essential to welfare continue to be provided, this strategy aims to support economic growth. A few things that can be done to prepare a comprehensive policy framework for green economic growth must include: encouraging investments that improve environmental sustainability, raising economic competitiveness, creating a better quality of life, and preparing for technologies that can cut costs, boost output, and lessen environmental impact.

References

[1] Acemoglu, D 2012, 'Introduction to economic growth', *Journal of Economic Theory*, vol. 147, no. 2, pp. 545-550. doi: https://doi.org/10.1016/j.jet.2012.01.023.

[2] Adebayo, TS 2021, 'Testing the EKC hypothesis in Indonesia: Empirical evidence from the ARDL-Based Bounds and Wavelet Coherence Approaches', *Applied Economics Journal*, vol. 28, no. 1, pp. 78-100.

[3] Al-Mulali, U, & Ozturk, I 2015, 'The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region', *Energy*, vol. 84, pp. 382-389. doi: https://doi.org/10.1016/j.energy.2015.03.004.

[4] Anderson, TW, & Hsiao, C 1982, 'Formulation and estimation of dynamic models using panel data, *Journal of Econometrics*, vol. 18, no. 1, pp. 47-82. doi: https://doi.org/10.1016/0304-4076(82)90095-1.

[5] Arellano, M 1989, 'A note on the Anderson-Hsiao estimator for panel data', *Economics Letters*, vol. 31, no. 4, pp. 337-341. doi: https://doi.org/10.1016/0165-1765(89)90025-6.

[6] Arellano, M, & Bover, O 1995, 'Another look at the instrumental variable estimation of error-components models', *Journal of Econometrics*, vol. 68, no. 1, pp. 29-51. doi: https://doi.org/10.1016/0304-4076(94)01642-D.

[7] ASEAN Secretary 2019, *ASEAN Economic Integration Brief, 06*, viewed 22 June 2021 <https://asean.org/wp-content/uploads/2021/08/AEIB_6th_Issue.pdf>.

[8] Aslam, B, Hu, J, Ali, S, Algarni, TS, & Abdullah, MA 2022, 'Malaysia's economic growth, consumption of oil, industry and CO2 emissions: evidence from the ARDL model', *International Journal of Environmental Science and Technology*, vol. 19, pp. 3189-2000. doi: https://doi.org/10.1007/s13762-021-03279-1.

[9] Asongu, S, El Montasser, G, & Toumi, H 2016, 'Testing the relationships between energy consumption, CO2 emissions, and economic growth in 24 African countries: a panel ARDL approach', *Environmental Science and Pollution Research*, vol. 23, no. 7, pp. 6563-6573. doi: https://doi.org/10.1007/s11356-015-5883-7.

[10] Begum, RA, Sohag, K, Abdullah, SMS, & Jaafar, M 2015, 'CO2 emissions, energy consumption, economic and population growth in Malaysia', *Renewable and Sustainable Energy Reviews*, vol. 41, pp. 594-601. doi: https://doi.org/10.1016/j.rser.2014.07.205.

[11] Borhan, H, Ahmed, EM, & Hitam, M 2012, 'The impact of CO2 on economic growth in ASEAN 8', *Procedia-Social and Behavioral Sciences*, vol. 35, pp. 389-397. doi: https://doi.org/10.1016/j.sbspro.2012.02.103.

[12] Borhan, H, Ahmed, EM, & Hitam, M 2018, 'Co2, quality of life and economic growth in ASEAN 8', *Journal of ASIAN Behavioural Studies*, vol. 3, no. 6, pp. 55-63. doi: https://doi.org/10.21834/jabs.v3i6.237.

[13] Chen, PY, Chen, ST, Hsu, CS, & Chen, CC 2016, 'Modeling the global relationships among economic growth, energy consumption and CO2 emissions', *Renewable and Sustainable Energy Reviews*, vol. 65, pp. 420-431. doi: https://doi.org/10.1016/j.rser.2016.06.074.

[14] Coxhead, I 2003, 'Development and the environment in Asia', *Asian-Pacific Economic Literature*, vol. 17, no. 1, pp. 22-54. doi: https://doi.org/10.1111/1467-8411.t01-1-00013.

[15] Da Silva, PP, Cerqueira, PA, & Ogbe, W 2018, 'Determinants of renewable energy growth in Sub-Saharan Africa: Evidence from panel ARDL', *Energy*, vol. 156, pp. 45-54. doi: https://doi.org/10.1016/j.energy.2018.05.068.

[16] Davis, LS, & Knauss, M 2013, 'The moral consequences of economic growth: An empirical investigation', *The Journal of Socio-Economics*, vol. 42, pp. 43-50. doi: https://doi.org/10.1016/j.socec.2012.11.007.

