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Article

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The Influence of Natural Resources, Energy Consumption, and Renewable Energy on Economic Growth in ASEAN Region Countries

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ABSTRACT

This research aims to identify and analyze the role of natural resources, CO_2 emissions, and renewable energy on the economic growth of countries in the ASEAN region. In this study, we tested whether a dynamic process occurred based on a dynamic panel data model while comparing it with static panel data. The dataset used is ASEAN region countries with time series data from 2000 to 2021. The analysis tools used are static and dynamic panel data. The research results found that natural resources, FDI, and renewable energy significantly positively affect economic growth in the ASEAN region. Conversely, CO_2 has a negative and insignificant effect. These results prove that the ASEAN region's economic development has been clean energy-oriented.

Keywords: Natural Resources, Energy Consumption, CO_2 Emissions, Renewable Energy, Economic Growth
JEL Classifications: C33, O44, O47, R11

1. INTRODUCTION

The economic growth of a region is part of achieving Sustainable Development Goals (SDG's) number 8, namely inclusive and sustainable economic growth (SDG's UN, 2023). Attention economists worldwide argue that achieving economic growth in developing countries is still a top priority in development (Acemoglu, 2008). Therefore, research developments related to economic growth are ongoing today, especially in one region.

Explaining economic growth in a country is relatively easy by looking at the productivity produced each year. However, explaining growth in countries in one region will be more complicated because each country has its economic characteristics. This condition also applies to the Southeast Asia or ASEAN region, where there are differences in the economic growth rate. ASEAN is a geopolitical and economic organization of Southeast Asian countries. This area has diverse economic drivers, and some purely depend on petroleum, natural gas, and mining products (coal). Based on Figure 1, average economic growth data for 2010-21, it can be seen that it is very heterogeneous. The highest achievement was in Lao PDR at 6.35%, and the lowest was in Brunei Darussalam at 0.38%. Brunei is one of the largest petroleum-producing countries in ASEAN, and petroleum is an essential part of its economy, so it is vulnerable to fluctuations in world oil prices and declining lifting. Furthermore, the achievement of oil and gas-producing countries is below 5%.

Until now, economic growth has still been required to get out of the Middle Income Trap, so each country is trying to grow its industrial sector until it becomes industrialized. The development of the industrial sector is closely related to the massive use of energy, both from electrical power and from the use of fossil natural resources, as explained by the research results of Hadi et al. (2021) that the use of electricity and diesel fuel is significant in supporting the industrial sector. Furthermore, Franck and Galor (2019) stated that industrialization harmed long-term prosperity resulting from adopting technology with the level of human resources, thus requiring incentives for equalization of skills and ultimately that industrial technology could become a source of prosperity.

On the other hand, industrialization affects environmental damage in the long term. Opoku and Boachie (2020) stated that in recent years, the main environmental concern has been greenhouse gas emissions and their impact on climate change. There is great interest among researchers in conducting research related to factors that contribute to environmental degradation. Internationally and in the joint decision, namely SDG's 2030, the importance of clean energy is highly appreciated in the context of sustainable development. Therefore, this article aims to determine the influence of natural resources, carbon dioxide (CO_2) emissions, and renewable energy with FDI as a control variable on economic growth in Southeast Asian countries.

This research is structured as follows: the next section briefly reviews research that has been conducted on the subject. The following section explains the dataset and methodology, and the fourth section presents and explains the empirical results along with a discussion. The final section offers conclusions and policy implications.

2. LITERATURE REVIEW

The neo-classical growth theory pioneered by Solow states that capital and labor are the main growth factors and include technological developments, which are usually denoted by the symbol *A*. As time progresses, the technological variable depends on the constant rate of technological improvement and the domestic economy's energy consumption level. Energy is the main input supporting the development of modern technology (Mirza and Kanwal, 2017; Sultan and Alkhateeb, 2019; Tang et al., 2016; Audi et al., 2021; Camara, 2023). Schumpeter's "creative destruction" concept will increase new technology development through re-investment and equipment modernization. At the same time, energy consumption helps accelerate the innovation process, leading to economic growth.

