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The Damaging Growth: An Empiric Evidence of Environmental Kuznets Curve in Indonesia

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ABSTRACT

This study examines the short-run and long-run relationships between economic growth, carbon dioxide (CO_2) emissions and energy consumption within a sample period of 1990-2016. The study used autoregressive distributed lag approach to test the cointegration relationship and Granger vector error correction model causality test to investigate the direction of causality. This study does not support the hypothetical relationship (environmental Kuznets curve) for a significance level of 5%. The long-run test of Granger causality shows that there is a two-way causal relationship of economic growth, CO_2 emissions, and energy consumption. This result indicates that a reduction in energy consumption is an effective way to control CO_2 emissions but will simultaneously impede economic growth. Therefore, setting suitable policy related to efficient consumptions of energy resources and renewable energy resources is necessary.

Keywords: Environmental Kuznets Curve, Carbon Dioxide Emissions, Energy Consumption
JEL Classifications: Q42, Q43, C10

1. INTRODUCTION

The relationship between energy consumption, economic development, and environmental damage has increasingly been discussed in various studies lately triggered by the increasing concern for environmental damage along with increasing awareness of global warming and climate change.

Energy is one of the most important factors in transforming the country from a developing to a developed one. But at the same time, energy consumption can have a negative impact on the environment (Saboori and Sulaiman, 2013). Intensive fuel consumption, especially fossil fuels, is the main cause of impact on air environment. The combustion process of fossil fuels emit air pollutants and compounds, such as total suspended solids (dust), carbon monoxide, total hydrocarbons, nitrogen oxide, sulfur oxide, lead particles, and photochemical oxidants (Soedomo, 2001). Indonesia is experiencing various environmental problems including climate change threat caused by rapid economic growth and extensive consumption of natural resources especially the burning of fossil fuels (Sugiawan and Managi, 2016). The World Bank estimates that economic loss due to climate change in Indonesia is to reach 2.5-7% of GDP by 2100. Meanwhile, the health impact of air pollution could cost more than US$ 400 million per year (Leitmann, 2009). An alternative to do to overcome emission problems is by reducing energy consumption especially fossils energy consumption. However, this reduction will lead to a "trade-off" for economic growth, which enables unexpected economic growth (Lotfalipour et al., 2010) as the consequence of significant relationship between economic growth, energy consumption, and carbon dioxide (CO_2) emissions.

The dependency on fossils energy in fulfilling domestic consumption is still high - 48% on oil, 18% on natural gas and 30% on coal - of total national energy consumption (International Energy agency (https://www.iea.org/statistics/), 2014; US Energy Information Administration (EIA) data, 2014). Similarly, high dependency on fossil fuels is also found out in the electricity sector. In 2014, the total power plant was around 288 TWh, 88%

of which is generated from fossil fuels, with coal contributing around 52.8% of the total figure (National Energy Council, 2015).

Environmental Kuznets curve (EKC) hypothesis testing is becoming increasingly important to prove whether economic growth is the solution to future environmental problems without any policy intervention. A number of studies have been conducted to investigate the existence of the EKC hypothesis regarding CO_2, both for developed and developing countries. However, most of them depend on cross-country panel data analysis. Consequently, it is only able to describe the general conclusions of the EKC hypothesis which tend to ignore the complexities of the economic environment and the historical experience of each country (Ang, 2008; Hill and Magnani, 2002; Dinda, 2004; Stern, 2004). Those studies emphasized the need for a specific EKC study relating to CO_2 for a particular country to provide in-depth analysis. This is necessary to develop effective energy and environmental policies for each country. Therefore, this study aims to find empirical evidence from the EKC hypothesis for CO_2 in Indonesia by examining the relationship between economic growth and environmental degradation. In addition, a high correlation between economic growth, energy consumption and environmental degradation is an interesting subject to reveal (Bhattarai and Hammig, 2001; Bulte and Soest, 2001; Dasgupta et al., 2002; Hasan et al., 2012) [Figure 1].

