Renewable energy consumption and economic growth in Indonesia. Evidence from the ARDL bounds testing approach

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ABSTRACT

This study serves to examine the effects of renewable energy consumption on economic growth in Indonesia. Quarterly time series data was used for the period 1990 – 2014. Applying the autoregressive distributed lag (ARDL) bounds testing approach, the study established that there is a long run relationship between economic growth, renewable energy consumption, carbon dioxide emissions, capital and employment. It is established that renewable energy consumption has a significant positive effect on economic growth both in the long run and short run. The findings from the vector error correction model (VECM) technique suggest that there is a long run causality flowing from renewable energy consumption, carbon dioxide emissions, capital and employment to economic growth. The findings of this study suggest that the government, energy policy makers and associated bodies should act together to improve on the renewable energy infrastructure and lower carbon growth in Indonesia.

Keywords: Renewable energy consumption, Economic growth, Co-integration, Causality, Indonesia

JEL Classification: D04, C32, Q47, Q42, Q01

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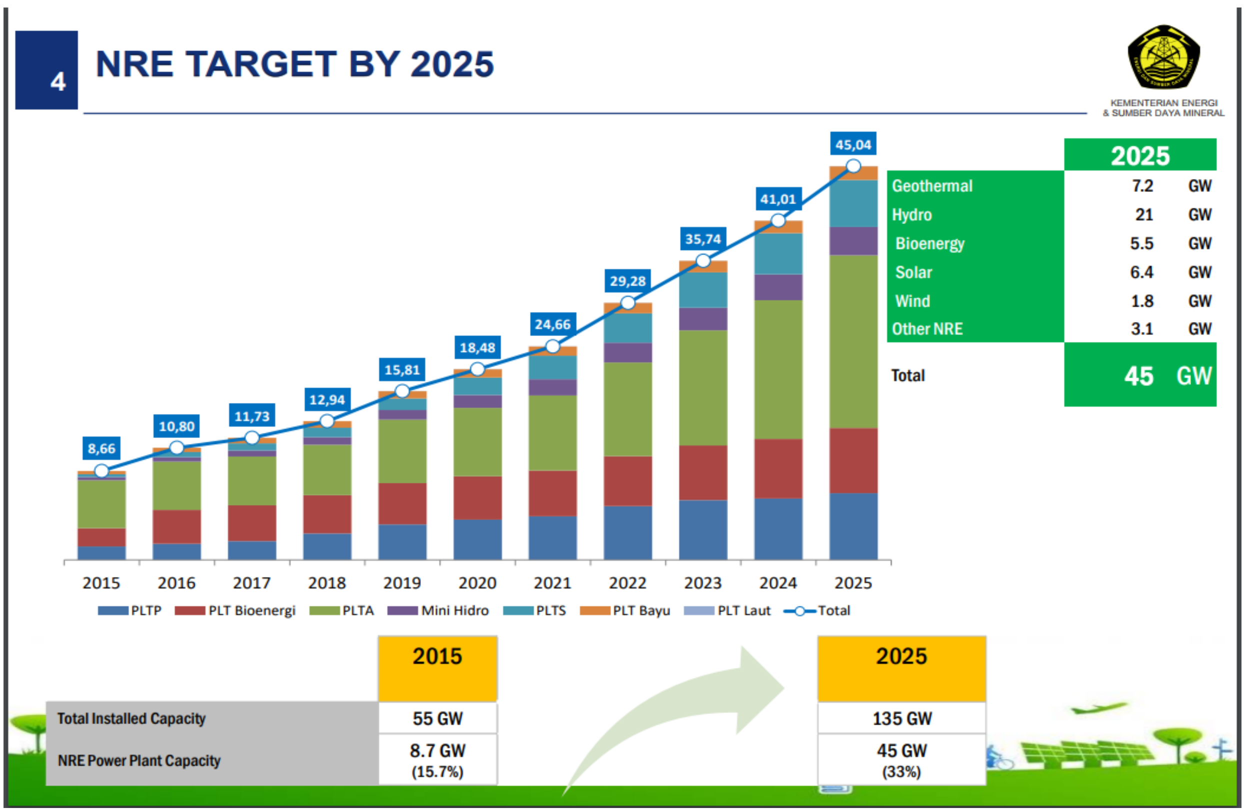
1. ITRODUCTION

The ongoing debate on the notion of whether energy consumption is the driver for economic growth or whether economic growth promotes energy consumption has been an extensive topic of interest since the past two decades. This topic has been motivated by the fact that an increase in energy demand triggers industrial revolution and rapid growth in both developing and developed countries. This has also resulted in a much discussed phenomena such as global warming and climate change. The major concern of the energy economist is coming up with energy conversation policies that will enhance economic growth without causing environmental degradation. In the past two decades, global warming and climate instability has been attributed to the increase in carbon dioxide emissions (Ocal and Aslan 2013). This leads to a dilemma regarding whether the energy policy should be geared towards energy saving and carbon reduction or economic growth. Most studies that served to tackle the linkage between energy consumption and economic growth followed the pioneers of this notion, Kraft and Kraft (1978). They used different methodologies, various countries and focusing on different time periods. As a result, these studies established different results, which can be classified into four categories. The first category is the growth hypothesis, which indicates that there is a unidirectional causality flowing from energy consumption to economic growth. This growth hypothesis implies that if energy conservation-oriented policies decreases energy consumption, this will deteriorate economic growth. The second type is the conservation hypothesis, which argues that there is a unidirectional causality flowing from economic growth to energy consumption. The conservation hypothesis implies that a decrease in energy consumption caused by energy conservation-oriented policies may have no impact on economic growth. The third type is feedback hypothesis, which states that there is a bidirectional causality flowing between energy consumption and economic growth. The fourth type is the neutrality hypothesis and it indicates that there is no causality flowing between energy consumption and economic growth.