Research by Parveen et al. (2020) shows that increasing energy consumption from natural gas and petroleum will boost economic growth in Pakistan. Furthermore, Akinlo (2008) found that energy consumption was cointegrated with economic development in Cameroon, Ivory Coast, Gambia, Ghana, Senegal, Sudan, and Zimbabwe. In the long term, it significantly impacts economic growth in Ghana, Kenya, Senegal, and Sudan. Furthermore, the results from Bakirtas and Akpolat (2018) state that there is a causality between per capita energy consumption and per capita income to urbanization. Sultan (2012) found that using electrical energy and exports can influence long-term economic growth in Mauritius. Furthermore, from the research results of Hidayat et al. (2022; 2023), the opposite is true: electrical energy infrastructure harms achieving convergence, as convergence is long-term economic growth in achieving a steady state.

The research results by Tran et al. (2020) show that energy consumption negatively impacts the trade balance. Then, the results from Fernandes and Reddy (2020) show that energy consumption and economic growth are integrated into the long term in China and India. Research by Meidani and Zabihi (2014) found a strong one-way causality from energy consumption in the industrial sector to real GDP. Increasing energy consumption in the industrial sector can encourage economic growth. Nayan et al. (2013) provide evidence of a one-way causality between energy consumption and GDP, where GDP significantly determines energy consumption and has a less significant impact on GDP.

Awodumi and Adewuyi (2020) revealed evidence of the asymmetric effect of oil and natural gas consumption on economic growth and carbon emissions in all selected countries except Algeria. Although positive changes in non-renewable energy consumption hinder growth in Nigeria, they can reduce emissions. Azam et al. (2021) found that long-term causality shows that natural gas does not contribute to economic growth and CO_2 reduction like nuclear and renewable energy. However, except for natural gas, the expansion and improvement of renewable energy and nuclear energy are essential to avoiding global warming and climate change and promoting economic growth.

Renewable energy is a sustainable electricity source and economic development (Ovwigho et al., 2020). The empirical results of Muhammad et al. (2017) show that the impact of renewable energy consumption on economic growth is positive and significant. The Granger causality panel shows a unidirectional causality relationship between renewable energy consumption, oil prices, and economic growth. Ozcan and Ozturk (2019) paper analyze the relationship between renewable energy consumption and economic growth in 17 developing countries. The results show that energy-saving policies, except for Poland, do not harm these countries' growth rates.

Eyuboglu and Uzar (2022) found asymmetric causality between negative shocks in economic growth and negative shocks in renewable energy consumption in South Africa, Thailand and Turkey, indicating that negative shocks in economic growth inhibit renewable energy consumption. Furthermore, the results suggest no causal relationship between renewable energy consumption and economic growth in most developing countries, except South Africa, Thailand, and Turkey. Anser et al. (2021) found that renewable energy sources have an important impact on the economic growth of South Asian countries. Highlights the potential of renewable energy to drive environmentally friendly economic development.

Empirical results by Apergis and Payne (2010) found a long-term relationship between renewable energy and increased real GDP growth in OECD countries. Furthermore, Apergis and Payne (2012) found that renewable and non-renewable energy mutually influence economic growth in both the long and short term and that there are substitutes between the two energy sources. Dynamically, Apergis and Payne (2014) stated that there is a long-term relationship between renewable energy consumption, real GDP per capita, carbon dioxide emissions per capita, and real oil prices, and it is positive and statistically significant. The study by Deka et al. (2023) shows that carbon emissions, renewable energy, capital, effective capital, and population significantly impact GDP in the EU-27 countries.

Results from Akram et al. (2021) stated that there is a two-way causal relationship between renewable energy consumption and economic growth. Apart from that, Energy Efficiency is also useful for increasing renewable energy in BRICS countries. This study shows that more productive energy use can stimulate economic growth in BRICS countries through improving Energy Efficiency and renewable energy. Furthermore, Shahbaz et al. (2016) stated that biomass energy consumption drives the economic growth of BRICS countries. Research from Maji et al. (2019) revealed that renewable energy consumption slows economic growth in West African countries. Furthermore, a study by Chica-Olmo et al. (2020) stated that spatial changes in renewable energy consumption affect the GDP of neighboring European countries.

