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ENERGY CONSUMPTION SECTORAL AND ECONOMIC GROWTH NEXUS, EVIDENCE IN INDONESIA: AN AUTOREGRESSIVE DISTRIBUTED LAG APPROACH

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Abstract

The climate crisis that has occurred has caused concern for countries in the world. The potential increase in the average temperature of the earth's surface above the expected threshold makes most countries in the world agree to reduce the amount of carbon emissions. Energy conservation is one of the logical plans that every country can do. However, differences in the economic conditions of a country ultimately create obstacles in the transition of fossil energy to renewable energy, concerns about the economic slowdown as a result of the energy conservation process, especially for developing countries. So from becoming an important discussion regarding the relationship between energy use and the economy for developing countries, in this case Indonesia. The study uses time series data for the period 1990-2019. The approach used in examining the relationship between energy consumption and economic growth is the ARDL bounds test. The results show a unidirectional relationship from economic growth to the energy consumption of the transportation sector in the short run. In the long run, the unidirectional relationship runs from economic growth to energy consumption in the commercial and public services sectors.

Keywords: Energy consumption, Economic growth, Indonesia, ARDL bounds test

1. Introduction

Recently, the world is faced with a deteriorating environmental condition. Greenland, which was not supposed to rain, has now been raining for more than 24 hours on August 14, 2021. According to the National Science Foundations Summit Station, there are at least 7 billion tons of rainwater that have washed over the Greenland ice caps. The incident was later recorded as the heaviest rain since 1950. In addition, the rain caused the ice in Greenland to melt up to 872,000 sq km. The area is large enough to be almost the same as the area of a country on the mainland of Africa (CNN Indonesia, 2021). Based on the IPCC (2021) report, the air temperature will experience an average air temperature increase of up to 1.5℃ which will occur for the next 20 years. This phenomenon will certainly have a significant long-term impact on the survival of humans and other living things. Therefore, humans must prepare themselves how to deal with all possibilities that will occur caused by an increase in air temperature.

The Paris agreement is clear evidence from the government manifestos of various countries in an effort to maintain the increase in air temperature at the threshold of 1.5-2℃. Then various noble goals have been mutually agreed upon in the SDG's framework for the survival of humans today and humans who will live in the future. With this goal, various countries are expected to cooperate and contribute to balancing economic needs with current environmental conditions. One of the goals is to require a country to produce and use environmentally friendly energy. This is because the current consumption of fossil energy is one of the biggest contributors to environmental damage, starting from the exploitation process to the waste generated from burning that energy. Carbon emissions resulting from burning fossil energy are then largely a major factor in the increase in the average temperature on earth.

Although fossil energy has a negative effect on life on earth. Most of the existing countries still depend on the use of these non-renewable energy sources. Limited renewable energy resources and relatively expensive technology are other causes of the difficulty of removing dependence on fossil energy. The high price of production factors to produce a certain amount of energy from renewable energy resources ultimately causes the selling price of renewable energy products to be higher than fossil energy. However, it is different if the government intervenes in the price of the renewable energy product or with the subsidy policy it does.

Acceleration of the transition from fossil energy to renewable energy is certainly very much needed in order to reduce carbon emissions and achieve the goals of the Paris Agreement. For developed countries, making the clean energy transition is not difficult. The period of industrialization that has been passed and the achievement of the desired level of economic growth has made it a distinct advantage for developed countries to make an energy transition. Unlike the case with developing countries and underdeveloped countries which are still at the stage of industrialization to achieve higher economic growth, they will certainly experience a dilemma. The reduction in fossil energy consumption and the energy transition carried out will certainly result in changes in the production output of various economic sectors. Concern about the negative effects of the energy transition on economic growth is one of the main reasons for developing countries not to accelerate the transition from non-renewable energy to cleaner renewable energy.