Based on the debates above, it can be realised that the available evidence on the causality between economic growth and energy consumption is inconclusive. This led to the current study investigating the causal relationship between renewable energy consumption and economic growth to come up with energy policy recommendations that will boost economic growth. The study examined the linkage between renewable energy consumption and economic growth for Indonesia covering the period between 1990 and 2014. To the best of the author's knowledge, this is the first study to examine this phenomenon in Indonesia using the most recent approaches; the autoregressive distributed lag (ARDL) bounds testing approach and the vector error correction model (VECM) technique.

Indonesia was chosen because it is the largest energy using country in the Association of South East Asian nations (ASEAN). Although Indonesia has increased in dependence on coal and imported petroleum products in recent years, it has started adding more renewable capacity in its energy mix. According to IRENA (2017), the country purposes to achieve 23% renewable energy consumption by 2025 and 31% by 2050. Figure 1 below shows that Indonesia possesses abundant resources for solar, wind, ocean and bioenergy development. Indonesia has experienced an increase in the usage of renewable energy. Furthermore, figure 1 shows that in 2015 the 8.66% of the energy consumed in the country came from renewable energy. This came from a lower than 6% usage of renewable in 2014 (IRENA 2017). It can also be realised that it is projected that the renewable energy consumption will achieve annual growth rate of 12.94% in 2018, 18.48% in 2020 and 45.04% in 2025.

Figure 1: National Renewable Energy Target by 2025



Source: Kementerian Energy and Summer Daya Mineral (2017)

Due to the mention developments and the targeted annual growth rates in renewable energy consumption as well as the limited studies that focused on the linkage between renewable energy consumption and economic growth in Indonesia, the current study will be significant in that it will explore whether there is causality between these variables. As a result, the study will be able to come up with energy conservation policies that will be suitable for Indoneisa.

The remainder of the paper is structured as follows; section two outlines the brief literature about the linkage between renewable energy consumption and economic growth. Section three discusses the model specification, data sources and the estimation procedures used in the study. Section four presents the empirical findings followed by section five which concludes the study and gives policy recommendations.

2. LITERATURE REVIEW

The literature review shows that the linkages between economic growth, renewable energy consumption, carbon dioxide emission, employment and capital can be broadly classified into two research clusters. The first cluster focuses on the relationship between economic growth and aggregated energy consumption using the co-integration approaches and the Granger-causality techniques. The second cluster focuses on economic growth and renewable energy consumption nexus. Nevertheless, for Indonesia, a limited number of studies are available.

The pioneering work with regard to the causal relationship between economic growth and energy consumption was introduced by Kraft and Kraft (1978). This study purposed to establish the link between energy and Gross National Product (GNP) in the United States covering the period between 1947 and 1974. It results affirmed a unidirectional causality flowing from GNP to energy. It was recommended in this study that energy conservation policy could be implemented since reducing energy consumption does not negatively affect economic growth.

Since then, extensive research has been done on investigating the causal relationship between energy consumption and economic growth. It was learned that the knowledge of causality between energy consumption and economic growth has very important policy implications. Unidirectional causality flowing from energy consumption to economic, termed the growth hypothesis, implies the growth of the country is dependent on energy. Since, energy has both direct and indirect impact on economic growth, the conservation energy policies will have an adverse effect on economic growth (Fotourehchi 2017; Khobai and Le Roux 2017;Bhattacharya et al., 2016; Spetan 2016; Apergis and Danuletiu 2014;Leitao 2014; Payne 2010; Bowden and Payne 2009). However, the presence of a unidirectional causality flowing from economic growth to energy consumption, named conservation hypothesis, implies that energy conservation policies have little or no adverse effect on economic growth (Ocal and Aslan 2013; Aneje et al., 2017). The existence of a bidirectional causality between economic growth and energy consumption, called the feedback hypothesis, implies that energy consumption boosts economic growth and economic growth stimulates energy consumption (Rafindadi and Ozturk 2017; Lin and Moubarak 2014; Tugcu 2013; Fang 2011; Apergis and Payne 2010). The last instance is the neutrality hypothesis, which states that there is no causality flowing between energy consumption and economic growth. In this case, any conservation policy that can be implemented will have no effect on economic growth (Tugcu, Ozturk and Aslan 2012; Menegaki 2011; Payne 2010).

