OPEN ACCESS
Saudi Journal of Economics and Finance
Abbreviated Key Title: Saudi J Econ Fin
ISSN 2523-9414 (Print) |ISSN 2523-6563 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://saudijournals.com

Original Research Article

Analysis of Factors Affecting CO2 Emissions and the *Kuznets Curve Environmental Hypothesis:* Study on G-20 Countries 2013-2018 Period

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DOI: 10.36348/sjef.2022.v06i07.002 | **Received:** 26.05.2022 | **Accepted:** 01.07.2022 | **Published:** 12.07.2022

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Abstract

This study aims to determine the effect of economic growth, population, industrialization, energy consumption and fossil fuel consumption of CO2 emissions in G-20 countries. Panel data is used as a data analysis technique in this study. The variables used are based on the concept of the Environmental Kuznets Curve. The Kuznets hypothesis explains that an increase in economic growth reduces inequality and poverty in a certain period of time (or referred to as the turning point limit). This study focuses on the G-20 countries in the 2013-2018 period. Based on the regression results of the CO2 emission variables (CO2), gross domestic product (GDP), energy consumption (KE), population (JP), industrialization (IND) and fossil fuel consumption (BBF) it was found that all independent variables simultaneously (GDP, KE, JP, IND and BBF) have a significant effect on the dependent variable (CO2). Furthermore, partially significant variables that affect CO2 emissions are GDP, JP, IND and BBF, while the variables that have no significant effect on CO2 emissions are only KE. Support and commitment to policies both nationally and regionally are needed to reduce environmental degradation through inclusive economic growth in G-20 countries.

Keywords: CO2 Emissions, Economic Growth, Energy Consumption, Population.

INTRODUCTION

In 1997-1998 a number of G-20 countries experienced a global financial, monetary and political crisis. Apart from the financial, monetary and political crises, there are also problems regarding environmental damage. Air pollution due to smog (hereinafter referred to as smoke pollution) originating from forest and land fires has been going on for a long time in the Southeast Asian region (Heilman, 2015). This smoke pollution has become a dangerous threat not only in the local area of a country, but also transnationally (across national borders), because of the light nature of the smoke so that it easily spreads from one place to another (Echo BNPB, 2015). In Southeast Asia, smoke pollution is mostly caused by uncontrolled forest and land fires (hereinafter referred to as karhutla) from the territory of Indonesia (Jerger, 2014).

The G-20 is an informal grouping of 19 countries and the European Union, as well as representatives of the *International Monetary Fund* (IMF) and *the World Bank* (WB). The G-20 is the world's main economic forum that has a strategic position because it collectively represents around 65% of the world's population, 79% of global trade, and at least 85% of the world's economy. Indonesia is one of the countries in a cooperation between countries with the largest economy in the world which is named *group 20* (group 20) or often shortened to G-20. The formation of the G-20 cannot be separated from the disappointment of the international community towards the failure of the G-7 to find solutions to the global economic problems faced at that time. The view that emerged at that time was that it was important for middle-income countries and those with systemic economic influence to be involved in negotiations to find solutions to global economic problems.

The Kuznets hypothesis explains that an increase in economic growth reduces inequality and poverty in a certain period of time (or referred to as the *turning point limit*). Kuznets curve plays the role of problem analysis in endogenous economic variables,

namely technology, population, institutions (Syrquin, 2005) . This can also have an impact on fossil fuels and increasing the scale of political democratization, where this situation will affect changes in income distribution and injustices that occur in the economic system in society (Acemoglu & Robinson, 2002) .

In the research of Nikensari, SI, Destilawati, S., & Nurjanah, S. (2019) examining the EKC hypothesis in *high income countries* and *lower middle income* countries, the results show that the sample countries that has passed the *turning point* indicated that it can reduce CO2 emissions, it was found that for high income countries (*high income countries*) will be able to reduce CO2 emissions after reaching the turning point while for lower middle income countries (*lower middle income*) still cannot reduce CO2 emissions even though they have reached the turning point. beyond the turning point. In Firdaus' research (2017) found that an increase in population can increase CO2 emissions, this is caused by an increase in demand for energy consumption which continues to grow along with population growth .