Indonesia, which incidentally is still categorized as a developing country, certainly experiences problems similar to other developing countries. Especially problems in the transition of fossil energy to energy that is cleaner and environmentally friendly. Therefore, it has become imperative to know the relationship between energy users and the domestic economy. Although the relationship between energy and the economy has been widely discussed by researchers. However, differences of opinion are still found among researchers.

Several studies have found evidence of cointegration of energy consumption and output (the economy), such as that of Narayan & Smyth (2005), Faisal et al (2017), Tiwari et al (2021), Dantama (n.d.), Emir & Bekun (2019), Chang et al (2015), Acheampong (2018), Baz et al (2019), Tiwari et al (2021), Lin & Moubarak (2014), Cherni & Essaber Jouini (2017), Sbia et al (2017), Zhong et al (2019), Zhao & Wang (2015), Ahmad & Zhao (2018), Gregori & Tiwari (2020) dan Nguyen & Ngoc (2020). Furthermore, several researchers also failed to prove the cointegration relationship between energy consumption and economic growth, as was done by

Faisal et al (2018), Chang et al (2015) in Germany, Italy, the UK, the USA, and Hu & Fan (2020).

2. Method

Data description

This empirical research uses data in the form of time series in Indonesia which is in the period 1990-2019 in annual form. This study uses energy consumption variables in the industrial, transportation, household, and commercial and public service sectors as variables that represent energy consumption in toe units. And the real GDP variable is a variable that represents economic growth in USD units. Energy consumption data is based on data released by the International Energy Agency and real GDP is obtained from the World Development Indicators database (World Bank). Then all data are transformed into the natural logarithmic form so that the resulting first derivative can approach their respective growth rates (Zhong et al., 2019).

Stasionary

A stationary test is certainly very necessary in regression analysis. This is done because to avoid spurious regression results on the regression results. Then in this study used three stationarity testing methods to determine whether the research variables contain unit roots, namely Augmented Dickey-Fuller (ADF), Phillips-Peron (PP), and Zivot-Andrew (ZA) unit root tests with structural breaks. The research variable does not matter if it is in zero-order I(0) or first-order I(1), this is one of the advantages of using the ARDL bounds test method in the cointegration test.

In determining the optimum lag length in the ADF testing process, the study uses the Schwarz Bayesian criterion. Meanwhile, the PP test uses bandwidth based on the Newey-West Bartlett kernel. Furthermore, in this empirical study, we used two models on the ZA test. The first model is model A which allows to find out the break on the intercept on the trend function. The second model is model c which allows knowing the break on the intercept and slope.

The following is the form of the equation in model A:

$$\Delta y_t = k + \phi y_{t-1} + \beta t + \theta_1 DU_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \quad (1)$$

Model C has the following equation:

$$\Delta y_t = k + \phi y_{t-1} + \beta t + \theta_1 DU_t + \gamma_1 DT_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \quad (2)$$

Where, is the first difference operator, t is white noise with variance 2, and t is the time index. Δy_t in equations 1 and 2 and allow serial correlation and ensure that the disturbance term is white noise. DU_t and DT_t are dummy variables that represent the mean and trend shift. DU_t = 1 if t>TB, and 0 otherwise; $DT_t = t\text{-}TB$ t>TB, and 0 otherwise. Then the breakpoint is obtained from the estimation of the minimum T-statistic on the coefficient of the autoregressive variable. The asymptotic critical value for t-statistics based on Zivot and Andrews (1992). The results of the t-statistic computation are then compared with the critical value of ZA. If the absolute value of t-statistics is greater than the value of ZA, it successfully rejects the null hypothesis, which means the variable is stationary with structural breaks.

