Renewable Energy Consumption, CO2 Emissions and Economic Growth in Indonesia

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Abstract: This paper aims to examine the causation between renewable energy consumption, CO2 emissions and economic growth in Indonesia using time series data from 2000 to 2016. Economic growth and renewable energy consumption are endogenous variables, while CO2 emissions, and world oil prices as variables exogenous. Johansen co-integration, Granger's causality, and VAR model are used to measure the causalities effects of renewable energy consumption, CO2 emissions and economic growth. The results show that There is no one or two-way causality relationship between economic growth and consumption of renewable energy and CO2 emissions. There is one-way causality between renewable energy consumption and CO2 emissions but not vice versa, and there is no one or two-way causality between renewable energy consumption and world oil prices.

1 INTRODUCTION

Indonesia is faced with the energy crisis of fossil fuel and the national energy supply crisis. The depletion of petroleum reserves and increasing public awareness of environmental conservation becoming opportunities for renewable energy development in Indonesia. According to Agency for The Assessment and Application of Technology, in 2014, petroleum reserves of 3.6 billion barrels, natural gas of 100.3 TCF and coal reserves of 32.27 billion tons. Assuming if no new reserves are found, based on the R/P ratio (Reserve/Production) of 2014, the petroleum will be exhausted in 12 years, natural gas in 37 years, and coal in 70 years (Agency for The Assessment and Application of Technology, 2016). To overcome this problem, the concept of renewable energy as antithetical to the use of fossil energy should be encouraged. Indonesian Government has issued a series of policies in the field of development of renewable energy sources since the beginning of 2006 that is in Presidential Regulation Number 5 of 2006 on National Energy Policy. Renewable energy is believed to be more environmentally friendly, safe and also affordable by the community and quite a number of renewable energy sources that are feasible to be developed to meet energy needs, especially in Indonesia that includes water energy, geothermal, biofuels, waste/biomass, solar, and wind. Final energy consumption by type during the year 2000-2014 is still dominated by fuel (gasoline, solar oil, diesel oil, kerosene, fuel oil, avtur, and gas).

Furthermore, the consumption of renewable energy and economic growth have a very close relationship and a very decisive policy that must be taken. Al-Mulali et al. (2013) had proved mixed results regarding the long-term bi-directional relationship between renewable energy consumption and GDP growth in both upper-middle income, lower middle income and high-income countries. So (2014) stated that one of the factors affecting the failure of the implementation of energy conservation policy was the factor of economic growth. On the contrary, Dogan and Ozgur (2015) stated that renewable energy consumption could explain the role of renewable energy in stimulating economic growth. In Indonesia, many have researched on energy consumption such as Suryanto (2013) which examined the relationship between economic growth and electricity consumption in Indonesia. The result is no long-term relationship between economic growth and energy consumption. Susanto and Laksana (2013) also stated that energy consumption had no effect on economic growth, even energy supply was not an inhibiting factor for economic growth.

Another problem that also needs to get serious attention is about CO2 emissions in Indonesia. Hwang and Yoo (2014) in his research in Indonesia, stated the existence of energy conservation and/or CO2 emissions reduction policies could be initiated without the consequent destructive economic side

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effects. The occurrence of environmental degradation in the world especially in Indonesia becomes an important issue, given the increasing number of protests against environmental damage. The level of world dependency including Indonesia in fossil fuels has a serious impact on the environment. Carbon dioxide (CO2) emissions from fossil fuels are a major cause of global warming (Ozturk and Acaravci, 2010). Wang, Fang, and Zhou (2016) showed a two-way causal relationship between economic growth and energy consumption, and a direct causal relationship between energy consumption and CO2 emissions. Apergis and Payne (2011) and Apergis & Danuletiu (2014) showed a two-way causal relationship between renewable energy consumption and short-term and long-term economic growth.