Several studies have been published to identify economic phenomena through the EKC approach such as Febriana, Diartho, & Istiyani (2019) which examines the relationship of economic development to environmental quality with EKC as the basis of research. Research on the inverse Kuznets curve based on income and inequality as shown in the research of Firmansyah (2021) and Saputra (2016) which examines the relationship between economic growth and inequality in West Java which proves the existence of an inverted Kuznets U curve for the implementation of policy making on the relationship between GRDP and regional inequality. On the other hand, despite the criticism of these theories and hypotheses, the need for economic growth (and economic development) is better for the environment than nothing (Hussen, 2005) .

Energy consumption has a significant effect found by Yustisia and Sugiyanto (2014) stating that middle development countries have the characteristics of an inverted U-curve, while for high development countries and low development countries it is indicated that there is no turning point or continuous environmental damage. increase. Meanwhile, according to Arista and Amar (2019), they found that there is a causal relationship between economic growth and CO2 emissions in Southeast Asian countries , so that increasing economic growth in Southeast Asian countries will certainly increase CO2 emissions.

The population from year to year is increasing. Theoretically, a large population will increase the amount of economic productivity in various sectors. This occurs due to a concept where the population actually has autonomous consumption that must be met, causing all residents to carry out economic activities in daily life. The more people who are active using energy and technology that are not environmentally friendly, the greater the impact on the environment. Research conducted by Muhammad Uzair Ali, Zhimin Gong, Muhammad Ubaid Ali, Fahad Asmi, Rizwanullah Muhammad (2020) with studies conducted in India, Pakistan and Bangladesh found that the relationship between population and CO2 emissions was significantly positive. This is because the study in South Asia which has a large population and the absence of dominance in the use of environmentally friendly energy causes the increasing population, which will further increase CO2 emissions from economic activities that are not environmentally friendly.

Industrialization has an impact on increasing CO2 emissions with the emergence of output from production activities that can produce waste. Among the waste produced is CO2 emissions. Increasing the standard progress of developed countries that have a dominance on industrial activities, with all countries moving towards modernization and industrialization, will lead to an increase in CO2 emissions resulting from CO2 emission activities. Therefore, it is indicated that developing countries (or some developed countries) that start industrialization at an early stage of economic development have a tendency to increase significantly in CO2 emissions. However, in its development, it will decrease following a more environmentally friendly modernization pattern in the industry through the application of environmentally friendly technology.

Fossil fuels are one of the energy used in carrying out economic activities such as transportation, cargo, machinery and so on. The relationship that occurs between fossil fuels and CO2 emissions theoretically will have a positive effect. This is because theoretically and practically, fossil fuels will produce combustion compounds that are classified as greenhouse gases (GHG). In the main GHG component in terms of production, one of the three main emission components is CO2. Therefore, an increase in the consumption of fossil fuels will actually increase CO2 emissions.

RESEARCH METHODS

The type of data used is quantitative data, namely Panel data with annual data points starting from 2013 to 2018 in 19 countries that are members of the G-20 (for the European Union because it is not a country and only an economic community, it is not taken as the object of research). The variables used are CO2 emissions, economic growth, energy consumption, population, *industrialization*, and consumption of fossil fuels. This study uses secondary data from the World Bank Development Indicator. The data used in this study is panel data which has a picture as data consisting of many objects over a certain period of time. The data in this study were obtained from *the*

World Bank Development Indicator and ourworldindata.org.

The research method is a method that is generally systematically arrangced that is used to achieve certain goals and as an effort to achieve a goal in accordance with the problems to be solved (Sugiyono, 2017). The analytical method used is qualitative and quantitative (mixed) methods, namely using research by combining both methods to obtain proportional results and according to the objectives of the research (Sugiyono, 2017). The qualitative method used is a literature review and a time series of case studies. Literature review by searching for a number of literature that supports the search for answers to the objectives so that they are arranged as a good unit, and a historical case study is a sequence of events that is analyzed into a unified whole analysis in this study (*Martono*, 2015) .

Panel data is a combination of *time series* data and *cross section data* . Time series data usually includes one object/individual, but covers several periods. Cross data consists of several or many objects, often called respondents (eg companies) with certain types of time (Firmansyah, 2021b; Firmansyah *et al*., 2021) . When we make an observation of these units at the same time but also the behavior of these units at various time periods. Regression using panel data is called panel data regression model. There are several advantages to using panel data. First, panel data is a combination of time series and cross section data capable of providing more data so that it will produce a greater *degree of freedom*. Second, combining information from time series and cross section data can overcome problems that arise when there is a problem with eliminating variables (*committed -variables*).