Vol. 5, No.11; 2021

ISSN: 2456-7760

Cointegration

The Cointegration test aims to determine the long-term equilibrium relationship between energy consumption and economic growth. Then in the test, it involves *Unrestricted error correction model* (UECM)

$$\Delta \ln GDP_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{n} \alpha_{3i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{n} \alpha_{4i} \Delta ECres_{t-i} + \sum_{i=1}^{n} \alpha_{5i} \Delta \ln ECserv_{t-i} + \alpha_6 \ln GDP_{t-1} + \alpha_7 \ln ECtrans_{t-1} + \alpha_8 \ln ECin_{t-1} + \alpha_9 \ln ECres_{t-1} + \alpha_{10} \ln ECserv_{t-1} + \mu_{1t} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots (3)$$

$$\Delta \ln ECtrans_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{n} \beta_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \beta_{3i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{n} \beta_{4i} \Delta \ln ECres_{t-i} + \sum_{i=1}^{n} \beta_{5i} \Delta \ln ECserv_{t-i} + \beta_6 \ln ECtrans_{t-1} + \beta_7 \ln GDP_{t-1} + \beta_8 \ln ECin_{t-1} + \beta_9 \ln ECres_{t-1} + \beta_{10} \ln ECserv_{t-1} + \mu_{2t} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots (4)$$

$$\Delta \ln ECin_t = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{n} \gamma_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \gamma_{3i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{n} \gamma_{4i} \Delta \ln ECres_{t-i} + \sum_{i=1}^{n} \gamma_{5i} \Delta \ln ECserv_{t-i} + \gamma_6 \ln ECin_{t-1} + \gamma_7 \ln GDP_{t-1} + \gamma_8 \ln ECtrans_{t-1} + \gamma_9 \ln ECres_{t-1} + \gamma_{10} \ln ECserv_{t-1} + \mu_{3t} \quad \dots \dots \dots \dots \dots \dots \dots \dots (5)$$

$$\Delta \ln ECres_t = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta \ln ECres_{t-i} + \sum_{i=1}^{n} \delta_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \delta_{3i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{n} \delta_{4i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{n} \delta_{5i} \Delta \ln ECserv_{t-i} + \delta_6 \ln ECserv_{t-1} + \delta_7 \ln ECres_{t-1} + \delta_8 \ln GDP_{t-1} + \delta_9 \ln ECtrans_{t-1} + \delta_{10} \ln ECin_{t-1} + \mu_{4t} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (6)$$

$$\Delta \ln ECserv_t = \varepsilon_0 + \sum_{i=1}^{n} \varepsilon_{1i} \Delta \ln ECserv_{t-i} + \sum_{i=1}^{n} \varepsilon_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{n} \varepsilon_{3i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{n} \varepsilon_{4i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{n} \varepsilon_{5i} \Delta \ln ECres_{t-i} + \varepsilon_6 \ln ECserv_{t-1} + \varepsilon_7 \ln GDP_{t-1} + \varepsilon_8 \ln ECtrans_{t-1} + \varepsilon_9 \ln ECin_{t-1} + \varepsilon_{10} \ln ECres_{t-1} + \mu_{5t} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots (7)$$

Where represents the first-order operator (first difference), represents white noise or error, *lnGDP* represents the natural logarithm of GDP, as well as ln*ECtrans*, ln*ECin*, ln*ECres*, and ln*ECserv*. Parameters α ($\alpha_{1,2,3,4,5}$), β ($\beta_{1,2,3,4,5}$), γ ($\gamma_{1,2,3,4,5}$), δ ($\delta_{1,2,3,4,5}$), and ε ($\varepsilon_{1,2,3,4,5}$) is a short-term coefficient. Parameters α ($\alpha_{6,7,8,9,10}$), β ($\beta_{6,7,8,9,10}$), γ ($\gamma_{6,7,8,9,10}$), δ ($\delta_{6,7,8,9,10}$), and ε ($\varepsilon_{6,7,8,9,10}$) is a long-term coefficient.

