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ISSN: 0193-4120 Page No. 3550 - 3559

Existence of Environmental Kuznets Curve (EKC) in Indonesia: Evidence from Fossil Fuel and Renewable Energies

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Article Info
Volume 83
Page Number: 3550 - 3559
Publication Issue:
March - April 2020

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 23 March 2020*

Abstract.
This paper tests for the short and long-run relationship between economic growth, carbon dioxide (CO2) emissions and energy consumption using the Environmental Kuznets Curve (EKC) by using both the aggregated and disaggregated energy consumption data in Indonesia. The Autoregressive Distributed Lag (ARDL) methodology approach was used to test the cointegration relationship; and the Granger causality test, based on the vector error correction model (VECM), to test for causality. This study does not support an inverted U-shaped relationship (EKC) when aggregated energy consumption data was used. When data was disaggregated based on different energy sources such as oil, coal, gas and electricity, the study shows evidences of the EKC hypothesis. The long-run Granger causality test shows that there is two-way causality between economic growth and CO2 emissions, with coal, gas, electricity and oil consumption. This suggests that decreasing energy consumption such as coal, gas, electricity and oil appear to be an effective way to control CO2 emissions, but it will disturb economic growth at the same time. Thus, exact policies related to the efficient consumption of energy resources and consumption of renewable sources are required to solve this problem.

Keywords:*Environmental Kuznets Curve, Fossil Fuels, Indonesia, Renewable Energy.*

1. Introduction

Recently, greenhouse gases (GHG), resulted global warming and climate changes are top priority objects among everyone in the world. Firms around the world are currently under strict environmental pressures. Carbon dioxide (CO2) makes up the largest share of the greenhouse gases contributing to global warming and climate change [1].Carbon dioxyde (CO_2) gases are responsible for more than 60% of the greenhouse effect [2]; [3]. Transportations have the second biggest ‘contribution’ for almost a quarter of total emissions after the energy industries. The modal decomposition of transportations’ GHG emissions shows that road transportations have the primary role in GHG emissions with a share of 73% in 2014 [4]. In addition to global GHG emissions, ICE (internal combustion engine) vehicles also cause noise and local air pollution, creating harmful health effects, especially in urban society [4]. Car-related petrol and diesel demands can cause dependence on foreign energy sources [4].

While maintaining energy consumption may be the most direct way of managing the emissions

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problem, this reduction at the expense of economic growth may not be an expected outcome [3]. The cause of this event is the important relationship between economic growth, energy consumption and CO_2 emissions [3].

Indonesia contributed the largest carbon emissions from the land use and sector change by 50%, while the energy sector gives contribution of carbon emissions around 30% and from the transportation sector gives 12%. Meanwhile, 90% of air pollution is generated from ground transportation and as respiratory system infections. According to Yudha [5], this pollution problem can be pushed down through government policies, especially in the energy sector with the use of new and renewable energy called *Energi Baru Terbarukan* (EBT), which is environmentally friendly, in order to reduce carbon emissions and reach energy independence [5].

Another problem in Indonesia is the availability of energy for fuel of power generation, which is still dominated by fossil energy. According to Mujiyanto's analysis [5], in addition to coal, the dependence of power plants on fuel oil (BBM) is still high, whereas from the side of the availability of fuel is very limited and used to meet the needs of other sectors. The national electricity industry is also facing crucial problems due to unbalanced supply with its utilization, especially in areas with minimal access [5].

Specifically, in the field of energy independence in the Indonesian government, energy independence targets in 2017 are conducted in order to meet electrification ratio of 92.75% and electricity consumption per capital 0.58 KWh, increased production of energy resources such as petroleums, natural gases and coals. In terms of energy distribution, especially natural gases, the pressure point is on the construction of transmission and gas distribution pipelines along 12,597 km, 2 units of SPBG (state budget), and municipal gas networks in 12 locations [5].

