Energy Conservation, Fossil Fuel Consumption, CO2 Emission and Economic Growth in Indonesia

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Abstract

This paper discusses the relationship between fossil fuel consumption, carbon dioxide emissions and economic growth for the period of 1965-2012 in Indonesia by applying Vector Error Correction Model (VECM) Granger causality. This paper also estimate the effect of energy conservation policy that has already adopted the National Energy Conservation Master Plan (RIKEN 2005) by Indonesian Government to the pattern of energy consumption in Indonesia from 2014 until 2030. Empirical results show that in the short-run there are unidirectional Granger causalities running from coal consumption to economic growth (growth hypothesis) and from economic growth to oil consumption (conservation hypothesis). However, in the long run the results suggest unidirectional Granger causality only running from oil consumption to economic growth and CO_2 emissions. Thus, Indonesia should adopts different policies for each type of energies in order to maintain the economic growth while the effort of reducing fossil fuel consumption is in progress. The projection results imply that Indonesia government should revise the energy efficiency targets in RIKEN 2005 since the result of *LEAP* Projection based on RIKEN target shows a lower energy saving rate (17.32 percent) compared to the target (18 percent).

Keywords: Fossil Fuel Consumption; CO_2 Emission; Economic Growth.

JEL classification: Q43; Q53; O44

1. Introduction

Entering the 21st century, fossil fuels are still the dominant source of energy in the world energy demand. Compared with the energy demand conditions a few decades ago, the relative consumption patterns do not change much. In 1973, three-quarters (75.8 percent) source of energy consumed by the world comes from fossil fuels. Consumption of petroleum that time nearly half the world's energy consumption is 48.1 percent. Natural gas and coal accounted for 14.0 and 13.7 percent. In 2011 the share of fossil fuels decreased to 66.4 percent.

Petroleum is still a fossil fuel that is the most widely consumed is equal to 40.8 percent of total world energy consumption, and then followed in succession by 15.5 percent natural gas, and coal at 10.1 percent. (IEA, 2013a).

In an effort to maintain economic growth, energy consumption is needed to change the basic ingredient materials into goods and services that benefit society (Budiarto, 2013). By sector, the use of fossil fuel users are divided into several sectors, such as transport, industry, agriculture, commercial and public services, households and other sectors. In 2011, the transport sector absorbed 62.3 percent of petroleum consumption while the industrial sector absorbed 36.7 percent of natural gas consumption and 80.7 percent of world coal consumption (IEA, 2013a).

World's dependence on fossil fuels have serious implications for the environment. Emissions of carbon dioxide (CO2) that is released by fossil fuels is a major cause of global warming (Ozturk and Acaravci, 2010; Zhang and Cheng, 2009). In 2011, as many as 83 percent of greenhouse gases 93 percent in the form of CO2 emissions come from the energy sector. In the energy sector alone most of the CO2 emissions produced by the process of carbon oxidation (combustion) of the fuel (IEA, 2013b).

Until now, a wide variety of empirical studies have been conducted by academics and practitioners to explain the relationship between energy consumption, environmental pollution and economic growth in the domestic and regional levels. Various empirical studies have shown mixed results because of the differences in the object of study, the period of the study, and the methods of analysis used by the researchers (Hwang and Yoo, 2012). Therefore, further studies with the object of study, the period of the study, and different methods of analysis needs to be done to prove the relationship of the above three.

In this study, Indonesia was chosen as a case study object. This selection was based on three things. First, the primary energy consumption patterns in Indonesia from 1965 until 2012, still dominated by fossil fuels as seen in Figure 3. The share of fossil fuel consumption to primary energy in Indonesia as an annual average (1965-2012) is 96.5 percent, never even reached 98.98 percent in 1981. Second, the level of CO2 emissions in Indonesia continued to show a rising trend. In 1965, Indonesia has a CO2 emission level of only 20.35 million metric tons but by 2012 had reached 495.21 million metric tons, an increase of 2,333 percent. United States Energy Information Administration (EIA) puts Indonesia as the seventeenth ranked emitters of CO2 in the year 2011. Third, Indonesia is one of the developing countries which are members of the G20 forum and has the fourth largest population in the world after China, India, and the United States. This indicates that Indonesia has a great need for energy, especially fossil fuels.

