International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2018, 8(4), 90-97.

Fossil Fuels Consumption, Carbon Emissions, and Economic Growth in Indonesia

Traheka Erdyas Bimanatya[1], Tri Widodo[2]*

[1]Economics Department, Faculty of Economics and Business (ED-FEB), Gadjah Mada University, Indonesia, [2]Center for Southeast Asian Social Studies (CESASS), Department of Economics, Faculty of Economics and Business (ED-FEB), Gadjah Mada University, Indonesia. *Email: kociwid@yahoo.com

ABSTRACT

Environmental issues have become an issue of recent interest due to climate change associated with increased levels of pollution and degradation of environmental quality as a result of increased human economic activity. This paper discusses the relationship between fossil fuel consumption, carbon dioxide emissions, and economic growth, the impacts of energy conservation, as well as the projection of energy mix in Indonesia by applying vector error correction model Granger causality, and long-run energy alternatives planning (LEAP). Empirical results show that in the short-run there are unidirectional Granger causalities running from coal consumption to output (growth hypothesis) and from output to oil consumption (conservation hypothesis). However, in the long-run the results suggest unidirectional Granger causality only running from oil consumption to output and carbon emissions. The projection results show that the result of LEAP projection based on national master plan for energy conservation (RIKEN) 2005 target has a lower energy saving rate (17.32%) compared to the Vision 25/25 target (18%).

Keywords: Fossil Fuel Consumption, CO_2 Emission, Economic Growth
JEL Classifications: Q43, Q53, O44

1. INTRODUCTION

Until today, fossil fuels consumption still dominates the world energy market. In 1973, about 75.8% of total energy consumption was classified as fossil fuels with the consumption of petroleum at that time nearly reached half of the world energy consumption (48.1%). Natural gas and coal accounted for 14.0% and 13.7% respectively. Although in 2011 the share of fossil fuels decreased to 66.4%, there was only a little change in disaggregate level. International Energy Agency (2013a) reported that petroleum remained to have the largest share of consumption, which was equal to 40.8%, and then followed in succession by natural gas (15.5%) and coal (10.1%). The world's dependence on fossil fuels may have serious impact on the natural environment.

The carbon emissions that are released by fossil fuels is the major cause of global warming (Ozturk and Acaravci, 2010; Zhang and Cheng, 2009; Alshehry and Belloumi, 2014; Alam et al., 2016; Sasana and Ghozali, 2017; Nuryartono and Rifai, 2017). By 2011, around 93% of greenhouse gases was the carbon emissions that were produced from fuel combustion process (IEA, 2013b). Therefore, it is necessary to reduce the consumption of fossil fuel due to its harmful effect on nature. However, energy has a fundamental role for emerging market country such as Indonesia in order to promote economic growth, as it is needed to change the raw materials into final products that will be consumed by households (Budiarto, 2013). Reducing fossil fuels consumption can hamper economic growth in most non-developed countries. In this sense, fossil fuel consumption and economic growth have a negative relationship.

Nevertheless, a number of empirical researches have been conducted to investigate the relationship between energy consumption, environmental pollution and economic growth in across countries but those researches showed different results which may depended on the object of study, the period of the study, and the methods of analysis used by the researchers (Hwang and Yoo, 2012). Hence, a further study with a different object of study, period of the study, and methods of analysis need to be done to investigate the relationship of between fossil fuel consumption, carbon emission, and output level and thus we can provide a better solution for fossil fuel dependence problem. In this study, we conducted study for Indonesia since its fossil fuel consumption was dominant throughout since 1965. The share of fossil fuel consumption to primary energy in Indonesia on average was 96.55%. Moreover, Indonesia is an emerging market country that needs economic growth to become a more developed country and has the fourth largest population in the world after China, India, and the United States. All of these indicate that Indonesia has a great need for energy, especially fossil fuels.

This study aims to investigate the relationship between fossil fuel consumption, carbon emissions, and output level in Indonesia by using vector error correction model (VECM) approach. We disaggregate fossil fuels into three types (petroleum, natural gas, and coal) in order to design a better energy conservation policy that can avoid a decline in economic growth. Additionally, we also examine the impact of current energy conservation policy, the Energy Vision 25/25 that aims to increase the consumption of renewable energy by 25% of total energy consumption in 2025, on sectoral energy consumption in Indonesia. The rest of paper is organized as follows. Part 2 describes various empirical findings and theoretical concepts. Part 3 represents the methodology used in this study. The results and discussion are presented in Part 4. Part 5 shows the conclusions and policy recommendations.