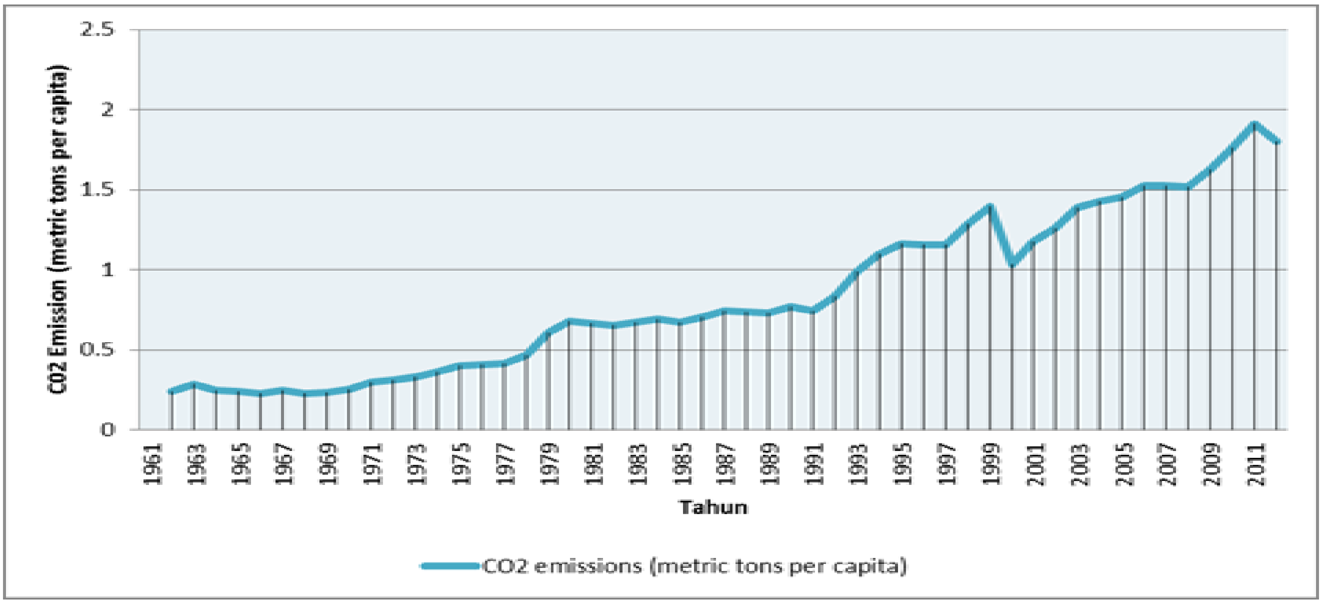

Figure 1. CO_2 Emissions in Indonesia, 1961 - 2011 (metric ton per capita)
Source: Rajagukguk, 2015, Christian University of Indonesia

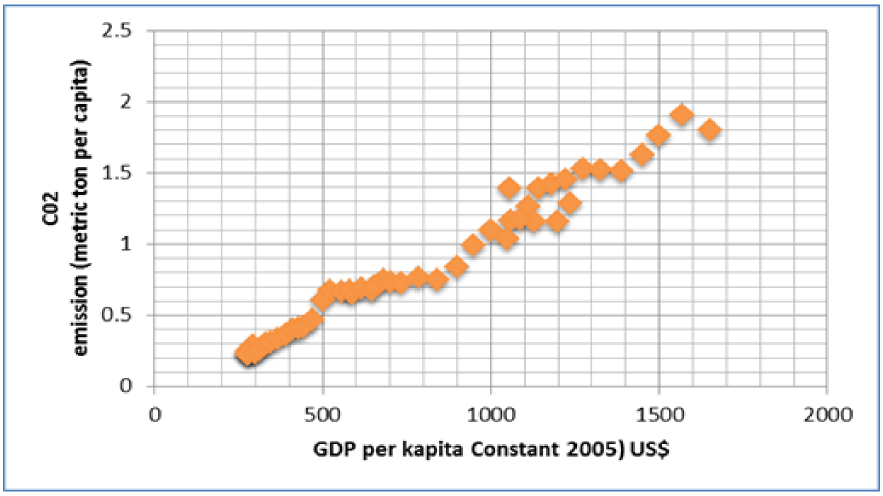

Figure 2. CO_2 Emission and GDP in Indonesia, 1961 – 2011
Source: Rajagukguk, 2015, Christian University of Indonesia

Ideally, the national economic growth can cause demand-driven, so it also results better changes in economic sector performances, especialy agriculture, which causes the increasing of agriculture commodities' productivity and intensity, which also affects the growth of agriculture sectors' outputs [6].