The first strand of the literature include studies that revealed a bidirectional causality flowing between renewable energy consumption and economic growth. These results were established in different countries for different periods. Rafindadi and Ozturk 2017 concentrated on Germany covering the period from 1971 to 2013; Lin and Moubarak 2014 focused on China for the period between 1977 and 2011 ; Tugcu 2013 focused on China for the period 1977 – 2011; Apergis and Payne 2010 worked on the panel of OECD countries covering the period 1985 – 2005.

The second strand of literature is the one that confirmed the growth hypothis hypothesis. Khobai and Le Roux 2017 confirmed a unidirectional causality flowing from renewable energy consumption to economic growth for South Africa covering the period 1990-2014 employing the vector error correction model (VECM). Fotourehchi 2017 found similar results focusing on 42 developing countries for the period between 1990 and 2012 using the Canning and Pedroni (2008) long-run causality test. Bhattacharya et al., 2016 affirmed causality flowing from renewable energy consumption to economic growth covering the 38 top renewable energy consuming countries from 1991 to 2012. Exploring 80 countries using Canning and Pedron (2008) long-run causality test, Apergis and Danuletiu (2014) validated that renewable energy consumption Granger-causes economic growth. Leitao (2014) evidenced a growth hypothesis for Portugal covering the period between 1970 and 2010 while Spetan (2016) evidenced growth hypothesis for Jordan for the period 1986 - 2012.

The third strand is the conservation hypothesis. Aneje et al., (2017) examined the relationship between renewable and non-renewable energy consumption and economic growth for BRICS countries covering the period between 1990 and 2012. Their panel error correction mechanism suggested that there is a unidirectional causality flowing from economic growth to renewable energy consumption. Ocal and Aslan (2013) affirmed a conservation hypothesis for Turkey by applying the Toda-Yamamoto causality test.

Furthermore, some studies established mixed results when investigating the linkages between renewable energy consumption and economic growth (Simelyte and Dudzevicuite 2017; Jebli et al., 2016; Pao and Fu 2013; Tugcu et al., 2012; Yildirim et al., 2012 Bowden and Payne 2010). Simelyte and Dudzevicuite (2017) found mixed results when conducting a study for 28 European Union countries covering the period from 1990 to 2012; The growth hypothesis was established in 12 countries, conservation hypothesis in 6 countries and neutrality hypothesis in 2 countries.

Aslan and Ocal (2016) experienced mixed results when studying new EU member countries for the period 1990-2009. This study realised growth hypothesis for Bulgaria, conservation hypothesis for Czech Republic and neutrality hypothesis for Cyprus, Estonia, Hungary, Poland and Slovenia. Pao and Fu (2013) focused on renewable energy consumption and non-hydroelectric renewable energy consumption and economic growth in Brazil. The results detected a unidirectional causality flowing from non-hydroelectric renewable energy consumption to economic growth and bidirectional causality flowing between renewable energy consumption and economic growth.

Tugcu et al., (2012) examined the renewable and non-renewable energy consumption and economic growth nexus covering the G7 countries for the period 1980 – 2009 and established a feedback hypothesis for all the countries in the case of classical production function but different results per country when the production was is augmented. Yildirim et al., (2012) considered disaggregated renewable energy consumption and economic growth nexus. The results revealed that only one causality flowing from biomass-wasted-derived energy consumption to economic growth was found. No causality was established between economic growth and all other renewable energy types such as total renewable energy consumption, hydro-electricity energy consumption, geothermal energy consumption, biomass energy consumption and biomass-wood-derived energy consumption. Bowden and Payne (2010) concentrated on the causality between sectorial renewable and non-renewable energy consumption and economic growth in the US for the period 1949-2006. The Toda-Yamamoto long run-causality suggested a unidirectional causality flowing from residential renewable energy consumption to economic growth and no causality was revealed between industrial and commercial renewable energy consumption and economic growth.

3. METHODOLOGY

This section discusses the generation of the model used to determine the long run and short causality between renewable energy consumption and economic growth. The different methodologies such as unit root test techniques, the co-integration approaches and the causality frameworks used in this study are discussed in this section.

3.1 Model specification

Numerous empirical research tested the similar hypotheses to the ones considered in the present study, which are: growth hypothesis which shows that renewable energy consumption is a key factor in boosting economic growth and conservation hypothesis which indicates that economic growth drives renewable energy consumption (Bhattacgarya et.al 2016; Khobai and Le roux 2017; Leitao 2014; Spetan 2016). Following the steps of Mankiw et.al (1992), using a Cobb-Douglas production function in aggregate form and assuming marginal contribution of capital and labour in production, the production function in period t is given below:

$$GDP(t) = A(t)K(t)^{\beta} L(t)^{1-\beta} \tag{1}$$

Where GDP stands for the gross domestic output, A represents technological process, K denotes capital stock, L is labour and β is the output elasticity of capital. Expanding the Cobb-Douglas production function by assuming technological process can be achieved through consumption of renewable energy. The empirical formulation of this study includes the causal relationship between renewable energy consumption and economic growth by incorporating carbon dioxide emissions in the model as endogenous variable into the aggregate production function as follows:

$$A(t) = \varphi CO2(t)^{\delta} \tag{2}$$

Where φ is a time-invariant constant, CO2 denotes carbon dioxide emission. Substituting Equation (2) into Equation (1)

$$GDP(t) = RE(t)^{\varsigma} CO2(t)^{\delta} K(t)^{\beta} L(t)^{1-\beta} \tag{3}$$