The calculated F-statistical value is then compared with the critical value calculated by Narayan & Smyth (2005) to find the significance of the long-term relationship between variables. This critical value is suitable for relatively small observations, between 30 and 80 observations. This number certainly fits perfectly with this empirical research, which is 50 observations. If the F-statistic falls below the lower critical value, then the test results fail to reject the null hypothesis in the form of no cointegration. However, if the F-statistic value is greater than the upper critical value, then the null hypothesis can be rejected. Thus, it can be concluded that there is a cointegration relationship between the dependent variable and the independent variable. Then if the critical value is between the lower critical value and the upper critical value, then the cointegration test results cannot be concluded.

If evidence of a long-term relationship is found in the equation, the next step is to estimate the long-term and short-term coefficients using the ARDL equation and error correction mechanisms. In addition, this step is used to determine the presence of Granger causality among the variables.

Granger Causality

At this stage, Granger causality testing uses augmented constructing standard Grangertype causality tests with a lagged error correction term on a series or variable that contains cointegration. Thus, it is possible to use the *p*-th order on the multivariate *vector error correction model* (VECM) in order to test the existence of Granger causality, as follows:

$$\Delta \ln GDP_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{p} \alpha_{3i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{p} \alpha_{4i} \Delta \ln EChouse_{t-i} + \sum_{i=1}^{p} \alpha_{5i} \Delta \ln ECserv_{t-i} + \alpha_{6i} ECT_{t-1} + \mu_{1t} \quad \dots\dots\dots\dots\dots\dots\dots (8)$$

$$\Delta \ln ECtrans_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \beta_{3i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{p} \beta_{4i} \Delta \ln EChouse_{t-i} + \sum_{i=1}^{p} \beta_{5i} \Delta \ln ECserv_{t-i} + \beta_{6i} ECT_{t-1} + \mu_{2t} \quad \dots\dots\dots\dots\dots\dots\dots (9)$$

Vol. 5, No.11; 2021
ISSN: 2456-7760

$$\Delta \ln ECin_t = \gamma_0 + \sum_{i=1}^{p} \gamma_{1i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{p} \gamma_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \gamma_{3i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{p} \gamma_{4i} \Delta \ln EChouse_{t-i} + \sum_{i=1}^{p} \gamma_{5i} \Delta \ln ECserv_{t-i} + \gamma_{6i} ECT_{t-1} + \mu_{3t} \quad \dots\dots\dots\dots\dots\dots\dots (10)$$

$$\Delta \ln EChouse_t = \delta_0 + \sum_{i=1}^{p} \delta_{1i} \Delta \ln EChouse_{t-i} + \sum_{i=1}^{p} \delta_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \delta_{3i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{p} \delta_{4i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{p} \delta_{5i} \Delta \ln ECserv_{t-i} + \delta_{6i} ECT_{t-1} + \mu_{4t} \quad \dots\dots\dots\dots\dots\dots\dots\dots (11)$$

$$\Delta \ln ECserv_t = \varepsilon_0 + \sum_{i=1}^{p} \varepsilon_{1i} \Delta \ln ECserv_{t-i} + \sum_{i=1}^{p} \varepsilon_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \varepsilon_{3i} \Delta \ln ECtrans_{t-i} + \sum_{i=1}^{p} \varepsilon_{4i} \Delta \ln ECin_{t-i} + \sum_{i=1}^{p} \varepsilon_{5i} \Delta \ln ECres_{t-i} + \varepsilon_{6i} ECT_{t-1} + \mu_{5t} \quad \dots\dots\dots\dots\dots\dots (12)$$

Where, ECTt-1 is a lagged error correction term derived from a long-term cointegration relationship (ECT is not included if there is no cointegration relationship). α, β, γ, δ, and ε are parameters to be estimated. μ_1, μ_2, μ_3, μ_4, and μ_5 are serial random errors. Then the lag length *p* is based on the Schwarz Bayesian Criterion.

3. Results

Unit root test

As previously stated, stationarity testing is very necessary for quantitative analysis to avoid false regression results. The test used is the unit root test of ADF, PP, and ZA. The null hypothesis contained in the ADF and PP tests is that it contains a unit root against the alternative stationarity hypothesis.