In order to achieve national economic growth goals, there are currently no clear strategies that can be used to anticipate the environment quality degradation, which is caused by the externalities from production process, thus the current economic growth is actually apparent. Since before 1960s, with economic growth approach as the economic development goal, it gave effects to the imbalance policies between agriculture sector and non-agriculture or capital development and real sector. First, it is leaning to the capital sector more than the agriculture sector because of the revenues produced by the first sector (the capital one), so the development of the agriculture sector is abandoned [6].

Most of studies in the relationship field are related to investigate the existence of an "Environmental Kuznets Curve (EKC)" hypothesis. The EKC hypothesis postulates that environmental degradation follows an inverted U-shaped curve relative to income. This means that the environmental degradation initially increases with the level of income, reaches a turning point or threshold, and then declines with further increases in income. On the other word, the environmental quality decrease with rising income but after a certain income level has been reached, it begins to increase [7].

The validity of the EKC hypothesis is very important for policy implications. If the hypothesis held generally, it would imply that economic growth is the means to environmental improvement. That is, as countries develop economically, moving from lower to higher levels of income, overall levels of environmental degradation will eventually fall. Therefore, it would be seemed that there is no need to curtail growth in the world of economy in order to protect the global environment. However, if the hypothesis proposition does not hold, public intervention would be necessary to curb the environmental degradation and make sustainable development a reality [7].

The objective of this study is two folds. *First*, this study is aimed to check the validity of EKC hypothesis for the case of Indonesia by looking into the impact of economic growth to carbon dioxide emission of the nation. *Second*, this study also seeks to inquire into the impact of energy consumption, both fossil fuels (petroleum and coal) and renewable energy toward the carbon dioxide emission in Indonesia. Finding from this study is expected to provide insights and recommendations for betterment of environmental action, particularly on carbon dioxide emission abatement in Indonesia.

2. Literature Review

According [3], there have been three research groups looking at economic growth, environmental pollutants and energy consumption relationship. The first group looks at economic growth and environmental pollutants nexus with the main objective being the testing of the validity of the Environmental Kuznets Curve (EKC) hypothesis. The EKC assumes that environmental degradation first increases as income increases then plateaus when income reaches a certain high level and finally decreases. Empirical results in literatures regarding this inverse U-shaped relationship between CO2 emissions and per capita income are many but inconclusive. The literature related to the EKC in Malaysia was done examines the link between per capita income and a number of air and water pollutants from the late 70s to the early 90s and concludes that EKC relationship does not exist as higher income is only associated with higher levels of pollution. In contrast, [3] reports the existence of the EKC for Carbon emissions in Malaysia.

The second group of studies focuses on energy consumption and the output nexus [3]. Economic growth has been shown to be closely and positively related to energy consumption, the higher the economic growth of an economy, the higher is the energy consumption. After a pioneer study ,a number of studies examined the long run and causal relationship between energy consumption and economic growth provides a comprehensive survey on energy consumption economic growth literature [3].

Employing a number of different econometric methodologies for different time periods in a range of countries and regions failed to achieve consensus conclusions [3]. Evidence of the uni-directional causality running from energy consumption to economic growth for both developed and developing countries has been reported by a number of studies [8]. In contrast there are many studies that found one-way causality running from economic growth to energy consumption. Bi- directional causality is also reported by a number of studies for different countries and regions . Finally, there are some studies that found no causal relationship between energy consumption and economic growth.

Recently studies employed disaggregate energy consumption to shed more light on the causal and cointegration relationship between different energy sources and economic growth. First, th causal relationship between different types of energy consumption and economic growth still remains inconclusive. Second, most of the existed literatures investigated the relationship between economic growth and one type of the energy consumption with the exception. Finally, most of the literatures suffer from the omitted variable biased as they examine the bivariate relationship between energy consumption and economic growth.

The CO2 emissions, economic growth and energy consumption nexus was later extended by including the effects of foreign trade labor and urbanization nuclear energy consumption and electricity consumption.

