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Energy-Growth Nexus in Indonesia: Fresh Evidence from Asymmetric Causality Test

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ABSTRACT

The purpose of this study is to examine the causality between energy consumption and economic growth with an asymmetric causality approach in Indonesia for the period of 1971-2014. Asymmetric causality using the Hatemi-J method (2012). Bootstrap simulation is also implemented because the data is not normally distributed and there is volatility to get a more reliable critical value than using asymptotic values. The first finding is that classical causality with Toda-Yamamoto finds no relationship between energy consumption and economic growth in Indonesia. The second finding shows that asymmetric causality shows no relationship between energy consumption and economic growth on a positive cumulative basis. However, the third finding obtained a bidirectional in negative cumulative. It is known that the impact of a decrease in energy consumption is greater on a decrease in economic growth than vice versa. Based on these findings, energy consumption in Indonesia has reached an optimal point so that additional energy consumption does not have an impact on economic growth. However, efforts to stabilize energy and economic growth are urgently needed.

Keywords: Energy Consumption, Economic Growth, Asymmetric Causality
JEL Classifications: C30, Q43

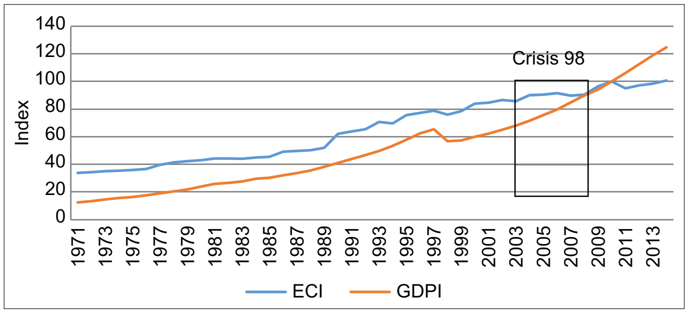
1. INTRODUCTION

In today's modern era, energy plays an important role in the economy. Energy becomes an important wheel in supporting every activity and production. The use of energy is inseparable as an input like capital and this is generally explained in the Cobb-Douglas extension model (Le and Nguyen, 2019). It started from research by Kraft and Kraft (1978) where at that time there was a crisis problem in 1970. However, the debate on the relationship between energy and economic growth is still ongoing.

Indonesia is a developing country that uses energy to promote optimal economic growth. Figure 1 shows that energy consumption has increased slowly from 1971 to 1998. However, entering a period of the financial crisis, the Indonesian economy declined drastically and unemployment increased significantly. As a result, energy consumption also decreases. After going through a period of crisis, the economy was seen recovering and energy consumption. In Indonesia, the difference between energy and economic growth has not yet clear. As the findings by Azam et al. (2015) with Soares et al. (2014). This will have an impact on the policies that will be taken.

Previous research issues were more about energy consumption and economic growth symmetrically but using different techniques. Referring to Figure 1 the increase and decrease are not always balanced. Consideration from the asymmetric perspective is important because the impact of negative energy shocks is different from the positive impact of energy on economic growth. For example, when energy is lost due to a 1-h blackout and the recovery time cannot be ascertained, it will have a huge impact on economic activity.

Figure 1: Economic growth and energy consumption in Indonesia



Source: WDI

The contribution of this research is seen as some literature review. First, this study differs from that of previous studies where the study used the general Granger method but we adopted the Hatemi-J (2012) technique for asymmetric causality. Second, this finding explains the paradox where energy does not have an impact on economic growth but energy is seen developing continuously. Third, to the best of the researcher's knowledge, this study is the first study in the context of energy consumption for economic growth, and that this study is few in Indonesia, especially in asymmetrical studies.

In this final section, the systematic steps of writing are described. The second part is a literature study. The third part is econometric data and methodology. Section four is describe the findings and discussion. Finally in section five is the conclusion about energy consumption and economic growth.

2. LITERATURE REVIEW

The relationship between energy and economic growth is an important study for a policy to be taken. According to the energy literature by Ozturk (2010), there are four possible relationships between energy consumption and economic growth: 1. Neutral hypothesis where there is no relationship between energy consumption and economic growth. 2. The conservation hypothesis where economic growth has a one-way effect on energy consumption. 3. The growth hypothesis where energy consumption has a one-way effect on economic growth. 4. The feedback hypothesis is that energy consumption and economic growth are related to each other at the same time.

Several studies examine the causal relationship between economic growth and energy consumption. The studies focus from 2004 to 2019 on various developed countries, developing countries, and groups of countries. Early research by Paul and Bhattacharya (2004) in India using the VEC Granger causality method from the period 1950-1996. The results of this study found a one-way effect of energy consumption on economic growth. Subsequent research by Erdal et al. (2008) with pairwise granger and found similar results that energy has a two-way effect on economic growth.

