Detection of Pseudo Economic Growth Towards Environmental Damage in Indonesia Using Error Correction Model

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Abstract. Economic growth is one of the indicators of economic development. The effort to increase economic growth doesn't pay attention to the environment be said the pseudo-economic growth. Using GDP per capita and CO₂ emissions as indicators of economic growth and environmental damage, this study aims to examine the relationship between them using the Environmental Kuznets Curve (EKC) framework. The EKC hypothesis proposes a turning point at a certain level of economic growth so that sustainable development can be achieved. This study attempts to estimate EKC in the case of Indonesia for the period 1965-2014 by considering the role of fossil energy consumption. The method of analysis used the Error Correction Mechanism (ECM). The result showed that Indonesia is at the early stage of EKC. It indicates that an increase in economic growth leads to an increase of CO₂ emissions and has not to reach a turning point. The type of fossil energy that has a positive and significant influence on CO₂ emissions is oil.

1. Introduction
Indonesia is one of the countries included in the lower-middle-income country category with GNI (Gross National Income) per capita of US $ 3,400 in 2016 [1]. In addition, together with other low and middle-income countries, Indonesia can also be categorized as a developing country. Characteristics of developing countries include lower living standards and productivity, lower levels of human morals, higher levels of inequality and absolute poverty and higher rates of population growth [2]. Based on data from BPS, the value of the Human Development Index (HDI) in Indonesia in 2017 amounted to 70.81 [3]. The number of poor people in September 2017 was 10.12 percent with a Gini coefficient of 0.391. From these data, it can be seen that the quality of Indonesian people life is classified as high but the poverty rate is still above 10 percent with the level of income inequality classified as moderate.

The problems of developing countries can be overcome by carrying out economic development in the country. Development in the viewpoint of economics is achieving a sustainable level of growth in per capita income so that the state can produce output that is greater than the rate of population growth. With the existence of economic development, it is hoped that people's living standards will increase, not only will their income increase but also the expansion of employment, improved educational facilities and greater attention to cultural and humanitarian values. This aside from improving living welfare materially, it also fosters individual and nation self-esteem [2]. Community with low economic status are expected to increase their accessibility of information related to the environment [4].
According to Tertzakian [5], an increase in welfare will lead to an increase in the consumption of energy. The development of technology and inventions such as electricity and motor vehicles has changed human life. This provides benefits to the community by providing comfort, increasing efficiency, and increasing productivity. According to Agency for the Assessment and Application of Technology Indonesia [6], final energy consumption always increases every year in the period 2000-2014, except in 2005 and 2006 with an average annual growth rate of 3.99 percent. In 2005 and 2006 there was a decrease in final energy consumption due to the increase in fuel prices. The highest final energy consumption in this period occurred in the industrial sector, followed by households and transportation.

Using Energy will have an impact on the environment. Based on the Intergovernmental Panel on Climate Change IPCC report in 2013 [7], the concentration of carbon dioxide (CO₂), methane (CH₄), and nitrogen dioxide (NO₂) in the atmosphere increased to a level that had never happened since 800,000 years ago. The concentration of carbon dioxide alone has increased by 40 percent since the pre-industrial era. This increase was mainly due to fossil energy burning and deforestation.

As an archipelago with more than 17,000 islands and most of the provincial capitals and 65% of the population living in coastal areas, Indonesia is vulnerable to climate change. The increase in temperature of the earth's surface will cause an increase in sea level. This has an impact on land narrowing and damage to coastal ecosystems. In addition, it will also have an impact on the welfare of coastal communities due to loss or change of livelihoods Ministry of Environment and Forestry [8].

However, economic development is not always detrimental to the environment. Panayatou [9] states that in the initial stages of development the level of environmental damage is relatively low due to the nature of the subsistence economy. Along with the increasing exploitation of natural resources and the growth of the industrial sector causing depletion of natural resources and increasing waste generated by the economy. Up to a higher level of development, there have been improvements in environmental quality due to more efficient technology and demand for improved environmental quality.

Based on this explanation, this study aims to describe the environmental conditions, economic growth and primary energy consumption derived from fossils in Indonesia. In addition, this study also wants to see the pattern of the relationship between economic growth and environmental damage and the influence of each fossil energy on environmental damage in Indonesia.