Primary energy supply, effective capital, and renewable energy have positively impacted economic growth in the EU-27 countries. The use of panel estimation techniques and causal inference in the research by Halilbegović et al. (2023) and Aliev et al. (2023) supports this finding. The study by Madaleno and Nogueira (2023) also confirms the positive contribution of renewable energy consumption to economic growth while highlighting the negative impact of CO_2 emissions. Additionally, the study by Sisodia et al. (2023) reveals that renewable energy and globalization can decrwwease CO_2 emissions, further supporting the idea that renewable energy benefits economic growth. The use of dynamic panel estimators, such as the two-step system GMM estimator, in the study by Mirziyoyeva and Salahodjaev (2023) provides a suitable method for analyzing the relationship between these variables.

3. METHODOLOGY

This research uses a quantitative method related to calculated values, which are analyzed using static panel regression and dynamic panel data to explore dynamic processes in economic growth on a regional scale in Southeast Asia. The scope of the analysis unit is 9 countries in the Southeast Asia region that are members of ASEAN, except Singapore, because this country is already in the developed country category. The year period used is from 2000–2021. The data source comes from the World Bank with the World Development Indicators module.

For the formulation of the model to be used, there are several variables whose operational definitions must be as follows: (1) Economic Growth (Y), proxied from the annual percentage of GDP at constant prices issued by the World Bank; (2) Natural Resources (NR) as a proxy for total natural resources rents (% of GDP); (3) Foreign Direct Investment (FDI) refers to foreign investment that occurs in the economy, data in current US$; (4) CO_2 emissions (CO_2) are proxied from total CO_2 emissions in kilo tons units. Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring; (5) Renewable energy (RE) is proxied from renewable energy consumption, which is the share of renewable energy in total final energy consumption.

Panel pooled data is a combination of cross-section units with time series. If we have T time periods (t = 1,2,…T) and N number of individuals (i = 1,2,…N), then panel data will have $N \times T$ observation units (Greene, 2012). If the number of time units is the same for each individual, then the data is called a balanced panel. If the opposite is true, namely, the number of time units is different for each individual, it is called an unbalanced panel (Verbeek, 2017). The current research uses a balanced panel.

In this research, the neoclassical growth theory of Solow (1956) is adopted, which considers the Cobb-Douglas production function (Tang et al., 2016)

$$Y_t = K_t^{\alpha} \left(A_t L_t \right)^{1-\alpha} \quad (1)$$

Where Y is output, K is the stock of capital used to produce output, L is labor, and A is a labor-augmenting factor indicating the level of technological innovation and efficiency in the economy. $\alpha < 1$, the returns of capital are decreasing.

In identifying factors that influence economic growth, the equation used is as follows:

$$Y_{it} = \alpha + \beta_1 NR_{it} + \beta_2 FDI_{it} + \beta_3 CO2_{it} + \beta_4 RE_{it} + \varepsilon_{it} \quad (2)$$

Next, the analysis uses static and dynamic panel data assisted by STATA software. Static panel data comprises the fixed effect model (FE) and the random effect model (RE). The stage for selecting the best model uses the Hausman test, where if the prob value is < 0.05, then the best model is FEM, and vice versa. The FE model applies dummy variables to change the intercept, but other coefficients remain the same for each observation unit. To consider the individuality of each cross-section unit, this is done by making different intercepts in each country. The least-square dummy variable method is used, in which the same number of dummy variables added as the number of cross-sections is reduced by one to avoid a dummy variable trap. The application of equation (2) is as follows:

$$Y_{it} = \alpha + \beta_j X_{it} + \sum_{i=1}^{8} D_i^c \alpha_i + \varepsilon_{it} \quad (3)$$