Various empirical studies have been conducted and show varying results due to differences in study objects, research periods, and methods of analysis used by researchers, and for variable consumption of renewable energy is still rarely used as research variables in particular. Also, this study has added world oil price variable as an exogenous variable to investigate whether the world oil price has a significant impact on the consumption of renewable energy or even a direct effect on economic growth. Based on that statements, researchers want to test the causality relationship between renewable energy consumption, CO2 emissions, and economic growth. As renewable energy policies continue to be encouraged and there are several energy issues in Indonesia, the authors are interested in conducting similar studies with cases that focus on Indonesia.

2 LITERATURE REVIEW

One hypothesis that can explain the relationship between economic growth and energy consumption is a growth hypothesis that shows that energy consumption is an important component in the process of economic growth either directly or as a complement of capital and labor as input production factors. This growth hypothesis is supported if there is unidirectional causality from energy consumption to economic growth. This means that the decline in energy consumption will cause a decline in real Gross Domestic Product, energy conservation policy will have a negative impact on economic growth (Belke et al., 2010; Jumbe, 2004)

Most previous studies employed the same methodology to investigate the relationship between Renewable Energy Consumption, CO2 Emissions, and Economic Growth. Hwang and Yoo (2014) examined the causality relationship between energy consumption, CO2 emissions, and economic growth using annual data for the period 1965-2006. The results show that there is a bi-directional causal relationship between energy consumption and CO2 emissions, meaning that an increase in energy consumption directly affects CO2 emissions and that CO2 emissions also stimulate further energy consumption. Also, the results show unidirectional causality from economic growth to energy consumption and CO2 emissions without feedback effects.

Pao & Fu (2013), to explore the causal relationships between the real Gross Domestic Product and four types of energy consumption (NHREC), total renewable energy consumption (TREC), non-renewable energy consumption (NREC) and the total primary energy consumption (TEC). The results of the vector error correction model reveal a two-way causal relationship between economic growth and TREC. These findings suggest that Brazil is an energy-independent economy and that economic growth is crucial in providing the necessary resources for sustainable development.

Lin & Moubarak (2014), examined the relationship between renewable energy consumption and economic growth in China for the period 1977-2011. The results show that there is a bi-directional long-term causality of Granger between renewable energy consumption and economic growth, that economic growth in China is favorable for the development of renewable energy sector which in turn helps to promote economic growth. Short run causality between CO2 and renewable energy consumption.

Alper & Oguz (2016) investigated the causality between economic growth, renewable energy consumption, capital, and labor for new EU member stated for the 1990-2009 period. The results support that renewable energy consumption has a positive impact on economic growth for all countries investigated and the fact that there is a causal relationship between economic growth to renewable energy consumption.

The results of the relationship between energy consumption, CO2 emissions, and economic growth are slightly different in developed countries and developing countries. Alshehry and Belloumi (2015), investigated the dynamic causal relationship between energy consumption, energy prices and economic activity in Saudi Arabia with Johansen's multivariate cointegration approach. The results show that there is a long-term relationship between energy consumption, energy prices, CO2 emissions, and economic growth. Furthermore, long-term causalities originate from energy consumption to economic growth and CO2 emissions, two-way causality between CO2 emissions and economic growth, and in the long run, there is a relationship of causality in the direction of energy prices to economic growth and CO2 emissions. In the short run, there is a causal relationship of CO2 emissions to energy consumption and economic output and from energy prices to CO2 emissions.

Sow and Wolde-Rufael (2010) explored the causal relationship between CO2 emissions, renewable and nuclear energy consumption and real Gross Domestic Product for the US for the period 1960-2007. The findings indicate a direct causal relationship from the consumption of nuclear energy to CO2 emissions. That nuclear energy consumption can help reduce CO2 emissions, but so far, the consumption of renewable energy has not reached the level at which it can contribute significantly to emissions reductions.