Table 1 shows the results of stationarity testing on real GDP (ln*GDP*) and energy consumption variables in the industrial sector (ln*ECin*), transportation (ln*ECtrans*), resident (ln*ECres*), commercial and public services (ln*ECserv*) using the ADF and PP methods.

Table 1. Unit root test result (ADF, PP)

	Variables	ADF test	PP test
Level			
• Intercept	ln*GDP*	-0.072543	0.072543
	ln*ECin*	-1.252062	-1.438215
	ln*ECtrans*	-0.268596	-0.268596
	ln*ECres*	1.738899	0.929350
	ln*ECserv*	-5.662051(0)[a]	-6.789773[a]
• Intercept and trend	ln*GDP*	-1.418655	-1.648107
	ln*ECin*	-2.351825	-2.263027
	ln*ECtrans*	-2.282366	-1.832824
	ln*ECres*	2.352823	2.525113
	ln*ECserv*	-3.375755(0)[c]	-10.32988[a]
First difference			
• Intersep	ln*GDP*	-3.909751(0)[a]	-3.847829[a]
	ln*ECin*	-5.430636(0)[a]	-5.572058[a]
	ln*ECtrans*	-3.495089(0)[b]	-3.493344[b]
	ln*ECres*	0.916179	2.882553
	ln*ECserv*	-3.362985(0)[b]	-3.270639[b]
• Intercept and trend	ln*GDP*	-3.867099(0)[b]	-3.743878[b]
	ln*ECin*	-5.393151(0)[a]	-6.654876[a]
	ln*ECtrans*	-3.425674(0)[c]	-3.415806[c]
	ln*ECres*	-0.662977	1.713515
	ln*ECserv*	-4.424058(0)[a]	-4.374987[a]

There are several notes to note in the results provided in table 2. First, the null hypothesis in the ADF and PP methods indicates that there is a unit root in the variable. second, the optimum lag length is based on the Schwarz information criterion and the maximum lag length is set to 5 at the time of calculation. Third, the number in brackets is the optimal lag based on the criteria used previously. Fourth, letters a, b, c indicate significant variables at the level of 1%, 5%, 10%.

Based on the results of the unit root test, all variables are not stationary at the level except for the variable energy consumption in the commercial sector and public services (ln*ECserv*) which is stationary at the critical level of 1%. After using the first difference to the variables, the results show that the research variables are stationary at critical levels of 10%, 5%, even 1% with the ADF and PP methods. Energy consumption in the household sector (ln*ECres*) is not stationary at either level $I(0)$ or the first difference $I(1)$. Thus, it can be concluded that based on the conventional unit root test, in general, variables are variables that are integrated in the first order I(1).

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The results of the ZA structural unit breaks root test on the ln*GDP*, ln*ECin*, ln*ECtrans*, ln*ECres*, ln*ECserv* variables can be seen in table 2. The critical values for 1%, 5%, 10% in the unit root test ZA are -5.34, - 4.80, -4.58 in model A. Then for model c the critical values of 1%, 5%, 10% are -5.57, -5.08, -4.82.

Table 2. ZA unit root test with structural breaks

	Variables	t-stat	*Break*
Level			
• Intercept	ln*GDP*	-13.58340(1)[a]	1998
	ln*ECin*	-5.260345(0)[b]	2013
	ln*ECtrans*	-3.605800(1)	2011
	ln*ECres*	-1.360164(4)	2001
	ln*ECserv*	-3.468839(0)	2014
• Intercept and trend	ln*GDP*	-20.63604(1)[a]	1998
	ln*ECin*	-4.167439(0)	2013
	ln*ECtrans*	-3.521389(1)	2011
	ln*ECres*	-1.916757(4)	2013
	ln*ECserv*	-3.355083(0)	2014
First difference			
• Intercept	ln*GDP*	-4.848977(0)[b]	1998
	ln*ECin*	-5.522249(0)[a]	2012
	ln*ECtrans*	-4.170948(0)	2008
	ln*ECres*	-1.386805(1)	1999
	ln*ECserv*	-5.531309(0)[a]	2011
• Intercept and trend	ln*GDP*	-5.557959(0)[b]	2000
	ln*ECin*	-6.912890(0)[a]	2013
	ln*ECtrans*	-4.080627(0)	2008
	ln*ECres*	-1.458365(1)	2001
	ln*ECserv*	-5.469511(0)[b]	2004