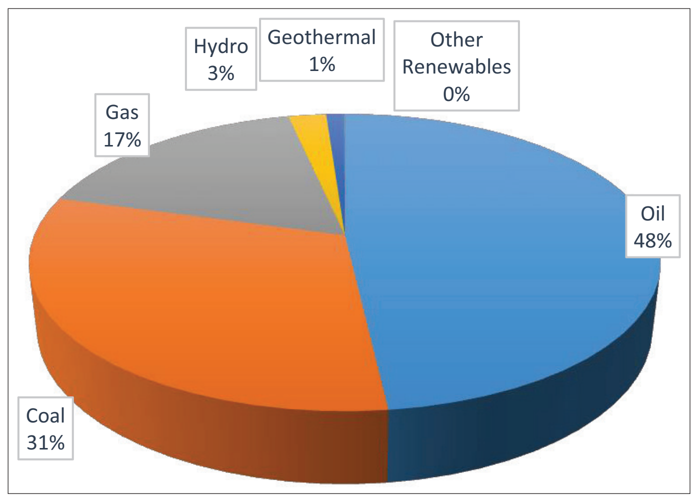
2. LITERATURE REVIEW

The 1971 Nobel Prize winner, Simon Kuznets, stated that when per capita income increases, income inequality also initially increases but then starting to decline after reaching the turning point (Kuznets, 1955). The inverted U-shape relationship between per capita income and income inequality is illustrated by a bell-shape curve, a popular phenomenon known as the Kuznets Curve. Similar inverted U-shape relationship is also found between per capita income and environmental degradation in the early 1990s through cross-country analysis (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Panayotou, 1993). Since then, the EKC hypothesis has become a topic that has been widely used as theoretical and empirical literature. The inverted U-shape relationship between economic growth and environmental degradation is explained by the EKC, in which environmental degradation increases along with initial economic growth and decreases at a certain point where the economy reaches a specific high level of income.

According to the EKC hypothesis, the level of environmental pollution initially increases due to economic growth. It then declines after GDP per capita reaches a threshold value (Panayotou 1993). Therefore, this hypothesis implies a dynamic process in which structural changes occur along with economic growth. Grossman and Krugger (1991) first clarified how the EKC emerged. They explored that economic growth affects environmental quality through three channels: (i) Scale effects, (ii) structural effects, and (iii) technological effects. Figure 2 shows EKC in periods (i), (ii) and (iii) (Panayotou, 1993).

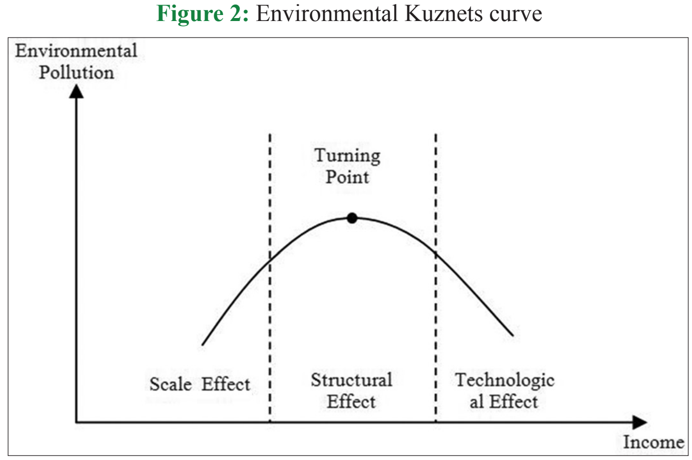
Period (i) scale effect is characterized by the low level of technology; more input is needed to produce output (commodities). More energy consumption is used for more additional production resulting in more waste and air pollutants that worsens environmental quality. (Vincent, 1997; Torras and Boyce 1998; Dinda, 2004; Fabien, 2009). Structural effect plays its role in stage (ii). The economy will undergo a structural transformation. Economic development will change the structure of the economy. Economic activities that cause a lot of pollution will gradually decrease, along with the increase in economic activities that cause less pollution. In addition, the economy also experiences a transition from industrial to service sector. The end of the stage of structural effect is characterized by the use of increasingly intensive technology in national production. (Copelan and Taylor, 2003; Alam, 2014). The last period (iii) of the EKC process is the period of technological effect. This period is characterized by a high-income economy, so that the allocation of resources for research and development is increasing. As a result, new environmentally friendly technologies emerge to replace old technologies that are not environmentally friendly. (Copelan and Taylor, 2003; Alam, 2014). The increasing number of people who value the environment also marks this period, which in turn, makes the regulations relating to the environment become more