Shahbaz, et al. (2013) examined the linkages between economic growth, energy consumption, financial development, trade openness, and CO2 emissions during the period 1975Q1-2011Q4 in Indonesia. The empirical findings show that economic growth and energy consumption increase CO2 emissions. The VECM causality analysis has demonstrated a feedback hypothesis between energy consumption and CO2 emissions.

Saboori and Mohd (2012) tested the long-term and short-term causality relationship between economic growth and carbon dioxide (CO2) emissions for Malaysia with data from 1980 to 2009. The empirical results indicate a long-term relationship between CO2 emissions per capita and Gross Domestic Product per capita real. Granger Causality Test based on the Vector Error Correction Model (VECM) shows no causality between CO2 emissions and economic growth in the short term, and there is unidirectional causality between economic growth and long-term CO2 emissions.

Neitzel (2017) examining renewable energy and economic growth from 22 OECD Countries. Granger's Causality test results show a two-way causal relationship between economic growth and renewable energy.

3 METHODOLOGY

This study applies empirical analysis and focuses on some variables such as GDP is Gross National Product Real (at constant 2010 prices), RE is the consumption of renewable energy (in a million kWh or GWh), CO2 is carbon dioxide emissions (per capita metric ton), P is the world oil price. The type of data of this research is secondary data that is time-series data in period 2000-2016. Data sources are obtained from The World Development Indicators (WDI) compiled by the World Bank.

Researchers used a system of simultaneous equations to find out various socioeconomic elasticities. Referring to previous literature such as Omri (2013) and Taghavee, Aloo & Shirazi (2016), Menyah & Wolde-Rufael (2010); Apergis and Payne (2012); Omri (2013), then there are two similarities in which economic growth and renewable energy consumption are endogenous variables, while CO2 emissions and world oil prices as predetermined variables are exogenous. The equation model is as follows:

$$\text{Ln GDP}_t = \beta_{01} + \beta_{11}\text{LnRE}_t + \gamma_{11}\text{LnCO2}_t + \varepsilon_{1t} \quad (1)$$

$$\text{Ln RE}_t = \beta_{02} + \beta_{12}\text{LnGDP}_t + \gamma_{12}\text{LnCO2}_t + \gamma_{22}\text{LnP}_t + \varepsilon_{2t} \quad (2)$$

Where:
GDP is the Real Gross Domestic Product Representing Economic Growth
RE is the Renewable Energy Consumption
CO2 is the Carbon Dioxide Emissions
P is the World Oil Price

4 DATA ANALYSIS AND RESULTS

Table 1 that the highest standard deviation of economic growth (LNGDP) and renewable energy consumption (LnRE) is the lowest. Jarque-Bera statistics show that all variables used in the analysis have a normal log distribution. Summary statistics of the variables are presented in Table 1.

Table 1: Descriptive Statistical Analysis

	LnGDP	LnRE	LnCO	LnP
Mean	14.861	3.706	0.534	4.066
Median	14.548	3.697	0.567	4.101
Maximum	16.333	3.819	0.879	4.605
Minimum	12.894	3.639	0.219	3.398
Std. Dev.	1.053	0.058	0.185	0.415
Skewness	-0.339	0.677	0.220	- 0.300
Kurtosis	2.203	2.179	2.216	1.672
Jarque-Bera	0.776	1.778	0.573	1.504
Observations	17	17	17	17

4.1 Stationary Test

The first stage in testing cointegration is to test to determine the existence of stationary on the data. The method used in this stationary test is the Unit Root Test or Augmented Dickey-Fuller (ADF) Test. The value of the test results with Augmented Dickey-Fuller Test (ADF) is shown by the statistical value of t on the observed variable regression coefficient (X). If the ADF value is greater than the test value of MacKinnon's critical values at Level 1%, 5%, or 10%, then the data is stationary. Table 2 below is the result of Stationeries test.

