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The Environmental Study on Causality Relationship among Energy Consumption, CO2 Emissions, the Value Added of Development Sectors and Household Final Consumption Expenditure in Indonesia

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Abstract

The long-run estimates indicate that there is a statistically significant positive association between electricity consumption and emissions and a non-linear relationship between emissions and real output, consistent with the Environmental Kuznets Curve. The present study investigate the causal relationship between CO2 emissions, energy consumption, the value added of three development sectors and household final consumption expenditure in Indonesia using annual time series data from 1971 to 2014. We applied Autoregressive Distributed Lag (ARDL) method and granger causality test in order to explore the direction of relationships among the variables. Our study revealed that the growth of energy consumption and an increases the value added of industry sector and services sector will causes a rise of CO2 emissions, while a rise of the value added of agriculture sector potentially reduced CO2 emission and increases energy consumption. The growth of value added on three development sectors, respectively, have a mutual relationship with household final consumption expenditure and a unidirectional relationship to energy consumption and CO2 emission in Indonesia. Furthermore, we also discovered that the value added of services sector has a mutual relationship with the value added of industry sector and agriculture sector, while the growth of value added on industry sector has a negative effect to the value added of agriculture sector. Based on these results, we concluded that the energy conservation policies can be applied to all energy user groups in Indonesia. In addition we also suggest that policy makers can implement economic policies that can encourage increased the value added of agriculture sector in Indonesia.

Keywords: CO2 emission, energy consumption, the value added of development sectors, household final consumption expenditure, Environmental Kuznets Curve

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INTRODUCTION

The issue of climate change, global warming and environmental pollution due to deforestation, fossil energy use and development activities have been become a major worldwide concern in recent decades (Dogan and Seker 2016, Lau et al. 2014). A large number of scientific evidences show that human activities, including energy use, have contributed significantly to global warming which then causes extreme changes in the Earth's climate. Scientists conclude that carbon dioxide (CO2) is the main greenhouse gas that contributes to the problem of environmental pollution (Fodha and Zaghdoud 2010). Energy consumption contributes to approximately 35% of global emissions of CO2 and accounts for more than 80% of total greenhouse gas emissions globally that generated from production, transformation, handling and consumption of all kinds of energy commodities. One indicator of the scale of the challenge to the energy sector is the fact that the total volume of global energy sector CO2 emissions over three past decades matched the total level of all previous years (International Energy Agency 2015).

Energy security and environmental degradation play an important role in economic growth and development activity in a country (Abidin 2015, Ahmed and Azam 2016, Ang et al. 2015, Sghari and Hammami 2016). Energy has become one of important factor that considered on determines domestic and foreign policies in a country and influences the political, economic, business and social decisions of the country's leaders. Energy security is related to broader concerns about

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national security, where energy scarcity can affect all development and social activities in a country. The United Nations Framework Convention on Climate Change (UNFCCC) even stipulates that the problem of energy selection and utilization is one of the main themes in bilateral and multilateral discussions between countries. The scheme to reduce greenhouse gas emissions is part of a global agreement resulting from this series of negotiations. Many decisions in resource management and energy consumption will have implications toward all development activities and social life of the community, both in the short and long term (Indriyanto et al. 2007).

International Energy Agency (2018) classifies energy users and producers of CO2 emissions from energy combustion into seven groups, namely industry, transportation, housing, commercial and private services, agriculture / forestry, fisheries, and unnamed energy users. Most categories of energy users are part of the three main development sectors in a country, namely industry, agriculture and services. The activities of these three main development sectors depend heavily on the availability of energy as their input and indirectly increase the amount of CO2 emissions from energy combustions. Therefore, the availability of energy is a necessity for all development sectors to be able to continue to grow and contribute to a country. Meanwhile, residential energy users are related to household consumption needs, where household activities also produce CO2 emissions from a variety of daily activities that are not derived from energy combustions. In some countries, the amount of consumption of energy users in housing is the largest compared to other categories of energy users.

Economic growth of a country is affected by the growth of added value incomes contributed by three main development sectors, namely Industry, agriculture and services. The growth rate of value added on three development sectors, respectively, depends on the performance of economic activities in the domestic and global markets, especially trade of good and services. Trade of good and services in domestic markets are driven by the level of demand and purchasing power of domestic people, which is certainly related to changes in the level of income and lifestyle of people. The level of demand growth and the purchasing power of domestic people for commodities and services in the domestic market can be measured by the growth of household final consumption expenditure. One of household expenditures is energy costs, because energy commodities have become a main input on most of daily human activities. Availability access to energy sources is a basic requirement to get benefits from energy services because energy availability is not possible without access. Supply availability also needs to meet the requirements of stability and good quality. This condition is needed to achieve energy security and sustainable development goals.

Indonesia is one of the most populous countries in the world and also archipelago countries that consisting of 17,508 islands which located in Southeast Asia region (Resosudarmo et al. 2012, Tharakan 2015). Indonesia’s economy is the largest in Southeast Asia, with a gross domestic product (GDP) estimated at $1,090.3 billion (at constant USD) in 2017 (World Bank 2018). Since implemented a range of economic reforms in the early 1990s, Indonesia has been fast growing to be one of Asian emerging economies. Currently Indonesia has been one of the largest economy in Southeast Asia and the sixteenth largest economic countries in the world. Over the past decades, the amount of Indonesia’s energy consumption increased rapidly concomitant with the growth of population and economic development in Indonesia. In 2017, Indonesia’s population growth rate is 1.1 per cent and approximately 55 per cent of total population is living in urban areas, while the real GDP growth rate of Indonesia was reached 5 per cent with sectorial growth is 3.4 per cent in agriculture, 3.8 per cent in industry and 5.6 per cent in services (World Bank 2018). Meanwhile, the amount of energy consumption in Indonesia was achieved 225,361 thousand tonnes of oil equivalent in 2015 and the amount of Indonesia’s CO2 emissions from energy combustion increased from 20.509 metric tonnes of CO2 emission in 1990 to 32,294 metric tonnes of CO2 emission in 2015 (International Energy Agency 2018).

The rapid growth of energy consumption and CO2 emission from energy combustion in Indonesia has been motivated the Indonesian government given serious attention and establish the green policies in order to face the future challenges related energy security and climate changes. Even more, The president Joko Widodo on the 21st Conference of the Parties in Paris expressed Indonesia’s commitment to reduce Indonesia’s CO2 emissions by 29 per cent in 2030 with own effort or approximately 41 per cent with international support. This momentum is the basis of the target change for the reduction of greenhouse gas emissions in Indonesia, where the energy sector gets a portion of GHG emission reduction of 314 million tons of CO2 (National Energy Council 2016). However, implementation of energy and environment policies certainly must take into account the condition and issues that occurring in Indonesia, especially related with productivity and challenge on each development sectors and the growth of household expenditure consumption in Indonesia.