From these literatures, it can be concluded that, energy consumption is an important determinant of carbon dioxide emissions. However, country studies show varying results on the validity of EKC and casual relationship. The inconclusive results in the existing literatures may be attributed to the fact that all of these studies are performed using aggregated energy data, thus

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said to suffer from aggregation bias. Discuss this inconclusive result through "the differences in the diversity of energy resources used"."Therefore it is not possible to identify the impact of a specific type of energy with aggregate data".

Since different energy sources have different effects on pollutant emissions and economic growth such problems are minimized when disaggregated energy data is used. This issue has inspired us to investigate the EKC hypothesis by using Malaysian energy aggregated and disaggregated data for the period 1980–2009. The ARDL bounds testing approach of cointegration by [9], cointegra- tion approach are used in this study. The Granger causality test based on vector error correction model (VECM) was used to test the causal relationships between variables. Disaggregated energy data (oil, coal, electricity, and gas consumption) was used to minimize the aggregation bias problem.

3. Methodology

To achieve the research objective, this study employs quantitative approach, covering annual data from Indonesia within period of 1986 to 2016. The variables employed with their sources of data are shown on the following table:

Table 1. Variables employed

	Name of the Variable	Unit of Measurement	Source of Data
Dependent Variable	CO_2 Emissions	Metric Tonnes (MT)	US Energy Information Administration (https://www.eia.gov)
Independent Variables	Consumption of Petroleum		
	Consumption of Coal		
	Consumption of Renewable and Nuclear energy	British Thermal Unit (Btu)	
	GDP Per Capita	Constant 2010 US$	World Development Indicators by World Bank (https://data.worldbank.org)

All variables above are transformed into natural log form (LN) in order to ease data analysis, by focusing on the impact of growth on certain variable to the dependent variable. The EKC hypothesis to be analyzed in this study is based on the following equation:

$$\ln E_t = \beta_0 + \beta_1 . \ln Y_t + \beta_2 . (\ln Y_t)^2 + \beta_3 . \ln Petroleum_t + \beta_4 . \ln Coal_t + \beta_5 . \ln Renewables_t + \varepsilon_t \ldots (1)$$

with E is CO^2 emissions, Y is GDP per capita, as well as petroleum, coal, and renewables represent source of energy consumption, in Indonesia. EKC hypothesis is proven to be true if the square of log of Y is negatively significant.

Given the nature of the data as time series variables, it is important to look into dynamic relationship among variables. Dynamic relationship among variables within this study is captured by employing Autoregressive Distributed Lag (ARDL) method. ARDL is chosen because its applicability for any time series variables as long as none of them are stationary at second difference (I(2)) [10]; [11]; [9] In this study, the ARDL framework from equation (1) is mathematically expressed as the following:

$$\Delta \ln E_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 . \Delta \ln E_{t-i} + \sum_{i=1}^{p} \beta_2 . \Delta \ln Y_{t-i} + \sum_{i=1}^{p} \beta_3 . (\ln Y_{t-i})^2 + \sum_{i=1}^{p} \beta_4 . \Delta \ln Petroleum_{t-i} + \sum_{i=1}^{p} \beta_5 . \Delta \ln Coal_{t-i} + \sum_{i=1}^{p} \beta_6 . \Delta \ln Renewables_{t-i} + \phi_1 . \ln E_{t-1} + \phi_2 . \ln Y_{t-1} + \phi_3 . (\ln Y_{t-i})^2 + \phi_4 . \ln Petroleum_{t-1} + \phi_5 . \ln Coal_{t-1} + \phi_6 . \ln Renewables_{t-1} + \varepsilon_t \ldots (2)$$

The terms ϕ_1 to ϕ_4 represent the long-run relationships among variables. A bound testing for cointegration is tested to ensure long run relationship among variables. Cointegration is marked by F-statistic value that higher than the lower bound (I(0)) and upper bound (I(1)). The critical value of the F-statistic in this study is based on (Narayan, 2005), due to small sample size (around 30). Upon establishing cointegration, the Error Corrrection Model (ECM) is estimated as the following:

$$\Delta \ln E_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 . \Delta \ln E_{t-i} + \sum_{i=1}^{p} \beta_2 . \Delta \ln Y_{t-i} + \sum_{i=1}^{p} \beta_3 . (\ln Y_{t-i})^2 + \sum_{i=1}^{p} \beta_4 . \Delta \ln Petroleum_{t-i} + \sum_{i=1}^{p} \beta_5 . \Delta \ln Coal_{t-i} + \sum_{i=1}^{p} \beta_6 . \Delta \ln Renewables_{t-i} + \phi . ECT_{t-1} + \varepsilon_t \ldots (3)$$