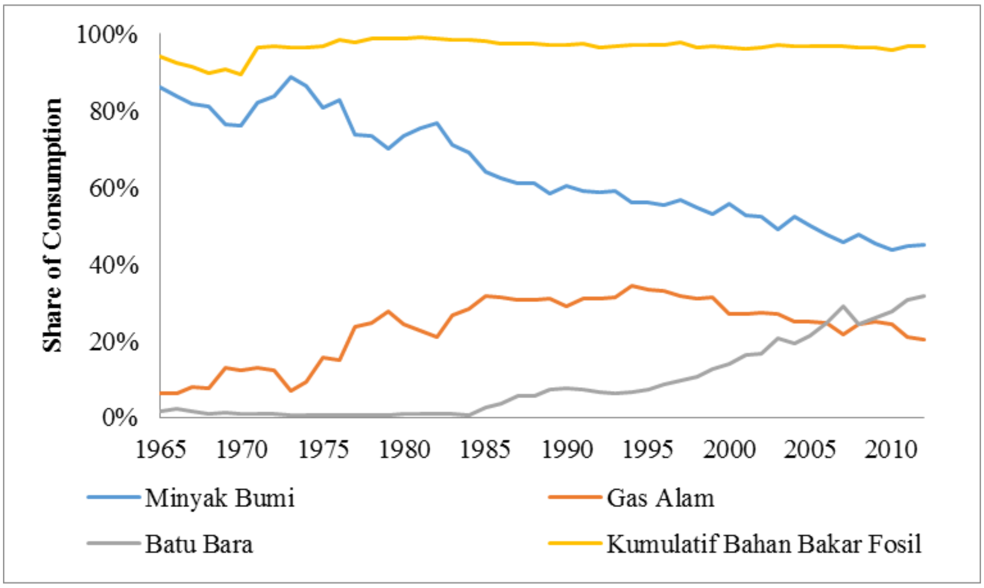

Figure 1 Fossil Fuel Consumption share of Indonesia to the Primary Energy, 1965-2012

Source: *BP Statistical Review of World Energy*, 2014

By paying attention to three things above, research on the inter-relationship between the consumption of fossil fuels, the level of CO2 emissions, and economic growth in Indonesia to be relevant to be done. In addition to the upcoming projected levels of energy consumption, especially when the government implemented a policy of energy conservation, it is necessary to know the change in consumption levels that may occur. This paper is addressed to answer critical questions as follow: Based on the background and formulation of the problem described by the researchers, the research question is formulated as follows: First, how causal relationship between the level of consumption of fossil fuels (petroleum, coal, and natural gas), the rate of economic growth and the level of CO2 emissions in Indonesia? How does the impact of the implementation of energy conservation policy in Indonesia against the energy consumption levels of society?

2. Literature Study

Tiwari (2011 and 2010) states that there are four kinds of hypotheses that explain the relationship between energy consumption and economic growth. The first hypothesis, Growth Hypothesis, expressed energy consumption directly influence the rate of economic growth. The more energy that is consumed as inputs in the production process, the more the output produced so that the economic growth rate is also higher. The second hypothesis, Conservation Hypothesis, otherwise stated rate of economic growth determine the extent of the energy consumed by the public. Thus, a country's policy to limit its energy consumption levels will not reduce economic growth.

The third hypothesis, Feedback Hypothesis, stating the level of energy consumption and economic growth are interdependent. That means between the two influence each other or with other words having a two-way causality. Latter hypothesis, Neutrality Hypothesis, states that there is a relationship of mutual influence between the levels of energy consumption with economic growth so that it can be interpreted both variables are independent of each other.

The fourth hypothesis above is empirical proof of the theory of economic growth that became mainstream in the study of energy economics, namely the Augmented Solow Growth Model. The model is the development of a model of economic growth created by Robert Solow (1956).

Various empirical studies have been conducted to determine the relationship between economic activity and environmental quality of life. Most of these studies use the concept of environmental Kuznets Curve (EKC) as a theoretical basis as in Choi et al. (2010), Granados and Carpintero (2009), and Azomahou et al. (2005). Based on the concept of EKC, the relationship of economic activity, represented by per capita income, and environmental conditions, represented the level of pollutant emissions, can be illustrated by the graph in the form of "U" upside down (inverted-U). EKC concept itself comes from an article written by Gene M. Grossman and Alan B. Krueger in 1991 and then popularized by the World Bank in its World Development Report 1992 (Stern, 2003).