Meanwhile, the study of Odiambo (2009) by testing the causality of the two variables during the period 1971-2006. The research method uses ECM. The results show that energy consumption affects economic growth in one direction. Similar results were also found by Tsani (2010) in Greece but using the Toda-Yamamoto causality method. The study was conducted with a sample of 1960-2006 and Nyasha et al. (2018) in Ethiopia with sample of 1971-2013.

The study in China was carried out by Zhixin and Xin (2011) using the Granger causality method and Zhang-Wei and Xun-Gang (2012) using the VAR model. The findings were different. Zhixin and Xin (2011) found that energy consumption and economic growth have a two-way relationship. Meanwhile, Zhang-Wei and Xun-Gang (2012) found that energy consumption has a one-way effect on economic growth.

Subsequent research by Ozturk et al. (2013) where this study uses the VECM method in Turkey with a period of 1960-2006. The results of this study indicate that in the short term economic growth and consumption do not have a causal relationship. However, in the long-term estimation, it is found that economic growth has a unidirectional with energy consumption These findings are different from Mele (2019) where he found bidirectional in long-term for Brazil with a sample of 1980-2017.

Research in Indonesia was reviewed by Soares et al. (2014). This study uses the VECM method. The data used are from 1971 to 2010. The results of this study explain that in the short term, there is no causal relationship between energy consumption and economic growth, but the results of long-term causality are found to have a bidirectional. This finding is also reinforced by Azam et al. (2015) through the approach of 5 ASEAN countries with the period 1920-2012 and Carfora et al. (2019) in selected Asian countries with the period 1971-2015. The results of both studies explain that Indonesia does not have a causal relationship or netral.

Mutascu (2016) employs a different approach in his study, the bootsrap panel granger. This study focused on the G-7 countries from 1970-2012. He found there is a unidirectional from economic growth on energy consumption for France and Germany, whereas for Canada, Japan, and the United States found bidirectional. Meanwhile, Faisal et al. (2017) tested the robustness of the non-causality Toda-Yamamoto Granger method on several lags. Belgian data from 1960 to 2012 is used in this study. The findings reveal a consistent unidirectional energy use on economic development from lag 1 to lag 4.

Based on previous studies, there is an interesting thing where the findings of hypotheses between one study and another, even though in the same scope have different results were found, such as Erdal et al. (2008) and Ozturk et al. (2013). This study focuses on Indonesia that the results are very consistent where energy consumption and economic growth have no relationship at all. This is proven by 2 out of 3 studies finding these results. However, referring to other countries that have developing country status, different results are found. At least have a unidirectional. This is a stark contrast considering the development of the two data in Figure 1 has an increasing trend every year in Indonesia, especially during the 1998 financial crisis there was a significant decline. This increase and decrease are not linear.

3. DATA AND ECONOMETRIC METHODOLOGY

The study uses annual data in the form of real GDP and Energy Consumption from 1971-2014 due to data availability. The data is sourced from the World Development Indicators (WDI, 2020). Measurement of economic growth variables with GDP based on 2010 constant prices in dollars and energy consumption using energy use proxies with metric tons per capita. This study aims to capture asymmetric causality as research conducted by Hatemi-J (2012). Symmetrical conditions where the rise and fall of an effect give the same effect. However, the effect is not symmetrical. It may possibly that the impact of the increase will not be as large as the impact of the decrease or vice versa. Thus, asymmetrical studies are important. The data in the natural logarithm and the study model are explained as follows:

$$E_t = E_{t-1} + \varepsilon_{1t} = E_0 + \sum_{i=1}^{t} \varepsilon_{1i} \tag{1}$$

$$Y_t = Y_{t-1} + \varepsilon_{2t} = Y_0 + \sum_{i=1}^{t} \varepsilon_{2i} \tag{2}$$

Where E is energy consumption, Y is economic growth, E_0, Y_0 is a constant and $\varepsilon_{1i}, \varepsilon_{2i}$ is a residual. Positive asymmetric variable shocks are known as $\varepsilon_{1i}^{+} = \max\left(\varepsilon_{1i,} 0\right) \text{dan} \varepsilon_{2i}^{+} = \max\left(\varepsilon_{1i,} 0\right)$. while negative shocks are thus $\varepsilon_{1i}^{-} = \min\left(\varepsilon_{1i,} 0\right) \text{dan} \varepsilon_{2i}^{-} = \min\left(\varepsilon_{1i,} 0\right)$. Therefore, $\varepsilon_{1i} = \varepsilon_{1i}^{+} + \varepsilon_{1i}^{-}$ and $\varepsilon_{2i} = \varepsilon_{2i}^{+} + \varepsilon_{2i}^{-}$ can be applied in equations (1) and (2) so that:

$$E_t = E_{t-1} + \varepsilon_{1t} = E_0 + \sum_{i=1}^{t} \varepsilon_{1i}^{+} + \sum_{i=1}^{t} \varepsilon_{1i}^{-} \tag{3}$$

$$Y_t = Y_{t-1} + \varepsilon_{2t} = Y_0 + \sum_{i=1}^{t} \varepsilon_{2i}^{+} + \sum_{i=1}^{t} \varepsilon_{2i}^{-} \tag{4}$$