Over the past three decades many researchers have been investigate the causal relationship among energy consumption, economic growth and CO2 emission in Indonesia and produced various conclusions about the relationship and effects of economic growth on energy consumption and CO2 emissions, and vice versa. Indonesia has several differences compared to other countries in the world, especially in the challenges, conditions and situations faced related to energy, economy and environment. The income and welfare gap between rich people and poor people is also very far away and hence per capita income may not be appropriate in projecting the average income and expenditure of Indonesia's people. In addition, there is a considerable imbalance in economic growth between the agricultural sector and two other development sectors. Differences in the economic structure, activity and criteria of energy users in the three development sectors, of course build the assumption that economic growth in each development sector may have a different contribution to the growth rate of energy consumption and CO2 emissions from energy combustion in Indonesia.

Based on overviews above, we then determined to investigate the causal relationship among energy consumption, CO2 emission, the added value of three development sectors, and household final consumption expenditure in Indonesia. This study has expected to fill the limitations of previous studies and provide useful additional information as underlying on determining the sustainable development policies in Indonesia. The paper contributes and fills the gap on the existing literature with two inputs. First, we employ the value added of development sectors and household final consumption expenditure as economic growth indicators; substitute the real GDP and GDP per capita that is commonly used on previous studies. Second, we applied structural break unit root test and then uses a dummy variable for single time break on our estimation models, respectively. Furthermore, this paper is organized into four main sections. Section two discusses theories and empirical evidences from previous literature studies. Data sources and methods analysis methods explained on third section. Section four discusses empirical findings from our results. The last section confirms conclusion and policy implications.

LITERATURE REVIEWS

Many researchers and scientists in various countries are very interested to investigate the causal relationship between energy consumption, environmental degradation, and economic growth because this issue related with determination of strategies and policies for sustainable development (see, Antonakakis et al. 2016, Lacheheb et al. 2015, Mrabet and Alsamara 2017, Murad et al. 2015, Youssef et al. 2016). Reference and knowledge from empirical studies that reflect current issues related to the direction of relationship among energy consumption, economic development and environmental emissions has considered important and useful as underlying factor on determining sustainable policies in many countries (Arouri et al. 2014, Ghali and Sakka 2004). In general, most of previous studies that investigate for case in a countries have difference on time periods, modeling techniques and proxy variables that used to investigate the relationship between energy consumption, economic growth and CO2 emissions (see, Al-Mulali and Sheau-Ting 2014, Alshehry and Belloumi 2015, Bento and Moutinho 2016, Ojewumi and Akinlo 2017), which commonly discussed within two theoretical approaches, i.e. (1) energy-economic nexus and (2) the impact of energy consumption and economic growth on environment degradation.

Over three past decades, the relationship among energy consumption and economic growth in Indonesia has been widely studied by experts. The direction and policy implications of the causal relationship between energy consumption and economic growth are generally tested using four hypotheses, namely conservative, growth, neutrality, and feedback (Apergis and Payne 2009, 2010, Ozturk et al. 2010, Shahbaz et al. 2013) The energy conservation hypothesis is based on the idea that economic growth tends to affect the amount of energy consumption, which indicates that energy conservation policies do not cause adverse effects on economic growth. For the case in Indonesia, Masih and Masih (1996) is the first classical study that concluded conservation hypothesis and found unidirectional causality that runs from Gross National Product for energy consumption during the period 1960-1990. Soile (2012) examined the direction of causality between energy consumption and economic growth using annual data from 1971 to 2010 and found that economic growth is a key indicator that influenced energy consumption in Indonesia. Furthermore, Hwang and Yoo (2012) used the Granger causality test for annual data from 1965-2006 and found that Gross Domestic Product (GDP) had a significant effect on energy consumption in Indonesia. Similar findings were also expressed by Azam et al (2015a) who investigated the determinants of energy consumption for cases in Indonesia, Thailand and Malaysia during the period of 1980-2012 using autoregressive distributed lag (ARDL) procedures and found that real GDP growth, foreign direct investment, trade prosperity, rate of population growth, urbanization, and the human development index are determinants factors that influenced energy consumption per capita in Indonesia.

The growth hypothesis is based on the idea that energy consumption is a major determinant of economic growth. In this situation, an energy conservation policy that leads to a reduction in the amount of energy consumption has the potential to cause a negative impact on economic growth. Initially the evidence for the growth hypothesis for cases in Indonesia during the period 1973-1995 was discovered by Asafu-adjaye (2000) using co integration tests and error correction modelling techniques. Furthermore, Yoo and Kim (2006) used Hsiao version of causal causality and annual data during the period 1971-2002 had found that electric power consumption had a significant contribution to economic growth in Indonesia. Using a causality granger test based on VECM, Wahid et al (2013) studied the relationship between energy consumption, economic growth and CO2 emissions for Malaysia, Indonesia and Singapore during the period 1975-2011 and found a unidirectional relationship that occurred from energy consumption to economic growth and from economic growth to CO2 emissions for cases in Indonesia. Likewise, Chandran and Tang (2013) who used the granger causality test and annual data from 1971 to 2008 revealed evidence of a growth hypothesis, a unidirectional relationship that runs from economic growth to CO2 emissions and from CO2 emissions to energy consumption for cases in Indonesia.

The neutrality hypothesis explains a situation where there is no relationship between energy consumption and economic growth. In this case, conservative energy policy or energy crisis does not have a significant influence on the sustainability of economic growth (Tang and Abosedra 2014). The neutral hypothesis in Indonesia was found by several researchers both in the bivariate and multivariate models. Soytas and Sari (2003) who investigated the causal relationship between energy consumption and income for G7 countries and emerging markets revealed that energy consumption and income in Indonesia did not have a mutually influential relationship. Saboori and Sulaiman (2013) who study the causality relationship between energy consumption, economic growth and CO2 emissions for five selected ASEAN countries also provide evidence that energy consumption has no relationship with economic growth and CO2 emissions, while CO2 emissions and economic growth have a mutual relationship. Yildirim et al. (2014) used a bootstrapped autoregressive causality approach investigated energy consumption and economic growth in 11 countries and found that absence relationship between energy consumption and economic growth in Indonesia. Then, Azam et al. (2015b) who examined the causal relationship between energy consumption and economic growth in five selected ASEAN countries also did not found relationship between energy consumption and economic growth in Indonesia.

The feedback hypothesis refers to a situation where energy consumption and economic growth complement each other and thus two-way causality occurs between the two indicators. This condition shows that increasing energy consumption has a role in economic growth and vice versa (Eggoh et al. 2011). Mahadevan and Asafu-adjaye (2007) used annual data from 1971 to 2002 and found evidence of feedback hypothesis in the short term for case in Indonesia. Chiou et al. (2008) used annual data series from 1971-2003 for Indonesia and also found that energy consumption and economic growth had mutual affect. Shahbaz et al. (2013) examined the relationship between economic growth, energy consumption, financial development, trade openness and CO2 emissions in Indonesia for the period 1975Q1–2011Q4 and then revealed a bidirectional relationship between energy consumption and economic growth and between consumption energy and CO2 emissions. In addition, they also concluded that energy consumption causes CO2 emissions and economic growth is a major contributor of CO2 emissions.

