ISSN 1998-6041

ENVIRONMENTAL ECONOMICS

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Environmental Economics

ISSN 1998-6041 (print), 1998-605X (online)

Issued since November 2010

Publisher LLC "Consulting Publishing Company "Business Perspectives"

Founder LLC "Consulting Publishing Company "Business Perspectives"

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doi: http://dx.doi.org/10.21511/ee.13(1).2022.14

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“Economic growth and environmental degradation paradox in ASEAN: A simultaneous equation model with dynamic panel data approach”

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ARTICLE INFO	Supriyanto, Wiwiek Rabiatul Adawiyah, Arintoko, Dijan Rahajuni and Nunik Kadarwati (2022). Economic growth and environmental degradation paradox in ASEAN: A simultaneous equation model with dynamic panel data approach. *Environmental Economics*, *13*(1), 171-184. doi:10.21511/ee.13(1).2022.14
DOI	http://dx.doi.org/10.21511/ee.13(1).2022.14
RELEASED ON	Monday, 05 December 2022
RECEIVED ON	Thursday, 27 October 2022
ACCEPTED ON	Tuesday, 22 November 2022

JOURNAL	"Environmental Economics"
ISSN PRINT	1998-6041
ISSN ONLINE	1998-605X
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
21	**1**	**10**

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ECONOMIC GROWTH AND ENVIRONMENTAL DEGRADATION PARADOX IN ASEAN: A SIMULTANEOUS EQUATION MODEL WITH DYNAMIC PANEL DATA APPROACH

Abstract

Economic variables are dynamic in nature. This paper uses a simultaneous equation model to assess the complexity of the link between economic expansion and environmental deterioration in ASEAN. The study examines how CO2 emissions, economic growth, public health initiatives, and control factors interact using dynamic panel data from 2011 to 2020. The population, the amount of forested land, the use of renewable energy, foreign investment, the inflation rate, the total amount of foreign exchange reserves, and government health policies are just a few examples. In order to provide a reliable and accurate assessment of the long-term relationship, this study employs the generalized approach of the Arellano-Bond moment method. The econometric technique deals with the issues of nonstationary, endogeneity, cross-error correlation, and heteroscedasticity.

Additionally, the two stage least square (2SLS) method was used to assess the results' robustness. According to the statistical results, there is a causal link between CO2 emissions and economic growth, and between CO2 emissions and energy consumption. Furthermore, according to the data, ASEAN CO2 emissions showed a monotonically growing relationship during the sample period. Policymakers may use these findings since they can aid in implementing economic measures to promote sustainable and ecologically friendly development.

Keywords simultaneous equation model, CO2 emissions, dynamic panel data, economic growth, energy consumption, ASEAN

JEL Classification Q43, 044, C30, C33

Received on: 27th of October, 2022
Accepted on: 22nd of November, 2022
Published on: 5th of December, 2022

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Conflict of interest statement:
Author(s) reported no conflict of interest

INTRODUCTION

Environmental damage has become a global issue and a common concern for people worldwide. Industrial growth has contributed to widespread environmental damage, especially in recent decades, and has affected the world's health, ecology, and climate balance (Radmehr et al., 2021). With the rapid expansion of industry, there has been exploitation and depletion of the earth's minerals and resources, as well as environmental degradation in the form of an increase in critical land, water pollution, and air pollution. The expansion of essential land has had unfavorable effects, such as flooding throughout the wet season and drought throughout the dry season. Ten ASEAN nations were compelled to reach a regional agreement on smog pollution that crosses international borders due to the severe effects of air pollution (Mughal et al., 2021) from smog and forest fires (Nazeer & Furuoka, 2017; Thanh et al., 2019). Energy use has both immediate and long-term effects on environmental quality in various ASEAN nations (Haruna & Mahmood, 2018).

Environmental degradation increased due to the significant increase in the economic growth of numerous ASEAN nations (Haruna & Mahmood, 2018; Hu et al., 2021; Mughal et al., 2021; Thanh et al., 2019). Due to this phenomenon, numerous studies have provided empirical evidence that economic growth will affect environmental quality changes during the early stages of development until a specific limit is reached. After this point, the condition will result in improved environmental conditions.

Using a yearly data set covering the years 1980–2014, Bakhsh et al. (2017) identified the factors that influence foreign direct investment (FDI) inflows into Pakistan as well as their direct effects on the environment's degradation and the growth of the economy. CO_2 emissions in the atmosphere are another factor that can be used to gauge the severity of air pollution. Rizk and Slimane (2018) analyzed the association between poverty and CO_2 emissions from 146 nations between 1996 and 2014 as a kind of environmental deterioration. The major finding is that poverty and CO_2 emissions have a nonlinear relationship that might cause poverty to increase and the environment to degrade. Therefore, the fundamental policy advice is that all nations should strengthen their institutional foundation to reduce poverty and environmental damage (Abdouli & Hammami, 2020).

In most nations worldwide, environmental deterioration is mainly caused by economic expansion and FDI (Bakhsh et al., 2017; Ren et al., 2021). Through technological transfer, higher productivity, and the introduction of new managerial techniques and procedures, the flow of foreign investment serves as a direct source of capital to promote economic growth. Additionally, FDI inflows aid in the financial development of the investing nation. This suggests that FDI increases the amount of money the financial system has access to. As a result, these funds support economic growth as well as the development of financial markets. It is also claimed that international businesses can use banking services to get loans, overdraft facilities, or to pay suppliers of semi-finished items. On the other hand, higher FDI inflows and economic expansion result in a reduction in the environment's quality.