A negatively significant ECT is expected as an indication of long-run causality, while significant lag independent variables denote short-run causality [12]; [11]. The model utilised in this study is based on [3] with little modification by employing petroleum, coal as well as renewable and nuclear as sources of energy consumption. To check stationarity of variables, two tests, namely Augmented Dickey Fuller (ADF) and Phillips Peron (PP) are conducted. Meanwhile robustness of the estimated model is conducted by utilizing several diagnostic tests, including: i) Bruesch-Godfrey LM test for serial correlation; ii) Breusch-Pagan test for heteroscedasticity; iii) Jarque-Bera test for residual normality; and iv) Ramsey RESET for model specification. All data analysis process conducted by using EViews 9 software.

Result

The following table shows descriptive statistics of the variables:

Variable and Unit of Measurement	Mean	Median	Maximum	Minimum	Std. Dev.	Obs.
E (Million MT)	295.3168	273.0315	513.1493	112.7016	121.7217	31
Y (US$)	2471.03	2333.097	3974.724	1438.391	714.347	31
PETROLEUM (Thousand MT)	51554.11	56527.91	73941.01	22478.25	17175.58	31
COAL (Thousand MT)	34674.6	28438.08	93366.12	4354.995	26929.02	31
RENEWABLES	0.154869	0.156783	0.309203	0.054981	0.066969	31

(Quadrilion Btu)

Validity of the estimated model is hold when all variables are found to be stationary at level (I(0)), or at first difference (I(1)). The following table shows that most variables are stationary at first difference in both ADF and PP tests, except for renewables which on both tests is already stationary at level. Given the non-existence of I(2) variables and differences on degree of integration among variables, this condition confirms that ARDL is the appropriate approach to estimate the model.

Variable	**ADF**		**PP**	
	At Level	**First Difference**	**At Level**	**First Difference**
LN_E	-2.388663 (0.3775)	-5.975153 (0.0002) *	-2.382690 (0.3804)	-5.945422 (0.0002)*
LN_Y	-1.495745 (0.8086)	-3.848986 (0.0280)*	-1.723886 (0.7154)	-3.829559 (0.0292)*
$(LN\_Y)^2$	-1.368754 (0.8496)	-3.858974 (0.0274)*	-1.608674 (0.7655)	-3.839097 (0.0286)*
LN_PETROLEUM	-1.189462 (0.8947)	-6.570261 (0.0000)*	-0.676720 (0.9659)	-11.32943 (0.0000)*
LN_COAL	-1.855869 (0.6519)	-4.867497 (0.0027)*	-2.036016 (0.5588)	-4.860717 (0.0027)*
LN_ RENEWABLES	-4.531811 (0.0057)*	-	-4.484994 (0.0064)*	-

*: significant at 5% level of significance
p-values are within the parentheses

Meanwhile, the result of the bound testing for cointegration with critical values based on [8] is shown on the following table:

Indicator	**Value**
F-statistic	8.091*
K	5
Upper bound (I(1))	6.370
Lower bound (I(0))	4.537

*: significant at 5% level of significance

Upper and lower bounds are for 5% level of significance.

Above table shows that the F-statistic exceeds the upper bound critical value, which signifies existence of cointegration among variables.Thus, long-run relationships are found among variables. Meanwhile, the summary of the diagnostic tests taken are shown below:

Diagnostic Test	**Test Statistic**	**P-value**
Breusch-Godfrey test for serial correlation	χ^2 = 13.30949	0.3470
Breusch-Pagan test for heteroskedasticity	χ^2 = 3.933744	0.1399
Jarque-Bera test for normality	JB = 0.763	0.541
Ramsey RESET test	F-stat = 0.576205	0.4596

Above table shows that none of the diagnostic tests have significant value, signifies non-existence of serial correlation and heteroskedasticity problems, normality of residual distribution and the functional form has already well specified. In other values, the estimated model within this study is robust.