Table 2: Stationery Test Results

Variables	ADF test At level	ADF test At First Difference	Information	Lag Length
LnRE	-3.982 (0.010) *	-3.6470 (0.017) *	Stationer 1st Difference	2
$LnCO_2$	-0.1.693 (0.415)	-3.962 (0.010) *	Stationer 1st Difference	2
LnGDP	-1.371 (0.569)	-4.286 (0.005) *	Stationer 1st Difference	2
LnP	-1.782 (0.374)	-4.594 (0.003) *	Stationer 1st Difference	2

Note
* shows the level of significance and value of Critical Value of 1%, 5%, 10%
Source: Author‟s calculation

Of the four test stationeries on four variables of renewable energy consumption, CO2 emissions, economic growth and world oil prices where one variable is the consumption of renewable energy was already stationary at the level while the other three variables stationary on the first different. Thus, the next use VAR analysis (Vector Auto Regression) by using difference data (VAR in first difference). The unique order of integration shows that the cointegration tests can be investigated. But it is necessary to first find the maximum lag length. The results for the selection order criteria are illustrated in Table 2. Table 2 shows that the optimal lag length of p*=2 is chosen.

4.2 Co-integration Test Using Johansen-Juselius Technique

In this study, the cointegration test was conducted through Johansen Cointegration Test with optimal lag = 2, according to the SC-based determination previously performed. If the trace statistic value is greater than the critical value, then the equation is cointegrated. Co-integration test is used in this study to examine the short run and long run relationship between all variables. Based on the results of the cointegration test with Johansen's Cointegration Test method for the three equations can be seen in the following explanation:

Table 3: Cointegration Test

(Series: LnRE LnGDP LnCO2 LnP) Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.**
At most 1 *	0.820	45.362	35.010	0.002
At most 2 *	0.690	19.623	18.397	0.033
At most 3	0.126	2.023	3.841	0.154
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob.**
None *	0.981	59.463	30.815	0.000
At most 1 *	0.820	25.739	24.252	0.031
At most 2 *	0.690	17.599	17.147	0.043
At most 3	0.126	2.023	3.841	0.154

Note: * denotes rejection of the hypothesis at the 0.05 level and **MacKinnon-Haug-Michelis (1999) p-values
Source: Author‟s calculation

Table 3 shows the value of trace statistic> critical value, as well as the max eigenvalue statistic value> critical value, this means that there is a long-term relationship between renewable energy consumption, CO2 emissions, world oil prices and economic growth in Indonesia. In any short-term period, renewable energy consumption, CO2 emissions and world oil prices and economic growth are likely to adjust to each other, to achieve long-term equilibrium. These results are consistent with the findings of Sebri and Ben-Salha (2014), Apergis and Payne (2012), Saboori & Mohd (2012), Lin & Moubarak (2014) and Alshehry & Belloumi (2015), after confirming the existence of a long run relationship among the variables, then the Granger causality test as shown in table 4.

Based on the causality test with Granger Causality method, the following results are obtained: firstly, there are no causality one or two directions between economic growth and renewable energy consumption, it indicates that whether or not the movement of economic growth will not encourage the consumption of renewable energy to rise in Indonesia. The findings are in line with Shaari and Ismail (2012) who disclose any policies on energy consumption should be re-evaluated to ensure that it will not affect economic growth. The results of this study contradict Ikhide and Adjasi (2015) that there is one-way causality of renewable energy consumption and real GDP but not vice versa, contrary to Alper & Oguz (2016) that there is a causal relationship from economic growth to renewable energy consumption, and contrary to Pao and Fu (2013), Lin and Moubarak (2014), Dogan and Ozgur (2015) that there is a two-way causality between economic growth and renewable energy consumption. These findings have implications for government management in Indonesia that in implementing renewable energy conservation policies it must be ensured that it will not endanger economic growth because the results show that energy consumption does not affect economic growth so that the government can implement renewable energy saving policies. The results of this study do not support the growth hypothesis that implies the importance of renewable energy to economic growth (Belke et al, 2010; Jumbe, 2004; Alper & Oguz, 2016). These findings suggest that the consumption of renewable energy is not determined by economic growth in Indonesia and economic growth is not determined by the extent of renewable energy consumption.