2. LITERATURE REVIEW

Ozturk (2010) found that there are four kinds of hypotheses that explain the relationship between energy consumption and economic growth. The first hypothesis is that energy consumption directly influence the rate of output (growth hypothesis). The more energy that is consumed as inputs in the production process, the more the output produced and thus the economic growth rate is also higher. The second hypothesis, conservation hypothesis, in contrast stated that the rate of economic growth determines the amount of energy which are consumed by the society. Based on the second hypothesis, adopting energy conservation policy will not reduce economic growth in a country. The third hypothesis, feedback hypothesis, states that the level of energy consumption and economic growth have bidirectional causality relationship. It means that those variables simultaneously influence to each other. The last hypothesis is neutrality hypothesis, which states that there is no causality relationship between energy consumption and economic growth; both variables are independent of each other.

Those hypotheses above are an empirical proof of the augmented Solow growth model that were created by Robert Solow (1956). In this model, energy is classified as natural resources which becomes an input in production technology e.g., in Berndt and Wood (1975), Griffin and Gregory (1976), Ayres and Warr (2005), Stern (2011), Stern and Kander (2012), and Greiner et al. (2012). Mathematically, it can be written as in the following equations (Wang, 2012):

$$Y = (1-\gamma)K^{\beta}L^{1-\beta}+\gamma E,\ 0<\gamma<1, 0<\beta<1 \quad (1)$$

$$\dot{K} = s(Y-E)-\delta K,\ 0<s<1, 0<\delta<I \quad (2)$$

Where K denotes capital, L is labor, β and γ are the parameters for capital and energy respectively, E represents energy, Y is gross output, is the growth rate of the capital stock (investment), s is the saving rate, and δ is the depreciation rate for capital over time. The term $(Y-E)$ in equation 2 explains that energy consumption will adjust the accumulated capital. The model above assumes that the elasticity of substitution between energy and the other inputs such as capital and labor is <1. It implies that energy is needed in some minimum amount and should be combined with the other inputs to produce an output.

In order to determine the relationship between economic activity and pollution level, most studies use the environmental Kuznets Curve (EKC) model as a theoretical basis, for example Choi et al. (2010), Granados and Carpintero (2009), Azomahou et al. (2005), Ben Jebli et al. (2015), Al-mulali et al. (2016), Al-mulali and Ozturk (2016). The EKC model itself was discovered by Grossman and Krueger (1991) and then used by the World Bank in its World Development Report 1992 (Stern, 2003). This model suggests that economic activity that is represented by the per capita income and emission level have an inverted-U relationship. Figure 1 illustrates the EKC model.

Further development on the model that linked economic activity and environmental degradation was conducted by several studies. One of them, Brock and Taylor (2004), said that producers under the government regulation could control the level of emission. This statement is written as follows:

$$E = \text{pollution created} - \text{pollution abated} \quad (3)$$

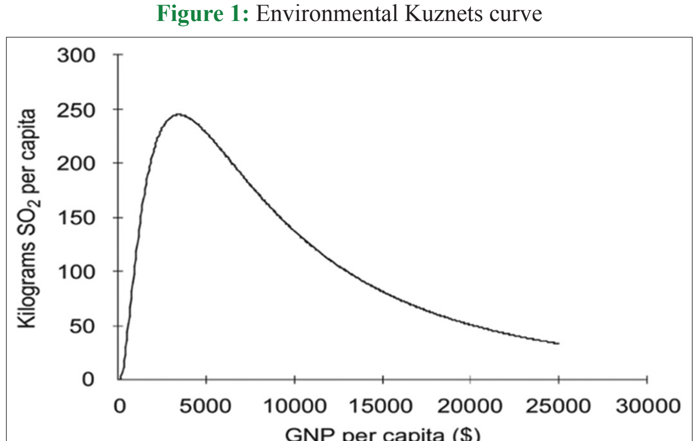
$$=\Omega F - \Omega A(F,F^{A})$$

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

$$=Fe(\theta)\ \text{where}\ e(\theta)^{o}\Omega[1\text{-}A(1,\theta)]\ \text{and}\ \theta\frac{F^{A}}{F}$$

Where E in this model the emission level, ΩF is emission that generated by economic activity, ΩA is the emission level that

Figure 1: Environmental Kuznets curve



Source: Stern (2004)

can be abated. The abatement process *(A)* is a function of the total scale of economic activity *(F)* and the economy's efforts at abatement *(F^a)* while the last line of equation implies that the emission level in a country is a function of the scales of economic activity and the production technology that is denoted by *e(θ)*.