Figure 1: Energy Mix in Indonesia, 2014



Source: US Energy information administration data, 2014

Figure 2: Environmental Kuznets curve



Source: Panayotou, 1993

effective. From these stages it can be concluded that environmental pollution initially increases and then decreases as a result of scale effect, structural transformation and technology that emerge along with economic growth.

Empirical evidence supporting the elimination of CO_2 emissions and economic growth has not been conclusive compared to other air and water pollutants (Selden and Song, 1994; Shafik, 1994; Sasana and Aminata, 2019) other pollutan such as sulphur (De Bruyn, 1997; Kaufmann et al., 1998; Rothman, 1998) or deforestation (Rothman, 1998; Koop and Tole, 1999) have been approved experienced EKC and rarely discussed on article nowadays. Some studies have found that EKC (CO2) does occur (Robers and Grimes, 1997; Cole et al., 1997; Schmalensee et al., 1998; Galeotti and Lanza, 1999; Azomahou et al., 2006; Apergis and Payne, 2009; Lean and Smyth, 2010; Saboori and Sulaiman, 2013; Sugiawan and Managi, 2016), or do not support the EKC hypothesis (Ibrahiem, 2016; Zakaria, 2017; Sasana and Aminata, 2019).

Research on EKC in Indonesia has been conducted by Saboori and Sulaiman (2013). Their research aims to examine cointegration and causal relations between economic growth, CO_2 emissions and energy consumption in 5 ASEAN countries. The approach used is autoregressive distributed lag (ARDL), with the time span of data used was 1971-2009. The results showed that the EKC hypothesis was not confirmed. Sugiawan and Managi (2016) examined the relationship of economic growth and CO_2 emissions with renewable energy as the control variable. The ARDL method was also used for the 1971-2010 study sample period. The results showed that the EKC was proven in the long-run with a GDP per capita turning point of USD 7.729. They also provided suggestions for research on EKC should include renewable energy in the model. Sasana and Aminata (2019) conducted a study to analyze the effect of energy-based economic growth on CO_2 emissions, with energy subsidies, energy consumption, population growth, and economic openness as exogenous variables. The study used Multiple Linear Regression for analysis approach. The result showed that EKC is not proven in Indonesia. Economic growth, primary energy consumption, and population growth positively affect CO_2 emissions, while consumption of renewable energy negatively affects CO_2 emissions.

3. DATA

The data for this study were selected based on the availability for all study series. The study years used in this study are from 1990-2016. CO_2 emissions were measured in metric tons of CO_2 per person. Real GDP is GDP per capita based on year 2010 price in US dollars. Per capita energy consumption is the aggregate energy consumption in tonne of oil equivalent (toe) or the equivalent ton of oil, which then is divided by the total population of Indonesia. All energy data and CO_2 emissions per capita are obtained from the US Energy Information Administration (EIA) available on the website (https://www.eia.gov/). As for real GDP per capita and total population are taken from the World Development Indicators (WDI) for the study period.

