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The Relationship Between Co2 Emission, Sectoral Economic Growth, Household Expenditures And Renewable Energy In Indonesia

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Abstract: **We investigate the relationship between sectoral economic growth, renewable energy, household expenditures, and CO_2 emissions in Indonesia using annual data from 1973 to 2017. The Autoregressive Distributed Lag (ARDL) techniques are employed in this study. Our findings revealed that Industrial growth potentially encouraged CO_2 emissions from energy combustions increased, while the growth of services sector and renewable energy use declined CO_2 emissions from energy combustions. The growth of industry sector caused declining the growth of agriculture sector, while the growth of service sector and agriculture sector are influenced each other. A rise in household expenditures stimulated economic growth in the agriculture sector, while rising in CO_2 emissions from energy use, increased household expenditures, and the growth of agriculture sector hampered the development of renewable energy. Our findings also indicated that the growth of industry sector and services sector provide a valuable impact on the sustainability development of renewable energy in Indonesia. Although an increase in household expenditures did not affect sectoral economic growth, instead it indirectly inhibited renewable energy development. Furthermore, we concluded that the sustainability of sectoral economic growth and a rise in household expenditures has a positive effect and stimulates the sustainability development of renewable energy in Indonesia.**

Keywords: CO_2 emissions; household expenditures; renewable energy; sectoral economic growth; Indonesia

JEL Classification: Q43, O44; B23

I. INTRODUCTION

A rise of CO_2 emissions is one of the main issues that contribute to global warming and climate change (Kangyin Dong et al., 2020; Waheed et al., 2019). Among greenhouse gases, CO_2 accounts for around 60% of total greenhouse gases and most of the CO_2 is generated from energy consumption by energy users in the productive sectors and households (Farabi et al., 2019). The sustainability of economic growth in a country requires the availability of sufficient energy supplies (Shahbaz et al., 2018) and hence the policymakers in developed and developing countries give important attention to both the issue of energy security and impact of energy use against environmental quality (Charfeddine, 2017). The dominance of final energy products from fossil on the structure of domestic energy supply in a country certainly provides a negative impact on environmental quality because it produces large amounts of CO_2 emissions (Uzar, 2020). Currently, a lot of strategies have been applied by the policymakers and also there are many innovative technologies that have been developed to solve environmental quality issues. However, any effort certainly should consider relevance with the sustainability of development and economic growth in a country.

The relationships between CO_2 emission and its determinants have significant differences both in the developed and developing countries that certainly have different income levels (Kangyin Dong et al., 2019). Most of the literature studies that investigate the relationship between energy, CO_2 emission, and economic growth applied the Environment Kuznet Curve (EKC) hypothesis. The evidence of EKC hypothesis has been found by Baek (2016) in The U.S, Zhang et al. (2017) in Pakistan, and Dong et al. (2018) in China. Meanwhile, the investigation related to the relationship between CO_2 emissions and renewable energy has provided different results. Sadorsky (2009) found that per capita GDP growth positively influenced per capita renewable energy. Tiwari (2011) found that non-renewable energy hampers GDP growth and caused a rise in CO_2 emissions in the European and Eurasian countries. While a study by Silva et al. (2012) revealed that a rise in renewable energy potentially reduced per capita CO_2 emissions.

The rate of economic growth in a country is highly dependent on the share of value-added contributed by the development sectors (Singariya & Naval, 2016). The development sector in a country can be grouped into three main sectors that are interrelated to one another, namely industry, agriculture, and services (Uddin, 2015). These development sectors comprise one or more final energy user categories which certainly generated CO_2 emissions from energy combustion (Nugraha & Osman, 2017). The most of activities on these development sectors required sustainable energy supply, in which energy has been one of important inputs on the production process of goods and services (Aslantürk & Kıprızlı, 2020). The depletion of fossil energy resources, declining environmental quality, and increasing energy prices have been critical issues as well as prediction factors that will certainly influence economic growth and the activities of development sectors. (Yusoff & Latif, 2013).

Sectoral economic growth is highly dependent on the growth of domestic and global markets (Singariya et al., 2016). In the domestic market, the growth rate of household expenditures has been considered as one indicator representing the purchasing power of domestic people and driving sectoral economic growth. In the life-cycle context, a rise in household expenditure provides environmental impact from the activity consumption of goods and services (Lenzen et al., 2006). Among various household necessaries, energy has become one of important commodities in daily activities (Nie et al., 2018). The intensity of energy consumption in the household is very closely related to lifestyles, consumption behaviors, and the level of community welfare (Ye et al., 2018). Household energy consumption remarkably is faster increasingly compared to the other sectors due to its association with population growth rate (Salari & Javid, 2017).

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Indonesia is one of populous countries in the world with an average annual economic growth rate was approximately 5.4 percent over the two past decades (World Bank, 2020). The economic structure of Indonesia has been dominated by the value-added from the service sector and industry sector, in which both sectors respectively contributed approximately 40 percent of the real GDP of Indonesia (Statistics Indonesia, 2020). During the period of 2002-2017, the service sector experienced the highest growth with an average growth rate of approximately 6.9 percent annually, followed by the industry sector that grew 4.3 percent annually and agriculture sector that grew only 3.7 percent annually. Sectoral economic growth progress is closely related to the growth rate of production and consumption of goods and services on the domestic market which can be measured from the growth rate of household expenditures. According to the annual report of the world development indicator (World Bank, 2020), the annual growth rate of Indonesia’s household expenditures increased approximately 4.8 percent over the period of 2003-2018. The growth of Indonesian household expenditures is predicted to continue increasing along with population growth and advance Indonesian people's welfare (Newman et al., 2004).

A rise in household expenditures and sectoral economic growth in Indonesia certainly has been stimulating the growth of domestic energy consumption. During the period of 2002-2017, the amount of Indonesia’s final energy consumption increased 41.53 percent (International Energy Agency, 2020). Most of Indonesia’s final energy users depend on final energy from fossil and also the amount of non-renewable energy consumption has reached two-thirds of total Indonesia’s final energy consumption. However, the growth rate of renewable energy consumption in Indonesia is slightly higher than non-renewable energy consumption (International Energy Agency, 2020). Over the past two decades, the growth of non-renewable energy consumption has increased by 0.84 percent annually, while the growth of renewable energy consumption has increased by 3.01 percent annually. The dominance of fossil energy in the structure of domestic energy consumption certainly also caused intensively increasing CO_2 emissions from energy combustion in Indonesia.

During two past decades, the amount of Indonesia's CO_2 emission from energy combustion increased 76.01 percent. This issue being serious concerns by Indonesia government because Indonesia is the third largest producer of greenhouse gases (GHG) that ratify the Kyoto protocol and declarating to reduce GHG emissions about 26–41% below BAU (Business as Usual) scenario by 2020 (Copenhagen Accord, 2009). Thefore, Minister of Energy and Mineral Resources with Regulation No.12 of 2015 is targeting to improve the utilization of biodiesel (30%) and bioethanol (20%) in 2025. In 2050, the target of bioethanol utilization is expected up to 50% and target of biodiesel utilization is expected up to 30% (National Energy Council, 2019). Furthermore, the utilization of induction stoves and electric vehicles is expected to be more than the BAU scenario and development of city gas is encouraged to increase up to 1 million household connections annually (Ministry of Energy and Mineral Resources Republic of Indonesia, 2018).

The development of new and renewable energy has become compulsion for Indonesia in order to overcoming the problem of environmental emissions caused by energy consumption activities (Swain & Karimu, 2020). Indonesia has several potential renewable energy resources such as geothermal energy, solar energy, hydro energy, biomass, wave energy, and wind energy (Nasruddin et al., 2016). Indonesia also is a tropical country that can produce renewable energy such as bioenergy, biomass, and biofuel from tropical biodiversity within the country (Mukherjee & Sovacool, 2014; Ong et al., 2013; Singh & Setiawan, 2013). According to National Energy Council (National Energy Council, 2019), the capacity of hydropower has reached 94.3 GW, Biomass has been up to 49,80 MW, Geothermal energy reached 28.5 GW, wind power reached 60.6 GW, Ocean energy has been about 17.9 GW, while Solar energy intensity has reached approximately 207.8 GWp. According to National Energy Council (National Energy Council, 2019), the capacity of hydropower has reached 94.3 GW, Biomass has been up to 49,800 MW, Geothermal energy reached 28.5 GW, wind power reached 60.6 GW, Ocean energy has been about 17.9 GW, while Solar energy intensity has reached approximately 207.8 GWp. Nevertheless, the research and development of renewable energy resources in Indonesia has still assessed slightly sluggish and tend to not maximal encouraged by the Indonesian government.