There are two studies that conducted causality test between energy consumption, economic growth, and emission level in Indonesia. Using the data that cover the period of 1971-2007, Jafari et al. (2012) applied Toda-Yamamoto procedures and reported that there is no causality relationship between those variables. Hence, government can adopt the energy conservation and the emission abatement policy without concerning economic growth. On the other hand, using a different data set, Hwang and Yoo (2012) found there is uni-directional causalities from economic growth to energy consumption and carbon emission. There is also bi-directional causalities between energy consumption and carbon emission in the long run.

3 METHODOLOGY

3.1. Data

The purpose of this study is to investigate the causality relationship between fossil fuel consumption, carbon emission level, and output level in Indonesia for the period of 1965-2012 using yearly data. Our data come from various sources as detailed in the Table 1.

Each variable then will be tested for its stationarity and co-integration among them in order to determine which model we should use in this study: Vector auto regression (VAR) or VECM. Lastly, we conduct Granger causality test to examine the causality direction between variables.

3.1.1. Unit root test

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 (Table 2). In contrast, all variables are 1% 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).

3.1.2. Co-integration test: Johansen procedure

Before conducting Johansen Co-integration test, the number of optimal lag should be determined using various criteria that are summarised in the Table 3 since the co-integration test is sensitive to lag. 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) show that the optimal lag VAR is four. In order to avoid autocorrelation and heteroscedasticity problems, we use lag 3 as an optimum lag for co-integration test (optimal VAR lag-1).

Table 4 presents the result of the Johansen co-integration test, based on the Max-Eigenvalue and trace methods. Both the maximum eigenvalue and trace statistics show a significant value at 5%, so the null hypothesis that there are only at most two cointegrating equations can be rejected. Thus there are three cointegrating equations at a maximum lag of three periods.

3.1.3. VECM Granger causality

VECM is firstly introduced by Sargan (1964) and later developed by Engle and Granger (1987) and Johansen (1988). It is also known as the VECM cointegrating vector autoregression models (CIVAR) or restricted VAR since the variables in VECM are cointegrated and there is error correction term in the estimation model. The application of error correction term 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-run. Both the concept of co-integration and error correction is used to prevent the occurrence of spurious regression (Lauridsen, 1998).

Procedurally, VECM is chosen as the estimation model when the results from unit root test indicate that the all variables are not stationary in level but they are co-integrated or in other words there is a theoretical relationship between those variables. According to Obayelu and Salau (2010), VECM assumes that

Table 1: Variable descriptions and sources

Variable	Description	Source
Gross Domestic Product-Riil (Output)	Natural logarithm of Gross Domestic Product (constant 2005 in USD)	World Bank
Carbon emission	Natural logarithm of Carbon Emission- only through consumption of oil, gas and coal, and are based on standard global (million tonnes carbon dioxide)	BP Statistical Review of World Energy 2013
Oil consumption	Natural logarithm of Oil Consumption - consumption of fuel ethanol and biodiesel is also included. (million tonnes oil)	BP Statistical Review of World Energy 2013
Natural gas consumption	Natural logarithm of Natural Gas Consumption – (million tonnes oil equivalent)	BP Statistical Review of World Energy 2013
Coal consumption	Natural logarithm of Coal Consumption – Commercial solid fuels only (million tonnes oil equivalent)	BP Statistical Review of World Energy 2013

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*
(Carbon Emission)	(0.9770)	(0.9531)	(0.0000)	(0.0000)
LGDPR	−1.65625	−1.249867	−5.221177*	−5.207384*
(Output)	(0.7544)	(0.8879)	(0.0005)	(0.0005)
LOIL	−0.32116	−0.635945	−6.151965*	−6.146971*
(Oil Consumption)	(0.9877)	(0.9719)	(0.0000)	(0.0000)
LGAS	−0.72075	−0.904911	−4.60061*	−7.337728*
(Natural Gas Consumption)	(0.9645)	(0.9468)	(0.0034)	(0.0000)
LCOAL	−2.1657	−2.165703	−6.891926*	−6.872561*
(Coal Consumption)	(0.4969)	(0.4969)	(0.0000)	(0.0000)