It is impossible to ignore environmental degradation, including water and air pollution, which can jeopardize the viability of development. Engineering and compositional impacts show that more economic expansion results in higher pollution emissions (Bakhsh et al., 2017). The scale effect demonstrates that while pollution has a detrimental impact on growth, the stock of labor and capital benefits Pakistan's economy. Economic expansion and FDI have a favorable and considerable impact on capital stock in terms of the effect of capital accumulation. Even if economic expansion increases pollution, economic growth declines when pollution levels go beyond a certain point. As a result, solutions must be found to combat more severe air pollution. However, the majority of research is based on cross-sectional studies, and very few studies have used the panel data simultaneous equation technique (Ali et al., 2021; Bakhsh et al., 2017; Garza-Rodriguez, 2018; Haruna & Mahmood, 2018; Ren et al., 2021; Rizk & Slimane, 2018; Thanh et al., 2019). The model, which is still the subject of discussion, calls for a substitute model with new variables, specifically fiscal and monetary policies.

A simultaneous equation system has the characteristic that it consists of several equations (Baltagi & Liu, 2009). In addition to mathematical and phenomenal, there is a relationship between these equations (Rose et al., 2020). The model in this simultaneous equation system has endogenous and explanatory variables in each equation, unlike the single equation system. Explanatory variables in one equation may also be endogenous variables in another. As a result, these variables can be correlated with other explanatory variables. In this case, the estimation of ordinary least squares (OLS) cannot be used because OLS in a simultaneous equation system will produce biased and inconsistent parameter estimates (Gujarati, 2022). One alternative for estimation is the two-stage least square (2SLS) method. This method will produce one estimator for one parameter and a standard error for each estimator (Gujarati, 2022). Several previous studies have shown that it is possible to use a simultaneous equation model in environmental economics because the variables tend to have a simultaneous relationship (Omri, 2013). Based on the phenomenon, there is a relationship between economic variables, so it cannot be modeled

http://dx.doi.org/10.21511/ee.13(1).2022.14

with a simple or multiple regression model. Thus, this study used the 2SLS method for factors that affect economic growth and environmental damage.

A simultaneous equation can also be used to model the correlation between economic upswing and poverty alleviation over the long and short term (Garza-Rodriguez, 2018). It was discovered through the vector error correction model (VECM) that poverty reduction and economic growth in Mexico are causally related in both directions. Ren et al. (2021) identified the crucial commitment to achieving China's sustainable development as the primary factor impacting the carbon emissions of China's steel sector. To determine the impact of malaria on working time during the agricultural production stage, Rose et al. (2020) used the three-stage least squares (3SLS) simultaneous equation model on cross-sectional data gathered from 252 agricultural employees.

This paper examines the interaction between CO_2 emissions, economic expansion, and national health policies in a panel of 10 ASEAN nations using simultaneous equation modeling on dynamic panel data. Unfortunately, there are still not many empirical studies that apply simultaneous equation modeling with growth rates in each ASEAN nation to investigate the link between CO_2 and GDP on fossil-based energy consumption, total foreign currency reserves, and renewable energy use. However, with the help of this model, it is possible to simultaneously analyze how government policies, CO_2 emissions, and economic growth are related (Saidi & Hammami, 2015). In particular, this paper makes use of a model with two structural equations that allow for the concurrent effects:

(I) The impact of CO_2 emissions, FDI, fossil fuel use, population, inflation rate, and overall reserves impact of foreign exchange on economic expansion is investigated.

(II) The impact of population expansion, economic growth, government health policies, FDI, fossil fuel consumption, and renewable energy consumption on environmental pollution is investigated. In this paper, the growth rate is considered in the modeling approach to evaluate the short-run elasticity rather than the long-run.

1. LITERATURE REVIEW AND HYPOTHESES

1.1. Theoretical literature review

A simultaneous equation model has multiple equations connected. As a result, a variable in a simultaneous equation can play the dual roles of both independent and dependent variables. This is possible in the simultaneous equation model. There are endogenous variables and predetermined variables in a simultaneous equation model. The predetermine variable is a variable whose value can be determined in advance but is not directly decided by the equation. In contrast, the endogenous variable is the dependent variable determined in the simultaneous equation system (non-stochastic). Exogenous variables and endogenous lag variables are the two categories into which predetermined variables fall (Gujarati, 2022).

In the simultaneous equation model, there are two kinds of equations: structural and reduced form. The structural equation is the original equation that describes the behavior of the relationship between the existing variables. In contrast, the reduced equation is an equation with endogenous variables only influenced by the predetermined variable and the error component.

In panel data regression, the dependent variable is also affected by the dependent variable from the preceding period (lag 1), so the model is said to be a dynamic panel data model. The dynamic panel data regression model in economic research is more suitable for finding the relationship between economic variables. This dynamic panel data model can be seen from the lag of the dependent variable between the independent variables. The dynamic panel data model can be written as (Gujarati, 2022):

$$Y_{i.t} = \delta Y_{i.t-1} + X'_{i,t}\beta + u_{i,t},$$
$$i = 1,2,\ldots,N, \quad t = 1,2,\ldots,T, \tag{1}$$

where N denotes the number of observations, T is the number of time periods, $Y_{i,t}$ response variable for individual i at time t, $Y_{i,t-1,}$ independent variable for individual i at time t (lag 1), $X_{'i,t}$ is vector transpose of the independent variable for the i-th individual on t-th time measuring 1 x k, δ is the intercept coefficient which is a scalar, β is independent variable parameter vector of size k x 1, and $u_{i,t}$ is component error model for individual i at time t.

The problem in the dynamic panel data model is when $y_{i,t}$ is a function of $u_{i,t}$, then the result $y_{i,t-1}$ is also a function of $u_{i,t}$. As a result, the independent variable on the right side of $y_{i,t-1}$ correlated with each other $u_{i,t}$ if the solution uses the usual panel data estimation method, it will cause the results to be biased and inconsistent. To overcome this problem, two approach methods can provide unbiased and consistent results: GMM Arellano Bond and GMM Blundel Bond. First, however, it is necessary to use an instrumental variable method to facilitate the estimation of the GMM method.

Over the past 20 years, some theoretical studies have concentrated on the relationship between political activities, CO_2 emissions, FDI inflows, and economic development. The neo-classical growth model postulates that FDI inflows can boost the capital stock, quickening economic expansion. The new growth hypothesis then contends that both long- and short-term economic development are aided by the technological advancements brought forth by FDI inflows. However, because of liberalization, deregulation, and privatization policies, FDI slows down economic growth. Furthermore, financial development and economic growth can happen independently of one another. However, a higher rate of economic expansion has been attained at the expense of environmental deterioration.