Table 4: Granger Causality Test

Pairwise Granger Causality Tests
Sample: 2000 2016
Lags: 2

Null Hypothesis:	F-Statistic	Prob.
LnGDP does not Granger Cause LnRE	0.246	0.785
LnRE does not Granger Cause LnGDP	0.963	0.414
LnCO2 does not Granger Cause LnRE	1.160	0.352
LnRE does not Granger Cause LnCO2	3.669	0.043
LnP does not Granger Cause LnRE	1.310	0.312
LnRE does not Granger Cause LnP	0.357	0.708
LnCO2 does not Granger Cause LnGDP	1.538	0.261
LnGDP does not Granger Cause LnCO2	2.799	0.108
LnP does not Granger Cause LNGDP	7.822	0.009
LnGDP does not Granger Cause LNP	0.058	0.943
LnP does not Granger Cause LnCO2	0.629	0.552
LnCO2 does not Granger Cause LnP	0.202	0.819

Second, there is one-way causality between renewable energy consumption and CO2 emissions, indicating that a movement of renewable energy consumption will reduce CO2 emissions in Indonesia. So CO2 emissions are influenced by renewable energy consumption, but not vice versa, CO2 emission reductions do not contribute to renewable energy consumption. The results of the research have implications to support the conditions and policies issued by the government to start switching to renewable energy that is believed to be more environmentally friendly, safe and quite a number of renewable energy sources that are feasible to be developed to meet energy needs, especially in Indonesia. The results of this study support Alshehry & Belloumi (2015), that in the long run there is unidirectional causality of energy consumption to CO2 emissions. Even Shahbaz, et al (2013) and Hwang and Yoo (2014) suggest there is two-way causality between energy consumption and CO2 emissions, meaning that increased energy consumption directly affects CO2 emissions and that CO2 emissions also stimulate further energy consumption. However, the results of this study contradict Apergis, Menyah & Wolde (2010) which indicates that renewable energy consumption does not contribute to CO2 emission reduction. The same is expressed by Menyah and Wolde-Rufael (2010) that renewable energy consumption has not reached the level at which it can contribute significantly to emissions reductions.

Third, there is no one or two-way causality between world oil prices and renewable energy consumption, indicating that whether or not the world oil price movement will not encourage renewable energy consumption up or down in Indonesia. The results of this study contradict Bekhet and Yusop (2009) that changes in world oil prices also affect the total energy consumption in Malaysia. Even though Indonesia is one of the oil exporting countries but so far Indonesia has also imported oil. Therefore, if oil prices increase and an increase in the number of oil imports will result in the increasing burden of the Indonesian Government in the provision of fuel originating from fossil, renewable energy sources that have not been well utilized related to the limited process or technology of renewable energy sources, making renewable energy consumption has not affected the changes in world oil price movements.

Fourth, there is no one or two-way causality between CO2 emissions and economic growth, indicating that CO2 emissions will not encourage economic growth to rise in Indonesia. By the results of Saboori and Mohd (2012) that there is no causality between CO2 emissions and economic growth in the short term. The results of this study do not support Shahbaz, et al (2013) Alshehry and Belloumi (2015), Khanalizadeh and Mastorakis (2014), which revealed that there is a long-term causality between economic growth and CO2 emissions, and economic growth complementary one of the actions of radical energy conservation.

Fifth, there is one-way causality between world oil prices and economic growth, indicating that there is a movement of world oil prices will push economic growth up in Indonesia. So economic growth is affected by world oil prices, but not vice versa. The existence of world oil price movements will have an impact on price increases in almost all consumer goods, increase in transportation, increase in basic electricity rates, and so on. Therefore, it can be said that the world oil price plays an important role for the way the wheels of the economy that ultimately affect the economic growth of one country.