Furthermore, the random effect model has a fundamental difference from the FE model, namely that the specific effect of each individual α_i is used as part of the error component, which is random and has no correlation with the observed explanatory variable X_{it}. Thus, the RE equation is written as follows:

$$Y_{it} = \alpha_i + \beta_j X_{it} + E_{it}$$

$$E_{it} = (\mu_{it} + v_t + w_{it}) \quad (4)$$

Note: $\mu_i \sim N(0, \delta_u^2)$ = Component *cross-section error*; $v_i \sim N(0, \delta_v^2)$ = Component *time series error;* $w_{it} \sim N(0, \delta_w^2)$ = Component combination error.

The formulation of the RE model is obtained from the FE model by assuming that the average effect of random time-series and cross-section variables is included in the intercept, and the random deviation from the average is equal to the error components, μ_i and v_t. The appropriate method for estimating random effects models is Generalized Least Squares (GLS) with homoscedastic assumptions and no cross-sectional correlation.

Dynamic panel data regression describes the relationship between dynamic economic variables. In line with the existence of cross-section and time series models in panel data, dynamic relationships are characterized by including the lag of the dependent variable as a regressor in the regression (Greene, 2012; Verbeek, 2017).

The general form of the dynamic panel data regression model by Baltagi (2005) is as follows:

$$y_{it} = \delta y_{i,t-1} + x_{it}^{'} \beta + u_{it} \quad (5)$$

where δ adalah scalar, $x_{it}^{'}$ is matrix 1×K and β is matrix K×1. Next, it is assumed u_{it} is a one-way error component as follows:

$$u_{it} = \varepsilon_{it} + \mu_{it} \quad (6)$$

where: μ_{it} is the individual effect and ε_{it} is the error term with each assumption $\mu_{it} - \text{IID}\left(0, \sigma_\mu^2\right)$ dan $\varepsilon_{it} - \text{IID}\left(0, \sigma_\varepsilon^2\right)$.

By combining equations (5) and (6), the dynamic panel equation is obtained as follows:

$$y_{it} = \delta y_{i,t-1} + x_{it}^{'} \beta + \varepsilon_{it} + u_{it} \quad (7)$$

So, the dynamic panel data regression model used in this research is:

$$Y_{it} = \delta Y_{it-1} + \beta_1 NR_{it} + \beta_2 FDI_{it} + \beta_3 CO2_{it} + \beta_4 RE_{it} + u_{it} + \varepsilon_{it} \quad (8)$$

The Generalized Method of Moments (GMM) uses the dynamic panel model. GMM has two models in estimation, namely First-Differences GMM and System GMM. The first-differences approach was developed by Arellano and Bond (1991) with the generalized method of moments (GMM), where the lag of the dependent variable starting from t-2, or called FD-GMM, is used. This approach will produce a consistent estimator of α when N→∞ with T is relatively small. The Sys-GMM method is useful for estimating systems of First-Differences equations and at levels where the instrument used at that level is the first-difference lag of the series (Blundell and Bond, 1998). The Sys-GMM estimator combines the first differentiation equation cluster with level values as the instrument, plus the level equation cluster with the first differentiation as the instrument.

Determination of the best dynamic model or GMM criteria suggested by Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998), there are two specifications: Firstly, Sargan test of over-identifying restrictions, which tests for overall validity of the instruments and hypothesis null is that all instruments as a group are exogenous. The second test examines the null hypothesis that the error term ε_{it} of the differenced equation is not serially correlated, particularly in the second-order (AR2).