Taking the logs, equation (3) can be moulded as follows

$$LGDP_t = \alpha + \beta_1 LRE_t + \beta_2 LCO2_t + \beta_3 LEM_t + \beta_4 LK_t + \mu_t \qquad (4)$$

Where α is a constant term, LGDP is economic growth, LRE is renewable energy consumption, LCO2 is carbon dioxide emission, LEM is employment, LK is capital and μ is the error term which is assumed to be constant

3.2 Unit root

In order to test for the stationarity of the variables, three unit root tests are employed. The study commences with the Augmented Dickey-Fuller (ADF) unit root test which test for the existence of unit root under the alternative hypothesis that the time series in question is stationary around a fixed time trend where the numbers of lags in the procedure are auto-determined by the level of significance of the lagged first-differenced term Dickey and Fuller (1979). The second unit root test is the Phillips and Perron. The PP test also has power when the time series of interest has serial correlation and there are structural breaks. The ADF and the Phillips-Perron tests have been criticised for their low power when variables are stationary but with a unit root close to non-stationary boundary (Brooks, 2014). On this accord, the third unit root test called Dickey Fuller Generalised Least Square (DF-GLS) is also tested. Elliot et al (1996) argue that the DF-GLS test has more power in the presence of an unknown mean or trend compared to the ADF and the Phillips-Perron tests

3.4 Co-integration test

The ARDL bounds test approach is employed in this study to investigate the long run linkage between economic growth, renewable energy consumption, carbon dioxide emissions, employment and capital. This model is chosen because it overcomes some of the demerits of the traditional co-integration models such as the Johansen test of co-integration. This technique is chosen because of the benefits it yields over strictly I(1) stationarity variable dependent co-integration test. The ARDL model provides valid results regardless of whether the variables of interest are I(0), I(1) or a combination of both. Again this model is asymptotically efficient in finite and small sample studies and applicable even in the case where the regressors are endogenous. Narayan and Narayan (2005) indicated that a dynamic unrestricted error correction model (UECM) can be derived from the ARDL through a simple linear transformation. The UECM integrates the short run dynamics with the long run equilibrium without losing any information for long run, taking each of the variables in turn as a dependent variable. Based on equation (4), the UECM can be moulded as follows:

$$\Delta LGDP_t = \alpha_1 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} + \alpha_{CO2} LCO2_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LCO2_{t-k} + \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{1t} \quad (5)$$

$$\Delta LRE_t = \alpha_2 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} + \alpha_{CO2} LCO2_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LCO2_{t-k} + \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{2t} \quad (6)$$

$$\Delta LCO2_t = \alpha_3 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} + \alpha_{CO2} LCO2_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LCO2_{t-k} + \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{3t} \quad (7)$$

$$\Delta LEM_t = \alpha_4 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} + \alpha_{CO2} LCO2_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LCO2_{t-k} + \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{4t} \quad (8)$$

$$\Delta LK_t = \alpha_5 + \alpha_T T + \alpha_{GDP} LGDP_{t-1} + \alpha_{RE} LRE_{t-1} + \alpha_{CO2} LCO2_{t-1} + \alpha_{EM} LEM_{T-1} + \alpha_K LK_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta LGDP_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta LRE_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta LCO2_{t-k} + \sum_{l=0}^{s} \alpha_L \Delta LEM_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta LK_{t-m} + \varepsilon_{5t} \quad (9)$$

Where: $LGDP_t$ is the natural logarithm of gross domestic product. LRE_t is the natural logarithm of renewable energy consumption. $LCO2_t$ is the natural logarithm of carbon dioxide. LEM_t is the natural logarithm of employment. LK_t denotes the natural logarithm of capital formation. T and Δ represent the time period and the first difference operator, respectively. It is assumed that the residuals ($\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}, \varepsilon_{5t}$) are normally distributed and white noise.

The study uses the F-test to determine the presence of a long run linkage among the variables of interest following the null hypothesis of no co-integration among the variables i.e. H_0: $\alpha_{GDP} = \alpha_{RE} = \alpha_{CO2} = \alpha_{EM} = \alpha_K = 0$ against the alternative hypothesis of co-integration (Pesaran et.al 2001) for Eq. (4). The F-test has a nonstandard distribution which relies on; firstly, whether the variables included in the ARDL model are I(0), or I(1), secondly, the number of regressors and lastly, whether the ARDL model contains an intercept and/or a trend. The critical values are reported in Pesaran et.al (2001) and are generated for sample sizes of 20,000 and 40,000 observations. Our study has a smaller sample size and as a result will adopt the critical values developed by Narayan (2005) because they are appropriate for small sample sizes. In order to reject or accept the null hypothesis, the value of the F-test is compared with critical value bounds.