In analyzing panel data, regression modeling is needed which is divided into the best model choices to be able to produce the best regression and research results. In econometrics using panel data, it is known that the three best models for this case are the *common effect model*, *the fixed effect model*, and *the random effect model* (Srihardianti *et al*., 2016) .

There are two commonly used panel data methods, namely static and dynamic panel data. The difference between the two is that in the dynamic panel data approach, there is a lag of the dependent variable which becomes the explanatory variable. Static panel data consists of three methods, namely *common least square* (CEM), *fixed effect model* (FEM), and *random effect model* (REM). Two models were developed to analyze the relationship of economic variables to $CO_{2\ emissions}$. The research stages are the first to determine the best model, this study will choose the best mode among *the common effects model* (CEM), *fixed effect model* (FEM), and *random effect model* (REM) (Firmansyah *et al*., 2021; Gujarati & Porter, 2012). To determine the best model, the Chow Test, Hausman Test and lagrange multiplier were carried out. Second, an additional test is performed, namely the normality test and the classical assumption test (for the regression equation of the *ordinary least square model*) (Widarjono, 2009).

The second step is to estimate the value through the panel data regression equation, which is as follows:

$$CO2_{it} = \alpha + \beta_1 PDB_{it} + \beta_2 LogKE_{it} + \beta_3 LogPOP_{it} + \beta_4 LogFDI_{it} + \beta_5 logBBF_{it} + \varepsilon_{it} \quad \text{..... (1)}$$

Information:

$CO2_{it}$ = CO2 gas emissions for country i in year t
GDP it = GDP per capita for country i in year t
to it = Energy consumption for country i in year t
POP it = Population for country i in year t
ENG it = Industrialization country i in year t
BBF it = Fossil Fuel Consumption of country i in year t
α = constant
β1,2,3,4,5 = Coefficient
ε = Residual (*error term*)

In determining the best model testing, the Chow test is used to determine whether the FEM model is better than the CEM model. Hausman test is used to determine whether the fixed effects model is better than the random effects model. To find out whether the random effects model is better than the common effects model, the Langrange Multiplier (LM) test is used which is based on the residual value of the *common effects model*. The classical assumption test used is the heteroscedasticity test and the multicollinearity test. To test the significance of the model used the coefficient of determination, F coefficient test for simultaneous effect and t coefficient test for partial effect.

RESULT AND DISCUSSION

The problem of environmental quality is not only a problem for developed countries or developing countries, but also a problem for all countries in the world. Environmental quality problems can occur due to a lot of pollution from factories, smoke from motor

vehicles, and also forest fires which can cause environmental quality to decrease. So with development that emphasizes the preservation of environmental quality, it is very necessary apart from development in the economic sector. The G-20 countries contribute the largest CO2 emitters, this is because almost the average ASEAN country has industries that produce CO2 emissions. The type of emission that is given the most is any activity that produces CO2 emissions, this percentage figure tends to increase due to the rapid growth in various sectors.

Model Selection Test

In panel data regression, it is necessary to determine the selection of the best model in estimating the research model that has been formed. In selecting the model, a number of tests can be carried out which depend on the type of comparison of the model to be selected. Panel data regression has three types of models, namely *Common Effect Model* (CEM), *Fixed Effect Model* (FEM) and *Random Effect Model* (REM).

Table 4.1: Chow Test Test Results

Effects Test	Statistics	df	Prob.
(1)	(2)	(3)	(4)
Cross-section F	114.533989	(16.80)	0.0000
Cross-section Chi-square	323,764610	16	0.0000

Source: Processed by the Author

Based on table 4.1, the value of Prob is obtained. *The cross-section Chi-square* is 0.0000 which means it is smaller than 0.05 or 0.0000 < 0.05. Based on this, H0 is rejected, which means Ha is accepted, meaning that the best model is the *Fixed Effect Model*. Therefore, the next test will be conducted, namely the Hausman test to determine the best model between the *Fixed Effect Model* and the *Random Effect Model*.