There are several previous studies related to the relationship between economic growth and environmental damage, one of which is research conducted by Saboori, Sulaiman and Mohd [10]. The study included other factors, namely energy consumption and degree of openness using the Autoregressive Distributed Lag (ARDL) method. The study produced a negative coefficient for economic growth and a positive coefficient for the square of economic growth. This shows that at the beginning of economic growth, carbon dioxide emissions decreased to a turning point and then increased along with higher levels of economic growth. The results of the study do not support the EKC hypothesis in Indonesia. In addition, Saputri and Budiasih [11] also conducted a study of the EKC hypothesis in Indonesia from 1971 to 2015 and focused the research on the relationship of per capita income, coal, petroleum and the degree of openness to environmental degradation. The research uses carbon dioxide and methane emissions as indicators of environmental degradation. The results of the study indicate that the hypothesis applies to carbon dioxide but does not apply to methane.

2. Methodology

2.1. Environmental Kuznets Curve

Hussen [12] states that one result of economic growth is an increase in real income per capita. Higher per capita income will increase demand for improving the environmental quality. This indicates an increase in expenditure for environmental improvement efforts. Thus, it is possible that economic growth has more benefits than losses.

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The relationship between economic growth and environmental quality can be described as an 'inverted U' curve. The curve shows that an increase in per capita income was initially followed by deteriorating environmental quality to a certain point, but then followed by an increase in environmental quality. This shows that a country must achieve a certain standard of living before realizing the importance of improving environmental quality. The 'inverted U' curve is sometimes referred to as Environmental Kuznets Curve (EKC) because of its similarity with the relationship between per capita income and income inequality formulated by Simon Kuznets in 1955 [13].

2.2. The Error Correction Mechanism Methods

This study uses the dependent variable, namely carbon dioxide (CO$_2$) emissions. According to the United Nations Framework Convention on Climate Change (UNFCCC), carbon dioxide (CO$_2$) is the largest contributor to greenhouse gases that cause global warming. These variables are used in this study to represent environmental damage. While the independent variables used are per capita income, the square of per capita income and fossil energy consumption which includes coal, petroleum, and natural gas. This study uses secondary data obtained from several sources. Data for variables of carbon dioxide (CO$_2$) emissions and per capita income are obtained from the World Development Indicators. While data for fossil energy consumption variables (coal, petroleum, and natural gas) are obtained from the Statistical Statistical of World Energy BP [14]. The data used in this study is Indonesia's annual data from 1965 - 2014 (50 observations).

This study uses descriptive analysis and inferential analysis. Descriptive analysis used in the form of graphs while inferential analysis uses the Error Correction Mechanism (ECM) methods. The method allows the analysis of time series data that is not stationary at the level but stationary at the same level of integration. The stages of forming the ECM model are as follows [15]: (1). Test the stationarity of each variable: Stationary testing on time series data needs to be done. If the data used is not stationary it will produce spurious regression. The data stationarity test used in this study is the Augmented Dickey Fuller (ADF) test. If the data is not stationary at the level then stationarity testing is carried out at a higher level of integration; (2). Establish long-term equations. Long-term equations are obtained by applying regression with the OLS estimation method using data levels that are not stationary.

$$\ln(CO_2_t) = \beta_0 + \beta_1 \ln(GDP_t) + \beta_2 (\ln(GDP_t)^2) + \beta_3 \ln(coal_t) + \beta_4 \ln(petroleum_t) + \beta_5 \ln(gas_t) + u_t$$

Equation (1) involves the value of GDP per capita and the square of GDP per capita to estimate EKC. The model provides several possible relationships between GDP per capita and carbon dioxide emissions. When there is no relationship between the two variables. Linear relationships occur when and for monotonous relationships that increase or for decreased monotonous relationships. A squared relationship occurs when or. If there is a quadratic relationship, the value of the turning point can be calculated using a formula:

$$\ln GDP = -\frac{\beta_1}{2\beta_2} \text{ or } GDP = e^{-\frac{\beta_1}{2\beta_2}}$$
Test the existence of cointegration: The co-integration test used in this study is Engle-Granger (EG) and Augmented Engle-Granger (AEG) test. The procedure is by testing the residual stationary in the long-term equation.