The results conclude in favour of co-integration, if the calculated F-statistics exceeds the upper critical bound value, this means that the H_0 is rejected. On the contrary, H_0 cannot be rejected if the F-statistics falls below the lower critical bound value. Finally, if the F-statistics falls within the two bounds, then the co-integration test becomes inconclusive. To determine the reliability of the ARDL result, the study checks for serial correlation, functional form, normality and heteroskedasticity of the ARDL model. In addition, the stability of the parameters will be tested using the Cumulative Sum of Recursive Residual (CUSUM) and the Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ)

3.5 Granger-causality

Once the ARDL bounds technique has validated the existence of a long run relationship between economic growth, renewable energy consumption, carbon dioxide emissions, employment and capital, then the vector error correction model (VECM) is conducted to determine the causal relationship among the series. The exact direction of causality between the variables helps policy makers to sustain growth and attain fruitful impacts of renewable energy consumption. The VECM granger causality is applicable when the variables are integrated of the same order of integration. To determine the direction of causality between the variables, the VECM is presented by the following equations:

$$\Delta LGDP_t = \alpha_{10} + \sum_{i=1}^{q} \alpha_{11} \Delta LGDP_{t-i} + \sum_{i=1}^{r} \alpha_{12} \Delta LRE_{t-i} + \sum_{i=1}^{s} \alpha_{13} \Delta LCO2_{t-i} + \sum_{i-1}^{t} \alpha_{14} \Delta LEM_{t-i} +$$

$$\sum_{i-1}^{u}\alpha_{15}\Delta LK_{t-i} + \psi_1 ECT_{t-1} + \varepsilon_{1t} \quad (10)$$

$$\Delta LRE_t = \alpha_{20} + \sum_{i=1}^{q}\alpha_{21}\Delta LRE_{t-i} + \sum_{i=1}^{r}\alpha_{22}\Delta LCO2_{t-i} + \sum_{i=1}^{s}\alpha_{23}\Delta LGDP_{t-i} + \sum_{i-1}^{t}\alpha_{24}\Delta LEM_{t-i} +$$

$$\sum_{i-1}^{u}\alpha_{25}\Delta LK_{t-i} + \psi_2 ECT_{t-1} + \varepsilon_{2t} \quad (11)$$

$$\Delta LCO2_t = \alpha_{30} + \sum_{i=1}^{q}\alpha_{31}\Delta LCO2_{t-i} + \sum_{i=1}^{r}\alpha_{32}\Delta LRE_{t-i} + \sum_{i=1}^{s}\alpha_{33}\Delta LGDP_{t-i} + \sum_{i-1}^{t}\alpha_{34}\Delta LEM_{t-i} +$$

$$\sum_{i-1}^{u}\alpha_{35}\Delta LK_{t-i} + \psi_3 ECT_{t-1} + \varepsilon_{3t} \quad (12)$$

$$\Delta LEM_t = \alpha_{40} + \sum_{i=1}^{q}\alpha_{41}\Delta LEM_{t-i} + \sum_{i=1}^{r}\alpha_{42}\Delta LRE_{t-i} + \sum_{i=1}^{s}\alpha_{43}\Delta LCO2_{t-i} + \sum_{i-1}^{t}\alpha_{44}\Delta LGDP_{t-i} +$$

$$\sum_{i-1}^{u}\alpha_{45}\Delta LK_{t-i} + \psi_5 ECT_{t-1} + \varepsilon_{4t} \quad (13)$$

$$\Delta LK_t = \alpha_{50} + \sum_{i=1}^{q}\alpha_{51}\Delta LK_{t-i} + \sum_{i=1}^{r}\alpha_{52}\Delta LRE_{t-i} + \sum_{i=1}^{s}\alpha_{53}\Delta LCO2_{t-i} + \sum_{i-1}^{t}\alpha_{54}\Delta LGDP_{t-i} +$$

$$\sum_{i-1}^{u}\alpha_{55}\Delta LEM_{t-i} + \psi_5 ECT_{t-1} + \varepsilon_{5t} \quad (14)$$

Δ denotes the difference operator, α_{it} is the constant term and ECT represents the error correction term derived from the long run co-integrating relationships. ε_{1t}, ε_{2t}, ε_{3t}, ε_{4t}, and ε_{5t}, are error term and are assumed to be normally distributed.

The long run causality among the variables is estimated by the significance of t-statistic connecting the coefficients of the error term (ECT_{t-1}). However, the causality between the variables in the short run are determined by the significance of the chi-square in the first differences of the variables of equations 10 to 14. The Wald-test is used to estimate the chi-square. The null hypothesis is whether the coefficients of lagged independent variables together equal zero.

Moreover, the joint significance of both the long run and short run causality are denoted by the joint significance of both the estimated lagged independent variables and ECT. Rejection of the null hypothesis indicates that there is causality. For instance, when $\alpha_{12} \neq 0$ and significant for any $I(1)$, it indicates that renewable energy consumption Granger-causes economic growth. This means that there is one way causality flowing from renewable energy consumption to economic growth. Again when $\alpha_{21} \neq 0$, it indicates that there is a unidirectional causality flowing from economic growth to renewable energy consumption.

3.6 Data sources

The data for the variables such as economic growth, capital and employment have been sourced from World Development Indicator while renewable energy consumption and carbon dioxide emissions were sourced from International Energy Agency (IEA). The data set comprises of observations for economic growth proxies by gross domestic product measured in millions of 2010 constant US dollars and renewable energy consumption, which is measured in million kilowatt-hours. Additional variables include, carbon dioxide emissions measured in metric tones, capital proxies by gross fixed capital formation and employment proxies by commercial, agricultural and manufacturing employments. The data used in this study covers a period between 1990 and 2014 and its extrapolated into quarterly data.