4. RESULTS AND DISCUSSION

Before we proceed to the analysis of the results, model selection is carried out from static and dynamic panels. In the statics panel, choose the best model between the fixed effect model (FE) and the random effect model (RE) using the Hausman test. Based on Table 1, the Hausman Prob value is smaller than 0.05, meaning that the best static panel data model is FE. Meanwhile, the dynamic panel data model between FD-GMM and Sys-GMM is selected using two standard procedures, namely by carrying out the Sargan test as a valid instrument test. There is no serial correlation in errors, and then the Arellano-Bond test is used as a consistency estimator check. Based on Table 1, the Sargan test probability value for both models is obtained with a value less than 0.05, indicating that the instrument is invalid and there is a serial correlation in error. Therefore, according to Law (2018), calculations using a robust model are used in STATA by adding the command vce(robust) to improve the two approaches. After carrying out calculations using the robust model, the Arellano-Bond test was then carried out. The prob m_2 value for FD-GMM was 0.3670, and Sys-GMM was 0.2772. This value was greater than 0.05, so H_0 was accepted, meaning the estimator was consistent. Thus, the results of the robust model will be used to analyze economic growth from a dynamic point of view.

The dynamic panel data model is characterized by a significant lag-Y variable value in equation (3). Based on Table 1, the lag-Y variable (Yt-1) value is significant at the 1% level for the FD-GMM and Sys-GMM models. Therefore, the results of the two models can illustrate the existence of a dynamic relationship between variables. The lag-Y coefficient value for FD-GMM is 0.2433, and Sys-GMM is 0.2562, thus stating that economic growth in the previous period can influence economic growth in the current period, assuming that the other variables contained in the model are considered constant or cateris-paribus.

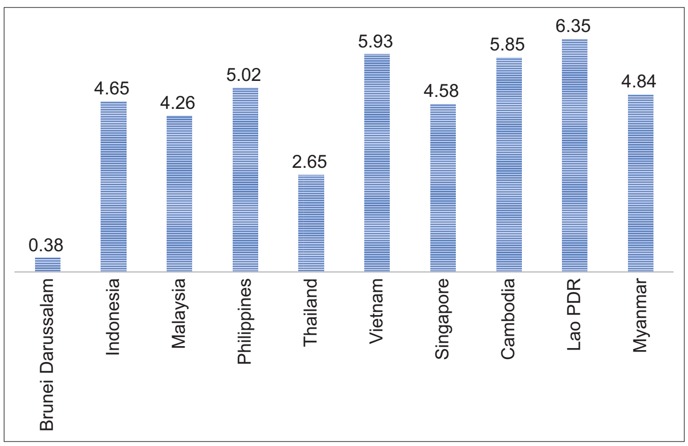
The results of static panel data based on the FE model show that two variables significantly influence economic growth: Natural resources and FDI. The natural resources coefficient has a positive value of 0.2495, which means that every increase in the percentage of natural resources rent to GDP will increase economic growth in the ASEAN region with a cateris-paribus assumption. For FDI, a coefficient value of 0.0000000003 means that every increase in foreign investment of 1 million US$ will significantly increase economic growth by 0.0003%. Furthermore, two variables were not significant, namely CO_2 and renewable energy.

Table 1: Static and dynamic model results

Item	FEM	FD-GMM	Sys-GMM
NR	0.2495**	0.1096***	0.057
	(0.0889)	(0.0403)	(0.0716)
Fdi	0.0000000003**	0.0000000003***	0.0000000003***
	(0.00000000009)	(0.00000000009)	(0.00000000008)
CO_2	−0.000009	−0.00001	−0.00001
	(0.00001)	(0.00001)	(0.000008)
RE	0.1369	0.1709***	0.1048***
	(0.0761)	(0.0667)	(0.0293)
Y_{t-1}	-	0.2433***	0.2562***
		(0.0931)	(0.0918)
Hausman (Prob)	0.000	-	-
Sargant test (Prob)	-	0.000	0.000
Prob m_1		0.0161	0.0138
Prob m_2	-	0.3670	0.2772
R^2	0.50		-
N	198	180	189

Notes: Heteroskedasticity robust standard errors are shown in parentheses. *P<0.1; **P<0.05; ***P<0.01

Figure 1: Average GDP Growth in ASEAN Countries 2010–2021



Source: Worldbank.org (2023)

Furthermore, there are three significant variables for the dynamic model results from FD-GMM: Natural resources, renewable energy, and FDI, while CO_2 is not significant. Meanwhile, in the results of the Sys-GMM dynamic model, there are only two significant variables, namely FDI and renewable energy. From the results of the two models, the coefficient values are not too different, and the direction of the relationship between the dependent and independent variables is the same. Therefore, the FD-GMM model is considered more efficient or robust and used for analysis and discussion.