The role of economic growth and energy consumption on CO2 emissions di Indonesia also investigated using the environment Kuznets curve (EKC) approach by several scientists. The EKC hypothesis illustrated that economy growth at the initial stage leads carbon-dioxide emissions increase, but then carbon dioxide starts gradually decrease after economic growth has achieved a certain threshold level. Specifically, The EKC hypothesis suggest that economic growth has a significant role to reducing CO2 emissions in the long term. In case of Indonesia, the

Table 1. Descriptive statistics

Statistics	**lnCO2**	**lnEC**	**lnVA**	**lnVI**	**lnVS**	**lnHE**
Mean	12.079	11.505	11.044	11.839	11.642	12.101
Median	12.247	11.636	11.100	11.967	11.793	12.148
Maximum	13.365	12.326	11.730	12.883	12.902	13.167
Minimum	10.571	10.464	10.357	10.345	10.165	10.776
Std. Dev.	0.754	0.596	0.390	0.719	0.757	0.699
Skewness	-0.255	-0.262	-0.102	-0.408	-0.250	-0.333
Kurtosis	2.099	1.664	1.981	2.032	2.107	1.982
Jarque-Bera	1.964	3.778	1.979	2.938	1.922	2.715
Observations	44	44	44	44	44	44

empirical studies by Saboori et al. (2012) and Saboori and Sulaiman (2013) asserted absence the evidence of EKC hypothesis for Indonesia, while conversely Alam et al (2016) as well as Diputra and Baek (2018) confirmed existence the evidence that supports the EKC hypothesis for Indonesia. Moreover, Alam et al. (2016) as well as Diputra and Baek (2018) also found the evidence of unidirectional relationship that runs from energy consumption to CO2 emission for case in Indonesia.

Based on empirical findings from previous studies that studied the causal relationship between economic growth, energy consumption, and CO2 emission in Indonesia, we concluded that those previous studies generated mixed results which certainly did not appropriate to be underlying on establish energy, economic and environment policies in Indonesia. In addition, previous research has not considered the phenomena that occur in energy user groups and CO2 emissions producers, which mostly are a part on three main development sectors in Indonesia. Therefore, further study regarding this topic should be develops as an effort to fill the gap of previous studies. Approaches that tend to vary can certainly produce useful input and reference for policy makers in implementing policies that are appropriate to the conditions that occurring in Indonesia.

DATA AND METHODOLOGY

Our empirical study uses annual data series from 1971 to 2014 for Indonesia which obtained from the World Development Indicators produced by the World Bank (2018). In this paper, carbon dioxide emissions is expressed in millions of CO2, energy consumption is expressed in thousand tonnes of oil equivalent, the value added of three main development sectors and household final expenditures are expressed in millions of constant 2010 US$. We transform all variables in logarithmic forms in order to address the issue of heteroskedasticity and induce stationary in the variance-covariance matrix (Ahmad et al. 2016, Fatai et al. 2004). Furthermore, in order to estimate the causality relationship between variables, we develop specified multiple regression equations as follows:

$$\begin{aligned} lnCO_t &= \alpha_1 + \beta_1 lnEC_t + \beta_2 lnVA_t + \beta_3 lnVI_t \\ &\quad + \beta_4 lnVS_t + \beta_5 lnHE_t + \varepsilon_t \end{aligned} \tag{1}$$

where, α is intercept, β_i $(i = 1,2,3,4,5)$ are coefficient of independent variables, $lnCO2$ denotes the natural logarithms of CO2 emissions, $lnEC$ denotes the natural logarithms of energy consumptions, $lnVA$ denotes the natural logarithms of value added of Agriculture sector; $lnVI$ denotes the natural logarithms of value added of Industry sector, $lnVS$ denotes the natural logarithms of value added of services sector, $lnHE$ denotes the natural logarithms of household final consumption expendicture, ε_t is stochastic error terms, and *t* denotes time period in years. The descriptive statistics of the entire data represented in **Table 2**.

In this study we apply the Autoregressive Distributed Lag (ARDL) procedures introduced originally by Pesaran and Shin (1998) and further extended by Pesaran et al. (2001). In recent years, a number of studies have used this method in order to scrutinize the causal relationships between energy use, economic growth, and CO2 emissions (e.g., Chindo et al. 2015, Jayanthakumaran et al. 2012, Shahbaz et al. 2015, Zhang et al. 2014). Compared with other co integration methods, the ARDL bounds testing approach for co integration enjoys certain econometric advantages. First, it does not require analysis of singular integration unlike other approaches such as Johansen-Juselius co integration test (Johansen and Juselius 1990). Second, it is applicable irrespective whether the regressors in the model are I(0), I(1) or I(0)/I(1). Third, the short-run and long-run coefficients of the model can be estimated simultaneously. Four, this approach generally provides unbiased estimates of long-run model and valid 't' statistic even when some of the regressors are endogenous. However, the limitation of the ARDL bounds testing is that this approach is unable to provide any empirical results in the presence of I(2) series.

Specifically, we use the dummy variables for single time breaks on the short-run and long-run models in order to investigate the relationship among energy consumption, the value added of three development sectors, household final consumption expenditure and CO2 emissions in Indonesia. Based on equation 1, we then develop specification of ARDL models as follows:

$$\begin{aligned}\Delta lnCO_t = \alpha_{10} &+ \sum_{i=1}^{p} \beta_{11i}\, \Delta lnCO_{t-i} + \sum_{i=1}^{p} \beta_{12i}\, \Delta lnEC_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{13i}\, \Delta lnVA_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{14i}\, \Delta lnVI_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{15i}\, \Delta lnVS_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{16i}\, \Delta lnHE_{t-i} + \sum_{i=1}^{p} \beta_{17i}\, \Delta DT_{t-i} \\ &+ \psi_1 ECT_{t-1} + \varepsilon_{1t}\end{aligned} \tag{2}$$