The Environmental Kuznets Curve (EKC) is a tool for analyzing the relationship between government and environmental policies. This suggests that as financial development increases industrial activity to achieve profitable growth, environmental degradation increases during the primary stage. However, as financial development advances to the next stage, investments in environmental projects and access to cutting-edge technology are made to slow down environmental degradation. However, the environment was considered another production element in the traditional trade perspective on comparative advantage. However, this view contends that developing nations should adopt lax environmental standards to increase FDI inflows.

Furthermore, wealthy nations enforce strict environmental laws to reduce pollution output, which promotes FDI in developing nations or places with lax environmental laws. Additionally, the environment and FDI inflows are thought to be positively correlated, according to the Neo-Technology Trade Theory. This suggests that because of stringent environmental rules, FDI inflows utilize technology regarding the environment.

In the early 1980s, the theoretical links between governmental policy and economic growth (as measured by FDI and GDP proxies) were examined. To encourage investment in cutting-edge technology, a structure for financial development is necessary yet insufficient. Furthermore, according to some studies, FDI inflows and financial developments are tightly associated. This implies that FDI can help countries with more developed financial markets benefit more from economic growth promoting FDI.

1.2. Analyzing empirical literature and formulating hypotheses

Economic growth is proxied by the variables of GDP (Mughal et al., 2021), population (Rizk & Slimane, 2018), FDI (Ren et al., 2021), and fuel consumption (Ali et al., 2021; Garza-Rodriguez, 2018). Indicators of the success of a country's economy are reflected in the high GDP, the increased flow of investment into the country, stable inflation and interest rates, and ultimately the implications for creating new jobs. Under the pretext of accelerating the development process to catch up with developed countries, developing countries (Ali et al., 2021) carry out various maneuvers to achieve high economic growth

http://dx.doi.org/10.21511/ee.13(1).2022.14

without carrying out further studies of changes in the large-scale transformation of the economic system so fast (Rizk & Slimane, 2018).

The impact of economic growth on the deterioration of the natural environment has been the subject of many studies. For example, according to Bakhsh et al. (2017), who studied the impact of economic growth on carbon dioxide emissions, waste, and foreign investment in Pakistan, increased economic growth is likely to increase the amount of emissions that contribute to pollution.

The impact of pollution has a detrimental effect on the country's environmental quality. In contrast, the investment and labor of foreign nationals have a positive impact on the expansion of Pakistan's economy. This also occurred in several other countries that are still developing (Ali et al., 2021), such as Vietnam (Hu et al., 2021), Malaysia (Haruna & Mahmood, 2018), Nigeria, and Mexico (Garza-Rodriguez, 2018). Furthermore, for the ASEAN region (Thanh et al., 2019; Mughal et al., 2021), economic growth generally affects environmental pollution (Khan et al., 2019). Therefore, this study hypothesizes:

H1: There are contributions of CO_2 emissions, government policies in the health sector, FDI, consumption of fossil fuels, population, inflation rates, and total foreign exchange reserves to economic growth in ASEAN countries.

Over the past two decades, a number of empirical studies have examined the connection between FDI inflows, economic growth, the environment, and governmental policy. A similar quadratic association between income and CO_2 emissions is demonstrated by Thanh et al. (2019). This suggests that China has an inverted U curve. In line with that, Garza-Rodriguez (2018) tested the EKC hypothesis in Malaysia from 1980 to 2009 using the auto-regressive distributed lag (ARDL) methodology. Using the fixed-effect model and the generalized methods of moment (GMM) methodology, Haruna and Mahmood (2018) discovered a unidirectional relationship between GDP and carbon dioxide emissions.

In addition, it was found that Indonesia is one of the countries in which there is a link in the shape of an inverted U between the governmental policies and the amount of carbon emission (Nazeer & Furuoka, 2017). More specifically, they draw attention to the fact that as the financial sector matures, government initiatives initially result in a drop in CO_2 emissions. Hu et al. (2021) have discovered that Pakistan's CO_2 emissions that are reduced because of financial factors are significantly smaller than those that are increased due to rising per capita income. The hypothesis to be tested is:

H2: There is an influence of economic growth, government policies in the health sector, forest area, FDI, consumption of fossil-based energy, population, and consumption of renewable energy on environmental pollution.

In observing development, increasingly forgetting about natural preservation, further research is needed on the extent to which the use of the environment as natural capital is efficient (Hu et al., 2021). Moreover, it is vital to understand the consequences of environmental degradation and how the concept of environmental sustainability is associated with policies or regulations that apply to the environment appropriate to minimize environmental degradation in the context of sustainable development (Nazeer & Furuoka, 2017). Theoretical representations of the connection between economic growth (Breunig & Majeed, 2020) and environmental degradation have been formulated by many previous researchers using regression models (Ali et al., 2021; Haruna & Mahmood, 2018) and panel data (Hu et al., 2021; Mughal et al., 2021; Nazeer & Furuoka, 2017; Rizk & Slimane, 2018; Rose et al., 2020) and 3SLS (Bakhsh et al., 2017). Thus,

H3: There is an interaction between increasing economic growth and concurrent environmental deterioration with support from government policy factors in the health sector, forest area, FDI, consumption of fossil-based energy, population, consumption of renewable energy, inflation rate, and total foreign exchange reserves.

Current research on ASEAN nations has produced a mixed bag of findings. As a result, it is challenging to offer the proper guidance and counsel to decision-makers as they develop each nation's foreign, environmental, economic, and financial policies. One possible explanation is that prior research should have considered the four-way interaction between each country's economic growth, FDI inflows, CO_2 emissions, and government policies. Therefore, the simultaneous equation model analyzes panel data from 10 ASEAN nations from 2011 to 2020.