Based on the coefficient value, evidence is obtained that natural resources positively affect economic growth with a value of 0.2495, which means that increased use of natural resources will boost economic growth by 0.2495% with the cateris-paribus assumption. The positive renewable energy coefficient value is 0.1369, which means that the increasing use of renewable energy from the total energy produced will increase economic growth by 0.1369% with the cateris-paribus assumption. The same thing is obtained from the FDI coefficient, which has a positive value, that the more incoming foreign investment of 1 million US$ will impact economic growth of 0.0003. Finally, the CO_2 coefficient is -0.00001, which means an increase in CO_2 emissions will reduce economic growth in the ASEAN region by 0.00001.

The results from the static and dynamic models state that natural resources positively and significantly affect economic growth in the ASEAN region. Thus, this proves that almost all countries depend on their natural resources. These natural resources are used for their own country and export commodities. Natural resources are often associated with the exploration of oil and gas resources, but mineral and coal commodities are also part of large exploration. If this activity continues for a long time and is massive, it will result in environmental degradation. Therefore, regulations are needed to achieve environmental sustainability. As is known, many ASEAN countries are still heading towards becoming developed countries or part of the middle-income trap. Therefore, the motive for accelerating development is to make industrialization an economic driver, making these countries still dependent on existing natural resources. These results align with research by Parveen et al. (2020), who say that energy consumption from oil and gas can increase economic growth.

Furthermore, FDI from both static and dynamic results has a positive and significant influence on economic growth in countries in the ASEAN region. These results support the Solow model of the neo-classical growth concept, where investment is one of the driving forces of economic growth. These findings prove that ongoing and sustainable investment activities can increase economic growth. These results align with the findings of Hidayat et al. (2022; 2023) state that investment influences economic growth and supports the achievement of convergence conditions.

The dynamic model results found that renewable energy significantly influences economic growth. Thus, countries in the ASEAN region also implement and develop renewable energy in total energy consumption, which is very beneficial for achieving a green economy and clean energy-oriented development as planned by the UNDP in the SDG's program. These findings are in line with many studies that have been discussed in literature reviews, such as Akram et al. (2021); Anser et al. (2021); Chica-Olmo et al. (2020); Halilbegović et al. (2023); Madaleno and Nogueira (2023); Mirziyoyeva and Salahodjaev (2023).

This trend of increasing renewable energy can reduce total CO_2 emissions, especially in power plants using oil, gas and coal, by switching to solar panels, hydropower and wind. Furthermore, if we synchronize with the previous results that CO_2 emissions negatively influence economic growth, then the use of renewable energy should be developed. It does not have to be massive immediately, but gradually to abandon total energy production from oil and gas and coal so that oil and gas and coal can be used for other benefits.

5. CONCLUSION

Based on the description of the results of the discussion above, it can be concluded that there is a dynamic process in economic growth in ASEAN, so it can be said that last year's economic growth influenced the current year's growth. Furthermore, two variables significantly influence economic growth from the static model: natural resources and foreign investment. Meanwhile, from the dynamic model, there are three significant variables: natural resources, foreign investment and renewable energy. CO_2 emissions are not significant for the economic growth of the ASEAN region. Based on the variables used and their significance, it is stated that the ASEAN economy is clean energy-oriented and has green economic opportunities. Increased consumption of energy products drives economic growth while improving environmental quality.

Based on the results, policymakers can use them to implement state development planning. This research suggests that policymakers need to plan for environmental issues while making policies regarding energy use and economic development and look for environmentally friendly energy sources such as building dams and providing solar systems and windmills. It would be good if it could be put on the agenda at the ASEAN forum and continuous follow-up to achieve SDG's 2030.

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