[17] Fisher, AC, & Hanemann, WM 1986, 'Environmental damages and option values', *Natural Resource Modeling*, vol. 1, no. 1, pp. 111-124. doi: https://doi.org/10.1111/j.1939-7445.1986.tb00006.x.

[18] Grossman, GM, & Krueger, AB 1995, 'Economic growth and the environment', *The Quarterly Journal of Economics*, vol. 110, no. 2, pp. 353-377. doi: https://doi.org/10.2307/2118443.

[19] Haseeb, M, Kot, S, Hussain, HI, & Jermsittiparsert, K 2019, 'Impact of economic growth, environmental pollution, and energy consumption on health expenditure and R&D expenditure of ASEAN countries', *Energies*, vol. 12, no. 19, p. 3598. doi: https://doi.org/10.3390/en12193598.

[20] Heidari, H, Katircioğlu, ST, & Saeidpour, L 2015, 'Economic growth, CO2 emissions, and energy consumption in the five ASEAN countries', *International Journal of Electrical Power & Energy Systems*, vol. 64, pp. 785-791. doi: https://doi.org/10.1016/j.ijepes.2014.07.081.

[21] Im, KS, Pesaran, MH, & Shin, Y 2003, 'Testing for unit roots in heterogeneous panels', *Journal of Econometrics*, vol. 115, no. 1, pp. 53-74. doi: https://doi.org/10.1016/S0304-4076(03)00092-7.

[22] International Energy Agency (IEA) 2019, *Southeast Asia energy outlook 2019*, viewed 22 June 2021 <https://www.iea.org/reports/southeast-asia-energy-outlook-2019>.

[23] Jalil, A, & Feridun, M 2011, 'The impact of growth, energy and financial development on the environment in China: a cointegration analysis', *Energy Economics*, vol. 33, no. 2, pp. 284-291. doi: https://doi.org/10.1016/j.eneco.2010.10.003.

[24] Kim, S 2019, 'CO2 emissions, foreign direct investments, energy consumption, and GDP in developing countries: A more comprehensive study using panel vector error correction model', *Korean Economic Review*, vol. 35, no. 1, pp. 5-24. doi: https://doi.org/10.22841/kerdoi.2019.35.1.001.

[25] Levin, A, Lin, CF, & Chu, CSJ 2002, 'Unit root tests in panel data: asymptotic and finite-sample properties',

https://scholarhub.ui.ac.id/efi/vol68/iss2/4
DOI: 10.47291/efi.2022.04

Journal of Econometrics, vol. 108, no. 1, pp. 1-24. doi: https://doi.org/10.1016/S0304-4076(01)00098-7.

[26] Mankiw, NG 2009, *Macroeconomics* (7th ed). Worth Publishers.

[27] Namahoro, JP, Wu, Q, Xiao, H, & Zhou, N 2021, 'The impact of renewable energy, economic and population growth on CO_2 emissions in the East African region: Evidence from common correlated effect means group and asymmetric analysis', *Energies*, vol. 14, no. 2, pp. 312. doi: https://doi.org/10.3390/en14020312

[28] Pedroni, P 2001, 'Purchasing power parity tests in cointegrated panels', *Review of Economics and Statistics*, vol. 83, no. 4, pp. 727-731. doi: https://doi.org/10.1162/003465301753237803.

[29] Pedroni, P 2004, 'Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis', *Econometric Theory*, vol. 20, no. 3, pp. 597-625. doi: https://doi.org/10.1017/S0266466604203073.

[30] Pesaran, MH, & Smith, R 1995, 'Estimating long-run relationships from dynamic heterogeneous panels', *Journal of Econometrics*, vol. 68, no. 1, pp. 79-113. doi: https://doi.org/10.1016/0304-4076(94)01644-F.

[31] Pesaran, MH, Shin, Y, & Smith, RP 1999, 'Pooled mean group estimation of dynamic heterogeneous panels', *Journal of the American Statistical Association*, vol. 94, no. 446, pp. 621-634. doi: https://doi.org/10.1080/01621459.1999.10474156.

[32] Prawoto, N, & Basuki, AT 2020, 'Effect of macroeconomic indicators and CO2 emission on Indonesian economic growth', |it International Journal of Energy Economics and Policy, vol. 10, no. 6, pp. 354-358. doi: https://doi.org/10.32479/ijeep.10031.