Table 4.2: Hausman test results

Test Summary	Chi-Sq. Statistics	Chi-Sq. df	Prob.
(1)	(2)	(3)	(4)
Random cross-section	17.191957	5	0.0041

Source: Processed by the Author

Based on table 4.1, the value of Prob is obtained. *The random cross-section* is 0.0703 which means it is greater than 0.05 or 0.0041 < 0.05. Based on this, Ho is rejected, which means Ha is accepted, meaning that the best model is the *Fixed Effect Model*. Furthermore, data processing and data interpretation will use the *Fixed Effect Model*.

Classic assumption test

In processing data using *ordinary least squares* (OLS) analysis techniques, a number of classical assumption tests are needed. In econometrics we encounter a number of differences in the data used, such as *cross-section data*, *time series* and panel data. The heteroscedasticity test aims to test whether in the regression model there is an inequality of variance from the residuals of one observation to another observation. Heteroscedasticity testing in this study was carried out by the glejser test. The presence or absence of heteroscedasticity can be known from the probability value of Obs*R-square which will be compared with the level of significance. If the significance probability value is above 0.05, it can be concluded that there is no heteroscedasticity. However, if the test uses an estimation of the RESABS significance relationship on the independent variable, a model does not occur heteroscedasticity if the prob value. owned is > 0.05. The results of the heteroscedasticity test test are shown in the table below as follows:

Table 4.3: Heteroscedasticity Test Results

Variable	Coefficient	Std. Error	t-Statistics	Prob.
(1)	(2)	(3)	(4)	(5)
A. Without transformation in logarithmic form				
C	0.018531	0.003553	5.215595	0.0000
GDP	-7.64E-08	1.27E-07	-0.602269	0.5484
TO	-4.52E-06	3.33E-06	-1.358910	0.1774
JP	-3.41E-09	6.60E-09	-0.516655	0.6066
ENG	5.49E-15	6.43E-15	0.853732	0.3954
BBF	4.27E-06	3.91E-06	1.091725	0.2777
B. By transforming to logarithmic form				
C	-0.003842	0.006208	-0.618811	0.5375
LOG(GDP)	-0.018150	0.011486	-1.580144	0.1174

LOG(TO)	-0.000940	0.006553	-0.143505	0.8862
JP	0.010373	0.006877	1.508391	0.1347
LOG(ENG)	0.006416	0.011110	0.577499	0.5650
LOG(BBF)	-0.118324	0.071137	-1.663328	0.0995

Source: Processed by the Author

In table 4.9, it can be seen that the probability value of each variable is greater than 0.05. So it can be concluded that in this model there is no heteroscedasticity. With the model free from the heteroscedasticity problem, it can be concluded that the next test can be carried out, namely by testing multicollinearity.

Multicollinearity is a condition where there is a perfect or close linear relationship between the independent variables in the regression model. A regression model is said to have multicollinearity if there is a perfect linear function on some or all of the independent variables in the linear function.

Table 4.4: Multicollinearity Test

	CO2	**TO**	**JP**	**ENG**	**BBF**	**GDP**
CO2	1	0.980486833	0.76049310	0.95261684	0.98594222	-0.09400216
TO	0.98048683	1	0.68978978	0.97106160	0.9981875	0.01733269
JP	0.76049310	0.68978978	1	0.61247567	0.7073425	-0.40226248
ENG	0.95261684	0.971061608	0.61247567	1	0.9673493	0.14176541
BBF	0.98594222	0.998187540	0.70734251	0.9673493	1	-0.01381127
GDP	-0.09400216	0.017332691	-0.40226248	0.14176541	-0.0138112	1

Source: Processed by the Author

In this study, testing multicollinearity using *Pearson Correlation*. The results found that each non-dominant variable has a correlation greater than 0.80, this indicates that the model is free from multicollinearity problems.