4. FINDINGS OF THE STUDY

4.1 Unit root tests

The null hypothesis for the test (in ADF, PP and DG-GLS) suggest that the data series under consideration has unit root and is tested against the alternative hypothesis that the series has no unit root (that is it is stationary). As can be seen in Table 1, the ADF, PP and DF-GLS tests witnessed that GDP, RE, EM, K and CO2 in natural logs at levels have unit root. This is because we fail to reject the null hypothesis of unit root at 1% and 5% level of significance. On the other hand, when the first difference of natural log of GDP, RE, EM, K and CO2 is considered, the variables become stationary. The natural log of GDP becomes stationary at 5% level of significance under ADF and significant at 1% under the PP and DF-GLS. Natural logs of RE, EM, K and CO2 become stationary at 1% level of significance under PP and 5% level of significance under DF-GLS. Lastly, under ADF, natural logs of RE and EM become stationary 10%, natural log of K becomes stationary at 1% and natural log of CO2 becomes stationary at 5% level of significance. In general, the ADF, PP and DF-GLS test depicts that all the variables are integrated of order one, I(1). Thus, the examination of co-integration among the variables using the ARDL technique does not face a problem from the existence of I (2) or beyond variables in the model specified.

Table 1: Unit root tests

	Levels			**First difference**		
Variable	**ADF**	**PP**	**DF-GLS**	**ADF**	**PP**	**DF-GLS**
LGDP	-0.0494	-0.1887	-1.2318	-3.1314**	-4.5482*	-2.8706*
LRE	-2.7091	-1.7500	0.4366	-2.636***	-6.0076*	-2.4594**
LEM	-3.2597	-2.4320	0.2209	-2.6118***	-4.7974*	-2.4768**
LK	-0.6738	0.4668	0.2156	-4.6934*	-5.4166*	-2.1223**
LCO2	-0.0972	-0.0937	0.2632	-3.1027**	-4.7684*	-2.0577**

Source: Own calculation

The unique order of integration suggest that the co-integration tests can be explored. However, it is necessary to first determine the maximum lag length. The results for the selection order criteria are presented in Table 2. Table 2 shows that the optimal lag length of p*=2 is chosen

Table 2 Selection order criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1054.87	NA	2.18e-16	-21.8723	-21.7388	-21.8183
1	2013.04	1796.57	7.8e-25	-41.3134	-40.5120	-40.9895
2	2108.12	168.359*	1.84e-25*	42.7732*	-41.3041*	42.1794*
3	2120.26	20.2494	2.42e-25	-42.5055	-40.3686	-41.6417
4	2130.61	16.1571	3.36e-25	-42.2001	-39.3954	-41.0664

Source: own calculation

The ARDL bounds technique is employed to estimate the long run relationship among the variables. An initial estimation of the presence of a long-run relationship between the variables in equations 5 to 9 are followed by an examination of the short run and long run parameters. The ARDL bounds test results is illustrated in Table 3.

The findings in Table 3 confirm that there is a long run relationship between economic growth, renewable energy consumption, carbon dioxide emissions, capital and employment when economic growth, capital and employment are used as the dependent variables. This is because the F-statistics of economic growth, capital and employment, also written as F_{GDP}(GDP/RE, CO2, K, EM) = 7.50, F_K(K/GDP, RE, CO2, EM) = 7.57 and F_{EM}(EM/GDP, RE, CO2, K) = 17.38, are greater than both the 95% upper bound critical values of Narayan and Smith (2005) which is 4.797.

Furthermore, it was established that when renewable energy consumption is used as the dependent variable, there is an existence of a long run relationship between the variables as its F-statistics is greater the 95% upper bound critical values of Naraym and Smith (2005) which is 3.625. However, considering each of the remaining variables when carbon dioxide emissions is the dependent variable, no co-integration between the variables is validated as its calculated F-statistics is less than the 95% lower bound critical value in all cases. The existence of a single co-integrating equation reveals that there is a unique long run relationship among the variables under consideration (Pesaran et.al 2001). Since we found four co-integrating equations, we can conclude that there is a long run relationship between economic growth, renewable energy consumption, carbon dioxide emissions, capital and employment in Indonesia. These results are consistent to the findings of Bhattacharya et.al (2016); Apergis and Danuletiu (2014); Leitao (2014) and Lin and Moubarak (2014).