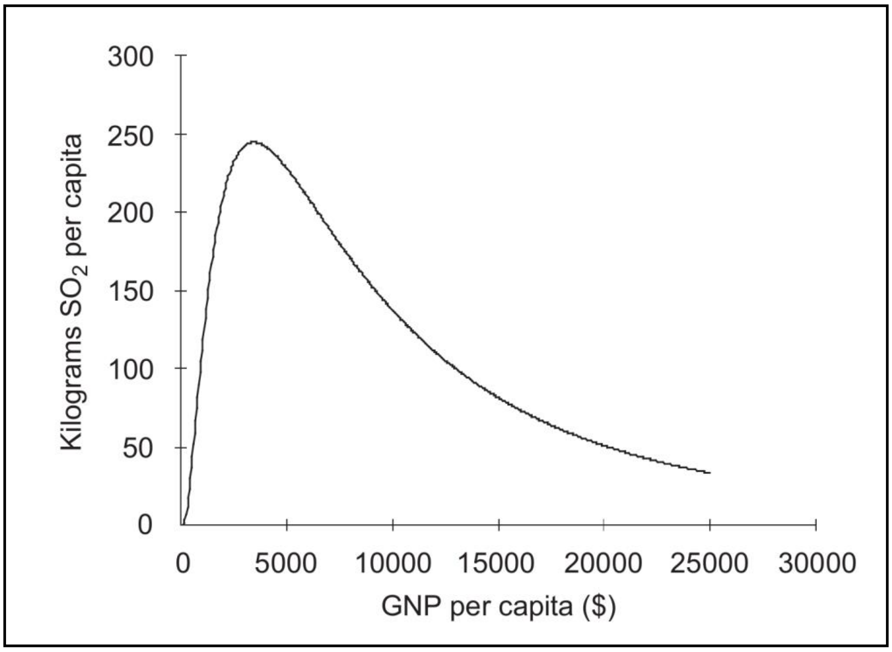

Figure 2. ***Environmental Kuznets Curve***

Source: Stern (2004)

The relationship between environmental degradation with the economic activity later clarified by the model developed by several researchers. One is the model proposed by Brock and Taylor (2004). According to them, the amount of residual pollutant emissions released into the natural production may vary when there are efforts to control (abatement) of the manufacturer. Mathematical notation of the model is as follows:

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$$= \Omega F - \Omega A(F, F^A)$$

$$= \Omega F \left[1 - A\left(1, \frac{F^A}{F}\right)\right]$$

$$= Fe(\theta)\ dengan\ e(\theta) \equiv \Omega[1 - A(1, \theta)]dan\ \theta\ \equiv \frac{F^A}{F}$$

The second line of equation (1) shows that the level of aggregate emissions (E) is the reduction of the level of emissions generated by economic activity (ΩF) with emission levels that were reduced by the manufacturer through control efforts (ΩA). The level of control efforts (A) itself is a function of aggregate economic activity scale (F) and the economic activity that is used for emission control measures (F^A). In addition, the last line can be seen that the level of aggregate emissions are generally influenced by two things: the scale of aggregate economic activity (F) and the production technology is denoted by e (θ).

3. Methodology

3.1. Model

By combining the two models above study, researchers formulate a mathematical model to explain the relationship between economic growth, fossil energy consumption and CO2 emission levels in Indonesia as follows:

$$CO_2 = f(Y, FE) \tag{2}$$

Real GDP is used in the model to explain the economic growth variable (Y). While variable consumption of fossil energy (FE) is divided into three types, namely energy consumption of petroleum, coal, and natural gas. The division is intended to determine the relationship of each individual type of fossil energy to other variables. Value of all the variables are expressed in natural logarithm form large elasticity between variables that can be known. In addition, a dummy variable was also added in 1998 to capture changes in the trend of the data before and after the economic crisis of 1997-1998.

Researchers using the Vector Error Correction Model (VECM) to examine the relationship above five variables. Model specification testing in this study are as follows:

$$\Delta \boldsymbol{C_t} = \beta_{10} + \sum_{i=1}^{L_{11}} \beta_{11i} \Delta C_{t-i} + \sum_{j=1}^{L_{12}} \beta_{12j} \Delta G_{t-j} + \sum_{k=1}^{L_{13}} \beta_{13k} \Delta E1_{t-k} + \sum_{l=1}^{L_{14}} \beta_{14l} \Delta E2_{t-l} + \sum_{m=1}^{L_{15}} \beta_{15m} \Delta E3_{t-m} + \beta_{16} D1998 + \beta_{17} \varepsilon_{t-1} + \mu_{1t} \tag{2}$$

$$\Delta \boldsymbol{G_t} = \beta_{20} + \sum_{i=1}^{L_{21}} \beta_{21i} \Delta G_{t-i} + \sum_{j=1}^{L_{22}} \beta_{22j} \Delta C_{t-j} + \sum_{k=1}^{L_{23}} \beta_{23k} \Delta E1_{t-k} + \sum_{l=1}^{L_{24}} \beta_{14l} \Delta E2_{t-l} + \sum_{m=1}^{L_{25}} \beta_{25m} \Delta E3_{t-m} + \beta_{26} D1998 + \beta_{27} \varepsilon_{t-1} + \mu_{2t} \tag{3}$$

$$\Delta \boldsymbol{E1_t} = \beta_{30} + \sum_{i=1}^{L_{31}} \beta_{31i} \Delta E1_{t-i} + \sum_{j=1}^{L_{32}} \beta_{32j} \Delta C_{t-j} + \sum_{k=1}^{L_{33}} \beta_{33k} \Delta G_{t-k} + \sum_{l=1}^{L_{34}} \beta_{34l} \Delta E2_{t-l} + \sum_{m=1}^{L_{35}} \beta_{35m} \Delta E3_{t-m} + \beta_{36} D1998 + \beta_{37} \varepsilon_{t-1} + \mu_{3t} \tag{4}$$