2. METHODOLOGY

2.1. Econometric model

This study model uses a production function approach to explain the impact of CO_2 emissions, fossil fuel energy consumption (FFEC), total foreign exchange reserves (TR), inflation (INF), the government budget for health (DGGH), foreign investment (FDI), and population (POP) to economic growth (GDP) in the form of a function model:

$$GDP = f\left(CO2, FFEC, TR, Inf, DGGH, FDI, Pop\right). \quad (2)$$

Bakhsh et al. (2017), Haruna and Mahmood (2018), and Hu et al. (2021) included energy consumption, population growth, and CO_2 emissions as variables in their empirical models to examine how these two factors affected economic growth. While they generally discover that energy use and CO_2 emissions contribute to the explanation of economic expansion. A different study demonstrated that foreign investment had a statistically significant impact on economic growth (Ali et al., 2021; Bakhsh et al., 2017; Ren et al., 2021). In line with previous research, Mughal et al. (2021) showed that fiscal and monetary policies affect the country's economic growth. Thus, the model proposed in equation (2) is consistent with the wider literature on the determinants of economic growth cited above. Functional relationship between CO_2 emissions, GDP, governmental budget for health (DGGH), foreign investment (FDI), fossil fuel energy consumption (FFEC), population (POP, forest area (FA), and use of renewable energy (REC) can be represented in equation (3) as follows (Haruna & Mahmood, 2018):

$$CO2 = f\left(GDP, DGGH, FDI, FFEC, Pop, FA, REC\right). \quad (3)$$

In the case of economics, variables that have a two-way relationship are often encountered. This two-way relationship that influences each other can be summarized in a system of simultaneous equations. Almost all approaches in macroeconomics have a simultaneous nature. Identifying a simultaneous equation with the order conditions provides information that an equation is exactly identified or over-identified. Based on the order conditions, the model is said to be identified if the equations (2) and (3) meet the requirements if the model shows $K - k \geq m - 1$, then called over-identified. If $K - k = m - 1$, then it is called precisely identified, and if $K - k < m - 1$, then the equation is unidentified.

Due to the correlation between endogenous variables and disturbances in simultaneous equations, the OLS estimator will result in a biased and unstable estimate. Therefore, an alternative estimation method is needed, which is called the 2SLS method. The 2SLS method is the application of OLS in two stages. First, a simultaneous test (Hausman test) is needed to test whether explanatory endogenous variables correlate with disturbance. In data processing using panel data, there are several stages of testing that aim to determine the best model to be used in a panel data study (Gujarati, 2010). The three models in panel data regression processing are the common effect model, the fixed effect model, and the random effect model. In addition, there are three stages of testing the model selection on the panel data: the Chow test, the Hausman test, and the LM test. The Chow test is useful for testing the model selection between the common effect model and the fixed effect model. The Hausman test is used to test the model selection between the fixed effect model and the random effect model. At the same time, the LM test is used to test the model selection between the random effect model and the common effect model. After knowing the best model to be used in the study, hypothesis testing, such as the coefficient of determination and partial and simultaneous significance tests, will be carried out.

Two basic specifications of the panel data simultaneous equation model are as follows (Figure 1).

http://dx.doi.org/10.21511/ee.13(1).2022.14

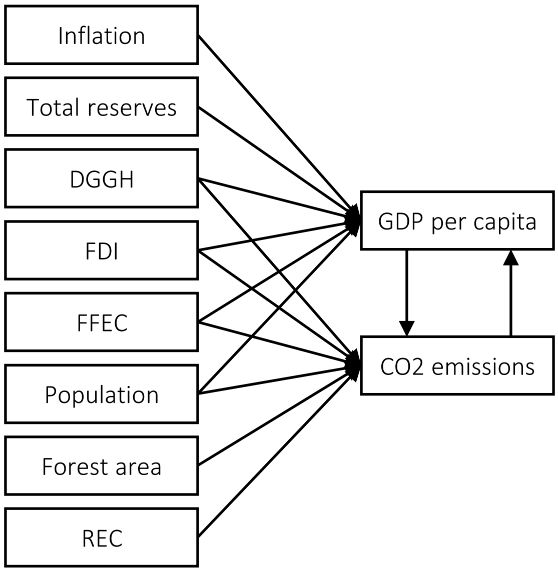

Figure 1. Simultaneous relationship model between variables

The panel data simultaneous equation model for economic growth is:

$$GDP_{it} = \alpha_0 + \alpha_1 CO2_{it} + \alpha_2 Inf_{it} + \\ + \alpha_3 TR_{it} + \alpha_4 DGGH_{it} + \alpha_5 FDI_{it} + \\ + \alpha_6 FFEC_{it} + \alpha_7 Pop_{it} + \varepsilon_{1it}. \quad (4)$$

The simultaneous equation model of panel data for air pollution is:

$$CO2_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 DGGH_{it} + \\ + \beta_3 FDI_{it} + \beta_4 FFEC_{it} + \beta_5 Pop_{it} + \\ + \beta_6 FA_{it} + \beta_7 REC_{it} + \varepsilon_{2it}. \quad (5)$$

The classical assumption test will be carried out in three stages, namely the classical assumption test of heteroscedasticity, autocorrelation, and multicollinearity. These three stages must be met so that the data used is tested for validity. Heteroscedasticity resulted in unbiased coefficient values, but the variance of the estimated regression coefficients was no longer minimal. The Harvey test can test the existence of heteroscedasticity. To prove the presence of heteroscedasticity with the white test, it can be done by comparing the value of n (amount of data) and R-square of the unadjusted R-square value in the auxiliary model. Autocorrelation shows the regression residual that is not independent from one observation to another. Autocorrelation can arise from an inappropriate specification of the relationship between endogenous variables and explanatory variables. The presence of autocorrelation can be detected through the Durbin-Watson Test. Multicollinearity arises when the independent variables are correlated with each other. Multicollinearity is the relationship between independent variables, which is a condition of a strong correlation between independent variables or vice versa. The existence of multicollinearity can be determined through a correlation matrix or regression between independent variables in the equation model.