Form the ECM equation (short term equation): To form a short-term equation, the data that is stationary is used is the same difference by including a lag of error correction term. The coefficient of the error correction lag term will then show how fast the balance will be achieved. The sign of the coefficient is expected to be negative and significant. The following is the ECM model that will be formed:

$$\Delta \ln CO_2 = \alpha_0 + \alpha_1 \Delta \ln GDP + \alpha_2 \Delta (\ln GDP)^2 + \alpha_3 \Delta \ln coal + \alpha_4 \Delta \ln petroleum + \alpha_5 \Delta \ln gas + \alpha_6 u_{t-1} + \varepsilon_t$$  (2)

Description:  
- $u_{t-1}$ : lag from error correction term
- $\alpha_i$ : coefficient of short-term equations
- $\varepsilon_t$ : white noise error term

Test classic assumptions about short-term equations are done to find out whether short-term equations have met the assumptions of normality, non-multicollinearity, homoskedasticity, and non-autocorrelation. The assumption of normality was tested using the Jarque-Bera test, the assumption of non-multicollinearity was tested using Variance Inflation Factors (VIF), assuming homoskedasticity was tested using the Breusch-Pagan-Godfrey test while non-autocorrelation assumptions were tested using the Lagrange Multiplier (LM) Test.

3. Result and Discussion

3.1. Overview of Carbon Dioxide (CO₂) Emissions in Indonesia in 1965 - 2014:
The level of CO₂ emissions in Indonesia tends to increase from year to year. This can be seen from Figure 1, the level of CO₂ emissions had experienced a significant decline in 1998. This was probably due to the monetary crisis that crippled the Indonesian economy that year. In addition, the emission level also increased significantly, namely from 2010 to 2012. This is in line with the increasing level of global CO₂ emissions, where the average annual increase from 2011 to 2012 is greater than the average growth rate over the past decade [16].

![Figure 1. CO₂ emissions per capita in Indonesia in 1965-2014. Source: World Development Indicators](image-url)
3.2. Overview of Economic Development in Indonesia in 1965-2014:
Based on Figure 2, it can be seen that GDP per capita tends to increase. From year to year. A significant decline had occurred in 1997 amounting to 2433.34 US $ to 2084.23 US $ in 1998. The decline in the value of GDP per capita in 1998 was inseparable from the monetary crisis that hit Indonesia. The crisis began with economic turmoil in Thailand until the beginning of July 1997 the country floated the value of its currency, the Baht. This causes capital out in congregation in Asia, resulting in currency exchange rates in the region shaking including the rupiah [17].

![Figure 2. Gross Domestic Product (GDP) per capita in Indonesia in 1965-2014. Source: World Development Indicators](image)

3.3. Overview of Coal Production and Consumption in Indonesia in 1965-2014:
Based on Figure 3 above, it can be seen that coal production and consumption tends to increase from year to year. But the growth of coal production is greater when compared to coal consumption. This shows a wide gap between production produced and consumed. According to Bappenas [18] in the period 2000 to 2009, the value of coal production experienced an increase accompanied by an increase in coal exports. The increase was caused by rising coal prices. From 2000 to 2009 there was a commodity price boom or an explosion in commodity prices caused by increasing demand from developing countries such as China, India, and Taiwan. Increasing coal prices and coal demand has resulted in coal mining companies increasing production capacity. In response to export demand, the majority of the allocation from Indonesia's coal production is aimed at exports to coal consumer countries such as China, India, Japan, Korea, Taiwan, and others.

3.4. Overview of Petroleum Production and Consumption in Indonesia in 1965-2014
Based on Figure 4 it can be seen that petroleum production fluctuates from year to year but tends to decline in recent years. On the other hand, petroleum consumption tends to increase from year to year although there has been a decline in the last decade due to the increase in fuel prices in 2005 and 2008. During the period 1965-2003 domestic oil consumption needs could still be met with domestic production. However, since 2004 the value of domestic production has been unable to meet domestic needs, making Indonesia an importer of oil since then. According to BPPT [6], the decline in petroleum production is due to the fact that oil refineries in Indonesia are currently on average an old oil refinery so that oil production is also limited. Since 1994, there has been no construction of new refineries so that the production of fuel is limited, making dependence on imports even greater.
Figure 3. Coal production and consumption in Indonesia in 1965-2014. Source: BP Statistical Review of World Energy 2017.