*Significant at 1%; number in parentheses ( ) indicates the *P* value

Table 3: The results of lag length selection

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

This table compares the number of lag recommended by different criteria for a system of VAR. The number of maximum lag is 4. *Recommended lag by criterion

Table 4: The results of Johansen co-integration test

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

*Significant at 5%; number in parentheses ( ) indicates the *P* value for each statistics

these variables are linearly adjusted to the long-run equilibrium. While Engle and Granger (1987) concluded that the changes in the dependent variable is a function of changes in the value of the other independent variables as well as the value of error correction term (ECT). The ECT itself represents the long-term coefficients of the model.

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

$$\alpha\beta \quad {}_{t-1} \quad \sum_{i=1}^{p-1} \quad {}_{1} \quad {}_{t-1} \quad {}_{t} \quad {}_{t} \tag{4}$$

Where the notation Y_t denotes (*k x 1*) vector of endogenous variables, *α* is the adjustment coefficient that measures the speed adjustment of the endogenous variable *i* in the long-run, *β* is the cointegration vector, D_t is a vector of deterministic terms, $\Gamma_{1..p}$ is (*k x k*) matrix of coefficients, *C** is the matrix that associated with deterministic terms which are used in the model as a constant, with a trend or seasonal dummy; and u_t is the reduced form disturbance. While ECT variable is represented by the notation of *β* and Y_{t-1}.

Harris (1995) in Ajija et al. (2011) also formulated the VECM in the form of the following equation:

$$\underbrace{\begin{bmatrix}\Delta y_{1t}\\ \Delta y_{2t}\\ \Delta x_{1t}\\ \Delta x_{2t}\end{bmatrix} = \Gamma\begin{bmatrix}\Delta y_{1t-1}\\ \Delta y_{2t-1}\\ \Delta x_{1t-1}\\ \Delta x_{2t-1}\end{bmatrix}}_{Short-run\ term} + \underbrace{\begin{bmatrix}a_{11}\\ a_{12}\\ a_{31}\\ a_{41}\end{bmatrix} x[\beta_{11}\ \ \beta_{21}\ \ \beta_{31}\ \ \beta_{41}]x\begin{bmatrix}y_{1t-1}\\ y_{2t-1}\\ x_{1t-1}\\ x_{2t-1}\end{bmatrix}}_{Long-run\ term} \tag{5}$$

The VECM is often used in conjunction with the Granger Causality test which is developed by Granger (1969). Hence, this approach is known as the VECM Granger Causality. In addition to providing information towards the direction of causality relationships between variables, this approach also differentiates the time horizon of causality relationships: short-run and long-run. Tiwari (2011) revealed that the long-run relationship can be explained by the significance of the lagged ECT while the short-run relationship can be seen from the coefficient significance of the first-differenced independent variables. Mathematical modelling of VECM Granger Causality is as follows:

$$a_x \quad \sum_{i=1}^{k}\beta_{x,i} \quad X_{t-i} \quad \sum_{i=1}^{k} Y_{x,i} \quad Y_{t-i}\varphi_x ECT_{x,t-i} \quad \varepsilon_{x,t} \tag{6}$$

$$_{y} \quad \sum_{i=1}^{k}\beta_{y,i} \quad {}_{t-i} \quad \sum_{i=1}^{k}\gamma_{y,i} \quad {}_{t-i}\varphi_y \quad {}_{y,t-i} \quad \varepsilon_{y,t} \tag{7}$$

The above models are used to test the hypothesis that the variable *X* determines the value of the variable *Y*. The null hypothesis of equation (6) $H_0 : \sum_i^k \gamma_{x,i} = 0$ is and equation (7) is $H_0 : \sum_i^k \gamma_{y,i} = 0$. Thus, if the null hypothesis of equation (9) is failed to reject, then it can be concluded that the variable *Y* does not affect the variable *X*. On the other hand, if the null hypothesis of equation (7) is failed to reject, then the conclusion is that variable *X* has no effect on variable Y. If the models use only a single lag, then the hypothesis testing can be done by t-test. However, if the variables in the model use more than one lag (such as lag two, or three lag), the F-test should be employed. Similarly, it also applies to the hypothesis test for the long-run ECT variable in the both equations of VECM Granger causality.