$$\Delta \boldsymbol{E2_t} = \beta_{40} + \sum_{i=1}^{L_{41}} \beta_{41i} \Delta E2_{t-i} + \sum_{j=1}^{L_{42}} \beta_{42j} \Delta C_{t-j} + \sum_{k=1}^{L_{43}} \beta_{43k} \Delta G_{t-k} + \sum_{l=1}^{L_{44}} \beta_{44l} \Delta E1_{t-l} + \sum_{m=1}^{L_{45}} \beta_{45m} \Delta E3_{t-m} + \beta_{46} D1998 + \beta_{47} \varepsilon_{t-1} + \mu_{4t} \tag{5}$$

$$\Delta \boldsymbol{E3_t} = \beta_{50} + \sum_{i=1}^{L_{51}} \beta_{51i} \Delta E1_{t-i} + \sum_{j=1}^{L_{52}} \beta_{52j} \Delta C_{t-j} + \sum_{k=1}^{L_{53}} \beta_{53k} \Delta G_{t-k} + \sum_{l=1}^{L_{54}} \beta_{54l} \Delta E2_{t-l} + \sum_{m=1}^{L_{55}} \beta_{55m} \Delta E3_{t-m} + \beta_{56} D1998 + \beta_{57} \varepsilon_{t-1} + \mu_{5t} \tag{6}$$

The notation C represents the level of CO_2 emissions, the notation G is the number of real GDP, E_1 is the amount of petroleum consumption, E_2 is the amount of natural gas consumption, and E_3 is the amount of coal consumption. Dummy variable is explained by the 1997-1998 economic crisis notation D1998.

As for seeing the changes in the pattern of consumption of fossil fuels in society when the government implemented a policy of energy conservation, researchers using LEAP projection model with a focus on demand modules. The time span chosen for the projection of energy demand is ranging from 2012 to 2025 according to the Energy Vision 25/25, announced by the government. Graphically the model projections for the final energy demand module Indonesia is structured as follows:

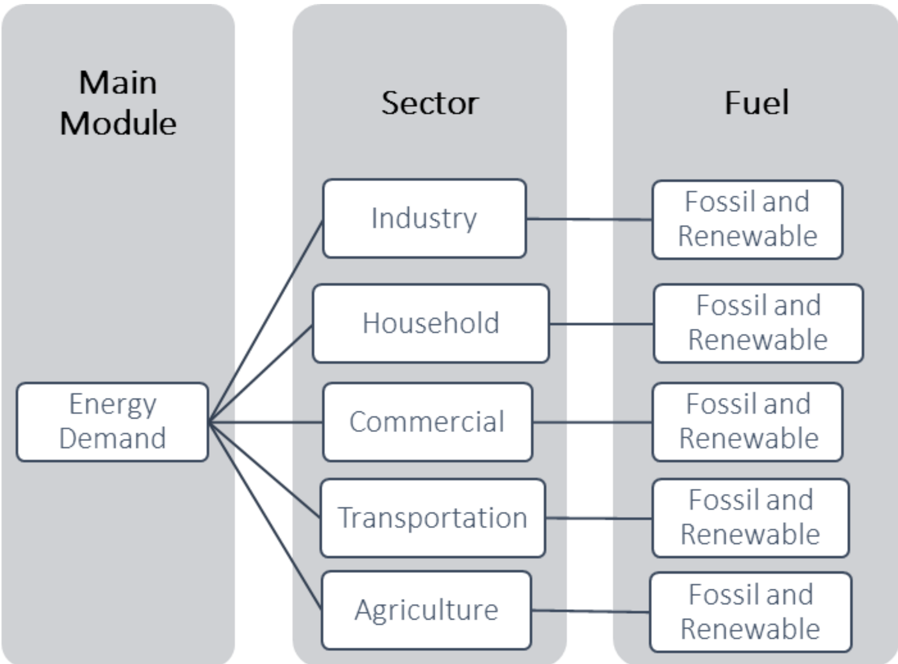

Figure 3. LEAP Projection Model of Indonesia Energy Final Demand, 2012 – 2025

Source: *International Energy Agency, Processed*

Request module is divided into five sectors namely industrial sector energy users, household, commercial, transportation and others. The agricultural sector also includes forestry and fisheries. Total energy demand in each sector is further divided into four types of energy, namely oil, coal, natural gas, and energy-energy from renewable sources. Types of renewable energy in this study follows the classification of the IEA, namely nuclear power, geothermal, hydro, biofuels, and others. In addition, historical data from 2005 to 2011 was also added in the model to see the trend of the development of sectoral energy demand in Indonesia. As a proxy for energy demand, the researchers used data types and energy consumption per user per sector published by the IEA.