From equations (3) and (4) can be defined positive and negative shocks of each variable. The cumulative form is described by $E_t^{+} = \sum_{i=1}^{t} \varepsilon_{1i}^{+}$, $E_t^{-} = \sum_{i=1}^{t} \varepsilon_{1i}^{-}$, $Y_t^{+} = \sum_{i=1}^{t} \varepsilon_{2i}^{+}$, and $Y_t^{+} = \sum_{i=1}^{t} \varepsilon_{2i}^{-}$. These components are used in asymmetric causality testing. For example, the null hypothesis is that a positive energy shock does not cause a positive shock to economic growth. In vector form, this can be defined as $X_t^{+} = \left(E_t^{+}, Y_t^{+}\right)$ and this is true in negative form. This causality test is implemented in the form of VAR (L) as follows:

$$X_t^{+} = v + A_1 X_{t-1}^{+} + \ldots + A_p X_{t-L}^{+} + u_t^{+} \tag{5}$$

$$HJC = \ln\left(\left|\hat{\Omega}_f\right|\right) + \frac{L}{2T}\left(m^2 \ln T + 2m^2 \ln\left(\ln T\right)\right)), \tag{6}$$

$L = 0, \ldots, L - \max$

Where $\left|\hat{\Omega}_f\right|$ is the determinant of the variance-covariance matrix which is estimated using the lag order L, m is the number of equations in the multivariate model and T is the sample size. After getting the optimal lag, we enter the null hypothesis, namely:

H_o: row *j*, column *k* elements in A_r are equal to zero for r = 1., *L*.

Testing the null hypothesis can be done with the Wald test. Before entering the test, it needs to be defined:

$Y := \left(X_1^{+}, \ldots, X_T^{+}\right)\left(m \times T\right)$ matrix,

$D := \left(v, A_1, \ldots, A_L\right)\left(m \times \left(1 + mL\right)\right)$ matrix ,

$$Z_t = \begin{bmatrix} 1 \\ y_t^{+} \\ y_{t-1}^{+} \\ \vdots \\ y_{t-p+1}^{+} \end{bmatrix} \left(\left(1 + mL\right) \times T\right) \text{matrix, for } t = 1, \ldots, T.$$

$\delta := \left(u_1^{+}, \ldots, u_T^{+}\right)\left(m \times T\right)$ matrix.

Using the denotation above, the VAR(L) model can be defined as follows:

$$Y = DZ + \delta \tag{7}$$

Statistical testing in the form of Wald can be used on the equation with the non-Granger hypothesis, namely:

$$Wald = (R\beta)'\left[R(Z'Z)^{-1} \otimes \sum\nolimits_U R'\right]^{-1}(R\beta) \tag{8}$$

Note that $\beta = vec(D)$ where vec is the operator column, ⊗ is the Kronecker product, and R is *a* $L \times m(1+mL)$ an indicator matrix consisting of one for the finite parameter and zero for the other. The variance and covariance matrices in the unrestricted model are defined by $S_U = (\hat{\delta}'_U \hat{\delta}_U)/(T-q)$, where q is the number of parameters of each equation estimate in the VAR system. Assuming that the assumption of a normal distribution applies to the regression so that the Wald test in equation (8) is asymptotically

Table 1: Unit root test

Variable	I (0)	I (1)
Y^+	-1.170 (0.126)	-2.325 (0.014)**
Y^-	-1.281 (0.106)	-5.000 (0.000)***
E^+	-2.958 (0.003)***	-5.120 (0.000)***
E^-	-0.037 (0.485)	-5.724 (0.000)***

***p<0.01, **p<0.05

Table 2: Multivariate Diagnostic test for Normality and ARCH

VAR model	Multivariate Normality (p-value)	Multivariate ARCH (P-value)
(Y^+, E^+)	0.000***	0.002***
(Y^-, E^-)	0.000***	0.004***

***P<0.01

distributed with χ^2 and L degree freedom. However, if the data are not normally distributed and there is an ARCH effect, the Wald test will not follow the assumption of an asymptotic distribution, especially in the case of a small sample. In general, various literature described bootstrap simulation can fix (remedy) this problem. This simulation used GAUSS software from Hatemi-J (2011) and is available online.