Model Significance Test

F-statistical test was conducted to determine the simultaneous effect of the independent variable on the dependent variable. F-statistical test is done by comparing the probability value of F-statistics to. The results of processing using panel data regression are shown in table 4.5 as follows:

Table 4.5: *Fixed Effect Model* Regression Results for F. Test

Effects Specification			
Cross-section fixed (dummy variables)			
Indicator	***Value***	***Indicator***	***Value***
(1)	**(2)**	**(3)**	**(4)**
R-squared	0.999556	Mean dependent var	13,51419
Adjusted R-squared	0.999439	SD dependent var	1.024283
SE of regression	0.024255	Akaike info criterion	-4,412001
Sum squared resid	0.047063	Schwarz criterion	-3.845831
Likelihood logs	247.0121	Hannan-Quinn Criter.	-4.182740
F-statistics	8573.616	Durbin-Watson stat	1.256796
Prob(F-statistic)	0.000000		

Source: Processed by the Author

Based on the table above, it is known that the probability value of the F-statistic is 0.000000, where 0.000000 <0.05. Then H0 is rejected and Ha is accepted, meaning that the variables of gross domestic product, energy consumption, population, industrialization and consumption of fossil fuels have a significant effect on CO2 emissions simultaneously.

T-statistical test was conducted to determine the effect of each independent variable on the dependent variable. The t-statistical test is carried out by comparing the probability value of the t-statistic to. The results of processing using panel data regression are shown in the table below:

Table 4.6: *Fixed Effect Model* Regression Results for t Test

Variable	***Coefficient***	***Std. Error***	**t-Statistics**	**Prob.**	**Decision**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
C	11.18379	2.395552	4.668567	0.0000	-
LOG(GDP)	0.766059	0,201840	3.795387	0.0003	Significant
LOG(TO)	-0.071519	0.205897	-0.347351	0.7292	Not significant
JP	-1.86E-06	6.53E-07	-2.845651	0.0056	Significant
LOG(ENG)	-0.509928	0.158812	-3.210883	0.0019	Significant
LOG(BBF)	1.205490	0.158882	7.587321	0.0000	Significant

Source: Processed by the Author

Based on the table above, it is found that the Gross Domestic Product (GDP) variable has a probability value of 0.0003, where this probability value has a decision of 0.0003 <0.05. This indicates that Ha is accepted and Ho is rejected, this means that the gross domestic product variable has a significant effect on CO2 emissions. In depth it is found that gross domestic product has a significant positive effect on CO2 emissions.

The coefficient of determination test was conducted to find out how much the endogenous variables were simultaneously able to explain the exogenous variables. The higher the R- *squared value*, the better the prediction model of the proposed research model. This test is carried out to measure the percentage of the total variation of the dependent variable that can be explained by the regression model. This is done to determine the good accuracy in the analysis which is indicated by the magnitude of the coefficient of determination R- *squared*.

Table 4.7: Coefficient of Determination

Effects Specification			
Cross-section fixed (dummy variables)			
Indicator	***Value***	***Indicator***	***Value***
(1)	**(2)**	**(3)**	**(4)**
R-squared	0.999556	Mean dependent var	13,51419
Adjusted R-squared	0.999439	SD dependent var	1.024283
SE of regression	0.024255	Akaike info criterion	-4,412001
Sum squared resid	0.047063	Schwarz criterion	-3.845831
(1)	**(2)**	**(3)**	**(4)**
Likelihood logs	247.0121	Hannan-Quinn Criter.	-4.182740
F-statistics	8573.616	Durbin-Watson stat	1.256796
Prob(F-statistic)	0.000000		

Source: Processed by the Author

Based on the table above, it is known that the R - *squared value* in this model is 0.999556. This means that the variables of gross domestic product, energy consumption, population, industrialization and consumption of fossil fuels are able to explain variations in CO2 emissions by 99.9556% and 0.0444% variations in CO2 emissions variables explained by other variables outside the study.

Based on the regression results of the CO2 emission variables (CO2), gross domestic product (GDP), energy consumption (KE), population (JP), industrialization (IND) and fossil fuel consumption (BBF) it was found that all independent variables simultaneously (GDP, KE, JP, IND and BBF) have a significant effect on the dependent variable (CO2). Furthermore, partially significant variables that affect CO2 emissions are GDP, JP, IND and BBF, while the variables that have no significant effect on CO2 emissions are only KE. In the results of the coefficient of determination, it was found that 99.9556% of the independent variables in this model were able to explain the dependent variable and then 0.0444% of the variation in CO2 emissions was explained by other variables outside the study. Furthermore, to prove the *Environmental Kuznets Curve* hypothesis which explains the relationship between GDP and CO2 emissions, it was found to form an inverted U-curve which was not proven in the 17 G-20 member countries. This indicates that the increase in economic level that occurred during the 2013-2018 period has not been accompanied by an increase in sustainable environmental awareness in each country.