The test results show similar results to tests using the ADF and PP methods. The difference in results only lies in the energy consumption variable in the transportation sector (ln*ECtrans*) which shows the results are not stationary at *I*(0) and *I*(1). Therefore, based on the evidence obtained from the use of the ADF, PP, and ZA methods, our study variables were stationary at *I*(1). Then these results also confirm the use of the ARDL bound test method by excluding the ln*ECres* variable which shows non-stationary results.

Cointegration test

Before carrying out the cointegration test with the bound test mechanism, the optimum lag at the first difference is determined for each research variable contained in equations 3, 4, 5, and 7 based on the minimum value of the Schwarz criterion. The results show that the optimum lag in equations 3, 4, 7 is one and the optimum lag in equation 5 is two. After knowing the optimal lag in each equation, then the lag is used in the process of determining the long-term relationship for each equation.

Table 3. Bound test for cointegration

Dependent Variable	Function	F-Statistik
ln*GDP*	$F_{lnGDP}(\ln GDP \mid \ln ECin, \ln ECtrans, \ln ECserv)$	0.256536
ln*ECin*	$F_{lnECin}(\ln ECin \mid \ln GDP, \ln ECtrans, \ln ECserv)$	2.267580
ln*ECtrans*	$F_{lnECtrans}(\ln ECtrans \mid \ln GDP, \ln ECin, \ln ECserv)$	2.576283
ln*ECserv*	$F_{lnECserv}(\ln ECserv \mid \ln GDP, \ln ECin, \ln ECtrans)$	11.72947[a]

Critical value bound					
10%		5%		1%	
I(0)	*I*(1)	*I*(0)	*I*(1)	*I*(0)	*I*(1)
3.008	4.15	3.71	5.018	5.333	7.063

Based on the results of bound tests, there is no long-term relationship running from energy consumption to economic growth at each level of significance. This can be seen in Table 3 which shows the F-statistic value which is below the lower bound value derived from Narayan (2005). When the energy consumption variable (ln*ECin*, ln*ECtrans*, ln*ECserv*) is used as the dependent variable, it is seen that only energy consumption in the commercial and public service sectors (ln*ECserv*) has a long-term relationship with the independent variable even at a significance level that is tighter 1%.

Table 4. Result of Granger causality F-test

Dependent variable	F-statistics [*p* value]				t-statistics [*p* value]
	$\sum\Delta\ln GDP_t$	$\sum\Delta\ln ECin_t$	$\sum\Delta\ln ECtrans_t$	$\sum\Delta\ln ECserv_t$	ECT_t
$\Delta\ln GDP_t$	-	0.9918[0.3312]	0.469[0.6433]	-0.8346[0.4122]	-
$\Delta\ln ECin_t$	1.5008[0.1464]	-	-1.5758[0.1282]	1.8745[0.0731]	-
$\Delta\ln ECtrans_t$	2.8370[0.0096]	-0.1048[0.9175]	-	0.233[0.8179]	-
$\Delta\ln ECserv_t$	-0.5321[0.5995]	1.5347[0.1379]	1.8978[0.0698]	-	-7.2652[0.0000]

The existence of cointegration in the energy consumption equation in the commercial and public service sectors (ln*ECserv*) indicates the presence of Granger causality at least one-way or uni-directional. However, these results have not been able to show a clearer relationship for each of the variables studied. Therefore, the use of ECM (error correction mechanism) needs to be done to obtain the results of short-run and long-run Granger causality calculations. The estimation results can be seen in table 4. In the short run, economic growth is only significant at the level of 1% in the energy consumption equation of the transportation sector (ln*ECtrans*). This indicates a strong short-run unidirection relationship from economic growth to transportation energy consumption, a 1% increase in economic growth will encourage an increase in energy consumption in the transportation sector by 0.34%. Another short-run relationship is found in the energy consumption of public services to industrial energy consumption and transportation energy consumption to public energy consumption services at a significance level of 10%.