3.2. Limitations of Study

This study is limited in several respects. First, the time period of data used in this study are in the period 1965 through 2012 Secondly, the type of energy that covers the entire studied the fossil fuels oil, coal, and natural gas. Third, this study only looked at the relationship between the level of consumption of fossil fuels with CO_2 emission levels and economic growth in Indonesia. Fourth, the projected level of energy consumption is only done in the public sector, industry, households, transport, commercial, and agriculture (including forestry and fisheries).

3.3. Hypothesis

In this study, the hypotheses used are as follows: Firstly, the rate of consumption of fossil energy (oil, coal, and natural gas) has a causal relationship to economic growth in Indonesia. *Second*, the rate of consumption of fossil energy (oil, coal, and natural gas) has a causal relationship to the level of CO_2 emissions in Indonesia. Economic growth has a causal relationship to the level of CO_2 emissions in Indonesia. Energy conservation policies influence the change in the pattern of consumption of fossil fuels Indonesian society

3.4. VECM Granger Causality

VECM first introduced by Sargan (1964) and later developed by Engle and Granger (1987) and Johansen (1988). Also known as the VECM Cointegrating Vector Autoregression models (CIVAR) or VAR which is restricted (restricted VAR) because VECM using variables and apply the concept of cointegrating error correction (Error Correction) in the estimation process. Widarjono (2009) states that the application of the concept of error correction aims to restrict the behavior of a long-term relationship between variables in order to converge to the cointegration relationship while still allowing dynamic changes in the short term. Both the concept of co-integration and error correction is used to prevent the occurrence of spurious regression (Lauridsen, 1998).

Procedurally, VECM chosen as the model estimation when the unit root test indicates the variables that exist largely stationary at level but cointegration test results indicate the presence of co-integration or in other words there is a theoretical relationship between variables. According Obayelu and Salau (2010), VECM assumes these variables are linearly adjusted to balance the long-term. While Engle and Granger (1987) concluded that the change in the dependent variable is a function of changes in the value of the other independent variables as well as great value for Error Correction Term (ECT). The ECT itself shows the long-term coefficients of the model.

Based on the above explanation, VECM can be formulated as follows (Suryaningsih et al., 2012):

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with the notation Y_t show ($k\ x\ 1$) vector of endogenous variables, α is the adjustment coefficient that measures the level of the endogenous variable speed adjustment in the long run i, β is the cointegration vector, D_t is a vector of deterministic terms, $\Gamma_{1\ \dots\ p}$ is ($k\ x\ k$) matrix of coefficients, C^* is the matrix associated with deterministic terms are used in the model as a constant, with a trend or seasonal dummy; and U_t is the reduced form disturbance. As indicated by the combined ECT variable notation β and Y_{t-1}. Harris (1995) in Ajija et al. (2011) also formulate VECM number 20 in the form of the following equation:

$$\underbrace{\begin{bmatrix}\Delta y_{1t}\\ \Delta y_{2t}\\ \Delta x_{1t}\\ \Delta x_{2t}\end{bmatrix} = \Gamma \begin{bmatrix}\Delta y_{1t-1}\\ \Delta y_{2t-1}\\ \Delta x_{1t-1}\\ \Delta x_{2t-1}\end{bmatrix}}_{\text{Short Run Equation}} + \underbrace{\begin{bmatrix}\alpha_{11}\\ \alpha_{21}\\ \alpha_{31}\\ \alpha_{41}\end{bmatrix} x[\beta_{11} \quad \beta_{21} \quad \beta_{31} \quad \beta_{41}] x \begin{bmatrix}y_{1t-1}\\ y_{2t-1}\\ x_{1t-1}\\ x_{2t-1}\end{bmatrix}}_{\text{Long Run Equation}} \tag{8}$$

In the analysis, VECM models often also used in conjunction with the Granger Causality test so this approach is often referred to as the VECM Granger Causality. This approach has the distinction of the causality test proposed by Granger (1969). In addition to providing information towards the relationship between variables, this approach also explains the relationship time horizon is short term or long term. Tiwari (2011) revealed that the long-term relationship can be explained by the significance of the lagged ECT while the short-term relationship can be seen from the significance of the coefficient of the first difference of the independent variables. Mathematical modelling VECM Granger Causality as follows:

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Error! Reference source not found. (10)

The above model is used to test the hypothesis that the variable X determines the value of the variable Y. The null hypothesis of equation (9) is **Error! Reference source not found.**and equation (10) is **Error! Reference source not found.**. Thus, if the null hypothesis is rejected fails equation (9) it can be concluded that the variable Y does not affect the variable X. Conversely, if the null hypothesis is rejected, the equation (10) fails the conclusion is no effect of variable X on variable Y. If the models using only a single lag, then hypothesis testing can be done by t-test. However, if the variables in the model using more than one lag (lag such as two, or three lag), the significance test used was the F-test. Similarly, the same applies to the hypothesis test for the long-term variable in the second equation ECT VECM Granger Causality.