Figure 4. Petroleum production and consumption in Indonesia in 1965-2014. Source: BP Statistical Review of World Energy 2017

3.5. Overview of Natural Gas Production and Consumption in Indonesia in 1965-2014

Based on Figure 5, it can be seen that the production and consumption of natural gas tend to increase from year to year. The value of natural gas production exceeds the value of domestic consumption. The average natural gas consumed domestically per year during 2003-2014 was 51.18 percent. This indicates that around 48.82 percent or almost half of the production of natural gas produced is exported abroad.

The domestic market is only able to absorb half of the natural gas production due to limited infrastructure. Natural gas is channeled to various consumer sectors such as industry, households, and transportation through a transmission and distribution pipeline network. However, many sectors have not been reached because of the location that spreads and is far from the pipelines that have been built, while the investment in the construction of natural gas pipelines is very high [14].
3.6. Proof of the Environmental Kuznets Curve (EKC) Hypothesis

The data used in this study is time series data. Most of the time series data are not stationary so that the resulting regression analysis using the data is spurious. Stationarity testing used in this study is the Augmented Dickey-Fuller test.

Based on the ADF test the results can be seen in Table 1, it can be seen that the data used in this study are not all stationary at the level. This is indicated by the p-value that exceeds the significance level of 5 percent both in tests involving constants and tests involving constants and trends. Further testing at a higher level of integration, namely at the first level of integration indicates that the data is stationary. This is indicated by the p-value at the first integration level which is less than the 5 percent significance level in tests involving constants and trends.

From stationarity testing, it can be concluded that integrated data at the same level of integration is at the first level of integration or can be denoted as I (1).

Furthermore, long-term equations based on the estimation results in Table 2 can be formed using data levels.

\[
\ln CO_2 = 5.0960 - 2.5890 \ln GDP + 0.2228 (\ln GDP)^2 - 0.0799 \ln coal + 0.4624 \ln petroleum + 0.0787 \ln gas
\]

(3)

Description: *) significant at the 5 percent significance level

Equation (3) shows that the coefficient of GDP per capita is negative while the coefficient of the square of GDP per capita is positive. This pattern is similar to the research conducted by Saboori [10] in Indonesia using the Autoregressive Distributed Lag (ARDL) method. Equation (3) itself has a turning point at the level of GDP per capita of 333.6525 US $. The turning point value is outside of the research period used in this study, precisely before 1965. This shows that in the period used in this study, Indonesia is in the stage of increasing carbon dioxide along with the increase in GDP per capita or in other words at the initial stage of the EKC curve. Graphs that illustrate the relationship can be seen in Figure 6.

Figure 5. Natural gas production and consumption in Indonesia in 1965-2014. Source: BP Statistical Review of World Energy 2017
| Variables      | ADF Test |   |   |
|---------------|----------|---|---|
|               | Constant | (1) | (2) | (3) |
| **Level**     |          |    |    |    |
| ln CO₂        | 0.5390   | 0.1668 |
| ln GDP        | 0.8903   | 0.3802 |
| (ln GDP)^2    | 0.9565   | 0.2827 |
| ln coal       | 0.9567   | 0.4717 |
| ln petroleum  | 0.3555   | 0.9909 |
| ln gas        | 0.0529   | 0.9898 |
| **First Difference** |          |    |    |    |
| ln CO₂        | 0.0000*  | 0.0000* |
| ln GDP        | 0.0000*  | 0.0003* |
| (ln GDP)^2    | 0.0000*  | 0.0004* |
| ln coal       | 0.0000*  | 0.0003* |
| ln petroleum  | 0.0000*  | 0.0000* |
| ln gas        | 0.6918   | 0.0012* |

Description: * ) significance level \( \alpha = 5\% \)