3.1.5. Long-range energy alternatives planning (LEAP)

LEAP is a software that is developed by the Stockholm Environment Institute in 1981 to assess the impact of energy and environmental policy in a particular region over a range of periods. 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. The total energy demand and supply are calculated by summing the usage and supply of each type of energy in each sector or activity. There are four main modules in LEAP: Key Assumptions, Demand, Transformation, and Resources. The key assumptions module contains main assumptions of macroeconomic variables such as population and gross domestic product (GDP) that may affect the value of variables in the other modules. Mathematically, the energy demand is defined as follows (Help for LEAP, 2014):

$$\textit{Energy consumption} = \textit{activity level x energy intensity} \quad (8)$$

In addition to the main module, LEAP also has three additional modules that are complementary to the main module: Statically differences, stock changes, and non-energy sector effects. The statically differences module contains the assumption of statistical difference between the demand and supply of energy due to the differences in the method of data calculation. The stock changes module accommodates the assumptions of changes in energy reserves between some periods. While the last module, non-energy sector effects, incorporates the impact of energy production and consumption on non-energy sectors such as air pollution level and the number of people with respiratory tract infections.

To see the impact of energy conservation policy on the fossil fuels consumption in society, we use LEAP projection model with a focus on demand modules. The time periods chosen in this research is ranging from 2012 to 2025, which based on the Energy Vision 25/25 of Indonesia. This policy aim to reduce the share of fossil fuel consumption and increase the usage of renewable energy by 25% of total energy consumption in 2025. Graphically, the projections model for the final energy demand module in Indonesia is structured as presented in Figure 2.

The final energy demand module is divided into five sectors namely industrial sector, household, commercial, transportation and agriculture. The agricultural sector also includes forestry and fisheries. The total energy demand in each sector then is further divided into four types of energy, namely oil, coal, natural gas, and renewable energy sources. While the types of renewable energy in this study follows the classification of the IEA, namely nuclear power, electricity, geothermal, hydro, biofuels, and others.

4. RESULTS AND DISCUSSION

Table 5 illustrates the descriptive statistical analysis of the data. All variables are expressed in logarithmic form to standardize the unit of measurement. dummy variable for 1998 crisis (0 for period before 1998, 1 for otherwise) is also added in the estimation model to solve the normality problem in data. The notation of LCO2 represents the data for carbon emission while LGDPR is Real gross domestic product (Output), LOIL is oil consumption, LGAS is natural gas consumption, and LCOAL is coal consumption.

The log-transformed output data has the highest mean, which is equal with 25.53. It is extensively higher among the other log-transformed series that only ranging from 0.52 (coal consumption) to 4.73 (carbon emission). On the other hand, the largest value of standard deviation belongs to coal consumption, which equals to 2.31 while the smallest value is in output and oil consumption (both are 0.82).

4.1. The Results of VECM Granger Causality

Tables 6 and 7 illustrate the result of short-run and long-run multivariate causality tests based on the VECM. This paper uses a significance of 10% 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 output (growth hypothesis) and also from output to oil consumption (conservation hypothesis).

While for the long run, there are several significant variables that have a strong causality. First, unidirectional Granger causalities from oil consumption to output and carbon emission level. Second, bidirectional Granger causalities from coal consumption to output and carbon emission level. Third, bidirectional Granger causalities from gas consumption to output and carbon emission level. Fourth, bidirectional Granger causality from output to the level of carbon emission.

4.2. LEAP Projections

There are two projection scenarios in this stduy. Additionally, historical data from 2005 to 2011, published by IEA, was also added in the model to see the trend of sectoral energy demand in Indonesia. The first scenario is the Business as Usual (BAU) scenario. This scenario assumes there is no change in the energy policy. The second scenario is the implementation of the National Energy Conservation Master Plan (RIKEN) 2005 scenario. RIKEN scenario assumes that 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 8.

The RIKEN scenario refers to the Energy Vision 25/25 whose goal is achieving a reduction in energy consumption by 18% from the BAU scenario by 2025 through energy conservation activities. The determination of the energy efficiency target figure itself is one of the programs to achieve the realization of the Vision 25/25. The LEAP projection of energy consumption level in 2025 with the BAU scenario is shown in the Table 9.