$$\begin{aligned}\Delta lnEC_t = \alpha_{20} &+ \sum_{i=1}^{p} \beta_{21i}\, \Delta lnCO_{t-i} + \sum_{i=1}^{p} \beta_{22i}\, \Delta lnEC_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{23i}\, \Delta lnVA_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{24i}\, \Delta lnVI_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{25i}\, \Delta lnVS_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{26i}\, \Delta lnHE_{t-i} + \sum_{i=1}^{p} \beta_{27i}\, \Delta DT_{t-i} \\ &+ \psi_2 ECT_{t-1} + \varepsilon_{2t}\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta lnVA_t = \alpha_{30} &+ \sum_{i=1}^{p} \beta_{31i}\, \Delta lnCO_{t-i} + \sum_{i=1}^{p} \beta_{32i}\, \Delta lnEC_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{33i}\, \Delta lnVA_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{34i}\, \Delta lnVI_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{35i}\, \Delta lnVS_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{36i}\, \Delta lnHE_{t-i} + \sum_{i=1}^{p} \beta_{37i}\, \Delta DT_{t-i} \\ &+ \psi_3 ECT_{t-1} + \varepsilon_{3t}\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta lnVI_t = \alpha_{40} &+ \sum_{i=1}^{p} \beta_{41i}\, \Delta lnCO_{t-i} + \sum_{i=1}^{p} \beta_{42i}\, \Delta lnEC_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{43i}\, \Delta lnVA_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{44i}\, \Delta lnVI_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{45i}\, \Delta lnVS_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{46i}\, \Delta lnHE_{t-i} + \sum_{i=1}^{p} \beta_{47i}\, \Delta DT_{t-i} \\ &+ \psi_4 ECT_{t-1} + \varepsilon_{4t}\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta lnVS_t = \alpha_{50} &+ \sum_{i=1}^{p} \beta_{51i}\, \Delta lnCO_{t-i} + \sum_{i=1}^{p} \beta_{52i}\, \Delta lnEC_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{53i}\, \Delta lnVA_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{54i}\, \Delta lnVI_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{55i}\, \Delta lnVS_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{56i}\, \Delta lnHE_{t-i} + \sum_{i=1}^{p} \beta_{57i}\, \Delta DT_{t-i} \\ &+ \psi_5 ECT_{t-1} + \varepsilon_{5t}\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta lnHE_t = \alpha_{60} &+ \sum_{i=1}^{p} \beta_{61i}\, \Delta lnCO_{t-i} + \sum_{i=1}^{p} \beta_{62i}\, \Delta lnEC_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{63i}\, \Delta lnVA_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{64i}\, \Delta lnVI_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{65i}\, \Delta lnVS_{t-i} \\ &+ \sum_{i=1}^{p} \beta_{66i}\, \Delta lnHE_{t-i} + \sum_{i=1}^{p} \beta_{57i}\, \Delta DT_{t-i} \\ &+ \psi_6 ECT_{t-1} + \varepsilon_{6t}\end{aligned} \tag{7}$$

where Δ denotes first difference form, DT is a dummy variable of single time break and ψ_n (n = 1,2,3,4,5) is coefficient of error correction terms (ECT). The equation of ECT represents equilibrium of long-run relationship among the variables which can write as follows:

$$\begin{aligned}ECT \;= Y - (\alpha + X_1 + X_2 + X_3 + X_4 \\ + X_5 + DT)\end{aligned} \tag{8}$$

where, Y is dependent variable, and X_n (n = 1,2,3,4,5) are independent variables.

The estimation process in this study is consisting into four steps. The first step is examines the stationary of the series or ensure whether all series integrated in I(0) and/or I(1). In this paper, we examines the stationary of series data set using ADF unit root test proposed by Dickey and Fuller (1981), PP unit root test proposed by Phillips and Perron (1988) and Zivot-Andrews unit root test proposed by Zivot and Andrews (1992). The choice of the PP test to complement the ADF test is motivated by the argument the ADF test has low power to reject a unit root, whereas the PP tests correct for serial correlation in unit root testing. Therefore, by combining these two tests, the order of integration for all series are robust. Moreover, we apply ZA unit root test in order to discover structural break on data series. We test stationary of data series with intercept only and expecting all series stationary at level and/or first difference forms.

The second step is to implement ARDL bounds test in order to detect if there is a co integrating relationship between the variables. If we found that all variables are co integrated, it is indicate that all variables have the same stochastic trend and thus have the same direction of movement within in the long run. The determination of the optimal lag becomes one of important procedures that have to be implemented in the modelling (Enders, 2004). In general, there are many parameters that can be used to determine the optimal lag length. In this study, author chooses the maximum lags by using Akaike information criterion (AIC) which proposed by Akaike (1974). The co integration test based ARDL bound test procedures is testing the hypothesis, $H0: \varphi_0 = \varphi_1 = \varphi_2 = \varphi_3 = 0$; against the alternative, $H1: \varphi_0 \neq \varphi_1 \neq \varphi_2 \neq \varphi_3 \neq 0$. As in conventional co integration testing, the acceptance of the null hypothesis implies the absence of a cointegrating relationship between the time series. A rejection of $H0$ implies that we have a long-run relationship. To decide on this, we perform an F-test.

Critical values for the F-test are based by Narayan (2005) for smaller and finite samples. Narayan (2005) gives critical values for less than 80 observations for different sample sizes, different levels of probability and different numbers of variables, there are lower and upper critical values. The lower critical value is determined by considering that all of the series are stationary on levels, whereas the upper critical value is determined by supposing that all the time series are integrated of order one. We obtain that the variables are co integrated when the value of the F-statistic exceeds the upper critical value, whereas we reject the co integrating relationship when the value of the F-statistic is lower than the upper critical value. In addition, we diagnostic tests in order to checks the robustness of selected ARDL models. The diagnostics tests are checking for normality of error term, serial correlation, heteroscedasticity, and the functional form of empirical model. Moreover, we also check stability of the long-run coefficients as well as the dynamics of the short-run using the plots of cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ), respectively.

Third step, if the variables are found to be co integrated, we estimate the long-run coefficients given based selected ARDL model, as well as a separate restricted error correction model (RECM) based ARDL model to determine the short-run effects and the speed of adjustment. If we have established that there is a long-run relationship between the various variables, we will keep all the variables in the long-run model, even some variables are individually not significant. In four steps, we apply the Granger-causality test in order to determine the short and long-run relationship among the variables. It is a composite of short-run and error correction estimates (i.e. ECT-error correction term). The error correction model allows testing for the existence of Granger causality in two ways. First, the short-run Granger causality is investigated by testing the significance of the sum of lagged differences of explanatory variables using Wald test and based on the significance level of F-statistics. Second, the long-run causality is checked by examining the coefficients of the ECT_{t-1} based on t-statistics. A single equation of ECT_{t-1} (error correction term) which has a negative sign and statistically significance at 5% level confirms existence of long run causality among the variables.

EMPIRICAL RESULTS

Table 2 report the results of the unit root test for all series data series. We tested stationary for all data series using equation with intercept only. It can be seen that the results of the ADF and PP unit root tests indicated that lnCO, lnEC, lnVA, lnVS, and lnHE are only stationary at first difference form, while LVI is stationary in level form. Meanwhile, the result of the ZA unit root test revealed that the series data of lnCO, lNEC, lnVA, lnVS, and lnVS are stationary at level, while lnHE only stationary on first difference form. Moreover, the result of the ZA unit root test shows that time breaks for data series of INCO, LNVI, and InVS are at 1998, time break for data series of LEC is at 1990, time break for data series of InVA is at 1997, and time break for data series of LNHE is at 1982. Overall, these results indicated that we can apply the ARDL bound test procedure to check whether there is a co integration relationship among the variables in the selected ARDL models, respectively.