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**Table 2.** The results of long-term equations estimation

| Variable   | Coefficient  | Std. Error | t-Statistic | Prob. |
|------------|--------------|------------|-------------|-------|
| C          | 5.095998     | 7.901105   | 0.644973    | 0.5223|
| LN_GDP     | -2.589013    | 2.073526   | -1.248604   | 0.2184|
| (LN_GDP)^2 | 0.222769     | 0.130013   | 1.713443    | 0.0937|
| LN_COAL    | -0.079906    | 0.023184   | -3.446645   | 0.0013|
| LN_PETROL  | 0.462439     | 0.161575   | 2.862069    | 0.0064|
| LN_GAS     | 0.078736     | 0.064551   | 1.219749    | 0.2291|

|                  |              | Mean dependent var | -0.195996 |
| Adjusted R-squared | 0.982947   | S.D. dependent var | 0.658662 |
| S.E. of regression | 0.086013    | Akaike info criterion | -1.956463 |
| Sum squared resid | 0.325525    | Schwarz criterion  | -1.727020 |
| Log-likelihood    | 54.91156    | Hannan-Quinn criter. | -1.869089 |
| F-statistic       | 565.8718    | Durbin-Watson stat  | 1.008325 |
| Prob(F-statistic) | 0.000000    |                      |          |

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3.7. Cointegration Test

Table 3 shows that error correction terms are generated from stationary long-term equations at the level.

Table 3. Cointegration test results

| Null Hypothesis: ECT has a unit root | Exogenous: None | Lag Length: 1 (Automatic - based on SIC, maxlag=10) |
|-------------------------------------|----------------|------------------------------------------------------|
| Augmented Dickey-Fuller test statistic | -4.845018 | 0.0000 |
| Test critical values: | | |
| 1% level | -2.614029 |
| 5% level | -1.947816 |
| 10% level | -1.612492 |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

| Dependent Variable: D(ECT) |
|----------------------------|
| Method: Least Squares |
| Sample (adjusted): 1967 2014 |
| Included observations: 48 after adjustments |

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|----------|-------------|------------|-------------|-------|
| ECT(-1)  | -0.773069   | 0.159560   | -4.845018   | 0.0000 |
| D(ECT(-1)) | 0.435724 | 0.147956 | 2.944955 | 0.0051 |

R-squared 0.337415 Mean dependent var -0.003550
Adjusted R-squared 0.323011 S.D. dependent var 0.083184
S.E. of regression 0.068444 Akaike info criterion -2.484841
Sum squared resid 0.215488 Schwarz criterion -2.406874
Log-likelihood 61.63618 Hannan-Quinn criter. -2.455377
Durbin-Watson stat 1.935931

Figure 6. CO₂ emissions prediction per capita based on observations
This shows the existence of cointegration between variables. The existence of cointegration indicates the existence of a long-term or equilibrium relationship between variables. Furthermore, short-term equations can be formed using data that is stationary at I (1). Table 4 shows a short-term equation based on the estimation results in Attachment 3.

**Table 4. Results of short-term equations estimation**

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|----------|-------------|------------|-------------|-------|
| C        | -0.036034   | 0.017602   | -2.047203   | 0.0469|
| D(LN_GDP)| -2.028741   | 4.067824   | -0.498729   | 0.6206|
| D((LN_GDP)^2) | 0.204242   | 0.265055   | 0.770563    | 0.4453|
| D(LN_COAL) | -0.007679  | 0.044573   | -0.172285   | 0.8640|
| D(LN_PETROL) | 0.775045   | 0.242677   | 3.193733    | 0.0027|
| D(LN_GAS)  | 0.073038    | 0.056935   | 1.282840    | 0.2066|
| ECT(-1)    | -0.539604   | 0.145830   | -3.700235   | 0.0006|

The coefficient of the error-correction term has the expected sign which is negative and significant at the 5 percent significance level. The error-correction coefficient value of -0.5396 shows that around 53.96 percent of the imbalance in the previous year will be corrected this year while the rest will be corrected the following year.

\[
\Delta \ln \text{CO}_2 = -0.0360 - 2.0287 \Delta \ln \text{GDP} + 0.2042 \Delta (\ln \text{GDP})^2 - 0.0077 \Delta \ln \text{coal} + 0.7750* \Delta \ln \text{petroleum} + 0.0730 \Delta \ln \text{gas} - 0.5396* u_{t-1}
\]  

(4)

Description: *) significant at the 5 percent significance level

Based on the classic assumption test that has been done with the results listed in Figure 7, Table 5, Table 6 and Table 7 it can be concluded that short-term equations have met the assumptions of normality, non-multicollinearity, homoskedasticity, and non-autocorrelation.