2.2. Data

The data used are annual data for GDP per capita (constant 2015 USD), CO_2 gas emissions (metric tons per capita), inflation, total reserves (including gold, current USD), fossil fuel energy consumption (% of total), renewable energy consumption (% of total final energy consumption), population (total), foreign direct investment, net inflows (BoP, current USD), forest area (sq. km), and domestic general government health expenditure (% of general government expenditure). The data were collected for 2011–2020, sourced from the World Bank's World Development Indicators. To estimate the model, the paper divided the variable by the population to get the variable in per capita terms. The study covered 10 ASEAN countries that were selected based on data availability. These countries are Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Laos, Philippines, Singapore, Vietnam, and Thailand. Descriptive statistics of various variables for individuals and panels are presented in Table 1.

http://dx.doi.org/10.21511/ee.13(1).2022.14

Table 1. Description of research variable data per ASEAN countries

Country	Descriptive statistics	CO2 emissions	GDP per capita	Inflation	Total reserves	Fossil fuel energy consumption	Renewable energy consumption	Population	Foreign direct investment	Forest area	Domestic general government health
Brunei	Avg	16.91835346	31,539.51106	–1.007741886	35,27,561,554	99.99854192	0.00441	416,580.1	515,039,321.8	3,800	6.016399526
	Std. dev	1.44032045	1,659.323029	10.76447439	438,897,667.4	0.002340927	0.005962	14,804.90325	235,866,554.6	0	0.703611169
	Maximum	19.35389761	34,244.2069	20.18050542	4,272,696,958	100	0.0149	437,483	864,905,527.5	3,800	7.13899708
	Minimum	14.41262527	29,802.78288	–17.61280313	2,583,674,788	99.99437899	0	393,687	150,550,827.3	3,800	5.12074184
Cambodia	Avg	0.478608348	1,194.607567	2.230207326	10,352,256,400	29.14059296	66.41803017	15,637,515.7	2,503,604,406	89,617.67	6.603743457
	Std. dev	0.150636891	172.9710883	1.434629544	6,138,256,293	2.498229959	3.426905774	735,975.8954	778,699,496.1	7,336.536185	0.445018657
	Maximum	0.710207176	1,441.179228	3.475254586	21,328,475,093	32.96813121	71.32559967	16,718,971	3,663,032,999	102,407.48	7.16890764
	Minimum	0.335613209	940.1118195	–0.865696886	4,061,785,157	24.43280442	61.46900177	14,541,421	1,538,883,425	80,683.7	5.70839548
Indonesia	Avg	1.900583372	3,389.71266	3.730182313	1.17246E+11	65.14695824	29.17991962	259,691,144.1	19,802,486,640	951,839.9	6.634999848
	Std. dev	0.148729516	350.9983597	2.174092191	11633834111	0.886518696	4.794287411	9,580,810.416	5,816,882,734	21,901.56537	2.028809953
	Maximum	2.178461553	3,877.382977	7.465943034	1.35916E+11	67.15478782	38.1792984	273,523,621	25,120,732,060	987,329.4	8.67722607
	Minimum	1.653210477	2,849.354985	–0.456130066	99,386,826,239	63.80707707	20.86389923	245,115,988	4,541,713,739	921,332	3.96187973
Laos	Std. dev	1.197511798	2,180.408249	4.637573877	1,131,583,292	90.49812731	56.52980042	6,801,970.5	925,492,889.5	167,507.5	3.392989075
	Std. dev	0.95346821	320.375924	2.920573489	140,781,847.4	5.227415579	8.454153332	313,339.7572	391,317,753.9	1,044.539372	1.074015763
	Maximum	2.662148349	2,579.253661	10.4687176	1,392,600,619	94.63801786	66.45030212	7,275,556	1,693,080,811	169,060	4.70540714
	Minimum	0.413100759	1,687.147369	1.852096761	916,030,473.8	84.14968302	41.88410187	6,347,564	300,743,507.1	165,955	1.76665986
Malaysia	Avg	7.273359125	10,026.20971	5.103978795	1.12905E+11	96.73070066	3.30539999	30,495,877.2	10,039,906,258	192,359.66	7.841254377
	Std Dev	0.383396334	959.6792015	3.150672322	17,133,611,020	0.200188553	1.255560672	1,248,377.241	2,941,420,592	1,231.822903	0.875816525
	Maximum	7.757158614	11,414.5787	8.677799133	1.39731E+11	96.94482833	5.310500145	32,365,998	15,119,439,204	194,642.2	8.76370335
	Minimum	6.526762285	8,550.154638	–2.651352414	94,481,267,074	96.21646697	1.95539999	28,650,962	4,313,013,745	190,509.64	6.51518917
Myanmar	Avg	0.326829819	1,272.100612	1.563082258	6,189,934,531	27.26229528	74.31700974	52,780,957.3	2,578,749,364	298,475.87	3.352140916
	Std. dev	0.166864829	219.8750129	1.870692999	1,503,800,868	4.02800422	9.381750194	1,142,156.287	1,127,972,162	8,771.43153	0.978610652
	Maximum	0.605492803	1,586.90232	5.41240809	8,835,555,373	31.70408856	85.58110046	54,409,794	4804272487	311,512.88	4.97641993
	Minimum	0.15183969	962.9954522	–0.77780922	4,509,489,139	20.8796747	60.11109924	50,990,612	1,333,856,137	285,438.9	1.64683187
Philippines	Avg	1.049645955	3,064.511787	1.998413176	84,314,479,934	58.2433612	26.96183014	102,746,642.3	6,408,021,984	70,315.96	7.234985352
	Std. dev	0.180425659	389.9833881	1.401186097	9,750,849,968	1.852358853	2.757161472	4,714,706.933	2,862,276,671	1,056.257297	0.770412409
	Maximum	1.33369096	3,664.79067	3.918805776	1.0999E+11	61.41213905	31.22660065	109,581,085	10,256,442,399	71,885.9	8.19224167
	Minimum	0.838832482	2,484.489204	–0.71968279	75,123,089,217	56.18237608	23.2201004	95,570,049	2,007,150,725	68,746.06	6.07696486
Singapore	Avg	3.672530757	56,228.09953	0.732192976	2.78505E+11	97.52192547	0.582879996	5,514,760.1	76,702,277,498	164.5405	13.86876393
	Std. dev	0.179703423	3,705.552157	1.977278357	36,126,714,156	1.388649317	0.098034083	171,487.1629	21,619,951,957	6.429658385	0.936438621
	Maximum	3.851520326	61,173.90477	3.347638991	3.69834E+11	98.71373917	0.727299988	5,703,569	1.20439E+11	174.866	15.33037758
	Minimum	3.309563004	50,685.2962	–2.91966152	2.43798E+11	94.00615626	0.47330001	5,183,688	49,155,657,316	155.7	11.97459507
Thailand	Avg	8.256578092	5,946.451584	1.544289408	1.89964E+11	80.83046839	22.95395012	68,768,727.7	7,980,512,101	200,054	14.28420448
	Std. dev	0.228147614	450.4341067	1.256683626	32,617,529,928	0.763163079	0.590424479	774,839.5156	4,656,322,353	741.6138558	0.429262561
	Maximum	8.636708073	6,617.542822	3.74309812	2.58104E+11	82.05719879	24.12770081	69,799,978	15,935,960,665	200,706	15.06272507
	Minimum	7.785349708	5,182.042369	–1.066259571	1.5646E+11	79.99305669	22.26580048	67,518,379	2,473,685,996	198,730	13.73816299
Vietnam	Avg	1.975363601	2,170.813333	5.209557239	44166944747	64.92374886	33.83905964	93,140,456.3	11,981,800,000	141,456.34	9.3609869
	Std. dev	0.408992745	329.9848058	6.415768699	25,636,306,572	4.215425552	4.602318905	2,870,322.867	3,333,290,193	4,050.993674	0.848983178
	Maximum	2.698805922	2,655.767774	21.26065929	94,833,616,150	70.32817751	38.10189819	97,338,583	16,120,000,000	146,430.9	10.21770763
	Minimum	1.512419303	1,733.311285	–0.190788132	13,539,119,001	58.26328476	23.49180031	88,871,384	7,430,000,000	135,228.2	7.89614296