Sixth, there is no one or two-way causality between world oil prices and CO2 emissions, indicating that whether or not the world oil price movement will not drive CO2 emissions up or down in Indonesia.

4.3 Empirical Model in VAR

Table 5 below shows VAR estimation results.

Table 5: Var Estimation Results

	LnRE	LnGDP	LnCO	LnP
LnRE(-1)	0.267	-9.089	-2.698	-6.3670
	[0.684]	[-2.109]	[-1.864]	[-0.941]
LnRE(-2)	-0.407	4.970	-0.792	-11.147
	[-0.773]	[0.856]	[-0.406]	[-1.223]
LnGDP(-1)	-0.031	0.445	0.069	-0.803
	[-1.000]	[1.276]	[0.589]	[-1.466]
LnGDP(-2)	-0.001	-0.223	-0.117	-0.078
	[-0.091]	[-1.243]	[-1.947]	[-0.276]
LnCO2(-1)	0.046	1.664	0.624	0.613
	[2.617]	[1.996]	[2.227]	[0.468]
LnCO2(-2)	-0.001	0.744	-0.256	2.168
	[-0.014]	[0.741]	[-0.759]	[1.375]
LnP(-1)	-0.031	-0.739	0.049	0.230
	[-1.530]	[-3.249]	[0.648]	[0.644]
LnP(-2)	-0.058	0.588	-0.156	-1.377
	[-1.163]	[1.055]	[-0.835]	[-1.573]
C	5.056	26.291	14.429	85.462
	[1.825]	[0.862]	[1.409]	[1.784]
R-squared	0.922	0.967	0.914	0.648
Adj. R-squared	0.818	0.924	0.799	0.179
F-statistic	8.913	22.353	7.978	1.382

From table 5 on the VAR model, there are only 3 relations between variables that pass the t test on the estimation result of CO2 emission variables and renewable energy consumption obtained t_{count} = 2.617> t_{table} = 2.145 or t_{count} value which is greater than t_{table} indicates that variable LnCO2 (- 1) have positive effect on LnRE in year 1. It can be explained that the CO2 variable takes time to affect Lnre next year, meaning it takes 1 year to know the impact of rising carbon dioxide (CO2) emissions on the consumption of renewable energy in the next stage.

The result of VAR model also shows the result of estimation of variable of world oil price (LnP) and Economic growth (LnGDP) obtained by t_{count} = 3.249> t_{table} = 2,145 or t_{count} which is bigger than t_{table} indicates that world oil / LnP (-1) negative to Economic growth (LnGDP) in year 1. It can be explained that the world oil price variable (LNP) takes time to affect economic growth (LnGDP) the next year, meaning it takes 1 year to know the impact of the ups and downs of the world oil price (LnP) on economic growth (LnGDP) in the next stage.

The result of estimation of carbon dioxide emission (CO2) and carbon dioxide emission CO2 (-1) is obtained t_{count} = 2,227> t_{table} = 2,145 or t_{count} which is bigger than t_{table} indicates that variable of carbon dioxide emission (CO2) have positive effect to carbon dioxide emission (CO2) in year 1. Can be explained that carbon dioxide (CO2) emissions can affect the increase in carbon dioxide emissions (CO2) in the next year. This means that if this year there is an increase in carbon dioxide emissions (CO2) emissions then the next year can directly increase the expenditure of carbon dioxide emissions (CO2), the same as the previous year.

5 CONCLUSIONS

1. There is no one or two-way causality relationship between economic growth and consumption of renewable energy and CO2 emissions.
2. There is one-way causality between renewable energy consumption and CO2 emissions but not vice versa, and there is no one or two-way causality between renewable energy consumption and world oil prices.

6 LIMITATION

The use of more data will minimize errors and the use of other analytical techniques in testing research models can be done such as ECM, ARDL model and so on.

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