Indonesian government argued that renewable energy development can motivate energy security programs and stimulates sustainable development efforts without causing Indonesia's economic growth rate to decline (Gielen et al., 2017). At a fundamental level, the government is targeting to ensure sustainable supply and production of renewable energy can fulfill domestic energy demand and keep continuing to support economic growth (Patterson, 2015). However, it is not clear whether improving the composition of renewable energy products on the structure of final energy supply will be solving the environmental degradation issues in this country. Moreover, if energy consumption and economic growth have a mutual linkages, the process of energy mitigation and conservation is predicted to slightly hamper economic growth process (Nugraha & Osman, 2018). Therefore, our study aims to investigate the causal relationship among CO_2 emissions, sectoral economic growth, household expenditures, and renewable energy consumption in Indonesia.

II. LITERATURE REVIEW

The relationships between CO_2 emission and its determinants has significant differences on the developed and developing countries that certainly has different income levels (Kangyin Dong et al., 2019). Most of literature studies that investigate the relationship among energy, emissions and economic growth applied the environment Kuznet Curve (EKC) hypothesis. In recent studies, Bölük and Mert (2015) found that environmental quality increased with renewable energy consumption in Turkey. Furthermore, the evidence of EKC hypothesis has found by Baek (2016) in The U.S, Zhang et al. (2017) in Pakistan, and Dong et al. (2018) in China. Meanwhile, the investigation of relationship between renewable energy and CO_2 emissions from energy use have reached different results. Sadorsky (2009) found that the growth of per capita GDP are positively influenced per capita renewable energy in G7 countries. For case in the European and Eurasian countries, Tiwari (2011) found that non-renewable energy hamper economic growth and caused a rise of CO_2 emissions. Further, a study by Silva et al. (2012) using annual data of four countries (the U.S, Denmark, Spain and Portugal) shows that a rise in renewable energy consumption potentially diminishes the amount of per capita CO_2 emissions.

The interrelationship among development sectors can be illustrated within production and consumption linkages (2019). The structural changes of an economy entail the dynamics of sectoral economic growth over the long run are interrelated to each other and certainly indirectly stimulate sustainable economic growth (Sepehrdoust & Adnan, 2012). Economic growth go hand-in-hand with structural changes on development process. Temporal changes that related to the productivity and composition level of different sectors and sub-sectors assumed could lead to unbalanced inter-sector economic growth in a country (Xinshen & Haggblade, 2007). The interrelationship between GDP and sectoral economic growth has widely examined by scientists, such as Verner (2001), Katircioglu (2004), Sepehrdoust and Adnan (2012), Uddin (2015), as well as Degu (2019). Overall, their findings show that the growth performance of development sectors are interrelated and significantly affect the growth performance of GDP in a country.

A study of Nugraha and Osman (Nugraha et al., 2017) found that sectoral economic growth and energy consumption influences household expendictures in Indonesia. According to Fri and Savitz (2014), household expenditures can control the level of energy consumption and CO_2 emissions if green technological innovations can be sustain adapted throughout the long-term process of energy mitigation systems. Furthermore, several studies also revealed that household energy consumption is affected by changes in energy prices (Rehdanz, 2007), income level (Price et al., 2007) and Gender (Permana et al., 2015). Regarding emissions, a empirical study by Ivanova et al. (2015) highlighting the importance of environmental pressures arising from household energy consumption which contribute more than 60% of global greenhouse gas (GHG) emissions. Werff (2015) argued that household energy use is an important contributor to the emission of greenhouse gases. Hence, to reduce environmental problems it is important that households reduce their energy consumption. Meanwhile, Druckman dan Jackson (2008) and Chitnis et al. (2012) in their studies concluded that there are a long-term relationship between energy consumption, income, and CO_2 emissions.

Renewable energy considered as an ideal substitute for final energy from fossil and generated lower CO_2 emissions (Bilgili et al., 2016). According to Saidi and Omri (2020) a rise of income level stimulates the growth of energy consumption and as consequently threaten sustainable environment quality. It is increasing concerns toward global warming and energy security as well as provides pressure toward the research and development of renewable energy. In recent years, a causal link between economic growth, renewable energy and CO_2 emissions has been studied by many economists and scientists (Vo et al., 2019). Menyah and Wolde Rufael (2010) investigates for the U.S and found that nuclear energy influenced the amount of CO_2 emissions, however, there are no relationship between renewable energy and CO_2 emissions. Apergis et al. (2010) found a causality relationship between those variables for case in Seven Central American countries. In G7 countries, a study by Raza and Shah (2018) revealed that economic growth stimulated the growth of CO_2 emissions. Moreover, their study also shows the existence of a mutual relationship between renewable energy and CO_2 emissions. Furthermore, a study by Lu (2017) found the causal relationships among economic growth, emissions and renewable energy in 24 Asian countries.

III. DATA AND METHOD

A. Data

The present study is using annual data for Indonesia over the period of 1973-2017 and we collecting data based on the availability of time series data on the database of World Bank and International Energy Agency (IEA). Annual data on the value-added of three development sectors (in billions of 2010 USD) and household final expenditures (in billions of 2010 USD), are collected from the World Development Indicator (World Bank, 2020), while annual data of renewable energy (in % of total final energy use) and CO_2 emission from energy combustions (in millions of CO_2 emissions) are collected from International Energy Agency (2020). In this study, we transform data series into natural logarithm forms to address the heteroskedasticity issue and induces stationary in the variance-covariance matrix (Apergis & Tang, 2013).

B. The unit root test

In the first step, we checked the integration order of data series by using the Augmented Dickey-Fuller (ADF) unit root test that developed by Dickey and Fuller (1979) and Phillips–Perron (PP) unit root test that proposed by Phillips and Perron (1988). We tested stationarity of each data series by using an equation with intercept only, where the determination of lag length for data series on both tests is automatically selected based on Schwarz Bayesian Criteria (SIC). In these tests, we expected all series have stationarity at I(0) and/or I(1).

C. ARDL Bound Test

In second step, we applying the autoregressive distributed lag (ARDL) procedures that introduced by Pesaran & Shin (1998) and then developed by Pesaran et al. (2001). This method has several advantages compared with other methods (Sebri & Salha, 2014; L. Zhang et al., 2019). First, this procedure can be applied although data series have mixed integration order I(0) and I(1). Second, this procedure estimates the short and long-run parameters in the same model. Third, this procedure eliminates endogeneity problems. Eventually, this procedure provides appropriate regression estimations for small samples. Furthermore, the relationship between sectoral economic growth, household expenditures, renewable energy, and CO_2 emissions are examined by using equations as follows:

$$\Delta lnCO2 = \alpha_1 + \beta_{11}\Delta lnCO2 + \beta_{12}\Delta lnVA + \beta_{13}\Delta lnVI + \beta_{14}\Delta lnVS + \beta_{15}\Delta lnHE + \beta_{16}\Delta lnREP + \theta_1 lnCO2 + \theta_2 lnVA + \theta_3 lnVI + \theta_4 lnVS + \theta_5 lnHE + \theta_6 lnREP + \varepsilon_1 \quad (1)$$

$$\Delta lnVA = \alpha_2 + \beta_{21}\Delta lnVA + \beta_{22}\Delta lnCO2 + \beta_{23}\Delta lnVI + \beta_{24}\Delta lnVS + \beta_{25}\Delta lnHE + \beta_{26}\Delta lnREP + \theta_1 lnCO2 + \theta_2 lnVA + \theta_3 lnVI + \theta_4 lnVS + \theta_5 lnHE + \theta_6 lnREP + \varepsilon_2 \quad (2)$$

$$\Delta lnVI = \alpha_3 + \beta_{31}\Delta lnVI + \beta_{32}\Delta lnCO2 + \beta_{33}\Delta lnVA + \beta_{34}\Delta lnVS + \beta_{35}\Delta lnHE + \beta_{36}\Delta lnREP + \theta_1 lnCO2 + \theta_2 lnVA + \theta_3 lnVI + \theta_4 lnVS + \theta_5 lnHE + \theta_6 lnREP + \varepsilon_3 \quad (3)$$