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The estimated long-run model in this study is shown on the following table:

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LN_Y	2.890028	1.110324	2.602869	0.0192**
$(LN\_Y)^2$	-0.13607	0.070874	-1.91989	0.0729*
LN_PETROLEUM	0.212916	0.078907	2.698313	0.0158**
LN_COAL	0.086358	0.034518	2.501788	0.0236**
LN_RENEWABLES	0.148828	0.046039	3.232649	0.0052**
C	-11.466	3.923234	-2.92259	0.01**

*: significant at 10% level of significance
**: significant at 5% level of significance

Above table shows that all variables are significantly affect carbon dioxide emission in the long-run at 5% level of significance in positive direction, except for LN_Y2 that negatively affect carbon dioxide emission in the long run, but significant at 10% level. In other words, EKC hypothesis is hold for the case of Indonesia in the long run.

The estimated ECM that contains short-run coefficients is shown on the following table:

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LN_E(-1))	0.547719	0.131638	4.160793	0.0007**
D(LN_Y)	2.734247	1.177146	2.322777	0.0337**
D(LN_Y(-1))	-0.89327	0.152235	-5.86769	0.0000**
$D(LN\_Y)^2$	-0.14704	0.074047	-1.98572	0.0645*
D(LN_PETROLEUM)	0.230075	0.101297	2.271291	0.0373**
D(LN_COAL)	0.022215	0.076686	0.289683	0.7758
D(LN_COAL(-1))	-0.22998	0.065444	-3.51417	0.0029**
D(LN_RENEWABLES)	0.086467	0.033218	2.603057	0.0192**
CointEq(-1)	-1.08059	0.150062	-7.20096	0.0000**

* : significant at 10% level of significance
** : significant at 5% level of significance

On above table, there is indication that economic growth and energy consumption typically lead to higher carbin dioxide emission. Higher level of economic growth in certain year will immediately raise emission level, but there will be a little abatement caused by previous years' growth. Also, as the case in the long-run model, the EKC hypothesis also holds for the case of Indonesia in the short-run, although only significant at 10% level.

Meanwhile, for the energy consumption, both petroleum and renewable energies significantly increase carbon dioxide emission with immediate effect. However, different direction is found for the coal, which its consumption negatively reduce carbon dioxide emission, but takes effect about

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one year. Lastly, if there is any short-run shocks in certain year, the adjustment process from the short-run shocks to the long-run equilibrium takes place about 108% in a year. In other words, there is a rapid adjustment process to overcome the shocks.

Above findings have several interesting points. First, EKC hypothesis exists in Indonesia in both short-run and long-run. This means, environmental action to solve carbon dioxide emission problem in Indonesia should consider the economic growth of the nation. However, the rate of abatement as the effect of higher economic growth is small relative to its adverse effect. Second, adoption of renewable energy in Indonesia does not reduce carbon dioxide emission but raise it instead. On the other hand, coal as one of the fossil fuels contributed to abatement of carbon dioxide reduction in the short run.

Result

This study is intended to look into the Environmental Kuznets Curve hypothesis and impact of consumption of various energy resources to the carbon dioxide emission in Indonesia. This study found that EKC hypothesis can explain the impact of economic growth to the carbon dioxide emission in both short-run and long-run, but the abatement process as result of economic growth is much slower that emission process. Moreover, it is found that all energy sources, including the renewables, significantly generate higher carbon dioxide emission in the long run. However, coal as one of the fossil fuels contributes to abatement of the carbon dioxide emission in the short run.

Findings from this study lead to recommendations regarding the issue of carbon dioxide emission management in Indonesia. First, learning from EKC hypothesis, it is important to consider economic growth as a factor for emission abatement in Indonesia. However, to strengthen the abatement process, there must be higher investment on green technology, mainly aiming to generate growth with reducing the emission. Second, carbon tax for fossil fuels, particularly petroleum can be a solution for Indonesia to reduce its emission, with the revenue generated should be channelled to investment in renewable energy and greener coal energy. This is important to consider because renewable energy still has minor share in Indonesia's energy consumption, and coal is found to be a contributor towards emission abatement in the short-run but still has adverse effect in the long-run.

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