4. RESEARCH METHODS

Following the latest research method by Acaravci and Ozturk (2010), Saboori and Sulaiman (2013), Sugiawan and Managi (2016), this study used the ARDL approach to cointegration developed by Pesaran et al. (2001) and the vector error correction model (VECM)-based Granger causality method to investigate the long-run and causal relationship between economic growth, CO_2 emissions and aggregate energy consumption in Indonesia during 1990-2016.

4.1. ARDL Test

The ARDL approach is chosen for this study to examine the long-run relationship between CO_2 emissions, economic growth and energy consumption in aggregate.The equation is specified as

$$LnE_t=\beta_0+\beta_1 LnY_t+\beta_2 LnY_t^2+\beta_3 LnEN_t+\varepsilon_t \quad (1)$$

where E is CO_2 emissions per capita, Y represents real per capita income, EN stands for energy use per capita and ε_t is an error term. Based on the EKC hypothesis, the sign of β1 is expected to be positive, while the negative sign is expected for $\beta 2$ with a significant level of significance. As for the energy consumption level variable, because higher energy consumption leads to greater economic activity and directly stimulates CO_2 emissions, then $\beta 3$ is expected to be positive.

Equation (1) shows a long-run relationship. To implement the ARDL cointegration approach into this model, first the short-run dynamics need to be added to the long-run. Short-run equation that corresponds to long-run equation (1) is written as equation (2)

$$\begin{aligned}\Delta lnE_t = {} & \alpha_0 + \sum_{k=1}\alpha 1_k \Delta lnE_{t-k} + \sum_{k=1}\alpha 2_k \Delta lnY_{t-k} + \\ & \sum_{k=1}\alpha 3\kappa \Delta ln(Y_{t-k})^2 + \sum_{k=1}\alpha 4_k \Delta lnEN_{t-k} + \\ & \phi_1 lnE_{t-1} + \phi_2 lnY_{t-1} + \phi_3 ln(Y_{t-1})^2 + \phi_4 lnEN_{t-1} + \varepsilon_t\end{aligned} \quad (2)$$

Next, the term lag in each equation is substituted by the lag value of ECT built with the same optimal lag number selected by AIC or SBC. ECT shows the speed of adjustment and shows how quickly the variable returns to long-run equilibrium and must have a statistically significant coefficient with a negative sign, then a cointegration relationship exists. The general ECM (Error Correction Model) of equation (2) is formulated as equation (3).

$$\begin{aligned}\Delta lnE_t = {} & \alpha_0 + \sum_{k=1}\alpha 1_k \Delta lnE_{t-k} + \sum_{k=1}\alpha 2_k \Delta lnY_{t-k} + \\ & \sum_{k=1}\alpha 3_k \Delta ln(Y_{t-k})^2 + \sum_{k=1}\alpha 4_k \Delta lnEN_{t-k} + \\ & \theta ECT_{t-1} + \varepsilon_t\end{aligned} \quad (3)$$

In the final step, to examine the suitability of the model several diagnostic tests such as the normality test for heteroscedasticity and autocorrelation are conducted. Furthermore, following Pesaran et al. (2001) Cumulative amount (CUSUM) and cumulative squared (CUSUMSQ) tests are conducted to test the stability of the long and short-run estimate.

4.2. VECM Granger Causality

Cointegration approach is employed to test whether there is a long-run relationship between variables. Meanwhile, to test the direction of causality between carbon emissions, economic growth and energy consumption, the VECM Granger test is conducted. Granger's approach (1969) based on the VECM answers the question whether x causes y or y to cause x. To find out the long-run relationship between variables in the model, the term Lagged Error Correction (ECTt - 1) is used as an indicator that can be obtained from Long-run cointegration relationships. Meanwhile, short-run causal relationships are detected through the F-statistics significance test and Wald test of the relevant coefficients. Criteria such as AIC and SBC to choose the appropriate lag length are employed in this study.