Table 3 ARDL Co-Integration Test

Critical value bound of the F-statistic						
K	90% level		95% level		99% level	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
3	2.022	3.112	2.459	3.625	3.372	4.797
4	1.919	3.016	2.282	3.340	3.061	4.486
Calculated F-statistics F_{GDP}(GDP/RE, CO2, K, EM) = 7.50 F_{RE}(RE/GDP, CO2, K, EM) = 4.40 F_{CO2}(CO2/GDP, RE, K, EM) = 2.01 F_{K}(K/GDP, RE, CO2, EM) = 7.57 F_{EM}(EM/GDP, RE, CO2, K) = 17.38 ……………………………………………. Note: The critical bound values were taken from Narayan and Smyth (2005: 470)						

After confirming the existence of a long run relationship among the variables, the study estimates the long run effect of renewable energy consumption, carbon dioxide emissions, employment and capital formation on economic growth. The estimated coefficients of the long run relationship are presented in Table 4. According to the results presented in Table 4, the long run equation can be written as follows:

$$LGDP_t = -18.26 + 2.50LRE + 0.15LCO2 + 2.81LEM + 0.29LK$$

The estimated coefficients suggest that renewable energy consumption and employment have a positive and significant impact on economic growth, which is in line with theoretical argument that renewable energy consumption and employment enhance economic growth. More specifically, the elasticity of renewable energy consumption suggested that a 1% increase in renewable energy consumption results in economic growth increasing by 2.5% on average, holding all else constant. Similarly, the long run elasticity of employment indicate that a 1 percent increase in employment leads to an increase of 2.81% in economic growth, ceteris paribus. However, carbon dioxide emissions and capital have insignificant effect on economic growth.

Table 4.4 Long run results

Dependent Variable = LGDP			
Long Term Results			
Variable	Coefficients	Standard Error	T-statistics
Constant	-18.26	20.3108	-0.8987
LRE	2.50**	1.8354	1.3637
LCO2	0.15	0.5671	0.2638
LEM	2.81*	2.0690	1.3615
LK	0.29	0.1973	1.4707
R-squared 0.99 Durbin Watson Stat 2.03			

Source: Own calculations

After estimating the long run coefficients, the next step is to estimate the short run dynamic growth model. The results for the short run are illustrated in Table 5. It is shown that ECM_{t-1} (-0.1357) is negative and significant, which affirms the existence of the long run relationship between economic growth, renewable energy consumption, carbon dioxide emissions, employment and capital. This coefficient indicates that a deviation from the long run equilibrium level of output in one quarter is corrected by 14 percent over the following quarter. Based on the results shown in Table 5, the short run dynamics of growth equation can be moulded as follows:

$$LGDP_t = 0.82LRE - 0.26LCO2 + 0.84LEM - 0.06LK$$

The elasticity of output with respect to renewable energy consumption and employment are positive and significant at 5 percent level of significance. This implies that renewable energy consumption and employment boosts economic growth in the short run. These results are in line with economic theory that renewable energy consumption and employment have a positive effect on economic growth. However, contrary to economic theory, capital has a negative effect on economic growth but it is not significant at 5% level of significance. Lastly, carbon dioxide emissions have a negative and significant effect on economic growth in the short run.

Table 5 Short run analysis

Variable	Coefficient	Standard error	T-statistics
LRE	0.82*	0.1639	5.0499
LCO2	-0.26**	0.1145	-2.2928
LEM	0.84**	0.3272	2.5610
LK	-0.06	0.0337	-1.6433
ECM_{t-1}	-0.1357*	0.0197	-6.8930
R^2	0.50		
D.W test	2.03		
*represent 1%, significance level			

Source: Own calculation

The results for the short-run diagnostics tests are shown in Table 6. The results posit that the error terms of the short run models have no serial correlation, they are free of heteroskedasticity and are normally distributed. It is established that the short run models are not spurious because the Durban-Watson statistics was found to be greater than the R^2. The Ramsey RESET test validated that the functional form of the model is well specified.

Table 6 Short-run diagnostics

Short run diagnostics		
Test	F-statistics	P-value
Normality	3.4242	0.1025
Heteroskedasticity	1.7191	0.1849
Serial correlation	2.2877	0.1076

Source: Own Calculation

The stability of the long run parameters were tested using the cumulative sum of recursive residuals (CUSUM) and CUSUM of recursive squares (CUSUMSQ). The results are illustrated in Figures 2 and 3. The results fail to reject the null hypothesis at 5 percent level of significance because the plot of the tests fall within the critical limits. Therefore, it can be realised that our selected ARDL model is stable.