$$\Delta lnVS = \alpha_4 + \beta_{41}\Delta lnVS + \beta_{42}\Delta lnCO2 + \beta_{43}\Delta lnVI + \beta_{44}\Delta lnVA + \beta_{45}\Delta lnHE + \beta_{46}\Delta lnREP + \theta_1 lnCO2 + \theta_2 lnVA + \theta_3 lnVI + \theta_4 lnVS + \theta_5 lnHE + \theta_6 lnREP + \varepsilon_4 \quad (4)$$

$$\Delta lnHE = \alpha_5 + \beta_{51}\Delta lnHE + \beta_{52}\Delta lnCO2 + \beta_{53}\Delta lnVI + \beta_{54}\Delta lnVA + \beta_{55}\Delta lnVS + \beta_{56}\Delta lnREP + \theta_1 lnCO2 + \theta_2 lnVA + \theta_3 lnVI + \theta_4 lnVS + \theta_5 lnHE + \theta_6 lnREP + \varepsilon_5 \quad (5)$$

$$\Delta lnREP = \alpha_6 + \beta_{61}\Delta lnREP + \beta_{62}\Delta lnCO2 + \beta_{63}\Delta lnVI + \beta_{64}\Delta lnVA + \beta_{65}\Delta lnVS + \beta_{66}\Delta lnHE + \theta_1 lnCO2 + \theta_2 lnVA + \theta_3 lnVI + \theta_4 lnVS + \theta_5 lnHE + \theta_6 lnREP + \varepsilon_6 \quad (6)$$

Where, lnCO2 is natural logarithm of CO_2 emissions from energy combustion; lnVA is natural logarithm of the value-added of agriculture sector; lnVI is natural logarithm of the value-added of industry sector; lnVA is natural logarithm of the value-added of service sector; lnHE is natural logarithm of household final expenditures; lnRE is natural logarithm of renewable energy; Δ is symbol of first different form; α_i (i = 1,2,..,N) are intercept terms; $\beta_{i1}, \beta_{i2}, \beta_{i3}, \beta_{i4}, \beta_{i5}, \beta_{i6}$ (i = 1,2,..,N) are the short-run coefficients; θ_i (i = 1,2,..,N) are the long-run coefficients; and ε_i (i = 1,2,..,N) are white noise error terms. Meanwhile, the optimal lags of the variables have been selected by using Schwarz Bayesian Criteria (SIC).

The existence of a cointegration and long-run relationship among the variables are determined by the F-statistic test. We conclude the variables are cointegrated when the value of F-statistics exceeded the upper critical values. On the contrary, we conclude there is no cointegration between the variables when the value of F-statistics did not exceed the lower critical bound value. Meanwhile, if the F-statistics value lies between the value of upper and lower critical bounds, it means that the cointegration relationship could not be determined. In this step, the critical bound values proposed by Narayan (2005) for small sample sizes ($n \leq 80$) are used due to the utilization of annual data throughout 45 years only.

D. The long-run model and diagnostic tests

After confirming the existence of cointegration between variables, the long-run coefficients on each ARDL equation are estimated. The long-run model presents individual long-run effects from the independent variables to the dependent variable in each ARDL equation model. Furthermore, we applied diagnostics tests such as Jarque-bera statistics to check the normality, the Lagrange Multiplier (LM) test to check the serial correlation issue, the Breush-Pagan-Godfrey test to check the heteroscedasticity issue, and the Ramsey Regression Equation Specification Error Test (RESET) to check the correctness functional form of selected models. In addition, author also checks the stability of regressors over the observation periods using the plots of CUSUM and CUSUM of squares that proposed and developed by Brown et al. (1975).

E. The Error Correction Model

In the last step, we estimated the short-run and error correction term (ECT) coefficients in each ARDL models under unrestricted error correction model (UECM) specification. The short-run coefficients imply there is an individual effect from independent variables the dependent variable in the short-term, while the coefficient of error correction term (ECT_{t-1}) is defined as the effectiveness of correction mechanism in stabilizing disequilibrium in the model. The specification of UECM in this study can be written as follows:

$$\Delta lnCO2 = \alpha_1 + \beta_{11}\Delta lnCO2 + \beta_{12}\Delta lnVA + \beta_{13}\Delta lnVI + \beta_{14}\Delta lnVS + \beta_{15}\Delta lnHE + \beta_{16}\Delta lnREP + \lambda_1 ECT_{t-1} + \varepsilon_1 \quad (7)$$

$$\Delta lnVA = \alpha_2 + \beta_{21}\Delta lnVA + \beta_{22}\Delta lnCO2 + \beta_{23}\Delta lnVI + \beta_{24}\Delta lnVS + \beta_{25}\Delta lnHE + \beta_{26}\Delta lnREP + \lambda_2 ECT_{t-1} + \varepsilon_2 \quad (8)$$

$$\Delta lnVI = \alpha_3 + \beta_{31}\Delta lnVI + \beta_{32}\Delta lnCO2 + \beta_{33}\Delta lnVA + \beta_{34}\Delta lnVS + \beta_{35}\Delta lnHE + \beta_{36}\Delta lnREP + \lambda_3 ECT_{t-1} + \varepsilon_3 \quad (9)$$

$$\Delta lnVS = \alpha_4 + \beta_{41}\Delta lnVS + \beta_{42}\Delta lnCO2 + \beta_{43}\Delta lnVI + \beta_{44}\Delta lnVA + \beta_{45}\Delta lnHE + \beta_{46}\Delta lnREP + \lambda_4 ECT_{t-1} + \varepsilon_4 \quad (10)$$

$$\Delta lnHE = \alpha_5 + \beta_{51}\Delta lnHE + \beta_{52}\Delta lnCO2 + \beta_{53}\Delta lnVI + \beta_{54}\Delta lnVA + \beta_{55}\Delta lnVS + \beta_{56}\Delta lnREP + \lambda_5 ECT_{t-1} + \varepsilon_5 \quad (11)$$

$$\Delta lnREP = \alpha_6 + \beta_{61}\Delta lnREP + \beta_{62}\Delta lnCO2 + \beta_{63}\Delta lnVI + \beta_{64}\Delta lnVA + \beta_{65}\Delta lnVS + \beta_{66}\Delta lnHE + \lambda_6 ECT_{t-1} + \varepsilon_6 \quad (12)$$

Where, λ_i (i = 1,2,3,4,5,6) is the error correction term (ECT_{t-1}) coefficients which reflects the speed adjustment of long-run disequilibrium. The adjustment of disequilibrium in the model exist if the coefficient of error correction term (ECT_{t-1}) is negative and statistically significant at least 5 percent level (Narayan, 2005).

IV. RESULT AND DISCUSSION

Table 1 reports the result of ADF and PP unit root tests by using an equation with constant only. It can be seen that the result of both unit root tests shows that data series of lnVI and lnCO2 are stationary at I(0) and I(1), while data series of lnVA, lnVS, lnHE and lnREP are stationary only at I(1). Based on these results, we confirmed that all series being used in this study is only stationary at I(0) and/or I(1). Meanwhile, Table 2 reports the result of ARDL bound tests for all equation models. It can be seen that when lnCO2, lnVA, lnHE and lnREP are determined as dependent variable in the model, the value of F-statistic exceeded the upper critical bound value at 1 percent significance level. Meanwhile, when lnVI and lnVS are determined as dependent variable in the model, the value of F-statistic exceeded the upper critical bound value at 5 percent significance level. These results confirms that there are cointegration relationships between the variables in all ARDL models, respectively.

Table 1. ADF and PP Unit Root Tests

Series	ADF		PP	
	Level	1st different	Level	1st different
lnVA	0.279	-6.228[(a)]	0.243	-6.237[(a)]
lnVI	-2.711[(c)]	-4.945[(a)]	-2.711[(c)]	-4.966[(a)]
lnVS	-0.962	-4.478[(a)]	-1.226	-4.478[(a)]
lnHE	-2.591	-4.890[(a)]	-2.591	-4.890[(a)]
lnCO2	-2.852[(c)]	-5.706[(a)]	-3.729[(a)]	-5.706[(a)]
lnREP	-1.814	-6.659[(a)]	-2.441	-6.659[(a)]

Note: [(a)], [(b)], [(c)] denotes significant at 1%, 5% and 10% levels.

