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Coal Consumption And Economic Growth In Indonesia: An Analysis Of Restricted Structural Var

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ABSTRACT

The aim of this paper is to investigate the effect of coal consumption, economic growth, and population to the greenhouse gas emission in the case of Indonesia. The foundation of this study is the reality that Indonesia's economic growth is spur by population growth which requires the consumption of electricity in the large amounts produced using coal as the main fuel. The consumption of coal as the main fuel causing fatal environmental damage. Theoretically, the higher the population and economic growth, the greater the environmental damage that will occur. The data used in the study are during the period of 1971 – 2018 with VAR restricted model and structural VAR as the methodology employed. The result of the analysis shows that the increase of coal consumption, population, and population in Indonesia effects positively to the increase of greenhouse gas emission where population contributes the biggest effect. In addition, the results also confirmed that the growth of population can spur the demand of coal consumption and economic growth which later increase the greenhouse gas emission. Population in Indonesia become the most contributor in affecting the fluctuation of greenhouse gas emission. The study recommends to the policy makers to start produce the electricity based on the renewable energies resources and reduce the consumption of fossil energy especially coal as the fuel of power plants. It is because, the biggest consumption of coal is used by the power plants to produce the electricity.

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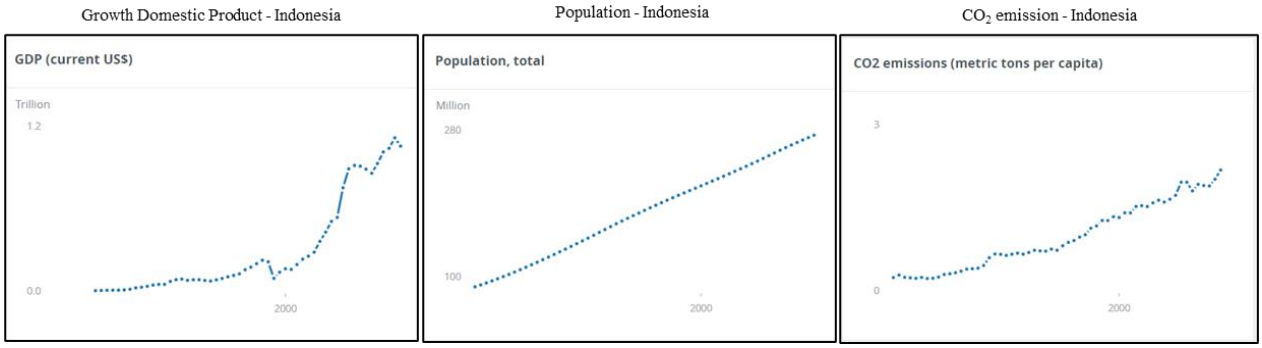
1. Introduction

As one of the main energy sources, the demand for electricity in Indonesia continues to increase drastically. The demand for electricity is predicted to increase with the planned migration of the transportation sector from fuel to electricity, this is marked by the mass production of electric cars and motorcycles for commercial purpose. In addition, the population growth also become a factor that increase the electricity demand in Indonesia drastically. With the high demand for electricity, it is certain that electricity is the main source of energy needed to drive economic growth in Indonesia. Based on those reality, there is a close relationship between the three variables where population will encourage economic growth and then increase the need for electricity consumption (Khan et al., 2020).

Unfortunately, most of Indonesia's electricity needs are met by steam power plants that use fossil energy sources as their main fuel, namely oil and coal. Consumption of fossil fuels produces carbon dioxide (CO_2). When the CO_2 released into the atmosphere in massive quantities, it will cause global warming and climate change. Therefore, briefly it can be concluded that increasing population will increase economic growth and will ultimately increase the natural damage which is reflected by increasing CO_2 emissions in the atmosphere. (Figure 1.1).