4.4. Long-range Energy Alternatives Planning (LEAP)

LEAP The term actually refers to a software (software) computer developed by the Stockholm Environment Institute first time in 1981 aims to facilitate the development of LEAP experts in assessing the impact of energy and environmental policy in a particular region over a range of periods. In addition, LEAP can also be used to model energy supply systems as well as systems of production and mitigation of greenhouse gas emissions in an economy. Since 1981, LEAP has been improved several times including in 2000, 2006, 2008 and 2014 in the last year doing modeling, LEAP uses accounting approach. Total demand and total energy supply is calculated by summing the usage and supply of each type of energy in each sector or activity (Wintarro, 2008).

There are four main modules in the LEAP module Assumptions Key (Key Assumptions), Demand (Demand), Transformation (Transformation), and Resources (Resources). Module generally contains key assumptions of macroeconomic variables that affect the value of the variables in other modules such as population and GDP. The module is used to accommodate the demand variables disaggregate energy consumption. Mathematically, the energy demand is defined as follows (Help for LEAP, 2014):

$$\textit{Energy consumption} = \textit{activity level x energy intensity} \qquad (11)$$

Transformation module is useful to calculate the amount of energy supply, both primary and secondary, through energy input-output tables. The resource module summarizes the results of a calculation module based on the type of energy transformation separately.

In addition to the main module, LEAP also has three additional modules that are complementary to the main module Difference Statistics (Statically Differences), Changes in Stock (Stock Changes), and the impact of non-energy sector (Non-Energy Sector Effects). Module contains statistical difference assumptions statistical difference between the demand and supply of energy due to differences in the method of calculating the data. Module stock changes to accommodate the assumptions change in energy reserves between periods. Modules incorporate the impact of non-energy sectors of the variables that capture the energy production and consumption externalities such as air pollution level and the number of patients with respiratory tract infections.

4. Results and Analysis

As shown in Figure 1, in term of primary energy, Indonesia still heavily relies on fossil fuel. This paper evaluates the relation between the fossil fuel consumption, economic growth, and pollution rate based on the annual data from World Bank and British Petroleum. The variable of fossil fuel consumption are divided into three energy type from BP s (Oil, Natural Gas, and Coal). Those data, together with CO_2 emissions, are taken Statistical Review of World Energy 2013 and measured in million tons oil equivalent (Mtoe) for energy consumption and million tons carbon dioxide for other. To make a proxy for real economic growth, this paper uses Constant Price 2005 GDP measured in US dollars obtained from the World Bank.

Table 1 illustrates the descriptive statistical analysis of the data. All variables are expressed in logarithmic form to standardize the unit of measurement. The econometric model also added dummy variable for 1998 crisis (0 for period before 1998, 1 for otherwise) to solve normality problem in data analysis.

Table 1. Descriptive statistical analysis

Variable	LCO2	LGDPR	LOIL	LGAS	LCOAL
Mean	4.729735	25.52754	3.209114	2.130647	0.521503
Median	4.842086	25.60484	3.289876	2.637422	1.078201
Maximum	6.204962	26.78115	4.271095	3.591818	3.919991
Minimum	2.954910	24.05553	1.740466	-0.693147	-2.302585
Std. Dev.	1.045926	0.819352	0.821498	1.419775	2.309221
Skewness	-0.334727	-0.292666	-0.476576	-0.804840	-0.011349
Kurtosis	1.805448	1.845921	1.895687	2.184273	1.421944
Jarque-Bera	3.750251	3.349024	4.256011	6.512963	4.981553
Probability	0.153336	0.187400	0.119075	0.038524	0.082846

Source: calculated from WB database and BP Statistical Review of World Energy, 2014

4.1. Unit Roots

This paper applies Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) test to investigate the existence of unit roots. By assuming that the test model has a trend and intercept, both the ADF and PP tests show that all variables are not stationary in levels. In contrast, all variables are one percent significant in first difference or in other words, the null hypothesis that the data contains time series unit root can be rejected. Therefore it can be concluded that the variables in this paper are integrated in the I(1).

Table 2 ADF and PP Unit Root Tests

Variable	Level		First Difference	
	t-stat	Adj. t-stat	t-stat	Adj. t-stat
LCO2	-0.55633	-0.849924	-6.374173*	-6.380551*
	(0.9770)	(0.9531)	(0.0000)	(0.0000)
LGDPR	-1.65625	-1.249867	-5.221177*	-5.207384*
	(0.7544)	(0.8879)	(0.0005)	(0.0005)
LOIL	-0.32116	-0.635945	-6.151965*	-6.146971*
	(0.9877)	(0.9719)	(0.0000)	(0.0000)
LGAS	-0.72075	-0.904911	-4.60061*	-7.337728*
	(0.9645)	(0.9468)	(0.0034)	(0.0000)
LCOAL	-2.1657	-2.165703	-6.891926*	-6.872561*
	(0.4969)	(0.4969)	(0.0000)	(0.0000)

rce: calculated from WB database dan BP Statistical Review of World Energy, 2014
Note: * significant at 1 per cent

4.2. Determining the Optimal Lag

Determination of the optimal lag VAR models using a variety of criteria summarized in table 3. Final Prediction Error (FPE) criteria, Schwarz Information Criterion (SIC), Hannan-Quinn Information Criterion (HQ) recommend one lag. While the criteria of sequential modified LR test statistic (LR) and the Akaike Information Criterion (AIC) shows the optimal lag VAR located on the lag of four.