4. E5. MPIRICAL RESULTS

Unit root tests were conducted to find the stationarity of the data using the Augment Dickey-Fuller (ADF) test plus Phillips-Perron (PP) (1988). Table 1 summarizes the results of the ADF and PP unit root tests at the level I (0) and First Difference I (1) levels. The results show that all stationary variables at the First Difference I (1) level. This test results validate the use of the ARDL approach for cointegration. The optimal lag in this study was determined using AIC with the ARDL model (1, 1, 0, 3). This model was chosen because it has a smaller error compared to other ARDL models. Next, the cointegration test using Bounds Testing Cointegration is conducted. Table 2 summarizes the results of the cointegration test of the model used.

F-statistic value is 6.35, where the value is greater than I (0) and I (1) Critical Value Bounds, so it can be concluded that the research variable has cointegration in the long-run. After cointegration is identified, estimation is then carried out. Table 3 provides long-term estimation results based on the ARDL approach with diagnostic test results. The results show that EKC does not occur in Indonesia.

Variables of GDP per capita (Y), and per capita energy consumption (EN) have a linear effect on CO_2 emissions significantly which means every increase in GDP per capita and per capita energy consumption would actually increase CO_2 emissions as in the EKC hypothesis at an early stage. This result is in line with research by Saboori and Sulaiman (2013) stated that in 5 ASEAN countries including Indonesia only Singapore and Thailand support EKC hypothesis for the long-run. Ibrahiem (2016) also found that the EKC curve in Egypt in 1980-2010 was not proven neither for the short nor the long-run. Sasana and Aminata (2019) also found that the EKC hypothesis was not supported in Indonesia.

The underlying argument is in line with the phase of the EKC formation, where Indonesia is still categorized as a developing country. The EKC hypothesis explains that developing countries at an early stage will prioritize its economic development by increasing production and income as technology is still not intensively employed in the production process, which causes large pollution and waste (Dinda, 2004; Hasan et al., 2012).

The variable GDP per capita squared (Y^2) has a coefficient marked negative but not significant for alpha 5%. It can be concluded that the behavior of the variable GDP per capita and CO_2 emissions form an inverted U-shape curve with a turning point when Indonesia's per capita income reaches approximately 7.819 USD. This figure is not found in the sample year used. The previous sample (in 2016) of Indonesia's per capita income based on constant prices in 2010, which was 3,974 USD. This finding is consistent with the findings of Jalil and Mahmud (2009) who reported EKC turning points outside the observed sample period. Iwata et al. (2010) argue that the probability of finding a turning point outside the sample period observed in developing countries is higher than in developed countries. The findings of the turning point from EKC are also not much different from the findings of Sugiawan and Managi (2016) which show that EKC is proven in the long run with a GDP per capita turning point of USD 7.729. The diagnostic test results of serial correlation, normality and heteroscedasticity show residual normality, an absence of serial correlation and no heteroscedasticity.

Short-term estimates are presented in Table 4 along with diagnostic tests. The results show that the EKC hypothesis is also not valid in the short-run in Indonesia. This result is similar with that of Saboori and Sulaiman (2013) that EKC does not occur in Indonesia in the short-run. The posiible underlying reason is that EKC is a long-run phenomenon (Dinda, 2004). No evidence of EKC in the short-run is rational because CO_2 emissions are a form of global pollution that increases or decreases over a long period. EKC itself, until now, is not able to guarantee whether all pollution indicators follow the inverted U-shape hypothesis. This argument arises based on

Table 1: Results of unit root tests

Level	ADF test statistic		PP test statistic	
	Intercept	Trend and Intercept	Intercept	Trend and Intercept
LnE	−1.74588	−2.374355	−1.44913	−2.199589
LnY	0.050495	−1.284146	−0.059253	−1.516996
LnY^2	0.211249	−1.176677	0.086874	−1.40923
LnEN	−1.824849	−1.981066	−1.899589	−1.98706
First difference	ADF test statistic		PP test statistic	
	Intercept	Trend and Intercept	Intercept	Trend and Intercept
LnE	−6.878768***	−7.166992***	−6.878768***	−7.181506***
LnY	−3.68482**	−5.819191***	−3.659948**	−3.620007**
LnY^2	−3.6665**	−5.935508***	−3.643175**	−3.62597**
LnEN	−4.906168***	−5.17418***	−4.905578***	−5.188305***