Table 2. The result of unit root tests

Series	ADF	PP	ZA		
			t-stat	Lag	Time Break
lnCO	-1.863	-2.495	-4.125**	1	1998
lnEC	-1.706	-1.875	-2.938***	0	1990
lnVI	-3.231**	-3.231**	-4.530***	1	1998
lnVA	-0.135	-0.134	-4.104***	0	1997
lnVS	-1.104	-1.421	-11.291***	1	1998
lnHE	-2.195	-2.195	-3.703	1	1979
ΔLCO	-5.814***	-5.957***			
ΔLEC	-6.347***	-6.347***			
ΔLVA	-4.692***	-4.689***			
ΔLVI	-6.288***	-6.289***			
ΔLVS	-4.385***	-4.382***			
ΔLHE	-4.807***	-4.775***	-5.740***	0	1982

Note: ***, **, * denotes series significant at 1%, 5%, and 10% levels, respectively.

Table 3. The result of bound test

Model	Time break	Lags	F-stat
Model 1 : lnCO || lnEC, lnVA, lnVI, lnVS, lnHE	1998	2,3,0,0,1,2	5.306***
Model 2 : lnEC || lnVA, lnVI, lnVS, lnHE, lnCO	1990	2,1,2,2,0,0	8.069***
Model 3 : lnVA || lnVI, lnVS, lnHE, lnCO, lnEC	1997	3,0,2,3,1,0	2.960
Model 4 : lnVI || lnVS, lnHE, lnCO, lnEC, lnVA	1998	1,2,1,0,1,0	4.338**
Model 5 : lnVS || lnHE, lnCO, lnEC, lnVA, lnVI	1998	3,2,0,0,1,3	5.483***
Model 6 : lnHE || lnCO, lnEC, lnVA, lnVI, lnVS	1982	1,0,0,2,2,0	4.267**
The critical values based Narrayan (1998) case III (n=45).	The significance levels		
	1%	5%	10%
Lower bounds, I(0)	4.030	2.922	2.458
Upper bounds, I(1)	5.598	4.268	3.647

Note: ***, **, * denotes series significant at 1%, 5%, and 10% levels, respectively.

Table 4. The long-run coefficients of selected ARDL models

Variables	Dependent Variables					
	lnCO	lnEC	lnVA	lnVI	lnVS	lnHE
C	11.565**	-3.995***	13.538	1.382	-8.814***	8.942
lnCO		0.021	-6.917	0.041	0.137***	-0.280
lnEC	-0.540		7.369	0.659***	-0.104	-0.001
lnVA	-1.853*	1.350***		-0.486	1.693***	-1.773
lnVI	0.831	1.135***	17.945		0.422**	1.266**
lnVS	1.309**	-0.820***	2.400	0.454*		0.972
lnHE	0.156	-0.299**	-20.634	0.208	-0.300*	
D82						-0.193
D90		0.149***				
D97			1.343			
D98	0.333***			-0.066	-0.118***	

Note: ***, **, * denotes series significant at 1%, 5%, and 10% levels, respectively.

Table 3 reports the result of bound test for all selected ARDL models. We found that the value of F-statistic is higher than the upper critical bound value at 1% significance level when lnCO, lnEC, lnVI, lnVS and lnHE are determined as dependent variable on equation model. This result implied that there are a relationships or long-run equilibrium between the variables on these selected ARDL models. In contrary, we found that when lnVA determined as dependent variable, the value of F-statistic is lies below than the lower critical bound value. This result indicated absence relationship between the variables when lnVA determined as dependent variable on equation model. Based on these result we concluded that there are a relationship or long-run equilibrium on five selected ARDL models.

Table 4 shows the long-run coefficients for all selected ARDL models, respectively. In first model, we found that the growth of value added on services sector and decreased the value added on agriculture sector causes increased CO2 emissions in the long-term. Moreover, we also found that increases or decreases the value added on industry sector and household final consumption expenditure did not any affect to the amount of CO2 emissions in the long-term. In second model, we found that increased the value added on industry sector and agriculture sector will caused increased energy consumption in the long-run,

Table 5. The coefficients of short-run and error correction term of selected ARDL models

Variables	**Dependent Variables**					
	ΔlnCO	**ΔlnEC**	**ΔlnVA**	**ΔlnVI**	**ΔlnVS**	**ΔlnHE**
C	11.205★★★	-3.211★★★	-0.096★★★	0.692★★★	-4.112★★★	1.810★★★
ΔlnCO		-0.005	-0.002	0.030	0.066★★	-0.060
ΔlnCO(-1)	0.536★★★					
ΔlnEC	-0.406		-0.045	0.219★★★	-0.038	0.016
ΔlnEC(-1)	0.317	0.115				
ΔlnEC(-2)	0.812★★★					
ΔlnVA	-1.607★	0.508★		-0.051	0.381★★	0.363
ΔlnVA(-1)			-0.581★★★			0.460★
ΔlnVA(-2)			-0.530★★★			
ΔlnVI	0.922★	0.475★★★	-0.172★		0.131	0.343★★
ΔlnVI(-1)		-0.323★			-0.146	-0.202★★
ΔlnVI(-2)					-0.182★★	
ΔlnVS	1.387★	-0.009	0.275★★★	0.670★★★		0.299★
ΔlnVS(-1)		0.175	0.143★★	-0.222★★	0.182★★	
ΔlnVS(-2)					0.130	
ΔlnHE	-0.022	-0.292★★	0.194★★	0.383★★★	0.099	
ΔlnHE(-1)	-0.635★		-0.070		0.226★★	
ΔlnHE(-2)			0.140★★			
ΔD82						-0.025
ΔD90		0.164★★★				
ΔD97			-0.019★			
ΔD98	0.081			0.033	-0.154★★★	
ECT(-1)	-0.965★★★	-0.805★★★	0.007★★★	-0.513★★★	-0.469★★★	-0.202★★★
R-squared	0.739	0.762	0.716	0.890	0.950	0.772
DW stat	2.244	2.191	2.182	1.999	1.984	2.275
JB stat	2.663 (0.265)	3.361 (0.186)	2.278 (0.320)	0.270 (0.874)	1.916 (0.384)	3.939 (0.140)
LM-test	0.762 (0.527)	0.595 (0.559)	1.157 (0.332)	1.972 (0.158)	1.010 (0.405)	1.027 (0.370)
BPG-test	0.874 (0.593)	0.748 (0.703)	1.000 (0.484)	2.037 (0.060)	1.079 (0.413)	1.070 (0.410)
ARCH	0.239 (0.868)	2.386 (0.106)	0.332 (0.802)	2.502 (0.096)	0.513 (0.676)	0.268 (0.767)
RESET	0.327 (0.572)	0.630 (0.434)	0.025 (0.876)	4.490 (0.489)	2.586 (0.119)	0.076 (0.784)

Note: ★★★, ★★, ★ denotes series significant at 1%, 5%, and 10% levels, respectively.

otherwise decreased the value added of services sector and household final consumption expenditure potentially reduced the amount of energy consumption in the long-term. In third model, the long-run coefficient of independent variables are statistically insignificant and it is indicates that there are no long-run relationship between the variables. In other word, an increase or decrease of CO2 emission, energy consumption, the value added of industry sector, the value added of services sector, and household final consumption expenditure did not affect to the value added of agriculture sector.