We summary empirical findings from the long-run model as follows. First, our result revealed that a rising of CO_2 emissions from energy combustion caused household expenditures declined and given negative impact on the progress of renewable energy development. These findings confirms that climate change and global warming, which one of caused by an increase in CO2 emissions from energy combustion motivates most of household to reduces their energy consumption and certainly it is influences their expenditure budgets. In addition, these findings also show that the progress of renewable energy development would be difficult to achieve if the use of non-renewable energy sources continues to increase and generated a lot of CO_2 emissions from energy combustion in the long-term.

Second, our results implied that the progress of economic growth in the agricultural sector did not only stimulates the progress of economic growth in the service sector, but also given negative impacts toward renewable energy development in the long-run. This finding confirms that a rise in the productivity and trade of agricultural commodities in the service sector not only drives income in agriculture sector increased, but also improves income the service sector in the long run. Even so, sustainable economic growth in the agricultural sector in the long run is predicted to hamper the progress of renewable energy development. It is because most of raw materials for produce biomass and biofuels are come from agricultural commodities and if all agricultural commodities are allocated to food products, certainly caused the production of biomass and biofuels will declined.

Table 2. The Bound Test

Model		Lags	F-stat
lnCO2 ‖ lnVA, lnVI, lnVS, lnHE, lnREP		1,0,0,0,0,0	18.077[a]
lnVA ‖ lnVI, lnVS, lnHE, lnREP, lnCO2		3,0,1,0,0,0	5.645[a]
lnVI ‖ lnVS, lnHE, lnREP, lnCO2, lnVA		1,1,1,0,0,3	4.773[a]
lnVS ‖ lnHE, lnREP, lnCO2, lnVA, lnVI		1,0,0,0,3,1	5.232[a]
lnHE ‖ lnREP, lnCO2, lnVA, lnVI, lnVS		3,3,2,4,4,1	8.116[a]
lnREP ‖ lnCO2, lnVA, lnVI, lnVS, lnHE		1,0,0,0,1,0	6.888[a]
CRITICAL BOUND Narayan (2005): Case III, k=5, n=45	**The Level of Significance**		
	1%	**5%**	**10%**
Lower critical value, I(0)	4.030	2.922	2.458
Upper critical value, I(1)	5.598	4.268	3.647

Note: [a], [b], [c] denotes significant at 1%, 5% and 10% levels.

Third, our result shows the growth of the industrial sector hamper and caused declining the growth of agricultural sector, but instead stimulated increased household expenditures, CO_2 emissions from energy combustions and renewable energy development. This finding confirms that industrialization has a negative impact on economic growth in the agricultural sector, on the contrary encouraging increased household expenditures, the use of energy that has the potential to produce CO_2 emissions from energy combustion as well as the productivity and development of renewable energy. Fourth, our result indicates that the growth of service sector driven the growth of agricultural sector and the development of renewable energy innovation, production and consumption. On the other hand, it is also caused declines household expenditures and CO_2 emissions from energy combustion. This finding shows that the increase in trade transactions in the service sector stimulates revenue growth in the agricultural sector and the sustainability development of renewable energy resources. However, the growth of economic activity in the service sector also causes a decrease in household expenditures and decline fossil energy consumption that intensively generated a lot of CO_2 emissions.

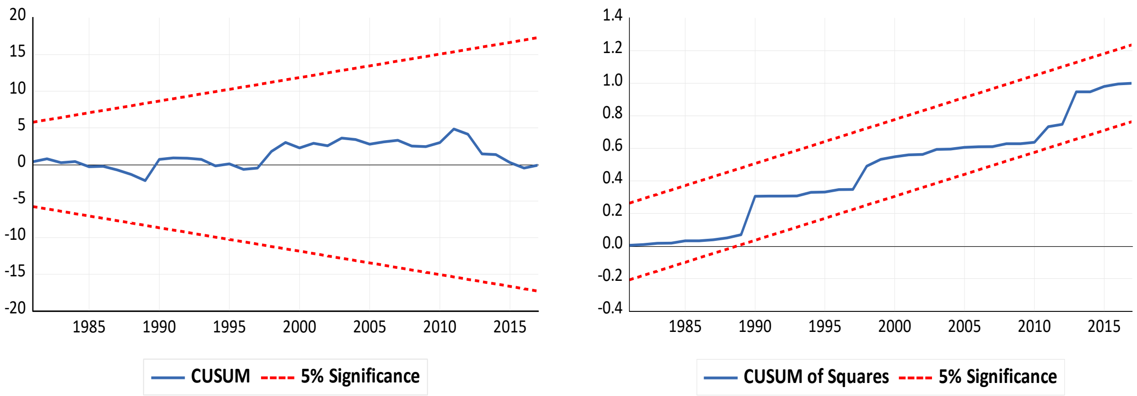

Figure 1. The plot of CUSUM and CUSUM of Squares (DV: lnCO2)

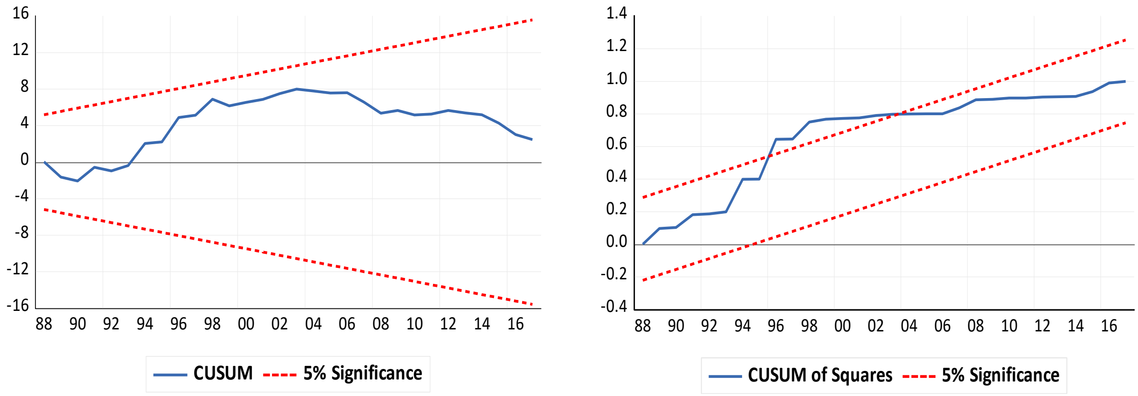

Figure 2. The plot of CUSUM and CUSUM of squares (DV: lnVA)

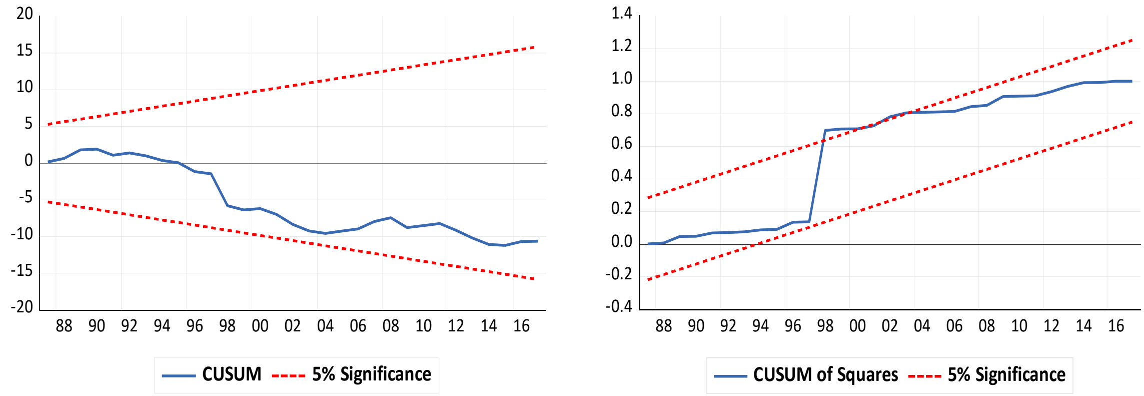

Figure 3. The plot of CUSUM and CUSUM of Squares (DV: lnVI)