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 27.66-65.35 Mtoe as presented in Table 10. That figures by percentage are equal with 17.32% and 13.46-31.80% of BAU scenario energy consumption level respectively. As shown in the table above,

Figure 2: LEAP projection model for final energy demand in Indonesia, 2012-2025

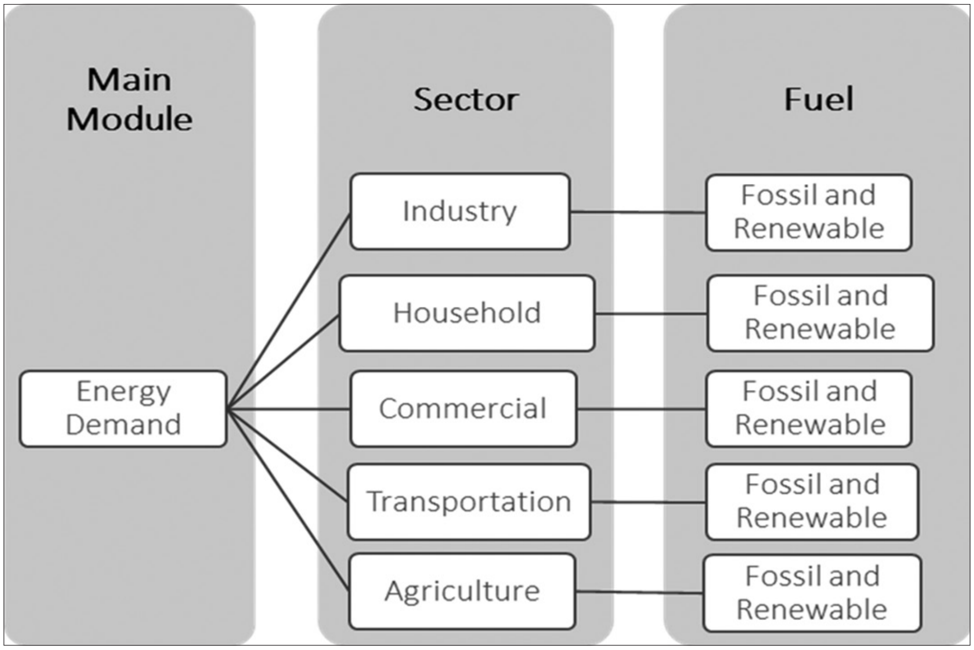


Table 5: Descriptive statistics

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
Standard deviation	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

Table 6: Short-run VECM Granger causality

Null hypothesis	Independent variable				
	Short-run (statistics - χ^2)				
	ΔLCO_2	ΔLGDPR	ΔLOIL	ΔLGAS	ΔLCOAL
Independent variables do not cause CO_2 emission level	-	3.727563	2.367751	3.395231	0.759597
		(0.2924)	(0.4997)	(0.3346)	(0.8591)
Independent variables do not cause economic growth	2.794514	-	0.057297	2.928688	25.53409*
	(0.4244)		(0.9964)	(0.4028)	(0.0000)
Independent variables do not cause oil consumption	0.599504	7.882641**	-	0.655319	0.639562
	(0.8965)	(0.0485)		(0.8837)	(0.8873)
Independent variables do not cause gas consumption	1.302281	3.097590	1.381021	-	1.678275
	(0.7286)	(0.3768)	(0.7100)		(0.6418)
Independent variables do not cause coal consumption	2.303587	3.689495	2.501159	4.352498	-
	(0.5118)	(0.2970)	(0.4751)	(0.2258)	

*,**,***Significant at 1, 5, 10% respectively; number in parentheses ( ) indicates the P value. VECM: Vector error correction model

the largest energy saving belongs to the transportation sector (14.82 Mtoe), then followed by the household sector (9.79 Mtoe), the industry sector (9.36 Mtoe), and the commercial sector (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.