http://dx.doi.org/10.21511/ee.13(1).2022.14

On average, the highest CO_2 emissions per capita (16,918) and fossil fuel energy consumption (99.998%) occurred in Brunei Darussalam. In contrast, GDP per capita (56,228.10), total foreign exchange reserves (278,505,095,437.544), and FDI (76,702,277,498.4464) were highest in Singapore. The highest average inflation occurred in Vietnam (5.21%), the largest population (259,691,144) and forest area (951,839.9) in Indonesia, the users of renewable energy in Myanmar (74,317), and the highest government budget for health in Thailand (14.284%). In contrast, the lowest average for CO_2 emissions (0.3268), fossil fuel consumption (27.262%), and health budget (3.352%) occurred in Myanmar. The lowest GDP (1,194.608) occurred in Cambodia, inflation (–1.008%), energy consumption (20.8796) in Myanmar , renewable resources (0.0044%), total population (416,580), and FDI (515,039,321.7593) occurred in Brunei Darussalam, the country's total foreign exchange reserves (1,131,583,292.036) were in Laos, and forest area (164.5405) was in Singapore.

3. RESULTS

3.1. Model identification

Before estimating the parameters, it is necessary to identify the problem first to see if the equation model formed can be used using the two-stage least square approach. In identifying these problems, the paper uses order condition tests. The test results with order conditions are described in Table 2.

Table 2. Problem identification with order conditions

Equation model	K	k	M	m
Economic growth	8	6	2	1
Environmental degradation	8	6	2	1

Based on the results in Table 2, equation (4) and equation (5) models are over-identified equations, which means that the two models are correctly identified so that the two-stage least square approach can be used.

3.2. Panel unit root test

The panel unit root test must first be run to determine if the pertinent variables in a panel data analysis are stationary. Levin et al. (2002) used the LLC approach for the panel unit root test. In the two-unit root tests mentioned above, the null hypothesis is that there is a unit root (i.e., the variable is not stationary), and the alternative hypothesis is that the series has no unit root (that is, the variable is stationary). Table 3 displays the outcomes of the panel unit root test for the variable level. All variables at the level can be demonstrated to be statistically significant in the LLC test, proving that they are all integrated and stationary.

Table 3. Panel unit root test results for research variables

Variable	LLC		Order
	t-test	p-value	differencing
GDP	–2.85314	0.0022	0
CO2	–4.84032	0.0000	1
Inflation	–3.53321	0.0002	1
Total reserves	–7.67206	0.0000	1
Fossil fuel energy consumption	–2.33517	0.0098	1
Renewable energy consumption	–3.3085	0.0005	1
Population	–17.8459	0.0000	0
Foreign direct investment	–4.90609	0.0000	1
Forest area	–1.69936	0.0446	0
Domestic general government health expenditure	–4.56086	0.0000	0

3.3. Hausman test

Hausman test aims to prove the existence of a simultaneous relationship between the two independent equations (Gujarati, 2022). The hypothesis for the Hausman specification test is H0, which means a simultaneous relationship between the GDP equation and CO_2 emissions, and H1, which means that there is no simultaneous relationship between the GDP equation and CO_2 emissions. The test statistic used is the t-test with the rejection area; if the p-value of the residual variable is less than 0.05, then H0 is rejected. Hausman test results are shown in Table 4.

Table 4. Hausman specification test results

Dependent variables	Residual variables	p-value
GDP	resCO2	0.7687
CO2	resGDP	0.7697

Table 4 shows that the p-value for the resCO2 and resGDP variables is greater than 0.05, indicatingthat the GDP equation has a simultaneous relationship with the CO2 equation. Therefore hypothesis 3 (H3) is supported.