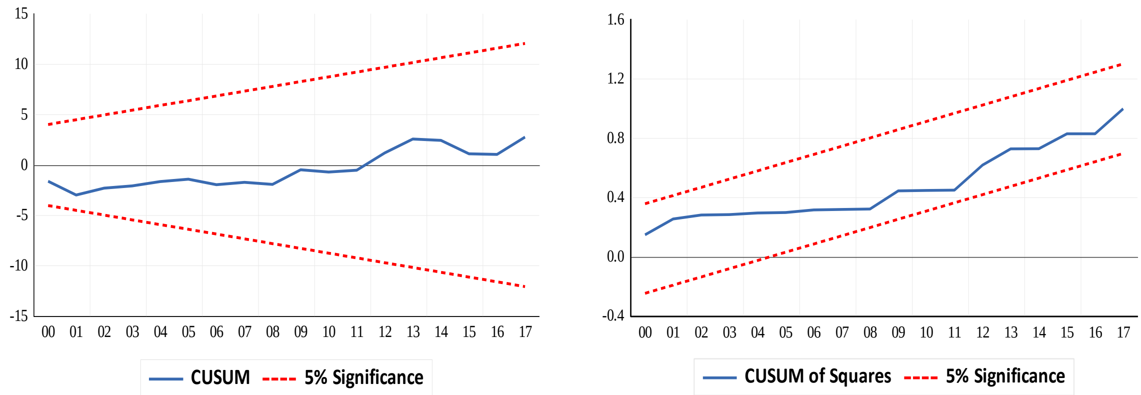

Figure 4. The plot of CUSUM and CUSUM of Squares (DV: lnVS)

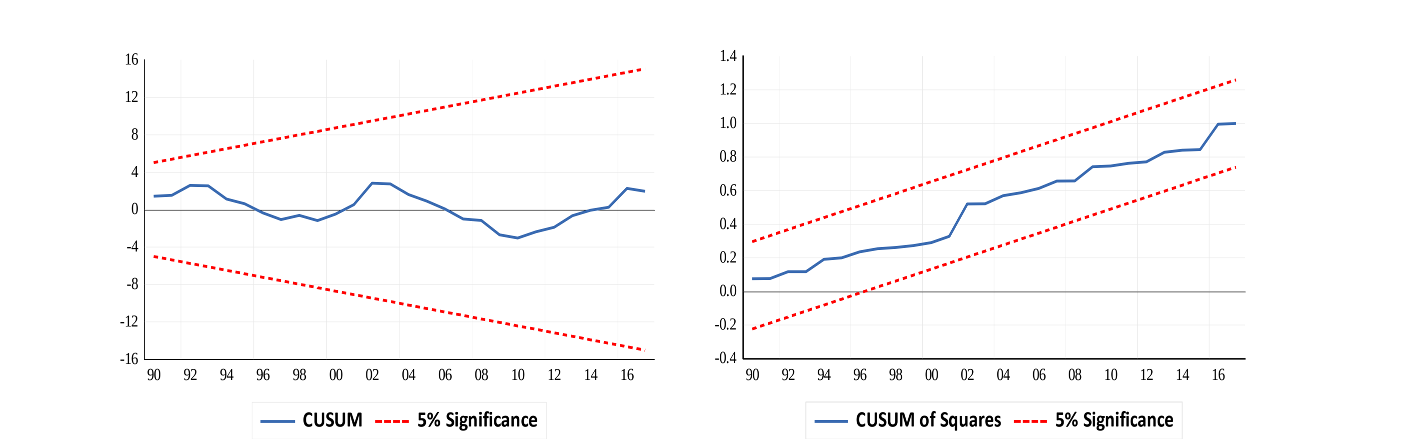

Figure 5. The plot of CUSUM and CUSUM of Squares (DV: lnHE)

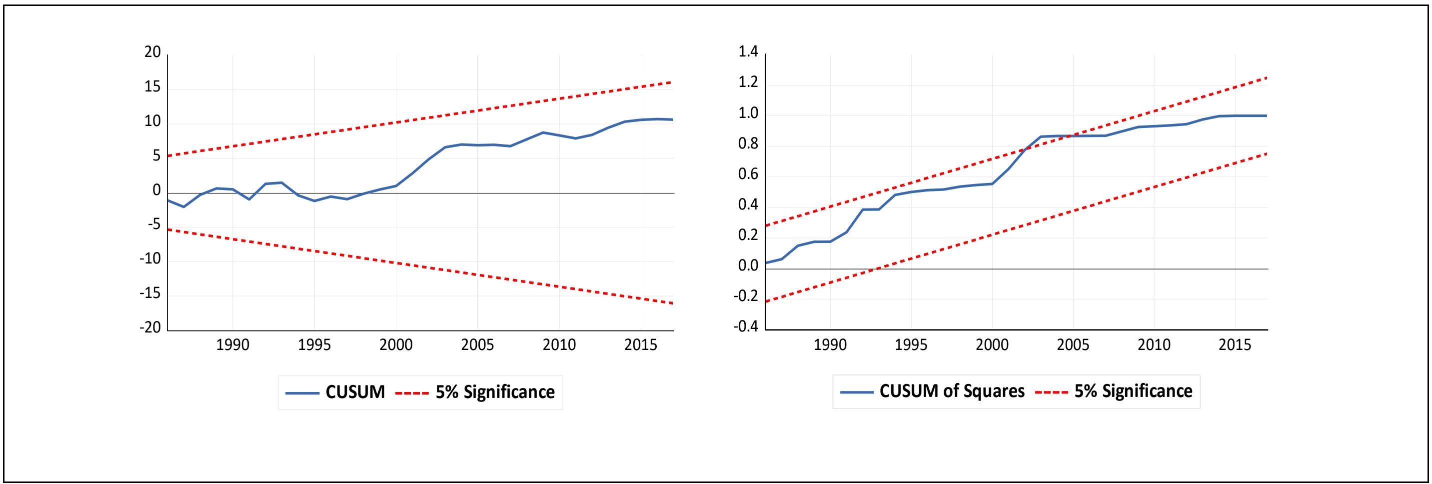

Figure 6. The plot of CUSUM and CUSUM of Squares (DV: lnREP)

Fifth, our results implies that the growth of household expenditures over the long-term did not only driven the progress of economic growth in agriculture sector but also obstructed the renewable energy development. Agricultural commodities are the main needs of community, hence a rise in the consumption agricultural commodities by household certainly encourage an increase in agricultural sector income in the long run. Nevertheless, an increase in household expenditure also has the potential to cause an increase in the amount of non-renewable energy and hamper the progress of renewable energy development in the long-term. Sixth, our result confirms that the progress of renewable energy development potentially reduces the amount of CO_2 emissions from energy combustion. Nevertheless, the sustainability of economic growth in three development sectors and the growth rate of household expenditures did not have any affect the progress of renewable energy development. Furthermore, the results of the Jarque-Statistics shows that normality problem occurred only in the first model, (lnCO2 as DV). The results of LM test shows that all models free from serial correlation issue. The BPG test shows that heterocedaticity problem only found in the fourth model (lnVS as DV) determined as dependent variable. The RESET test shows that the regressors in all models did not have any general specification error. In the stability test, the plots of CUSUM shows that the regressors in all models are stable during the observation periods, while the plot of CUSUM of squares plot shows instability problem on several ARDL models. Based on these findings, we then prefer to accepted the result from the plot of CUSUM and concluded that the regressors in all models are stable over the observation periods.

Table 5 reports the coefficients of short-run and error correction term for all ARDL models. In this part, the empirical findings on each error correction model will described consecutively. In first model (lnCO2 as DV), our result shows that the growth of industry sector in the short-term potentially caused a rise of CO_2 emissions from energy combustions. This finding implies that industry sector is a productive sector that intensively consumes fossil energy and generated CO_2 emissions from energy combustion. Therefore, this issue must be a concern for the Indonesian government and the comprehensive strategy to reduce the use of fossil fuels in the industrial sector must continue to be improved in order to reduce environmental impacts and the dependence of industry sector against fossil fuels. The ECT coefficient is -0.454 and significant at 1 percent level, which indicates that speed of adjustment to long-run equilibrium in this model is 45.4 percent annually. The value of R-squares shows that ability all independent variables to predict the changes of dependent variable approximately 54 percent, while the rest is described by other indicators that did not account in the model. Further, Durbin-Watson statistics implied that this model did not have autocorrelation issue.