Carbon dioxide emissions per capita and the value of GDP per capita in Indonesia tend to increase from 1965-2014, and in the period 1965-2014, Indonesia was at the initial stage of the EKC curve, which along with the increase in GDP per capita would increase CO₂ emissions. On the other hand, descriptively implied that be known the effect of fossil energy consumption on CO₂ emissions in Indonesia. Consumption and production of coal and natural gas tends to increase from 1965-2014. During this period the production of both types of fossil energy is able to meet domestic consumption needs.
Figure 7. Normality of short-term equations assumption test

Table 5. Non-multicollinearity of short-term equations assumption test

| Variable       | Coefficient Variance | Uncentered VIF | Centered VIF |
|----------------|----------------------|----------------|--------------|
| C              | 0.000310             | 2.850099       | NA           |
| D(LN_GDP)      | 16.54719             | 350.9109       | 164.7004     |
| D((LN_GDP)^2)  | 0.070254             | 329.8843       | 158.7071     |
| D(LN_COAL)     | 0.001987             | 1.348104       | 1.086951     |
| D(LN_PETROL)   | 0.058892             | 2.959456       | 1.538588     |
| D(LN_GAS)      | 0.003242             | 1.353630       | 1.112836     |
| ECT(-1)        | 0.021266             | 1.070874       | 1.066205     |

Table 6. Homoskedasticity of short-term equations assumption test

| Heteroskedasticity Test: Breusch-Pagan-Godfrey |
|-----------------------------------------------|
| F-statistic                                   | 2.088112 | Prob. F(6,42) | 0.0750   |
| Obs*R-squared                                 | 11.25839 | Prob. Chi-Square(6) | 0.0807 |
| Scaled explained SS                           | 11.53328 | Prob. Chi-Square(6) | 0.0732 |

Table 7. non-autocorrelation of short-term equations assumption test

| Breusch-Godfrey Serial Correlation LM Test: |
|--------------------------------------------|
| F-statistic                                | 4.034749 | Prob. F(1,41) | 0.0512   |
| Obs*R-squared                              | 4.390003 | Prob. Chi-Square(1) | 0.0362 |

Petroleum consumption tends to increase while oil production fluctuates but tends to decline in recent years. Since 2004 the value of consumption has exceeded production which has resulted in making Indonesia a petroleum importer country. Fossil energy has a positive and significant influence only on petroleum with a coefficient of 0.775. That is, at the 5 percent significance level and other constant
variables (ceteris paribus), the increase in oil consumption growth by 1 percent will increase CO$_2$ emissions growth by 0.775 percent.

Consumption of coal and natural gas is not significant at the 5 percent significance level with the respective negative and positive coefficients. This can be caused because the contribution of the two types of fossil energy to the national primary energy mix is relatively lower when compared to petroleum. According to the ESDM [14], the most dominant fossil energy is petroleum with a percentage of 47 percent. Followed by coal and natural gas each at 24 percent. The rest is new and renewable energy. Of the three types of fossil energy used in Indonesia, petroleum is an energy source that has a significant impact on the increase in CO$_2$ emissions in Indonesia.

4. Conclusion
Energy efficiency needs to be done through technology development and starting to increase the contribution of renewable energy in the national energy mix. Development of mass transportation needs to be maximized to reduce the number of motorized vehicles that consume a lot of energy, mainly derived from refined petroleum. Implement environmentally sound development strategies by developing environmentally friendly products, tightening business licenses based on the exploitation of natural resources, incorporating the costs of environmental improvements to the products produced and consequent law enforcement in cases of environmental destruction.

For further research can be added to other independent variables that are thought to affect environmental damage such as population and number of motorized vehicles and use indicators of environmental damage other than carbon dioxide (CO$_2$) such as deforestation.

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