Figure 1.1 Graph of GDP, population, and CO_2 emission Indonesia



Compared to oil, coal is a commodity with have a cheaper price relatively, easier to produce, and have abundant supply. That's why coal is preferred to be chosen as a fuel for power generation rather than oil. In fact, coal produces more carbon emissions than oil and other dangerous damages, which means the consumption of coal impacts more natural damage than other energy sources (Ahmad et al., 2016). Table 1.1 shows table 1.1 shows the amount of carbon emissions produced by coal are more than oil and gas. (Table 1.1).

Table 1.1 Pounds of CO_2 produced from various types of fossil fuels

Rank	Fuels	Pounds of CO_2 emitted per million British thermal units (Btu) of energy
1	Coal (anthracite)	228.6
2	Coal (bituminous)	205.7
3	Coal (lignite)	215.4
4	Coal (subbituminous)	214.3
5	Diesel fuel and heating oil	161.3
6	Gasoline (without ethanol)	157.2
7	Propane	139.0
8	Natural gas	117.0

This condition poses a big problem for countries in the world whose electricity is mostly produced by power plants that use coal as the main fuel. On the one hand, electricity is urgently needed as the main source of energy that supports economic growth and on the other hand burning

coal as fuel for power generation causes natural damage that endangers human survival (Ohlan and Ramphul, 2015).

Through the Kyoto Protocol, basically countries in the world already agreed to reduce carbon emissions in their respective countries, including Indonesia. This can be seen from the graph that the consumption of oil used to produce electricity in Indonesia has continued to decline since the 1985s. Unfortunately, this is not followed by the consumption of coal which has continued to increase drastically since 1985. In contrast with the consumption of oil, the dependence on coal is getting higher.

This study aims to investigate the effect of population, economic growth, and consumption of coal as the main fuel source for power generation and their effect on greenhouse gas emissions in Indonesia. By understanding the relationship between these variables, hopefully this study can provide a real picture of the natural damage condition caused by population and economic growth as well as provide suggestions & solutions to natural damage and the need for electrical energy. After that, it may create environmentally friendly economic growth.

The remains of the study consist of literature review which describe briefly the previous study on the relationship between coal consumption and economic growth in various countries. Next, the source of data and methodology employed in the study exposed in the chapter data and methodology. After that, the result of data processing describes at the next chapter. Finally, the conclusion of the study as well as the policy recommendation will be spelled out at the last chapter.

The issue of coal consumption has become a serious discussion among policy makers and academics. This is because coal is a cheap energy source and is available in large quantities but causes massive natural damage. In the case of South Africa, Odhiambo (2016) concludes that economic growth is not depend on coal consumption. Therefore, the country can reduce the consumption of coal to increase environmental quality without hinder the economic growth.

Adebayo et al. (2021) investigated the relationship between coal consumption and environmental quality by involving financial development and globalization in South Africa during the period 1980 – 2017. By employing the ARDL approached in addition to the Bayer and Hank combined co-integration, FMOLS, and DOLS, the study proved that the increase of coal consumption and economic growth will boost the natural damage simultaneously. Conversely, the escalation of financial development will reduce the environmental damage in the same level. Therefore, the study concluded that South Africa should encourage the policy of energy conservation and at the same time implement the financial reforms. Those things should be done together to curb environmental degradation. Previously, in the case of Africa, Odhiambo (2016) stated that in the short-run, economic growth causes coal consumption which implies that the energy conservation policy can implement in South Africa without harms to economic growth while Shahbaz et al. (2013) concluded that coal consumption is proven damaging to the environment in South Africa. However, it can be reduced by increasing the trade openness. In the case of Turkey, Ozturk and Ozturk (2018) found that the consumption of coal positively and negatively affected by economic growth and technological innovation respectively. Therefore, the study suggested that the country needs to allocate more resources on research of energy to increase the energy efficiency. Different results for the Turkish case were presented by Ocal et al. (2013) who concluded that there is no causal relationship between coal consumption and economic growth. The study encourages the government to immediately reduce coal consumption.