5. CONCLUSIONS AND POLICY RECOMENDATIONS

This paper investigates the long-run and short-run causality relationships between fossil fuel consumption (oil, natural gas, and coal), carbon emissions, and output in Indonesia by using VECM Granger Causality. Empirical results suggest each types

Table 7: Long-run VECM Granger causality

Null hypothesis	Joint statistic - χ^2					Statistic - χ^2
	ΔLCO_2	$\Delta LGDPR$	$\Delta LOIL$	$\Delta LGAS$	$\Delta LCOAL$	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)

*,**,***Significant at 1, 5, 10% respectively; number in parentheses ( ) indicates the P value. VECM: Vector error correction model

Table 8: The 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

Table 9: The projection results of indonesia energy consumption level in 2025 (Ktoe)

Energy Source	Industry	Commer-Cial	Transpor-Tation	Household	Agri-culture	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: Calculated by authors from IEA data

of fossil fuel have different causality direction both in the long-run and short-run. The main results are as follows: *First*, in the short-run there are unidirectional Granger causalities running from coal consumption to output (growth hypothesis) and from output to oil consumption (conservation hypothesis). *Second*, in the long run the results suggest unidirectional Granger causality (growth hypothesis) only running from oil consumption to output and carbon emissions while the other variables have a bidirectional Granger causality (feedback hypothesis). Moreover, we 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 show that the result of LEAP projection based on RIKEN 2005 target has a lower energy saving rate (17.32%) compared to the Vision 25/25 target (18%).

Some policy recommendations that can be given to the Indonesian government. First, energy conservation policies on petroleum and natural gas resources should be done quickly because reductions in petroleum and natural gas consumption will not have a direct impact on economic growth. Second, the government should immediately improve the provision of a more environmentally friendly nonfossil energy source as communities in the domestic and commercial sectors are heavily dependent on nonfossil energy sources. In addition, people also need to be encouraged to use cleaner energy sources and save energy use in daily activities. Third, energy efficiency targets in RIKEN 2005 draft need to be revised because the projection shows lower savings (17.32%) than the 25/25 Vision target (18%).

Table 10: The potential and energy efficiency target in 2025 based on RIKEN 2005

Sector	Energy efficiency potential (Mtoe)	Energy efficiency target in 2025 (Mtoe)
Industry	5.50-16.5	9.36
Commercial	0.81-2.42	1.62
Transportation	11.12-25.94	14.82
Household	9.79-19.57	9.79
Agriculture	0.45-0.9	0
Total	27.66-65.35	35.58

Source: Calculated by authors from IEA data

REFERENCES

Ajija, S.R., Sari, D.W., Setianto, R.H., dan Primanti, M.R. (2011), Cara Cerdas Menguasai Eviews. 1st ed. Jakarta: Salemba Empat. p191-192.

Alam, M.M., Murad, M.W., Noman, A.H.M., Ozturk, I. (2016), Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. Ecological

Indicators, 70, 466-479.

Al-Mulali, U., Ozturk, I. (2016), The investigation of environmental Kuznets curve hypothesis in the advanced economies: The role of energy prices. Renewable and Sustainable Energy Reviews, 54, 1622-1631.

Al-Mulali, U., Solarin, S.A., Ozturk, I. (2016), Investigating the presence of the environmental Kuznets curve (EKC) hypothesis in Kenya: An autoregressive distributed lag (ARDL) approach. Natural Hazards, 80(3), 1729-1747.

Alshehry, A.S., Belloumi, M. (2014), Investigating the causal relationship between fossil fuels consumption and economic growth at aggregate and disaggregate levels in Saudi Arabia. International Journal of Energy Economics and Policy, 4(4), 531-545.

Ayres, R.U., Warr, B. (2005), Accounting for growth: The role of physical work. Structural Change and Economic Dynamics, 16(2), 181-209.

Azomahou, T., Laisney, F., Van, P.N. (2005), Economic Development and CO_2 Emissions: A Nonparametric Panel Approach. ZEW Discussion Paper, 05-56.

Ben Jebli, M., Ben Youssef, S., Ozturk, I. (2015), The role of renewable energy Consumption and trade: Environmental kuznets curve analysis for sub-Saharan Africa countries. African Development Review, 27(3), 288-300.

Berndt, E.R., dan Wood, D.O. (1975), Technology, prices, and the derived demand for energy. The Review of Economics and Statistics, 57, 259-268.

Brock, W.A., Taylor, M.S. (2004), Economic Growth and the Environment: A Review of Theory and Empirics. NBER Working Paper Series, 10854.

Budiarto, R. (2013), Kebijakan Energi. 2nd ed. Banguntapan, Bantul, Yogyakarta: Samudra Biru.

Choi, E., Heshmati, A., Cho, Y. (2010), An Empirical Study of the Relationships between CO_2 Emissions, Economic Growth and Openness. IZA DP No. 5304.