***, ** and *indicate 1, 5 and 10 percent of significance, respectively. Optimal lag is automatically selected using Schwarz information criteria for the ADF test and the bandwidth used is Newey – West for the PP test. Source: Data processed, 2019 local pollution forming other greenhouse gases such as sulfur oxide, which follow an inverted U-shape (Paraskevopoulos, 2009).

$$ECM=EM-(0.0336*LNY-2.7287*LNY2-22.3007*EN-9.3020) \quad (4)$$

To check the short and long-run coefficient stability, CUSUM and CUSUMSQ techniques are used. Figure 3 presents plots of CUSUM and CUSUMSQ tests for all models (data processed, 2019). The results imply that the estimated parameters are stable during that period.

Table 2: Results of ARDL bound test

Test statistic	Value	k
F-statistic	6.351988	3
Critical value bounds		
Significance	**I0 Bound**	**I1 Bound**
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

Source: Data processed, 2019. ARDL: Autoregressive distributed lag

Table 3: Long run ARDL

Variable	Coefficient	Standard error	T-statistic	Prob.
LnY	5.125727	2.507838	2.226842	0.0398**
LnY^2	−0.304692	0.156668	−1.944830	0.0685*
LnEN	3.713972	0.258181	14.385125	0.0000***
C	−22.179499	9.960067	−2.043883	0.0568*
Diagnostic checks				
Normality (Jarque-Berra) *P* value				0.712219
Serial correlation (Breusch-Godfrey LM test) *P* value				0.2707
Heterocedasticity test				0.7189

Source: Data processed, 2019. ARDL: Autoregressive distributed lag

Table 4: Short run ARDL

Variable	Coefficient	Standard error	T-Statistic	Prob.
ΔlnY	4.771844	0.804717	5.929838	0.0000***
ΔLnY^2	0.759593	0.539634	−1.407607	0.1796
ΔLnEN	2.479125	0.292395	8.478674	0.0000***
C	−1.066177	0.182949	−5.827725	0.0000***
Diagnostic checks				
R^2			0.865609	
RSS			0.009066	
F statistic (P-value)			102.3961 (0.000209)	
SE of regression			0.021844	

Source : data processed, 2019

The long-run relationship between carbon emissions, economic growth and energy consumption shows that there must be at least one direction in Granger causality. The results of the causal relationship between variables using the VECM-based Granger causality test are summarized in Table 5.

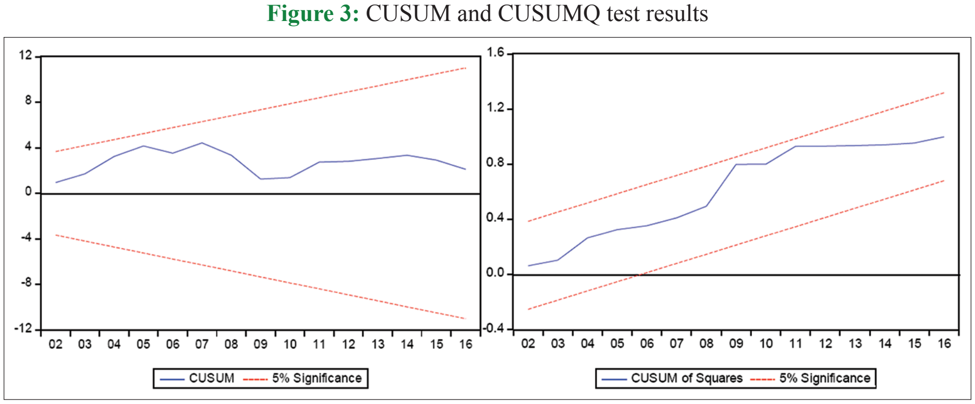
The long-run Granger causality test results show that there is a two-way Granger causality relationship between energy consumption and economic growth, CO2 emissions and energy consumption and CO_2 emissions and economic growth. This finding is in line with the results of Pao and Tsai (2011) in Brazil, Pao et al. (2011) in Russia, Al-Mulali (2011) in 15 countries in the Middle East and Northern Africa (Middle East North Africa), Saboori and Sulaiman (2013) in the Philippines, Indonesia and Malaysia, for a sample of 5 ASEAN countries, and Saboori and Sulaiman (2013) in Malaysia. This is proof that carbon emissions, energy consumption and economic growth are interrelated.