Coal is the main energy source in China with a contribution of 70% in primary energy sources and 80% as a source of energy for power generation. With the high pollution generated, it is certainly a serious environmental problem in relation to economic development. Thus, the efficiency of coal consumption must be done immediately to maintain sustainable economic growth (Bhattacharya et al., 2015). In the case of Nigeria, Nasiru (2010) obtained the conservation hypothesis of coal consumption. Therefore, the slowdown of coal consumption should not hamper economic growth of Nigeria. Coal is also the main source of energy in Korea & Taiwan which drives growth and on the other hand increases air pollution and environmental damage. Therefore, Yoo (2006) and Yang (2000) suggested to Korean and Taiwan governments must immediately take a policy to reduce dependence on coal consumption. The implementation of this policy is predicted not to interfere the economic growth in both countries.

There are several studies involved some countries in their studies when investigating the impact of coal consumption to economic growth. Bildirici and Bakirtas (2016) concluded that the environmental degradation in the countries caused by fossil fuels especially for BRICTS countries. Therefore, the government of BRICTS must encourage a decrease of coal consumption by reducing

fossil fuel subsidies and at the same time encouraging an increase in renewable energy sources to ensure economic growth and environmental quality improvements continuously. The investigation into the effect of coal consumption on economic growth in the largest coal consumption countries concluded the different result. Therefore, each country should design their own policies based on their own condition (Lei, et al., 2014). Coal was also found affected economic growth and environmental damage in 15 emerging market economies. In this condition, a study conducted by Apergis and Payne (2010) suggested to the government of the country concerned to limit coal consumption through the formulation of energy policies such as legislation.

In the case of Indonesia, Kurniawan & Managi (2018) stated that coal is the primary energy of Indonesia but cause the environmental degradation. Therefore, Indonesia needs to limit the consumption of coal by prioritizing the foreign investment to bring higher technology. The similar result about coal consumption in Indonesia showed by Kim and Yoo (2016). They found a feedback hypothesis between coal consumption and economic growth in Indonesia which means there is a interdependence relationship between both variables. The study suggests Indonesia to constrain the coal consumption even though it may harm the economic growth.

2. Methods

This study used annual time series data sourced from World Development Indicator – World Bank during the period 1971 – 2018. The proxies consist of growth domestic product (GDP) which reflects the economic growth, CO_2 emission which reflects the greenhouse gas emission (CO2), population (POP), and coal consumption (COAL) in the case of Indonesia. The analysis of restricted structural vector autoregressive (VAR) model used in this study to reach the objectives of the study. This is a combination model between restricted and structural VAR. The restricted VAR models where assumed that the variables are not affects one each other continuously. However, there is a restriction which determine based on the applicable theory. In addition, structural VAR is a restriction VAR based on the relevant theoretical. The theory used in the model should be sourced from previous research or put forward by the expert. It is important to determine the *variable ordering* in structural VAR before conducting all process of VAR in order to rank the independent variables based on their impact to dependent variable. Variable ordering will sort from the most until the least of restrictive variables or even without any restrictive. This step is very crucial to determine the significant level of the result of VAR regression.

The matrix of VAR restricted in this study can be written as follow:

$$\begin{pmatrix} POP \\ GDP \\ COAL \\ CO2 \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{pmatrix} + \begin{pmatrix} POP_{t-i} & POP_{t-i} & POP_{t-i} & POP_{t-i} \\ GDP_{t-i} & GDP_{t-i} & GDP_{t-i} & GDP_{t-i} \\ COAL_{t-i} & COAL_{t-i} & COAL_{t-i} & COAL_{t-i} \\ CO2_{t-i} & CO2_{t-i} & CO2_{t-i} & CO2_{t-i} \end{pmatrix} \begin{pmatrix} \beta_{11} & \beta_{12} & 0 & 0 \\ \beta_{21} & \beta_{22} & \beta_{23} & 0 \\ \beta_{31} & \beta_{32} & \beta_{33} & 0 \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} \end{pmatrix} + \begin{pmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \end{pmatrix}$$