Table 5 shows the coefficients of short-run and error correction term of selected ARDL models. In first model, our result implies that the growth of energy consumption and the value added of three development sectors potentially leads increases CO2 emission in the short-run period, whereas the growth of household final consumption expenditure has negative affect and cause declines CO2 emission in the short term. The coefficient of error correction term is -0.96 (negative) and statistically significant at 1% level, which indicates faster convergence to a long-run equilibrium amongst the variables. Furthermore, the estimated of short-run and error correction term passes all the diagnostic tests of serial correlation, heteroskedasticity, normality of residuals and regression specification. The stability of the estimated model over the sample period is also confirmed by the plots of CUSUM and CUSUMSQ as depicted in **Fig. 1**.

In second model, our findings indicate that increases the value added on agriculture sector and industry sector will caused increase energy consumption in the short-run. In contrary, increased the growth of household final consumption expenditure potentially reduces energy consumption in the short-term. Furthermore, we also found that a changes of the value added of services sector did not any affect to energy

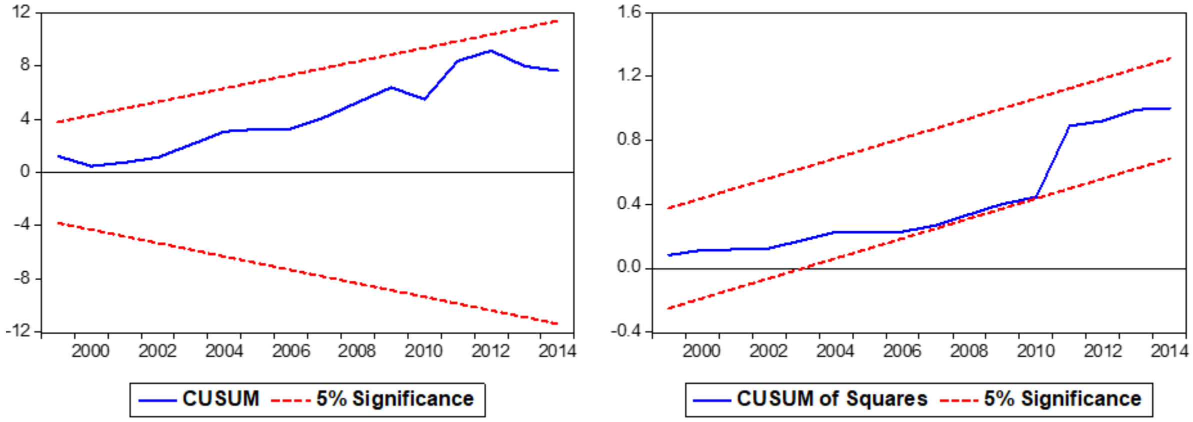

Fig. 1. The plots of CUSUM and CUSUM of squared model 1 (DV: LCO)

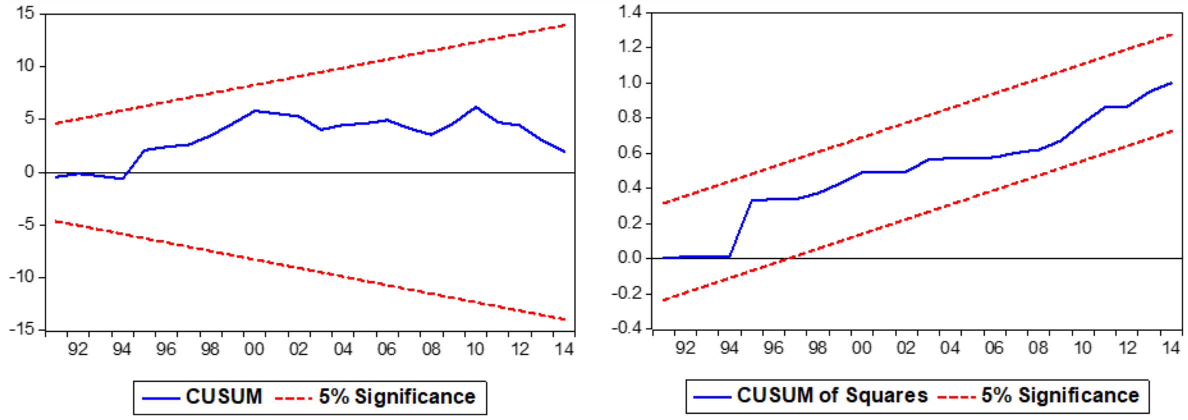

Fig. 2. The plots of CUSSUM and CUSSUM of squared model 2 (DV: LEC)

consumption in the short term. The coefficient of error correction term is -0.80% (negative) and statistically significant at 1% level which confirms faster converge to the long-run equilibrium. Furthermore, the estimated of short-run and error correction term passes all the diagnostic tests of serial correlation, heteroskedasticity, normality of residuals and regression specification. The stability of the estimated model over the sample period is also confirmed by the plots of CUSUM and CUSUMSQ as depicted in **Fig. 2**.

In third model, our result implied that increase the value added of industry sector will diminish the value added of agriculture sector in the short-term, whereas increase the value added of services sector and household final consumption expenditure will encourage increase the value added of agriculture sector in the short term. Moreover, our result also revealed that CO2 emission and energy consumption have not affected to the value added of agriculture sector in the short-run. The coefficient of error correction term is 0.07% (positive) and statistically insignificant which indicate absence a long-run equilibrium amongst the variables in the model. The underlying error correction representation has no autocorrelation problem and residuals are normally distributed. However, the LM test implies serial correlation problem which is solved within two lags. The regression is correctly specified and is found to be stable over the sample period as illustrated by the plots of CUSUM and CUSUMSQ at **Fig. 3**.

In fourth model, our findings indicated that the rise of energy consumption, the value added of services sector, and household final consumption expenditure potentially leads increasing the value added of industry sector in the short term, while CO2 emissions and the value added of agriculture sector did not affect to the value added of Industry sector in the short term. The moderate and significant speed of adjustment to equilibrium is 0.51, which again indicates good enough approximation of the equilibrium relationship amongst the underlying variables in the model. Furthermore, the estimated error correction indicates absence problem for normality of residuals, serial correlation, heteroskedasticity and regression specification. The stability of estimated model over the sample period is also confirmed by the plots of CUSUM and CUSUMSQ as depicted in **Fig. 4**.