Table 3. Result of Optimal Lag Test

by Using Various Criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	83.21482	NA	2.47E-08	-3.32795	-2.92245	-3.17757
1	330.506	415.8987	**1.02e-12***	-13.4321	**-12.01285***	**-12.90577***
2	345.4332	21.71241	1.71E-12	-12.9742	-10.5413	-12.072
3	369.9727	30.11658	2.01E-12	-12.9533	-9.50657	-11.6751
4	414.0967	**44.12400***	1.12E-12	**-13.82258***	-9.3621	-12.1684

Source: calculated from WB database dan BP Statistical Review of World Energy, 2014
Note: * recommended lag by criterion

4.3. Co-integration test and Vector error correction model

Table 4 presents the result of the Johansen co-integration test as determined by the Max-Eigenvalue and trace methods. This cointegration test uses optimal VAR lag-1 as an interval limit of test lag. Both the maximum eigenvalue and trace statistics show significant value at five per cent, so the null hypothesis that there are only at most two cointegrating equations can be rejected. Thus the five variables have three cointegrating equation at a maximum lag of three periods.

Table 4 Results of the Johansen co-integration test by the max-eigenvalue and trace methods

Rank	*Eigenvalue*	*Max-Eigen Statistics*	*Trace Statistics*
r = 0 *	0.936920	121.5874 (0.0000)	217.4141 (0.0000)
r ≤ 1 *	0.663914	47.97707 (0.0003)	95.82674 (0.0000)
r ≤ 2 *	0.465032	27.52415 (0.0296)	47.84968 (0.0149)
r ≤ 3	0.258682	13.17032 (0.3145)	20.32553 (0.2099)
r ≤ 4	0.150084	7.155202 (0.3286)	7.155202 (0.3286)

Source: calculated from WB database dan BP Statistical Review of World Energy, 2014
Note: * significant at 5 per cent; number in parentheses ( ) indicates the magnitude of P-Value for each statistics.

Table 5 and table 6 illustrate the result of short-run and long-run multivariate causality tests based on the vector error correction model (VECM). This paper uses a significance of 10 percent as a limitation for the causality test in both tables. In the short run there are two significant unidirectional granger causalities from coal consumption to economic growth (growth hypothesis) and also from economic growth to oil consumption (conservation hypothesis).

Table 5. Short-Run Multivariate Causality based on VECM

Null Hypothesis	Independent Variable				
	Short-Run (Statistics - χ^2)				
	ΔLCO2	ΔLGDPR	ΔLOIL	ΔLGAS	ΔLCOAL
Independent Variables do not cause CO_2 emission level.	-	3.727563 (0.2924)	2.367751 (0.4997)	3.395231 (0.3346)	0.759597 (0.8591)
Independent Variables do not cause economic growth	2.794514 (0.4244)	-	0.057297 (0.9964)	2.928688 (0.4028)	25.53409* (0.0000)
Independent Variables do not cause oil consumption	0.599504 (0.8965)	7.882641** (0.0485)	-	0.655319 (0.8837)	0.639562 (0.8873)
Independent Variables do not cause gas consumption	1.302281 (0.7286)	3.097590 (0.3768)	1.381021 (0.7100)	-	1.678275 (0.6418)
Independent Variables do not cause coal consumption	2.303587 (0.5118)	3.689495 (0.2970)	2.501159 (0.4751)	4.352498 (0.2258)	-

Source: calculated from WB database dan BP Statistical Review of World Energy, 2014
Note: *,**,*** significant at 1, 5, 10 per cent respectively; number in parentheses ( ) indicates the magnitude of P-Value for each statist

While for the long run, there are several significant variables and have a strong causality. First, unidirectional granger causalities of petroleum consumption to economic growth and CO_2 level. Second, bidirectional granger causalities of coal consumption to economic growth and CO_2 level. Third, bidirectional granger causalities of gas consumption to economic growth and CO_2 level. Fourth, bidirectional granger causality of economic growth to the level of CO_2.