Based on the matrix above, the equation of the restricted VAR model can be written as follow:

$$POP = \alpha_1 + \beta_{11} \sum POP_{t-i} + \beta_{12} \sum GDP_{t-i} + U_i$$

$$GDP = \alpha_2 + \beta_{21} \sum POP_{t-i} + \beta_{22} \sum GDP_{t-i} + \beta_{23} \sum COAL_{t-i} + U_2$$

$$COAL = \alpha_3 + \beta_{31} \sum POP_{t-i} + \beta_{32} \sum GDP_{t-i} + \beta_{33} \sum COAL_{t-i} + U_3$$

$$CO2 = \alpha_4 + \beta_{41} \sum POP_{t-i} + \beta_{42} \sum GDP_{t-i} + \beta_{43} \sum COAL_{t-i} + \beta_{44} \sum CO2_{t-i} + U_4$$

where a is a constantan, β is a regression coefficient, Σ is a *lag*, *t-i* is a lag of vector, and U is the residual. This study employed the dynamic analysis where there are several dependent variables affected by several independent variables as written above. The determination of the independent variables is based on the theoretical literature and the previous studies.

Before conducting VAR analysis, it is very important to conduct some tests as the preliminary tests namely unit root test, and optimum lag. The requirement of the VAR is the time series data used in the model should be stationer. The unit root test used to find the existence of

unit root in the data, the absence of unit root meaning that the data is stationer and vice versa. This study concern with the most popular unit root test namely ADF and PP tests. When conducting VAR and cointegration, it is important to input the optimum lag. This study will choose the most popular method to determine the optimum lag namely Akaike Information Criterion (AIC). The analysis of restricted VAR conducted by test of joint significance based on the test of influence tests between research variables that have been determined in the restriction matrix (zeros in matrices) of VAR analysis. Based on the zero matric, the influence relationship to be tested is the influence of each variable namely coal consumption (COAL), economic growth (GDP) and population (POP), to carbon emission sourced from coal (CO2). The next is the causality test which tries to find the causality direction between COAL and GDP as well as between the POP to COAL. The impulse response (IRF) define as the model which can analysis the reaction of shock of a variable to another variable during the period of observation. The reaction can possible either positive or negative. The Forecast Error Variance Decomposition (FEVD) indicates the number of information of each variable which effect to another variable in the autoregression. This can determine how many forecast error variances which exist in each variable in the form of percentage.

3. Results

The study employs test of ADF and PP as unit root test to find the presence of unit root in the time series data. The absence of unit root indicates that the data is stationer and vice versa. The H_0 hypothesis of ADF and PP unit root test is to accept H_0 based on the standard error 1%, 5%, and 10%. The result of ADF and PP test show that all variables are not stationer at the level. However, all of variables are stationer at the fist difference either with ADF or PP test. (Table 3.1).

Table 3.1 Result of unit root analysis
Null Hypothesis: Variable has a unit root

Variable	ADF				PP			
	Level		Δ		Level		Δ	
	Intercept	Trend & Intercept	Intercept	Trend & Intercept	Intercept	Trend & Intercept	Intercept	Trend & Intercept
POP	0.78	4.76	4.58*	3.28*	0.34	5.65	2.11*	3.41*
	(0.65)	(0.16)	(0.00)	(0.00)	(0.21)	(0.34)	(0.00)	(0.00)
GDP	2.90	9.38	3.93*	2.87*	6.98	3.76	4.47*	7.76*
	(0.56)	(0.88)	(0.00)	(0.00)	(0.45)	(0.28)	(0.00)	(0.00)
COAL	6.72	3.89	3.87*	2.77*	7.35*	6.84	0.49*	6.62*
	(0.76)	(0.32)	(0.00)	(0.00)	(0.65)	(0.30)	(0.00)	(0.00)
CO2	1.79	2.16	7.98*	7.48*	9.88	1.32	0.34*	3.34*
	(0.43)	(0.60)	(0.00)	(0.00)	(0.47)	(0.56)	(0.00)	(0.00)

Note: Δ is first difference. Variables are in natural logarithm. First line are t-statistics and second line are probability values.
* denotes significant at 1%, 5% and 10% level of significant.