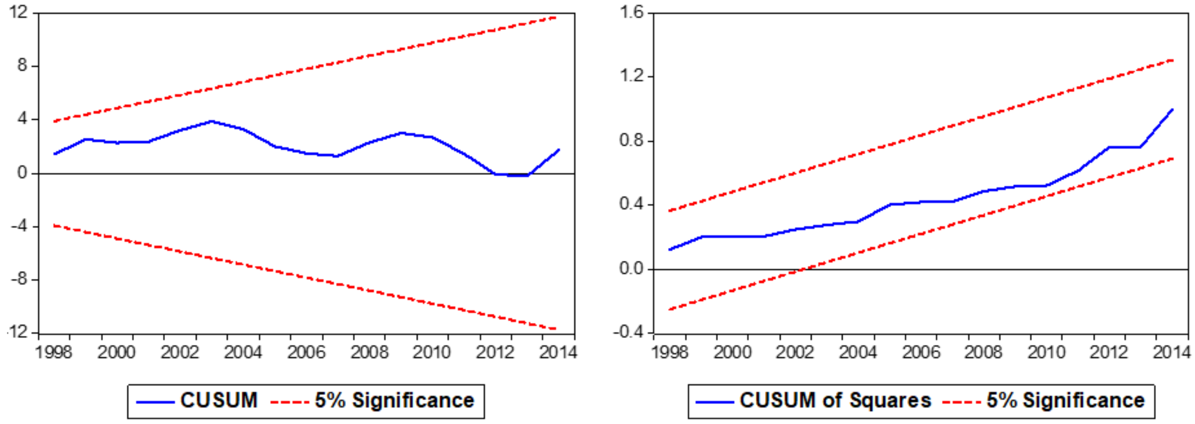

Fig. 3. The plots of CUSSUM and CUSSUM of squared for model 3 (DV: LVA)

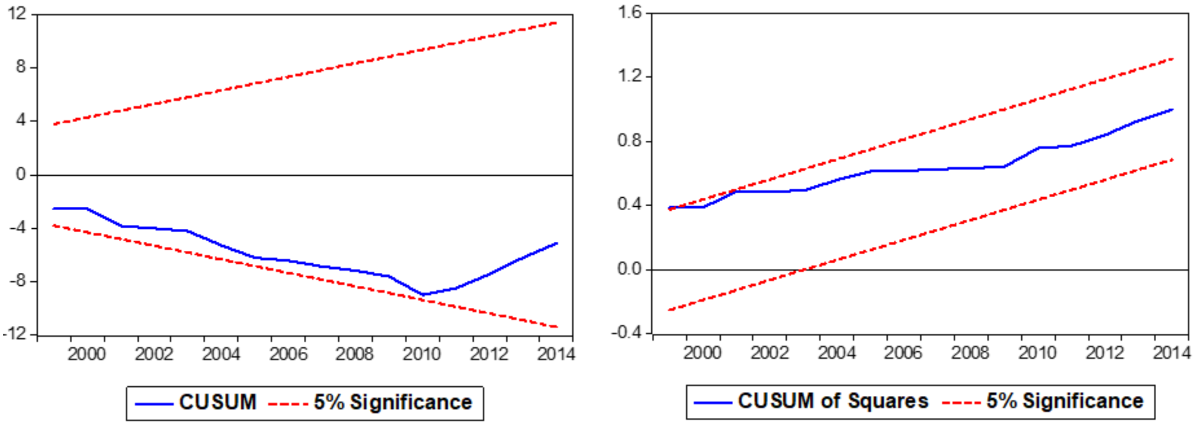

Fig. 4. The plots of CUSSUM and CUSSUM of squared for model 4 (DV: LVI)

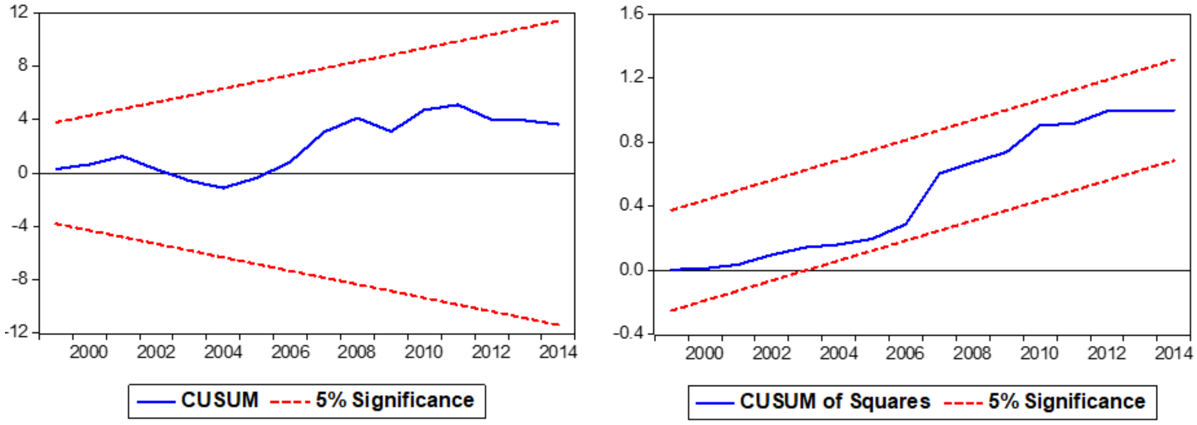

Fig. 5. The plots of CUSSUM and CUSSUM of squared for model 5 (DV: LVS)

In fifth model, our findings shows that an increases CO2 emissions, the value added of agriculture sector and household final consumption expenditure causes the value added of services sector rise in the short term, while an increase the value added of industry sector in the end of short term period potentially reduces the value added of services sector. Moreover, we also found that energy consumption did not have short-run affect to the value added of service sector. The coefficient of ECT is -0.46 and significant at 1% level which implies signals moderate converge to equilibrium and of course points to causality as well, although weak. The error correction estimates also passed all diagnostic tests and indicates absence problem for normality of residuals, serial correlation, heterocedastisity, and regression specification. The stability of estimated model over the sample period is also confirmed by the plots of CUSUM and CUSUMSQ as depicted in **Fig. 5**.