[33] Prieur, F 2006, 'The implication of irreversible pollution on the relation between growth and the environment: The degenerate Kuznets curve', *Environmental Economics & Management Memorandum, #45*. Center for Operations Research and Econometrics (CORE), viewed 22 June 2021 <https://www.researchgate.net/profile/Fabien-Prieur/publication/265280360_The_Implication_of_Irreversible_Pollution_on_the_Relation_between_Growth_and_the_Environment_The_Degenerate_Kuznets_Curve/links/58afeb9992851cf7ae89124c/The-Implication-of-Irreversible-Pollution-on-the-Relation-between-Growth-and-the-Environment-The-Degenerate-Kuznets-Curve.pdf>.

[34] Radmehr, R, Rastegari, S, & Shayanmehr, S 2021, 'Renewable energy consumption, CO_2 emissions, and economic growth Nexus: A simultaneity spatial modeling analysis of EU countries', *Structural Change and Economic Dynamics*, vol. 57, pp. 13-27. doi: https://doi.org/10.1016/j.strueco.2021.01.006.

[35] Saboori, B, & Sulaiman, J 2013a, 'CO_2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: A cointegration approach', *Energy*, vol. 55, pp. 813-822. doi: https://doi.org/10.1016/j.energy.2013.04.038.

[36] Saboori, B, & Sulaiman, J 2013b, 'Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia', *Energy Policy*, vol. 60, pp. 892-905. doi: https://doi.org/10.1016/j.enpol.2013.05.099.

[37] Salahuddin, M, Alam, K, Ozturk, I, & Sohag, K 2018, 'The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait', *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 2002-2010. doi: https://doi.org/10.1016/j.rser.2017.06.009.

[38] Sapkota, P, & Bastola, U 2017, 'Foreign direct investment, income, and environmental pollution in developing countries: Panel data analysis of Latin America', *Energy Economics*, vol. 64, pp. 206-212. doi: https://doi.org/10.1016/j.eneco.2017.04.001.

[39] Shaari, MS, Abdul Karim, Z, & Zainol Abidin, N 2020, 'The effects of energy consumption and national output on CO2 emissions: new evidence from OIC countries using a panel ARDL analysis', *Sustainability*, vol. 12, no. 8, p. 3312. doi: https://doi.org/10.3390/su12083312.

[40] Shahbaz, M, Hye, QMA, Tiwari, AK, & Leitão, NC 2013, 'Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia', *Renewable and Sustainable Energy Reviews*, vol. 25, pp. 109-121. doi: https://doi.org/10.1016/j.rser.2013.04.009.

[41] Shan, S, Ahmad, M, Tan, Z, Adebayo, TS, Man Li, RY, & Kirikkaleli, D 2021, 'The role of energy prices and non-linear fiscal decentralization in limiting carbon emissions: Tracking environmental sustainability', *Energy*, vol. 234, 121243. doi: https://doi.org/10.1016/j.energy.2021.121243.

[42] Shaw, D, Pang, A, Lin, CC, & Hung, MF 2010, 'Economic growth and air quality in China', *Environmental Economics and Policy Studies*, vol. 12, no. 3, pp. 79-96. doi: https://doi.org/10.1007/s10018-010-0166-5.

[43] Sultana, B, Raza, SN, Rana, K, & Qayyum, A 2021, 'The effect of economic growth, foreign direct investment, and energy use on environment degradation: Evidenced from ASEAN nations', *Pakistan Journal of Humanities and Social Sciences*, vol. 9, no. 2, pp. 114-124. doi: 10.52131/pjhss.2021.0902.0118.

[44] Tang, T.C., & Tan, PP 2016, 'Carbon dioxide emissions, energy consumption, and economic growth in a transition economy: Empirical evidence from Cambodia', *Labuan Bulletin of International Business & Finance*, vol. 14, pp. 14-51. doi: https://doi.org/10.51200/lbibf.v14i.1318.

[45] Todaro, MP, & Smith, SC 2015, *Economic development* (12th edition). Pearson.

[46] Vo, AT, Vo, DH, & Le, QTT 2019, 'CO2 emissions, energy consumption, and economic growth: New evidence in the ASEAN countries', *Journal of Risk and Financial Management*, vol. 12, no. 3, p. 145. doi: https://doi.org/10.3390/jrfm12030145.

[47] Wang, Q, & Zhang, F 2020, 'Does increasing investment in research and development promote economic growth decoupling from carbon emission growth? An empirical analysis of BRICS countries', *Jour-*

nal of Cleaner Production, vol. 252, p.119853. doi: https://doi.org/10.1016/j.jclepro.2019.119853.

[48] Yang, N, Zhang, Z, Xue, B, Ma, J, Chen, X, & Lu, C 2018, 'Economic growth and pollution emission in China: Structural path analysis', *Sustainability*, vol. 10, no. 7, p. 2569. doi: https://doi.org/10.3390/su10072569.