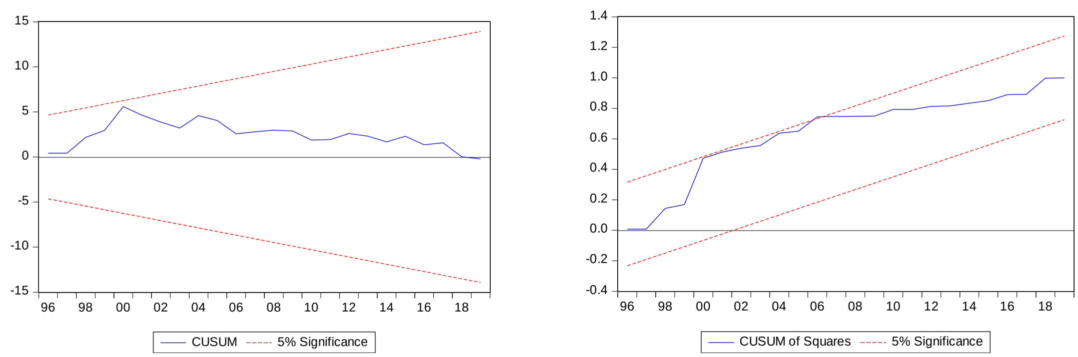
Vol. 5, No.11; 2021

ISSN: 2456-7760

The long-run relationship can be seen from the presence of the error-correction term (ect) coefficient in the equation. From the results obtained, ECT is only found in the energy consumption equation function of the commercial and public service sectors (ln*ECserv*) at a significance level of 1% and with a negative sign on the coefficient. The negative sign on the ect coefficient indicates the speed of adjustment towards the equilibrium point, in this case the balance will occur again two years after experiencing disequilibrium in the equation. In addition, in the long term, the variable of economic growth does not cause energy consumption, but industrial energy consumption (ln*ECin*) and transportation energy consumption (ln*ECtrans*) which causes energy consumption in the commercial sector (ln*ECserv*).

In time series regression, changes that occur over time in the estimation parameters are one of the problems that are often encountered. Parameters that are unstable and undetected will have the potential to bias the results (Narayan & Smyth, 2005). Therefore, a test is carried out on whether the estimation results are stable over time. This test uses cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ).

Fig. 1 Plot of CUSUM and CUSUMSQ



The test results can be seen in Figure 1. Statistically, the estimation results are within the critical bound 5% on CUSUM and CUSUMSQ. This shows that the parameter estimation results are stable over time. So that the model can be used as a policy determination.

4. Conclusion

This study finds a one-way relationship running from GDP, industrial energy consumption, and transportation energy consumption to commercial and public service energy consumption in the long run. This has important consequences for energy conservation policies in Indonesia. This is because the reduction in energy consumption in various economic sectors does not affect Indonesia's economic growth in the long term. So that energy conservation policies still need to be carried out to reduce carbon emissions as set by the Indonesian government. In the short term, economic growth triggers an increase in energy consumption in the transportation sector. This research then suggests increasing the development of renewable energy and triggering the development of sectors that support the use of clean energy. In this way, Indonesia can minimize the negative impacts resulting from economic activities. The one-way long-term relationship (GDP to energy consumption) in this study is in line with that of Narayan & Smyth (2005), Faisal et al (2017), and Tiwari et al (2021).

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