Table 3.2 Result of restricted VAR analysis

Variable	Wald test	P-Value	Critical value		Decision
			5%	10%	
LnCOAL → LnCO2	42,61	0,00051	12,59	10,64	Reject H_0
GDP → LnCO2	31,11	0,00000	12,59	10,64	Reject H_0
POP → LnCO2	76,77	0,00000	12,59	10,64	Reject H_0
GDP → LnCOAL LnCOAL → GDP	51,20	0,00071	21,03	18,55	Reject H_0
POP → LnCOAL	19,65	0,00065	12,59	10,64	Reject H_0

Sample: 1971 – 2018, variable: 4, lag 4

4. Discussion

The restricted VAR chosen as a method in this study due to there is a theory as a base of the influence between the variables. The lag used in this study is 4 based on the Akaike information criterion (AIC). Table 3.2 reveals the result of the VAR restriction. Based on the information in the table, it is clear that all system tested are significant where all of the p-value are less than 5% and Wald test values are greater than critical value at 5% and 10%. This reflects that all system is statistically significant.

The result of VAR structural analysis at table 3.3 shows that all system is significant and conclude to reject H_0 where the p-value are less than 0,05 as well as the value of Wald test is greater than the critical value at 5% and 10%. The result also reveals the consistency with the result of restricted VAR at the table 3.2. The important thing to highlight based on the result is that all variables have a positive effect on increasing CO_2 emissions in Indonesia. Therefore, support from all parties is needed to reduce CO_2 emissions produced by coal.

Table 3.3 VAR Structural Analysis

Variable	Wald test	P-Value	Critical Value		Decision
			5%	10%	
LnCOAL → LnCO2 GDP → LnCO2 POP → LnCO2	34,32	0,00001	8,92	7,51	Reject H_0
GDP → LnCOAL POP → LnCOAL	34,89	0,00000	6,87	4,73	Reject H_0

Sample: 1971 – 2018, variable: 4, lag 4

Separately, this study tests the effect of population growth to economic growth in Indonesia. Different from the other test, the test to analyze the effect of population to economic growth is conducted by employing t-test which compared with t-value and the value of t-table. The null-hypothesis will reject if the t-value greater than t-table. Table 3.4 reveals the result of the VAR structural analysis for the effect between population and economic growth. The result confirms that population does not affect the economy significantly due to t-value is less than t-table at the 5% and 10% level of significant.

Table 3.4 VAR Structural Analysis (2)

Variable	*t-value*	*t-table*		Decision
		5%	10%	
POP → GDP	3,2769	1,684	1,303	Reject H_0

Sample: 1971 – 2018, variable: 4, lag 4

5. Conclusion

The main purpose of this study is to investigate the effect of coal consumption to economic growth and pollution which reflected by CO_2 emission sourced by coal in the case of Indonesia during the period 1971 – 2018. The variable population also involved in the model to get deeper analysis. The restricted VAR choose as the methodology which preceded by unit root test due to there is a theory as the basis of the model. The result of the regression concludes that pollution in Indonesia positively affected by economic growth and population as the biggest contributor. The consumption of coal mostly used as the fuel of electricity generation which needed by people as the main energy for their daily activities. As the solution of the problem, this study suggests the government and policy makers to reduce the pollution sourced from the burning of coal. The demand of the electricity is too arduous to reduce. Therefore, this policy could be implemented by

changing the fuel of electricity generation from coal with more environmentally friendly fuel such as natural gas. It is due to natural gas produce carbon emission which much less than coal. Moreover, the government may construct the more power plant from renewable energy such as wind, heat, and hydroelectricity.

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