CONCLUSION

This study aims to examine the impact of GDP, energy consumption, population, industrialization and consumption of fossil fuels on CO2 emissions in the G-20 countries. Based on the results of research, calculations, and discussions in previous chapters, this study produces the following conclusions:

a. Partially found that GDP, population, industrialization and consumption of fossil fuels have an influence on CO2 emissions. The effect of GDP on CO2 emissions is positive. This indicates that an increase in GDP which represents an increase in economic output can have an increasing effect on CO2 emissions, when the economy's output increases it will increase CO2 emissions. The next variable is population that has a negative effect on CO2 emissions. This indicates that an increase in population will reduce CO2 emissions, while a decrease in population will increase CO2 emissions. This is indicated by the use of human resources in the industrial, logistics and mining sectors, where if the utilization is reduced, companies will tend to replace them with machines that will produce CO2 emissions. Furthermore, industrialization has a negative effect on CO2 emissions, this is indicated by the implementation of environmentally friendly technologies in developed countries, where almost 70% of the G-20 members are developed countries. So that when industrialization increases, it will reduce CO2 emissions dominantly. And the last variable is the consumption of fossil fuels which has a positive effect, where an increase in consumption will also increase CO2 emissions. This is because fossil fuels are the main focus in logistics, motor vehicles, industry and household consumption.
b. Meanwhile, GDP, energy consumption, population, industrialization and fossil fuels together have a significant influence on CO2 emissions in G-20 countries for the period 2013-2018. So that all variables can affect CO2 emissions. This indicates that in explaining the development of CO2 emissions, it can be seen from how the simultaneous performance of GDP, energy consumption, population, industrialization and fossil fuels on CO2 emissions in G-20 countries
c. By using curve estimation modeling, information is obtained that there is no proof of the inverted U hypothesis which indicates sustainable economic growth will reduce CO2 emissions at a certain *turning point* . This indicates that the G-20 countries do not yet have a significant role in reducing CO2 emissions globally from any environmental and economic policies that have been proclaimed. Therefore, a one-voice attitude is needed to be able to reduce the economic impact that can lead to environmental degradation in the G-20 countries. A shared commitment that is influential, binding and adhered to as part of a shared vision of sustainable development.

This research produces a number of findings and discussions that can be used as recommendations on current and future phenomena. The suggestions in this study are as follows:

a. Energy consumption is one of the very central consumptions in driving the economic development of a country. In this study it was found that energy consumption has an insignificant negative effect on CO2 emissions. This indicates that energy consumption has no effect on CO2 emissions because the G-20 member countries are dominated by developed countries that have commitments to reduce emissions and also climate agreements such as the Kyoto Protocol and COP26. Therefore, it is recommended for all countries to increase the consumption of environmentally friendly energy in order to increase economic output that does not damage the environment.
b. The population is one measure of how much a country can increase the sectoral output that can be achieved. A large population can be a challenge as well as the potential for a country to become a country with a large economy. In this study it was found that population has a significant negative effect on CO2 emissions. This is one of the strongest reasons that the G-20 population, which is dominated by developed countries, has a commitment not to consume energy that is not environmentally friendly. In addition, by using environmentally friendly energy, every increase in population that consumes energy will also reduce emissions. This is because emissions do not occur when people consume more environmentally friendly energy.
c. For governments, governments in G-20 countries must pay attention to the performance of GDP, population, industrialization and consumption of fossil fuels to be able to control environmental pollution caused by CO2 emissions. This can be done by strengthening international cooperation and agreements regarding commitments to reduce environmental pollution, adoption of environmentally friendly technology, implementation of a circular economy and creating a society that cares about the environment and is cultured. In addition, attention is also needed on energy consumption that is more environmentally friendly in various economic activities, especially in the G-20 countries.
d. For researchers and academics, especially if they are interested in researching and exploring the impact of GDP, energy consumption, population, industrialization and fossil fuels on CO2 emissions , it is hoped that they will develop their research by adding a

longer time span so that they can provide a clearer and more definite picture. to the research results. In addition, further research hopes to use other methods that are possible better than the variable analysis used in this study

e. For other parties, this research can be developed for economic growth, energy consumption, population, industrialization and fossil fuels for CO2 emissions, so that scientific development can be more developed and applicable to solve current and future challenges.

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