Table 3. The Long-run Model

Regressors	Dependent Variable					
	lnCO2	**lnVA**	**lnVI**	**lnVS**	**lnHE**	**lnREP**
C	-11.716	16.804[a]	-4.213	-5.681	-6.528	10.972[b]
lnCO2		-0.023	0.324	-0.036	-0.292[b]	-0.271[b]
lnVA	0.383		-0.038	1.269[a]	0.355	-0.255
lnVI	1.728[a]	-0.865[b]		0.651	1.355[a]	0.121
lnVS	-0.640[c]	0.742[a]	0.588		-0.278[c]	0.153
lnHE	-0.403	0.520[c]	0.320	-0.530		-0.176
lnREP	-0.893[c]	-0.427	1.008	-0.814	-0.178	
JB Stat	6.210 (0.045)	0.929 (0.628)	1.524 (0.467)	0.070 (0.965)	0.589 (0.745)	2.238 (0.327)
LM-test	0.333 (0.568)	0.083 (0.775)	2.509 (0.080)	1.203 (0.315)	3.255 (0.051)	1.415 (0.244)
BPG test	0.397 (0.876)	1.301 (0.275)	1.922 (0.077)	2.282 (0.038)	0.565 (0.899)	0.465 (0.918)
RESET	0.558 (0.460)	2.135 (0.154)	0.010 (0.921)	0.673 (0.418)	0.810 (0.380)	0.177 (0.677)

Note: [a], [b], [c] denotes significant at 1%, 5% and 10% levels. The values in parentheses are p-value of statistics test.

In second model (lnVA as DV), our result shows that the growth of industry sector caused the growth of agriculture sector declined. On the contrary, the growth of services sector and a rise in household expenditures stimulate the growth of agriculture sector. This findings indicates that a rising in household expenditures and the growth of services sector stimulates the growth of agriculture sector in the short-term period, while sustainable growth in industry sector hampers the growth of agriculture sector. This condition shows that the growth of household welfare and the advance of agricultural commodity trading activities in Indonesia significantly influenced the growth of agricultural sector in Indonesia. The ECT coefficient is -0.215 and significant at 1 percent level, which indicates that speed of adjustment to long-run equilibrium in this model is 21.5 percent annually. The value of R-squares describes ability all independent variables to predicted dependent variable only 46.7 percent, while the rest is influenced by other indicators that not accounted in the model. Further, Durbin-Watson statistics implied that there are no autocorrelation in this model.

In third model (lnVI as DV), our result shows that the growth of services sector, a rise in household expenditures and advancement in renewable energy development throughout the short-term period potentially driving the growth of industry sector. This finding implies that the growth of trade transactions in the service sector and an increase in household purchasing power contribute higher income in industry sector. Moreover, the advancement on renewable energy development motivates industrial energy users to be more efficient and economical to consuming energy sources and certainly driven higher income in industry sector. In other hand, the growth of agriculture sector in the short-term has a negative affect and hamper the growth of industry sector. Some agricultural commodities are production raw materials in the industrial sector, especially manufacturing industries. Therefore, it is confirms that increasing the prices of raw materials from agricultural commodities provides high income on agriculture sector and indirectly reduces income in industry sector. The ECT coefficient is -0.210 and significant at 1 percent level, which indicates that speed of adjustment to long-run equilibrium in this model is 21 percent annually. The value of R-squares describes ability all independent variables to predicted dependent variable approximately 90.2 percent, while the rest is influenced by other indicators that not accounted in the model. Further, Durbin-Watson statistics indicates that this model is free from autocorrelation issue.

Table 4. Error Correction Model

Regressors	Dependent Variable					
	ΔlnCO2	ΔlnVA	ΔlnVI	ΔlnVS	ΔlnHE	ΔlnREP
C	-5.323	3.618[b]	-0.886	-1.092	-4.614	18.109[a]
ΔlnCO2		-0.005	0.068	-0.007	-0.081	-0.133[b]
ΔlnCO2(-1)					0.205[a]	
ΔlnVA	0.174		-0.652[b]	0.782[a]	0.808[a]	-0.126
ΔlnVA(-1)		-0.347[b]	0.116	0.151	-0.060	
ΔlnVA(-2)		-0.243[c]	-0.714[a]	0.559[a]	-0.017	
ΔlnVA(-3)					0.716[a]	
ΔlnVI	0.785[a]	-0.186[b]		0.740[a]	0.541[a]	0.060
ΔlnVI(-1)					-0.139	
ΔlnVI(-2)					-0.248[b]	
ΔlnVI(-3)					-0.235[a]	
ΔlnVS	-0.291	0.318[a]	0.802[a]		0.091	-0.164
ΔlnHE	-0.183	0.112[b]	0.434[a]	-0.102		-0.087
ΔlnHE(-1)					0.206	
ΔlnHE(-2)					0.433[a]	
ΔlnREP	-0.406	-0.092	0.212[c]	-0.156	0.152	
ΔlnREP(-1)					0.371[b]	
ΔlnREP(-2)					-0.233	
ECT(-1)	-0.454[a]	-0.215[a]	-0.210[a]	-0.192[b]	-0.707[a]	-1.362[a]
R^2	0.467	0.540	0.902	0.898	0.950	0.994
DW statistics	2.145	2.024	2.177	2.044	2.311	1.711

Note: [a], [b], [c] denotes significant at 1%, 5% and 10% levels.

In fourth model (lnVS as DV), our result indicates that the growth of agriculture sector and industry sector significantly driven the growth of services sector in the short-term. This finding shows that sustainable economic growth in service sector over the short-term, especially in public and private services, has a positive affect on the growth of industry sector and agriculture sector. Moreover, our result also found that the growth of CO_2 emissions from energy combustion, household expenditures, and the renewable energy development in the short-term did not influences the progress of economic growth in services sector. The ECT coefficient is -0.192 and significant at 5 percent level, which indicates that speed of adjustment to long-run equilibrium in this model is 19.2 percent annually. The value of R-squares describes ability all independent variables to predicted dependent variable approximately 89.8 percent, while the rest is influenced by other indicators that not accounted in the model. Further, Durbin-Watson statistics indicates that this model is did not have autocorrelation issue.

In fifth model (lnHE as DV), our result indicates that a rise of CO_2 emissions, the progress of renewable energy development, and economic growth in agriculture sector driven household expenditures increased in the short-term. These findings confirms that climate change caused by an increase in CO_2 emissions motivates an increase in the consumption of renewable energy that is environmentally friendly. meanwhile, a rise in the production of agricultural commodities, which of course increases income in the agricultural sector, indirectly caused household expenditures increased. Meanwhile, our result shows that the progress of economic growth in industry sector encouraged a rise of household expenditures only in the first period of short-term. In next short-run periods the progress of economic growth in industry sector potentially caused household expenditures decreased. The ECT coefficient is -0.707 and significant at 5 percent level, which indicates that speed of adjustment to long-run equilibrium in this model is 70.7 percent annually. The value of R-squares describes ability all independent variables to predicted dependent variable approximately 95.0 percent, while the rest is influenced by other indicators that not accounted in the model. Further, Durbin-Watson statistics indicates that this model is did not have autocorrelation issue.

In sixth model (lnREP as DV), our result shows that a rise in the amount of CO2 emissions from energy combustions and the growth of agriculture sector and services sector over the short-term period inhibited the development and innovation of renewable energy resources in Indonesia. On contrary, the growth of industry sector over the short-term period stimulates the advance of renewable energy development and innovation. These findings indicate that the development and innovation of renewable energy resources in Indonesia predicted will rapid growth if the amount of CO2 emission declines in the short-term period. Moreover, the development and innovation of renewable energy resources in Indonesia also will be achieved if the growth of agriculture sector and services sector declined over the short-term period. Overall, these findings confirm that economic growth in the industrial sector in the short-term period has a positive impact on the progress of renewable energy development in Indonesia. The coefficient of ECT is -1.362 and significant at 5 percent level, which indicates that speed of adjustment to long-run equilibrium in this model is 136.2 percent annually. The value of R-squares describes ability all independent variables to predicted dependent variable approximately 99.5 percent, while the rest is influenced by other indicators that not accounted in the model. Further, the value of Durbin-Watson statistics indicates that this model is did not have autocorrelation issue.