4. RESULTS AND DISCUSSION

Before discussion the asymmetric analysis, the data needs to be tested about stationarity. The test was carried out using the Augmented Dickey and Fuller approach (1979). The results of this test are shown in Table 1. Variable E^+ shows that it is stationary at the level but variables Y^+, Y^-, E^- are not stationary. At the first difference level, all variables are stationary. Since this test found stationarity in the form of mix or first difference for each variable, it is necessary to add extra lag constraints in the VAR model as recommended by Toda and Yamamoto (1995).

The next stage is checking for normality and ARCH. Testing of multivariate normality through measurements by Doornik and Hansen (2008) with the null hypothesis in the form of normally distributed data. For multivariate ARCH testing available by Hacker and Hatemi-J (2005) and simulation of ARCH tests tested with software invented by Hacker and Hatemi-J (2009). This check follows the steps of the articles Hatemi-J and Uddin (2012), Hatemi-J (2012), and Hatemi et al. (2016). The results of both tests are shown in Table 2 where both VAR models in positive and negative shocks show rejecting Ho, which means the data are not normally distributed. Meanwhile, the multivariate side of ARCH explained that both have volatility that varies overtime at the level of 1%. According to Hatemi-J (2012), If these two elements are violated, the asymmetric model is tested with bootstrap simulation.

Table 3 is the result of testing in symmetric and asymmetrical in Indonesia. The first test with the symmetric method using the Toda and Yamamoto technique (1995) found that energy consumption and economic growth had no relationship. These results are consistent with the findings of Azam et al. (2015) and Carfora et al. (2019). However, when testing asymmetrically, the results show a positive shock from economic growth to energy consumption and vice versa

Table 3: The Symmetric and Asymmetric Causality Result

Null Hypothesis	Causal Parameter	W-stat	Bootstrap CV			Optimal Lags
			1%	5%	10%	
$E \rightarrow Y$		0.024	8.298	4.297	2.902	1
$Y \rightarrow E$		0.001	9.133	4.387	2.926	1
$E^+ \rightarrow Y^+$		0.172	7.514	4.164	2.855	1
$Y^+ \rightarrow E^+$		0.099	7.493	4.145	2.893	1
$E^- \rightarrow Y^-$	1.635	17.115*	101.399	57.769	15.282	4
$Y^- \rightarrow E^-$	1.197	126.163***	21.513	12.293	9.115	4

E→Y means E does not cause Y. CV is a critical value. Optimal lag based on Hatemi-J criterion (HJC). *P<0.1 ***P<0.01

is not significant because the W-stat value is lower than the critical bootstrap value. This explains the increase in energy has no impact on increasing energy consumption in Indonesia. In addition, the data also shows that energy consumption has experienced a stable movement from 2010 to 2014. Energy consumption has likely experienced an optimal point. Meanwhile, the negative shock found different things, namely the decrease in energy had a significant impact on the decline in economic growth. While energy decrease about 1% so that means economic growth will decrease too by 1.639%. Furthermore, in terms of negative economic growth, it has a significant impact on decreasing energy consumption. The interpretation of these findings is that a 1% decrease in economic growth will reduce energy consumption by 1.197%. In addition, both negatively have a causal relationship and the impact of negative energy is greater than the negative impact of economic growth.

5. CONCLUSION

The purpose of this research study is to examine the relationship between economic growth and energy from the asymmetric side from 1971 to 2014. This test is based on bootstrap simulation with leverage correction to produce an accurate critical value. This simulation is very necessary because the sample of this study is small and there is a violation of assumptions in the form of abnormal data and there is volatility. To go through this estimation, we tested the unit root using the ADF approach and found a stable variable in the first difference state. The results of the normality test show that the data is not normally distributed and there is a volatility problem.

The first estimation result is shown by the initial symmetrical test using the Toda-Yamamoto approach where there is no relationship between energy and economic growth. Furthermore, the second estimate when tested through asymmetry found positive shocks had no effect at all between energy and economic growth. However, the negative shock session found a relationship from energy to economic growth and vice versa. This empirical result explains that the increase in energy consumption is not proven to significantly increase economic growth. This indicates that energy consumption in Indonesia is starting to reach its optimal point. However, when there is a loss of energy consumption, it has a significant impact on economic growth, where decrease in energy causes economic growth to decrease by 1.635%. On the other hand, decrease in economic growth will reduce energy consumption by 1.107%. Therefore, based on this study, policymakers need to maintain energy stability and economic growth.

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