3.4. Model estimation using the generalized method of Arellano-Bond moment

The equation estimation uses the GMM estimation that consists of equations (4) and (5). Based on the calculation results, the panel data simultaneous equation models for the GDP and CO_2 equations are obtained, as shown in Tables 5 and 6.

Table 5. Estimation results of the regression coefficient with the dependent variable log(GDP)

Variables	Coefficient	Std. error	t-statistic	Prob.
log(GDP)(–1)	1.061778	0.309590	3.429633	0.0009
CO2	0.016286	0.005945	2.739297	0.0074
DGGH	–0.017750	0.005837	–3.041210	0.0031
log(FDI)	0.218758	0.051567	4.242200	0.0001
FFEC	0.005423	0.000736	7.367219	0.0000
log(POP)	–0.516775	0.034506	–14.97636	0.0000
Inflation	–0.006128	0.002878	–2.129145	0.0359
log(TR)	0.383726	0.051116	7.506975	0.0000

It is indicted in Table 5 that the free variables of CO2 emissions, DGHH, log(FDI), FFEC, log(Pop), inflation and log(TR) have significance influence on economic growth. Thus, the first hypothesis *(H1)* is supported.

Then, from Equation (5) and Table 5, the following simultaneous equation is formulated:

$$\log(GDP) = 0.0163CO_2 - \\ -0.018DGGH - 0.2188\log(FDI) + \\ -0.0054FFEC - 0.5178\log(Pop) - \\ +0.0061Inf + 0.3837\log(TR). \tag{6}$$

Table 6. Estimation results of the regression coefficient with the dependent variable CO_2 emissions

Variables	Coefficient	Std. error	t-statistic	Prob.
CO2(–1)	30.60480	12.84430	2.382753	0.0192
log(GDP)	5.535230	2.686844	2.060124	0.0422
DGGH	0.418852	0.059462	7.043982	0.0000
log(FA)	4.064589	0.475518	8.547710	0.0000
log(FDI)	–2.509603	0.622581	–4.030966	0.0001
FFEC	0.078115	0.012013	6.502819	0.0000
Log(POP)	4.846382	0.832686	5.820179	0.0000
REC	–0.121500	0.031691	–3.833878	0.0002

Based on study results presented in Table 6, it is concluded that all independent variables have a significant effect on CO2 emissions, therefore the second hypothesis (H2) is supported.

Referring to Equation (4) and Table 6, the simultaneous equation is obtained:

$$CO_2 = 5.5352\log(GDP) + \\ +0.4189DGGH + 4.0646\log(FA) - \\ -2.5096\log(FDI) + 0.0781FFEC + \\ +4.8484\log(Pop) - 0.1215REC. \tag{7}$$

3.4.1. *Significance of the parameters simultaneously*

If there is a relationship between the variables in an equation model, it will be found via parameter significance testing. The parameter significance test also examines whether the independent variable impacts the dependent variable. Table 7 shows the results of the simultaneous parameter significance test.

Table 7. Simultaneous significance test results

Equation model	F-statistic	Chi-square	p-value
Log (GDP)	13311.64	5324.658	0.0000
CO2	4038.371	1615.348	0.0000

Based on Table 7, it can be seen that the p-value of the two equations, namely GDP and CO_2, are less than 0.05, thus making the independent variables of the two models have a significant effect on the dependent variable (*H0* is rejected).

3.4.2. *Significance of the parameters partially*

The paper performs the partial parameter significance test to determine whether the independent variable only has a partial impact on the dependent variable. Tables 5 and 6 show that all independent variables have p-values that are less than 0.05, so it is concluded that all independent variables have a significant effect on the equation (3) and (4) models.

http://dx.doi.org/10.21511/ee.13(1).2022.14

3.5. Classic assumption test and normality test

The assumptions used in this study are the normality test, Arellano-Bond (AB) test, and Sargan test. The objective of the normality test in a regression analysis is to establish whether the model's independent and dependent variables have a normal distribution. The Jarque-Bera test is a statistical method that can determine whether the model is normally distributed (Gujarati, 2022). From Table 8, information is obtained that the residuals of the two models are normally distributed.

Table 8. Simultaneous significance test results

Equation model	Jarque-Bera statistic	p-value
Log(GDP)	0.790035	0.673668
CO2	1.841905	0.093268

3.5.1. Arellano-Bond (AB) test

The Arellano-Bond test aims to test the consistency of the model. In the Arellano-Bond test, there are two tests with different functions, namely the ab(1) test, which serves to determine the influence of individual effects between observations, and the ab(2) test, which functions to determine whether or not there is a correlation between the first difference error in the i-th observation (Gujarati, 2022).

Based on Table 9, the p-value for ab(1) both models is 0.000, so the decision rejects H0, and it can be concluded that the GDP and CO_2 equation model does not have individual effects between variables. For the ab(2) test results, the P-values obtained are 0.774 and 0.9158, so H0 is not rejected. Thus, it is concluded that there is no lag effect of the dependent variable on the first difference error in the GDP and CO_2 models. Therefore, because the ab(1) and ab(2) tests are met, it can be concluded that the GDP and CO_2 equation models are consistent.

Table 9. Arellano-Bond test's result

Dependent variable	Test order	m-statistic	rho	SE(rho)	p-value
Log(GDP)	AR(1)	–5.971336	–0.049369	0.008268	0.0000
	AR(2)	–0.287108	–0.002059	0.007171	0.7740
CO2	AR(1)	–6.039716	–0.001869	0.000309	0.0000
	AR(2)	–0.105762	–0.000032	0.00030	0.9158

3.5.2. Sargan test

The Sargan test is used to evaluate the validity of using instrument variables that are more numerous than the estimated parameters (over-identified) (Gujarati, 2022). Table 10 shows the results of the Sargan test of the two-equation models.

Table 10. Sargan test results

Equation model	Prob (J-statistic)
Log(GDP)	0.2901
CO2	0.2927

Based on Table 10, the results show that both models have a p-value of more than 0.05. The GDP equation model has a p-value of 0.2901. In contrast, the CO_2 equation model has a p-value of 0.2927, so the decision is to fail to reject H0. It can be concluded that the two models have no problem with the validity of the instrument variables.