Table 6. Long-Run Multivariate Causality based on VECM

Null Hypothesis	**Joint Statistic - χ^2**					**Statistic - χ^2**
	ΔLCO2	**ΔLGDPR**	**ΔLOIL**	**ΔLGAS**	**ΔLCOAL**	ε_{t-1}
Independent Variables do not cause CO_2 emission level	-	13.62879** (0.0341)	11.99765*** (0.0620)	12.12108*** (0.0593)	8.811611 (0.1845)	8.654258** (0.0343)
Independent Variables do not cause economic growth	176.3363* (0.0000)	-	183.9862* (0.0000)	172.9715* (0.0000)	184.8821* (0.0000)	163.0336* (0.0000)
Independent Variables do not cause oil consumption	1.625955 (0.9507)	9.367858 (0.1539)	-	2.068045 (0.9133)	2.027601 (0.9171)	1.465999 (0.6901)
Independent Variables do not cause gas consumption	20.75767* (0.0020)	20.45929* (0.0023)	18.82662* (0.0045)	-	24.70850* (0.0004)	18.44682* (0.0004)
Independent Variables do not cause coal consumption	7.913258 (0.2445)	12.97702** (0.0434)	9.749208 (0.1356)	8.505578 (0.2034)	-	7.106852*** (0.0686)

Source: calculated from WB database dan BP Statistical Review of World Energy, 2014
Note: *,**,*** significant at 1, 5, 10 per cent respectively; number in parentheses ( ) indicates the magnitude of P-Value for each statistics.

4.4. Energy Consumption Projection Using LEAP

This paper uses two kinds of projection scenarios. The first scenario is Business as Usual (BAU) scenario. This scenario assumes no change in energy policy in the future. The second scenario is the implementation of the National Energy Conservation Master Plan (RIKEN) 2005 by the government scenario. RIKEN scenario assumes in 2025 each sector can do a certain level of energy efficiency. In detail, the potential assumption of energy efficiency in each sector are presented in the following table:

Table 7. Potential and Energy Efficiency Target in 2025

Sector	Energy Efficiency Potential (%)	Energy Efficiency Target in 2025(%)
Industry	10-30	17
Commercial	10-30	15
Transportation	15-35	20
Household	15-30	15
Agriculture	15-30	0

Source: Draft of RIKEN 2005-Energy Conservation Directorate, ESDM Ministry

RIKEN scenario refers to the Vision 25/25 whose goal is achieving a reduction in energy consumption by 18 percent from the BAU scenario by 2025 through energy conservation activities. Determination of the energy efficiency target figure itself is one of the programs to achieve the realization of the Vision 25/25. The projection of energy consumption level in 2025 with the BAU scenario is shown in the table 8 below:

Table 8. Projection of Indonesia Energy Consumption Level in 2025 (Ktoe)

Energy Source	Industry	Commercial	Transportation	Household	Agriculture	Total
Oil	13.057,88	890	73.219,89	2.133,21	2.993,32	92.294,31
Coal	7.636,48	0	0	0	0	7.636,48
Natural Gas	21.217,21	512,5	53,04	18,78	0	21.801,54
Non-fossil fuel	13.133,36	6.678,57	833,46	63.097,07	0	83.742,46
Total	**55.044,94**	**8.081,07**	**74.106,39**	**65.249,07**	**2.993,32**	**205.474,8**

Source: projection of IEA data using *LEAP*

Based on the projection results, if government implements RIKEN 2005 scenario in 2025, there will be a 35.58 Mtoe energy saving with potential energy efficiency interval of 27.66 to 65.35 Mtoe. That figures by percentage are equal with 17.32 per cent and 13.46 - 31.80 per cent of BAU scenario energy consumption level respectively. As shown in the table above, the largest energy saving belongs to transportation sector (14.82 Mtoe), then followed by household sector (9.79 Mtoe), industry (9.36 Mtoe), and commercial (1.62 Mtoe). In the agricultural sector, the Government does not establish special targets so that the amount of energy consumption in the agricultural sector in RIKEN scenario same with BAU scenario.

6. Conclusions

This paper evaluates the long run and short run causality issues between fossil fuel consumption (oil, natural gas, and coal), CO_2 emissions, and economic growth in Indonesia by using Vector Error Correction Model (VECM) Granger Causality for the period of 1965-2012. Empirical results suggest each types of fossil fuel has different causality direction both in the long run and short run. The main results for the existence and direction of VECM granger causality are as follows: *First*, in the short-run there are unidirectional Granger causalities running from coal consumption to economic growth (growth hypothesis) and from economic growth to oil consumption (conservation hypothesis). *Second*, in the long run the results suggest unidirectional Granger causality (growth hypothesis) only running from oil consumption to economic growth and carbon dioxide emissions while other variables have bidirectional Granger causality (feedback hypothesis).

This paper also projects the effect of energy conservation policy that has already adopted (RIKEN 2005) by Indonesian Government to the pattern of energy consumption in Indonesia from 2014 until 2030. The projection results imply that Indonesia government should revise the energy efficiency targets at RIKEN (National Energy Conservation Master Plan) 2005 since the result of *LEAP* Projection based on RIKEN target shows a lower energy saving rate (17.32 percent) compared to the Vision 25/25 target (18 percent).

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