Figure 2 CUSUM

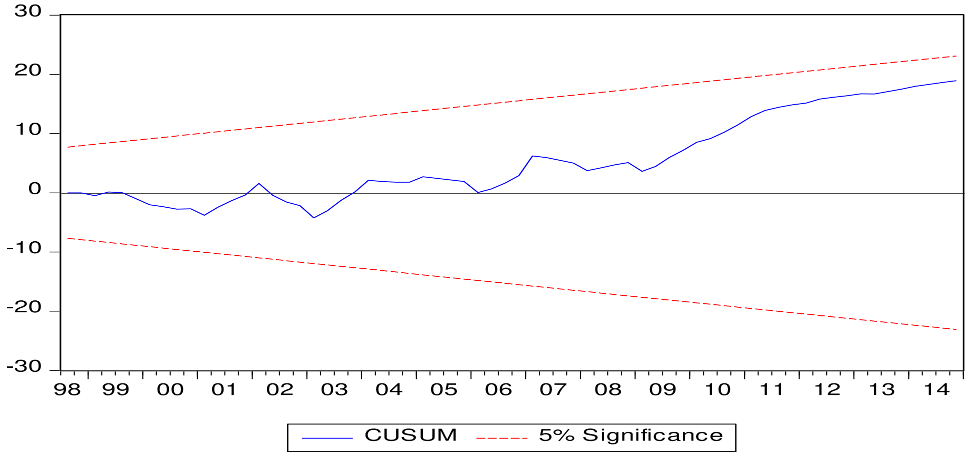
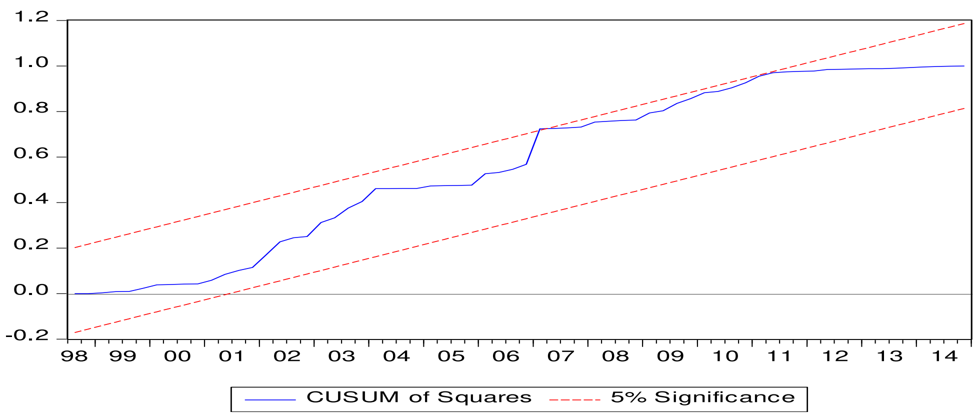


Figure 3 CUSUMSQ



Granger Causality

The existence of a long run relationship between the variables stipulates that there is an existence of a causal relationship. To determine the direction of causality between the variables, the VECM Granger causality technique was used. The short run and long run Granger causality results are reported in Table 7. Commencing with the long run causal relationship, the results validated that there is a long run causality flowing from renewable energy consumption, carbon dioxide emissions, capital and employment to economic growth. This is because the error correction term (-0.0115) is negative and significant at 1% level of significance. These results confirm the findings of Khobai and Le Roux (2017); Fotourehchi (2017); Bhattacharya et.al (2016) and Spetan (2016).

Another long run causality was established flowing from economic growth, renewable energy consumption, carbon dioxide emissions and employment to capital. This on account that the error correction term (-0.0243) is negative and significant at 1% level of significance. Lastly, a weak long run causality was found flowing from economic growth, renewable energy consumption, carbon dioxide emissions and capital to employment. This is on account that the error correction term (-0.0021) is negative and significant at 10% level of significant.

Table 7 Vector Error Correction Model (VECM)

Dependent variable	Types of Causality					
	Short run					Long run
	∑ΔLgdp	∑ Δlre	∑ Δlco2	∑ Δlk	∑ Δlem	ECT_{t-1}
ΔLgdp	……..	0.23	0.06**	0.57*	1.14**	-0.0115*
Δlre	1.97	……….	0.39	0.40	0.11	0.0124
Δlco2	0.29	1.06	…………..	0.001	0.86	0.0034
Δlk	1.06	0.60	0.11	………..	0.84	-0.0243**
Δlem	3.58	0.07**	0.02	0.33	……….	-0.0021***

Source: Own calculation

The short run causality was established flowing from carbon dioxide emissions, capital and employment to economic growth. Another short run causality running from renewable energy consumption to employment was established.

CONCLUSION

The attention towards sustainable development globally has accelerated the focus on renewable energy consumption in recent decades. This paper aimed to explore the relationship between renewable energy consumption and economic growth in Indonesia covering the period from 1990 to 2014. In doing so, the study applied the autoregressive distributed lag (ARDL) bounds testing approach to determine co-integration among the variables. It further employed the vector error correction model (VECM) technique to examine the direction of causality between the variables. The results from the ARDL bounds testing approach reveal that there is a long run relationship between economic growth, renewable energy consumption, carbon dioxide emissions, capital and employment. Furthermore, it is established that renewable energy consumption has a significant positive effect on economic growth both in the long run and short run. More specifically, the elasticity of renewable energy consumption suggested that a 1% increase in renewable energy consumption results in economic growth increasing by 2.5% on average, holding all else constant.

The findings from the vector error correction model (VECM) technique suggests that there is a long run causality flowing from renewable energy consumption, carbon dioxide emissions, capital and employment to economic growth. More specifically, renewable energy consumption Granger-causes economic growth, which implies that renewable energy consumption is a driver for economic growth in Indonesia. Another long run causality was established flowing from economic growth, renewable energy consumption, carbon dioxide emissions and employment to capital.

The empirical results of this study provide the policy makers with a better understanding of renewable energy consumption and economic growth linkage to formulate investment policies in Indonesia. To practically concern about the environmental awareness and the increased demand for renewable energy consumption that accompanies rapid economic growth, the government, energy policy makers and associated bodies should act together to improve on the renewable energy infrastructure to ensure that they enhance renewable energy usage. The study further recommends that there is a need for targeted carbon pricing techniques that will bring about lower carbon growth in Indonesia.

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