4. DISCUSSION

Based on Table 5, it is shown that the coefficient of lag indicator of economic growth (GDPt-1) has a positive and statistically significant effect. Thus, every country in the ASEAN region can take appropriate macroeconomic policies with a backward look at achieving high and sustainable economic growth. For the panel results, FDI inflows per capita have a positive and significant effect on GDP per capita. Every 1% increase in FDI will increase GDP 0.219 times at the time of ceteris paribus. This shows that economic growth is elastic to FDI inflows. This implies that the technological changes brought about by FDI inflows promote economic development in the long run. This indicates that the influence of foreign investment has not been able to encourage economic growth for all countries in the ASEAN region. Although FDI is still only focused on a few countries, it positively affects economic growth in the ASEAN region. These results are in line with Bakhsh et al. (2017), Hu et al. (2021), and Ren et al. (2021). Therefore, each country can take appropriate macroeconomic policies by looking backward to obtain high and sustainable economic growth.

It demonstrates an indirect relationship between CO_2 emissions and energy consumption, as well as between energy consumption and economic growth, using the example of Malaysia. Meanwhile, Singapore shows that economic growth and energy consumption show no relationship to CO_2 emissions, but openness and industrialization have causality in CO_2 emissions. This proves that Singapore can maintain economic growth without causing environmental damage. The Environmental Kuznets Curve in Malaysia shows that it has yet to pass a turning point. However, Singapore has passed a critical point and is already in a state of environmental improvement while continuing economic development (Thanh et al., 2019). From a study in Pakistan, CO_2 emissions will increase as economic growth increases. The reason behind this relationship between economic growth and CO_2 emissions is based on the fact that large amounts of energy that are intensive in carbon are utilized to carry out economic activities in a variety of different fields (Bakhsh et al., 2017; Malik, 2021).

Another variable that affects the indicators of economic growth is the inflation indicator. An increase in the inflation indicator by one percent will be responded to by a decrease in economic growth by 0.006128 percent at the time of ceteris paribus. This result is in accordance with Ren et al. (2021), showing that inflation drives economic growth. The long-run multiplier on the inflation rate variable on economic growth indicators is much larger than the short-run multiplier. The phenomenon of inflation in developing countries such as Indonesia is still a threat to economic stability. The tendency of rising prices generally reflects the level of inflation that occurs in a country. The consumer price index is an indicator used to describe price movement. Changes in public consumption patterns in the long term trigger an increase in aggregate demand to encourage an increase in the inflation rate. In the long term, an increase in a country's economic growth reflects people's income and consumption. Business actors followed up the increase in demand by increasing their production output. With the addition of output, the costs incurred for the production process become greater, causing an increase in the selling price of the product. If, for a relatively long time, most of the traders do the same thing, then the increase in the prices of consumer goods, in general, can encourage an increase in inflation.

The role of government spending in the health sector has a positive effect on boosting economic growth. Government spending on health has a positive effect on attracting foreign investment. This will indirectly increase economic growth so that welfare will increase. Considering the benefits for investors in addition to quality labor, the region will become a significant consumer due to the increasing welfare. An increase in government spending (DGGH) by one percent causes an increase in the economic growth of 0.01775 percent at the time of ceteris paribus. In the long term, an increase in government spending can increase foreign investment by 1.203 percent. Nazeer and Furuoka (2017) also showed that government spending has a positive and statistically significant effect on increasing economic growth, concluding that simultaneously government spending has a positive effect on investment development in the ASEAN region.

The empirical findings for the global panel are shown in Table 6, demonstrating that energy consumption significantly reduces CO_2 emission levels at the 1% level. This implies that increased energy use may result in increased CO_2 emissions. Economic growth is significantly and favorably influenced by panel estimates. A robust energy policy is required to promote sustained economic growth because energy is a critical component. These findings concur with those of Thanh et al. (2019). In terms of the pollutant variable, it was discovered that CO_2 emissions have a sizable impact on worldwide panel economic growth. This demonstrates that a 1% increase in CO_2 emissions causes a 0.005423% rise in economic growth.

For almost all nations, population increase is statistically significant and negatively influences economic growth at a 1% level. Population growth raises the level of government policies, including health, fuel, and other subsidies. Additionally, fuel

http://dx.doi.org/10.21511/ee.13(1).2022.14

consumption has a 1% favorable impact on CO_2 emissions. If there is a population of 1%, in the short term, it will cause a slowdown in the economic growth of 0.516775%. On the other hand, an increase in population by 1% will increase CO_2 emissions by 4.846382%.

CONCLUSION AND IMPLICATION

The primary findings suggest a bidirectional causal relationship between rising CO2 levels and a greater spectrum of economic activities. The concept is supported by both economic expansion and carbon dioxide emissions. The empirical evidence demonstrates a unidirectional causal connection between economic expansion and CO2 emissions. Therefore, nations must adopt rules to protect their citizens from carbon pollution. In ASEAN nations, economic growth and CO2 emissions have a two-way causal link. This means that economic growth is causing environmental damage. Currently, high economic growth contributes to environmental degradation, while decreasing economic growth produces unemployment, placing a significant strain on the economies of ASEAN member states. In order to increase their efforts to combat global warming, governments should reduce CO2 emissions without jeopardizing short-term or long-term growth. It will promote ecologically friendly, long-term economic growth in practice. In contrast, pollutant emissions have a negative impact on economic growth, indicating that environmental degradation is a causal factor in economic growth. In addition, as a result of its effects on human health, persistent environmental deterioration can have a negative externality on the economy and eventually reduce productivity. This is consistent with the Environmental Kuznets Curve theory, which states that environmental degradation results in a decreasing slope of economic growth.

AUTHOR CONTRIBUTIONS

Conceptualization: Supriyanto, Wiwiek Rabiatul Adawiyah, Arintoko.
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