Engle, R.F., Granger, C.W.J. (1987), Co-integration and error correction: Representation, estimation and testing. Econometrica, 55(2), 251-276.

Granados, J.A.T., Carpintero, O. (2009), Dispelling the Smoke: CO_2 Emissions and Economic Growth from a Global Perspective. Working Paper, University of Michigan. 2009.

Granger, C.W.J. (1969), Investigation causal relations by econometric models and cross-spectral methods. Econometrica, 37, 424-438.

Greiner, A., Gruene, L., Semmler, W. (2012), Economic growth and the transition from non-renewable to renewable energy. Environment and Development Economics, 19(4), 1-34.

Griffin, J.M., Gregory, P.R. (1976), An intercountry translog model of energy substitution responses. American Economic Review, 66(5), 845-57.

Grossman, G.M., Krueger, A.B. (1991), Environmental Impacts of a North American Free Trade Agreement. NBER Working Paper No. 3914.

Harris, R. (1995), Cointegration Analysis in Econometric Modelling. New York: Prentice Hall. p77.

Hwang, J., Yoo, S. (2012), Energy consumption, CO_2emissions, and economic growth: Evidence from Indonesia. Quality and Quantity, 48(1), 63-73.

International Energy Agency. (2013a), Key World Energy Statistics. Paris: International Energy Agency.

International Energy Agency. (2013b), CO_2 Emissions from Fuel Combustion Highlights. Paris: International Energy Agency.

Jafari, Y., Othman, J., Nor, A.H.S.M. (2012), Energy consumption, economic growth and environmental pollutants in Indonesia. Journal of Policy Modeling, 34(6), 879-889.

Johansen, S. (1988), Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control, 12, 231-254.

Lauridsen, J. (1998), Spatial Cointegration Analysis in Econometric Modelling. Department of Statistics and Demography, Odense University. Campusvey 55 DK-5230 Odense M Available from: http://www.ou.dk/rrvf/statdem/lauriden.html.

Nuryartono, N., Rifai, M.A. (2017), Analysis of causality between economic growth, energy consumption and carbon dioxide emissions in 4 ASEAN countries. International Journal of Energy Economics and Policy, 7(6), 141-152.

Obayelu, A.E., Salau, A.S. (2010), Agricultural response to prices and exchange rate in Nigeria: Application of co-integration and vector error correction model (VECM). The Journal of Agricultural Science, 1(2), 73-81.

Ozturk, I. (2010), A literature survey on energy–growth nexus. Energy Policy, 38(1), 340-349.

Ozturk, I., Acaravci, A. (2010), CO_2 emissions, energy consumption and economic growth in Turkey. Renewable and Sustainable Energy Reviews, 14, 3220-3225.

Surjaningsih, N., Utari, G.A.D., dan Trisnanto, B. (2012), Dampak Kebijakan Fiskal Terhadap Output dan Inflasi. Buletin Ekonomi Moneter dan Perbankan, 389-420.

Sargan, J.D. (1964), Wages and Prices in The United Kingdom: A Study in Econometric Methodology. In: Hendry, D.F., Wallis, K.F., editor. Econometrics and Quantitative Economics. Oxford: Blackwell.

Sasana, H., Ghozali, I. (2017), The impact of fossil and renewable energy consumption on the economic growth in Brazil, Russia, India, China and South Africa. International Journal of Energy Economics and Policy, 7(3), 194-200.

Stern, D.I. (2003), The Rise and Fall of the Environmental Kuznets Curve. Rensselaer: Working Papers in Economics, 0302.

Stern, D.I. (2004), Environmental kuznets curve. Encyclopedia of Energy, 2, 517-525.

Stern, D.I. (2011), The role of energy in economic growth. Annals of the New York Academy of Sciences, 1219(1), 26-51.

Stern, D.I., Kander, A. (2012), The role of energy in the industrial revolution and modern economic growth. Energy Journal, 33(3), 1-11.

Tiwari, A.K. (2011), Energy consumption, Co_2 emissions and economic growth: Evidence from India. Journal of International Business and Economy, 12(1), 85-122.

Wang, D. (2012), A Dynamic Optimization on Energy Efficiency in Developing Countries. MPRA Paper No. 43749.

Zhang, X., dan Cheng, X. (2009), Energy consumption, carbon emissions, and economic growth in China. Ecological Economics, 68(10), 2706-2712.