V. CONCLUSION AND RECOMMENDATION

Our results shown that the sustainability of economic growth in industry sector and services sector encourage the amount of CO_2 emissions from energy combustion increased over the long-term period. The growth of service sector along the short-term period has a positive affect to environment quality and declining the amount of CO_2 emission from energy combustions. Our results also found that an increased CO_2 emission from energy combustion influences the growth rate of household expenditures, both in the short and long terms. The advance development of renewable energy innovation and the growth of CO_2 emissions from energy combustion affect each other over the long-term. Moreover, our findings revealed that the sectoral economic growth are interrelated and affect the growth rate of household expenditures and the sustainable development of Indonesia's renewable energy resaources, both in the short and long terms.

Based on these findings, we concluded that the sustainability of sectoral economic growth and improving household expenditures influences the growth rate of CO_2 emissions from energy combustion and renewable energy development in Indonesia. In addition, we also concluded that the sustainable of renewable energy development has potentially reducing the amount of CO_2 emissions from energy combustion over the long-term. Therefore, we suggest to government to improve the socialization of utilization renewable energy sources in the productive sectors and household in order to stimulate economic growth and the sustainability of environmental quality in Indonesia. Furthermore, we also recommend the development of renewable energy which can be directly applied by all final energy users in Indonesia, both in the productive and household. We argued that the sustainability growth of renewable energy development will be faster improved if all productive development sectors and household energy users are able to self-producing as well as use new and renewable energy resources for their daily activities, both in small or large scales.

REFERENCES

1. Apergis, N., & Payne, J. E. (2010). A panel study of nuclear energy consumption and economic growth. *Energy Economics*, *32*(3), 545–549. https://doi.org/10.1016/j.eneco.2009.09.015
2. Apergis, N., & Tang, C. F. (2013). Is the energy-led growth hypothesis valid? New evidence from a sample of 85 countries. *Energy Economics*, *38*, 24–31. https://doi.org/10.1016/j.eneco.2013.02.007
3. Aslantürk, O., & Kıprızlı, G. (2020). The role of renewable energy in ensuring energy security of supply and reducing energy-related import. *International Journal of Energy Economics and Policy*. https://doi.org/10.32479/ijeep.8414
4. Baek, J. (2016). Do nuclear and renewable energy improve the environment? Empirical evidence from the United States. *Ecological Indicators*, *66*, 352–356. https://doi.org/https://doi.org/10.1016/j.ecolind.2016.01.059
5. Bilgili, F., Koçak, E., & Bulut, Ü. (2016). The dynamic impact of renewable energy consumption on CO2emissions: A revisited Environmental Kuznets Curve approach. *Renewable and Sustainable Energy Reviews*, *54*, 838–845. https://doi.org/10.1016/j.rser.2015.10.080
6. Bölük, G., & Mert, M. (2015). The renewable energy, growth and environmental Kuznets curve in Turkey: an ARDL approach. *Renewable and Sustainable Energy Reviews*, *52*, 587–595. https://doi.org/https://doi.org/10.1016/j.rser.2015.07.138
7. Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for Testing the Constancy of Regression Relationships Over Time. *Journal of the Royal Statistical Society: Series B (Methodological)*, *37*(2), 149–192. https://doi.org/10.1111/j.2517-6161.1975.tb01532.x
8. Charfeddine, L. (2017). The impact of energy consumption and economic development on Ecological Footprint and CO2 emissions: Evidence from a Markov Switching Equilibrium Correction Model. *Energy Economics*, *65*, 355–374. https://doi.org/10.1016/j.eneco.2017.05.009
9. Chitnis, M., Druckman, A., Hunt, L. C., Jackson, T., & Milne, S. (2012). Forecasting scenarios for UK household expenditure and associated GHG emissions: Outlook to 2030. *Ecological Economics*, *84*, 129–141.

https://doi.org/10.1016/j.ecolecon.2012.09.016

10. Copenhagen Accord. (2009). *United Nation Framework Convention on Climate Change*.
11. Degu, A. A. (2019). The Causal Linkage Between Agriculture, Industry and Service Sectors in Ethiopian Economy. *American Journal of Theoretical and Applied Business*, *5*(3), 59–76. https://doi.org/10.11648/j.ajtab.20190503.13
12. Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series With a Unit Root. *Journal of the American Statistical Association*, *74*(336), 427–431.
13. Dong, K, Sun, R., & Dong, X. (2018). CO2 emissions, natural gas and renewables, economic growth: assessing the evidence from China. *Science of the Total Environment*, *640*, 293–302.
14. Dong, Kangyin, Hochman, G., & Timilsina, G. R. (2020). Do drivers of CO2 emission growth alter overtime and by the stage of economic development? *Energy Policy*, *140*, 111420. https://doi.org/10.1016/j.enpol.2020.111420
15. Dong, Kangyin, Jiang, H., Sun, R., & Dong, X. (2019). Driving forces and mitigation potential of global CO2 emissions from 1980 through 2030: Evidence from countries with different income levels. *Science of The Total Environment*, *649*, 335–343. https://doi.org/10.1016/j.scitotenv.2018.08.326
16. Druckman, A., & Jackson, T. (2008). Household energy consumption in the UK: a highly geographically and socio-economically disaggregated model. *Energy Policy*, *36*(8), 3177–3192.
17. Farabi, A., Abdullah, A., & Setianto, R. H. (2019). Energy Consumption, Carbon Emissions and Economic Growth in Indonesia and Malaysia. *International Journal of Energy Economics and Policy*, *9*(3), 338–345. https://doi.org/10.32479/ijeep.6573
18. Fri, R. W., & Savitz, M. L. (2014). Rethinking energy innovation and social science. *Energy Research and Social Science*, *1*, 183–187. https://doi.org/10.1016/j.erss.2014.03.010
19. Gielen, D., Saygin, D., & Rigter, J. (2017). Renewable Energy Prospects: Indonesia. In *International Renewable Energy Agency (IRENA)*. https://doi.org/10.1145/347642.347800
20. International Energy Agency. (2020). *Online Data Service*. https://www.iea.org/data-and-statistics/
21. Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., & Hertwich, E. G. (2015). Environmental Impact Assessment of Household Consumption. *Journal of Industrial Ecology*, *20*(3), 526–536. https://doi.org/10.1111/jiec.12371
22. Katircioglu, S. (2004). Co-integration and causality between GDP, agriculture, industry and services growth in North Cyprus: evidence from time series data. *Review of Social, Economic & Business Studies*, *5*(6), 173–187.
23. Lenzen, M., Wier, M., Cohen, C., Hayami, H., Pachauri, S., & Schaeffer, R. (2006). A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan. *Energy*, *31*, 181–207. https://doi.org/10.1016/j.energy.2005.01.009
24. Lu, W.-C. (2017). Renewable energy, carbon emissions, and economic growth in 24 Asian countries: evidence from panel cointegration analysis. *Environmental Science and Pollution Research*, *24*(33), 26006–26015.
25. Menyah, K., & Wolde-Rufael, Y. (2010). CO2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy*, *38*(6), 2911–2915.
26. Ministry of Energy and Mineral Resources Republic of Indonesia. (2018). *Handbook of Energy & Economic Statistics of Indonesia 2018 (Final Edition)* (A. Wahyu Kencono, M. Dwinugroho, E. Satra Baruna, & N. Ajiwihanto (eds.)). Ministry of Energy and Mineral Resources Republic of Indonesia.
27. Mukherjee, I., & Sovacool, B. K. (2014). Palm oil-based biofuels and sustainability in southeast Asia: A review of Indonesia, Malaysia, and Thailand. *Renewable and Sustainable Energy Reviews*, *37*, 1–12. https://doi.org/10.1016/j.rser.2014.05.001
28. Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics*, *37*(17), 1979–1990. https://doi.org/10.1080/00036840500278103
29. Nasruddin, Idrus Alhamid, M., Daud, Y., Surachman, A., Sugiyono, A., Aditya, H. B., & Mahlia, T. M. I. (2016). Potential of geothermal energy for electricity generation in Indonesia: A review. *Renewable and Sustainable Energy Reviews*, *53*, 733–740. https://doi.org/10.1016/j.rser.2015.09.032
30. National Energy Council. (2019). Indonesia Energy Outlook 2019. In S. Abdurrahman, M. Pertiwi, & Walujanto (Eds.), *National Energy Council* (2019th ed., Vol. 66). National Energy Council.
31. Newman, D. G., Eschenbach, T. G., & Lavelle, J. P. (2004). *Engineering Economic Analysis* (9th ed.). Oxford University Press.