In sixth model, our findings implied that an increases the value added of industry sector and agriculture sector have significant affect and driven the

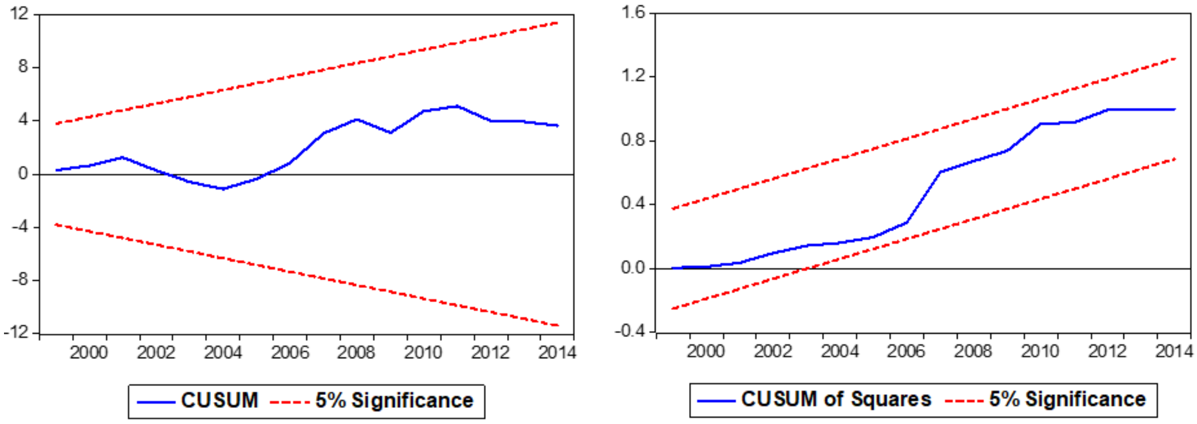

Fig. 6. Map of OMU Pond I and sampling station (Anonymous 1975)

Table 6. The result of Granger causality test

DV	**Short–run**						**ECT(-1)**
	ΔlnCO	**ΔlnEC**	**ΔlnVA**	**ΔlnVI**	**ΔlnVS**	**ΔlnHE**	
ΔlnCO		12.057★★★	3.700★	3.448★	3.741★	4.073	-6.390★★★
ΔlnEC	0.013		3.025★	10.883★★★	1.154	4.586★★	-5.161★★★
ΔlnVA	0.011	0.899		4.231★★	20.662★★★	24.288★★★	4.283★★★
ΔlnVI	0.986	7.965★★★	0.066		12.260★★★	17.435★★★	-5.924★★★
ΔlnVS	5.745★★	0.461	4.671★★	12.826★★★		6.792★★	-4.110★★★
ΔlnHE	2.575	0.027	4.590	11.048★★★	3.102★		-5.840★★★

Note: ★★★, ★★, ★ denotes significant at 1%, 5% and 10% respectively.

growth of household final consumption expenditure in the short term. Moreover, our result also revealed that CO2 emissions and energy consumption did not any affect to Household final consumption expenditure in the short term. The coefficient of ECT is -0.20 and statistically significant at 1% level which indicated moderate speed adjustment toward equilibrium and it is of course shows the evidence of weak causality in at least one direction. The estimated error correction also passed all diagnostic tests and indicates absence problem for normality of residuals, serial correlation, heterocedastisity, and regression specification. The stability of estimated model over the sample period is also confirmed by the plots of CUSUM and CUSUMSQ as depicted in **Fig. 6**.

Table 6 shows the result of granger causality tests. First, we found that there are unidirectional relationship that runs from energy consumption, the value added of agriculture sector, and the value added of industry sector to CO2 emission and a bidirectional relationship between the value added of services and CO2 emissions. Second, we discovered unidirectional relationship that runs from the value added of agriculture sector and household final consumption expenditure to energy consumption and a bidirectional relationship between energy consumption and the value added of industry sector. Third, we revealed existence of unidirectional relationship that runs from the value added of industry sector and household final consumption expenditure to the value added of agriculture sector and a bidirectional relationship between the value added of services sector and the value added of agriculture sector. Four, we found empirical evidences for a bidirectional relationship between the value added of industry sector and the value added of service sector, a bidirectional relationship between the value added of industry sector and household final consumption expenditure, and also a bidirectional relationship between the value added of services sector and household final consumption expenditure. Furthermore, the estimated t-statistics for error correction term on five equation models reconfirms existence long run equilibrium among the variables.

CONCLUSIONS AND POLICY IMPLICATIONS

Indonesia, such a project would be a useful topic for future research. Second, this study uses electricity consumption as a proxy for energy consumption and CO2 emissions as a proxy for environmental degradation. The present study investigate the causal relationship between CO2 emissions, energy consumption, the value added of three development sectors, and household final consumption expenditure in Indonesia using annual data from 1971 - 2014. The estimation procedures that carried out in this study consist of four stages. First, we examine stationary of data series using Augmented Dickey-Fuller (ADF), Phillip-Perron (PP), and Zivot-Andrews (ZA) unit root tests. After ensuring that all data series are only stationary in the form I(0) and/or I(1), we then checks whether existence of relationship between the variables using bound test procedure and found that the variables are co integrated on five equation models. The next step, we check significance the short-run and long-run coefficients as well as error correction term in order to explore the relationship between the variables in the short-run and long-run. In the final step, we applied the granger causality test in order to conclude the direction of short-run and long-run relationships between the variables in all selected ARDL models, respectively.

Our results indicated that energy consumption and the growth of value added on industry sector and agriculture sector are determinant factors that causes increased CO2 emissions. Household final consumption expenditure and the value added of agriculture sector have a significant contribution towards the growth of energy consumption in Indonesia. Moreover, we also found a mutual relationship between CO2 emissions and the value added of service sector as well as between energy consumption and the value added of industry sector in Indonesia, both in the short and long terms. These conditions implied that the energy conservation policies that encourages optimization production, distribution and consumption the new and renewable energy sources that environment friendly should be serious implemented by Indonesian policy makers in order to faces the energy and environmental issues in the future.

Our results also discovered that the value added of industry sector and agriculture sector have a mutual relationship with the value added of service sector, the value added of industry sector is a determinant factor that encourages the value added of agriculture sector, and household final consumption expenditure has a significant contribution towards the value added of three development sectors. These findings implied that economic growth on three development sectors have interrelationship each other's and the growth of household final consumption expenditure is a key factor that driven the growth of income on three development sectors in Indonesia. These conditions implied that sustainable economic policies that motivated improvement people's purchasing power in domestic markets should be applying to accelerate the growth rate of economic development in Indonesia. Moreover, the micro economic policies that aim to foster an investment climate on the small and medium enterprises must also be a special discourse for the policy makers in order to improvement the growth rate of Indonesia's domestic trade.

Based on our findings, we concluded that the determination of sustainable policies that considering challenge and issue relating energy security, environment degradation and economic growth has become imperative for Indonesia in order to accelerate sustainable development process in the future. A special attention to the sustainability of non-renewable energy resources and their impact on all economic activities and development are important things that must be prioritized by the government and private sectors in Indonesia. Even so, the determination of the strategy and policy certainly must be in accordance with the situation and conditions on each development sectors in Indonesia in order to immediately achieve the goals expected in the future.

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