Meanwhile, the short-run Granger causality test shows that there is a two-way causality between energy consumption and carbon emissions. The greater the energy consumption carried out will lead to greater carbon emissions, and vice versa (Bashir et al., 2019). In addition there is also a one-way relationship between economic growth and carbon emissions and economic growth and energy consumption. This implies that reducing energy consumption in the short-run can reduce air pollution but disrupt or reduce economic growth. Furthermore, in the absence of short-run causality from economic growth and CO_2 emissions it also indicates that economic growth is not the right solution to reduce CO_2 emissions levels in the short-run.

6. CONCLUSION

1. The results of the study indicate that the EKC hypothesis statistically (α = 5%) did not occur in Indonesia for the study period. But the relationship behavior between variables supports the EKC hypothesis by forming an inverted U-shape and a turning point at the level of Indonesia's per capita income reaching USD 7.819

Figure 3: CUSUM and CUSUMQ test results



Source: Data processed, 2019

Table 5: VECM Granger causality

	Short-run Granger causality F-statistics (prob)			Long-run Granger causality
	ΔlnEm	ΔlnY	ΔLnEN	ECTt-1 (t-stats)
ΔlnE	-	3.264004 (0.0471)	19.96182 (0.0002)	−0.545446 (−2.024811)
ΔlnY	0.009961 (0.9215)	-	1.965333 (0.1676)	−0.255369 (−2.120787)
ΔlnEN	10.40429 (0.0004)	4.399914 (0.0269)	-	−0.376114 (−3.820590)

VECM: Vector error correction model. Source: Data processed, 2019

2. Empirical results show that energy consumption has a positive effect on CO_2 emissions in the long-run. Energy consumption also contributes to emissions in the short-run. This is reasonable, considering that Indonesia still relies on fossils energy sources. This means that diversification of energy sources is completely necessary.
3. Results in the short-run also indicate that the EKC hypothesis does not apply to Indonesia. This means that economic growth (without policy intervention) is not the right solution in reducing CO_2, both in the short and long-run
4. ECTt - 1 coefficient has a coefficient with a negative sign as is expected and statistically significant. It means that CO_2 emissions will decrease over the period in Indonesia. The CUSUM and CUSUMSQ test results show that the short and long-run models are stable.
5. The results of Granger's long-run causality show that there is a two-way causal relationship between economic growth and energy consumption, CO_2 emissions and economic growth, energy consumption and CO_2 emissions. This implies that any limiting policy related to energy consumption can reduce CO_2 emissions but at the same time will impede economic growth.
6. The results of short-run causality indicate the existence of two-way causality between energy consumption and carbon emissions. The greater the energy consumption, the greater carbon emissions will be, and vice versa. In addition, there is also a one-way relationship between economic growth and carbon emissions and economic growth and energy consumption.
7. The gap between current economic level and the EKC turning point estimate shows that the Indonesian Government must evaluate current energy consumption and environmental policies to get a lower and more even EKC. In addition, the current energy and environmental policies should also be accompanied by alternative strategies that make it possible to encourage more efficient use of energy.

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