32. Nie, H., Kemp, R., Xu, J., Vasseur, V., & Fan, Y. (2018). Drivers of urban and rural residential energy consumption in China from the perspectives of climate and economic effects. *Journal of Cleaner Production*, *172*, 2954–2963. https://doi.org/10.1016/j.jclepro.2017.11.117
33. Nugraha, A. T., & Osman, N. H. (2017). The Energy-Economic Growth Nexus in Indonesia. *Journal of Business Management and Accounting, 7*(2), 61–75.
34. Nugraha, A. T., & Osman, N. H. (2018). The environmental study on causality relationship among energy consumption, CO2 emissions, the value added of development sectors and household final consumption expenditure in Indonesia. *Ekoloji*, *27*(106), 837–852.
35. Ong, H. C., Silitonga, A. S., Masjuki, H. H., Mahlia, T. M. I., Chong, W. T., & Boosroh, M. H. (2013). Production and comparative fuel properties of biodiesel from non-edible oils: Jatropha curcas, Sterculia foetida and Ceiba pentandra. *Energy Conversion and Management*, *73*, 245–255.
36. Patterson, S. (2015). Indonesia's Energy Requirements-Part One: Current Energy Dynamics. *Independent Strategic Analysis of Australia's Global Interest*, *February*, 1–6.
37. Permana, A. S., Norsiah, A. A., & Siong, H. C. (2015). Is mom energy efficient ? A study of gender, household energy consumption and family decision making in Indonesia. *Energy Research & Social Science*, *6*, 78–86. https://doi.org/10.1016/j.erss.2014.12.007
38. Pesaran, M. ., & Shin, Y. (1998). An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis. *Econometric Society Monographs*, *31*, 371–413. https://doi.org/10.1017/CCOL521633230
39. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Autoregressive Distributed Lag (ARDL) cointegration technique : application and interpretation. *Journal of Statistical and Econometric Methods*, *5*(3), 63–91. https://doi.org/10.1002/jae.616
40. Phillips, P. C. B., & Perron, P. (1988). Testing for a Unit Root in a Time Series Regression. *Biometrika*, *2*(75), 335–346. https://doi.org/10.1080/07350015.1992.10509923
41. Price, C. W., Brazier, K., Pham, K., Mathieu, L., & Wang, W. (2007). *Identifying fuel poverty using objective and subjective measures* (No. 07–11).
42. Rehdanz. (2007). Determinants of Residential Space Heating Expenditures in Germany. *Energy Economics*, *29*(2), 167–182.
43. Sadorsky, P. (2009). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economics*, *31*, 456–462.
44. Saidi, K., & Omri, A. (2020). The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. *Environmental Research*, *186*, 109567. https://doi.org/10.1016/j.envres.2020.109567
45. Salari, M., & Javid, R. J. (2017). Modeling household energy expenditure in the United States. *Renewable and Sustainable Energy Reviews*, *69*, 822–832. https://doi.org/10.1016/j.rser.2016.11.183
46. Sebri, M., & Salha, O. Ben. (2014). On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries. *Renewable and Sustainable Energy Reviews*, *39*, 14–23. https://doi.org/10.1016/j.rser.2014.07.033
47. Sepehrdoust, H., & Adnan, Q. M. A. (2012). An empirical study of inter-sectoral linkages and economic growth. *Trends in Applied Sciences Research*, *7*(7), 494–504.
48. Shahbaz, M., Zakaria, M., Shahzad, S. J. H., & Mahalik, M. K. (2018). The energy consumption and economic growth nexus in top ten energy-consuming countries: Fresh evidence from using the quantile-on-quantile approach. *Energy Economics*, *71*, 282–301. https://doi.org/10.1016/j.eneco.2018.02.023
49. Silva, S., Soares, I., & Pinho, C. (2012). The impact of renewable energy sources on economic growth and CO2 emissions - an SVAR approach. *European Research Studies*, *XV*(4), 133–144.
50. Singariya, M. R., & Naval, S. C. (2016). An Empirical Study of Inter-Sectoral Linkages and Economic Growth in India. *American Journal of Rural Development*, *4*(4), 78–84. https://doi.org/10.12691/ajrd-4-4-1
51. Singh, R., & Setiawan, A. D. (2013). Biomass energy policies and strategies: Harvesting potential in India and Indonesia. *Renewable and Sustainable Energy Reviews*, *22*, 332–345. https://doi.org/10.1016/j.rser.2013.01.043
52. Statistics Indonesia. (2020). *Statistical Yearbook of Indonesia 2019*. Statistics Indonesia-Bappenas.
53. Swain, R. B., & Karimu, A. (2020). Renewable electricity and sustainable development goals in the EU. *World Development*, *125*, 104693. https://doi.org/10.1016/j.worlddev.2019.104693
54. Tiwari, A. K. (2011). Comparative performance of renewable and nonrenewable energy source on economic growth and CO2 emissions of Europe and Eurasian countries: A PVAR approach. *Economics Bulletin*, *31*(3),

2356–2372.

55. Uddin, M. M. M. (2015). Causal Relationship between Agriculture, Industry and Services Sector for GDP Growth in Bangladesh: An Econometric Investigation. *Journal of Poverty, Investment and Development*, *8*, 124–130.
56. Uzar, U. (2020). Political economy of renewable energy: Does institutional quality make a difference in renewable energy consumption? *Renewable Energy*, *155*, 591–603. https://doi.org/10.1016/j.renene.2020.03.172
57. Verner, N. M. (2001). *Inter-sectoral dynamics and economic growth in Ecuador*. The World Bank Latin America and the Caribbean Region Economic Policy Sector Unit.
58. Vo, A. T., Vo, D. H., & Le, Q. T.-T. (2019). CO2 Emissions, Energy Consumption, and Economic Growth: New Evidence in the ASEAN Countries. *Journal of Risk and Financial Management*, *12*(3), 145. https://doi.org/10.3390/jrfm12030145
59. Waheed, R., Sarwar, S., & Wei, C. (2019). The survey of economic growth, energy consumption and carbon emission. *Energy Reports*, *5*, 1103–1115. https://doi.org/10.1016/j.egyr.2019.07.006
60. Werff, E. Van der, & Steg, L. (2015). One model to predict them all: predicting energy behaviours with the norm activation model. *Energy Research & Social Science*, *6*, 8–14.
61. World Bank. (2020). *World Development Indicators*.
62. Xinshen, D., & Haggblade, B. F. S. (2007). *Agricultural Growth Linkages in Ethiopia: Estimates using Fixed and Flexible Price Models*. Washington: international food policy.
63. Ye, Y., Koch, S. F., & Zhang, J. (2018). Determinants of household electricity consumption in South Africa. *Energy Economics*. https://doi.org/10.1016/j.eneco.2018.08.005
64. Yusoff, N. Y. B. M., & Latif, N. W. B. A. (2013). Measuring the Effects of World Oil Price Change on Economic Growth and Energy Demand in Malaysia: An ARDL Bound Testing Approach. *International Journal of Trade, Economics and Finance*, *4*(1), 29–36. https://doi.org/10.7763/IJTEF.2013.V4.256
65. Zhang, B., Wang, B., & Wang, Z. (2017). Role of renewable energy and non-renewable energy consumption on EKC: evidence from Pakistan. *Journal of Cleaner Production*, *156*, 855–864. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.03. 203
66. Zhang, L., Pang, J., Chen, X., & Lu, Z. (2019). Carbon emissions, energy consumption and economic growth: Evidence from the agricultural sector of China’s main grain-producing areas. *Science of the Total Environment*, *665*, 1017–1025. https://doi.org/10.1016/j.scitotenv.2019.02.162