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Renewable Energy Consumption and Economic Growth in Indonesia: Evidence from VECM Causality

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Abstract

Attention to SDGs has accelerated the point on renewable energy consumption in recent more than ten years. The study discusses the causality between carbon dioxide emissions, renewable energy consumption-hydropower, renewable energy consumption-geothermal, biomass, and other sources on economic growth. Using the VECM and Granger Causality methods to see the relationship between variables in the long term and short term. This study using time series data from 1990-2020 in Indonesia. The results of the study are that carbon dioxide emissions and renewable energy consumption-hydropower are significantly positive for economic growth in the long term and short term, while renewable energy consumption-geothermal, biomass, and other sources are significantly negative for economic growth. In terms of causality, in the long term, all variables have a one-way causal relationship, while in the short term, carbon dioxide emissions and economic growth and renewable energy consumption-geothermal, biomass, and other and economic growth have an alternating causality relationship.

Keywords:

Renewable Energy Consumption, Economic Growth, VECM, Granger Causality

Introduction

Energy is very important for the survival of all humans on earth. Energy and life are two things that are interrelated and have a very close relationship. In everyday life, humans really need energy, both oil energy and electrical energy. According to BP Statistical Review of World Energy 2021 data, it shows that world energy consumption in 1965-2016 was dominated by non-renewable energy such as oil, gas, and coal. These non-renewable energy sources are used on average above 20% of the world's total energy consumption, while renewable energy sources such as hydropower, geothermal, biomass and other renewable energy sources are only 6% and 1% of the world's total energy consumption.

The use of energy sourced from non-renewable energy can increase carbon dioxide or CO2 emissions, while Indonesia produces CO2 emissions of 145.1 Million Tonnes in 1990 and increases to 299.81% in 2020 by 579.9 Million Tonnes (BP Statistical Review of World Energy 2021). At the 21st Conference of Parties (COP) climate negotiations of the United Nations Framework Convention on Climate Change (UNFCCC) which took place from November 30 to December 13, 2015 in Paris, a legally binding agreement was established, known as the Paris Agreement or the Paris Agreement. The Paris Agreement deals with climate change. The Paris Agreement is aimed at increasing the ability to adapt to the negative impacts of climate change, so as to create climate-resilient and low-emission areas without threatening food production and ready to provide funding for the development of low-emissions and climate-resilient areas. To date, 195 countries have ratified the Paris Agreement. This Paris agreement is the first binding agreement since the Kyoto Protocol at the 3rd COP meeting (Kompasiana, 2018).

If examined in depth, the actual use of natural resources will depend on the effective management of natural resources itself. Developing countries must make a plan to make it effective and efficient in its use (Iqbal, 2020). Indonesia is an example of developing countries that must maximize the use of these resources. The use of hydropower, biomass, geothermal, etc. is one example of renewable resources, all of which must be maximized, especially global warming is an actual issue until now.

The main objective of maximizing the use of renewable resources is to limit energy consumption for the community, while also saving more reserves of energy sources so that their use is not wasted (Iqbal, 2020). Especially at this time the increase in industrialization activities will increase the use of energy, industrialization activities should have an impact on increasing GDP, especially for Indonesia, but problems arise when the process is carried out will have a major impact on the environment.

Global warming is an actual issue at the present time, it is very important to anticipate, especially in relation to the rate of economic growth (Valentinday, 2021). On the one hand, the use of renewable energy will have an impact on increasing the rate of economic growth, but on the other hand it will cause a problem where the energy source seems to be exploited so that it is not friendly to the environment. Of course, all of this will affect the increasing CO2 production.

Based on the explanation above, it is necessary to conduct research in this study with the aim of analyzing the causal relationship between economic growth, renewable energy consumption and carbon dioxide emission in Indonesia.

Literature Review

Several studies have been conducted to examine the relationship between hydropower energy consumption with economic and environmental aspects. Hlalefang Khobai (2018) examines the effect of renewable energy consumption on economic growth in Indonesia, using data in the period 1990–2014. Using metode the autoregressive distributed lag (ARDL) whit limit testing approach to find the result. This study established a long term relationship between economic growth, renewable energy consumption, carbon dioxide emissions, capital and employment.

The result of this study is the consumption of renewable energy has a significant positive effect on economic growth in both the long term and short term. According to the vector error correction model (VECM) method, there is a long-term link between economic growth and the consumption of renewable energy, carbon dioxide emissions, capital, and employment.

Fattah (2021) make a study about causality between economic variables, namely economic growth, economic openness, and energy consumption on carbon dioxide emissions. To analyze the long term and short term for the relationships between research variables. The object of this study is in Indonesia during the period 1971 to 2018 with study using VECM and Granger Causality analysis. The VECM analysis in this study find that in the long term, the variables of economic growth, economic openness, and energy consumption have an effect significant contribution to carbon dioxide emissions in Indonesia, and in the short term the variables of carbon dioxide emissions in the previous period, economic openness, and energy consumption have a significant effect on carbon dioxide emissions in Indonesia. Granger Causality analysis found a two-way causality between energy consumption and carbon dioxide emissions and found a unidirectional causality between economic growth and carbon dioxide emissions.

Bildirici (2016) conducted a test of the relationship between environmental pollution, economic growth and hydropower energy consumption in G7 countries in the period 1961-2013 using the MS method. -VAR and MSGranger Causality. In this study, it was found that there is a two-way Granger causality between carbon dioxide emissions and economic growth in times of crisis and during times of high growth there is also has causality in carbon dioxide emissions on economic growth. The result of this model is that there is a two-way causality between hydropower energy consumption and economic growth in general, and in some G7 countries, Granger's carbon dioxide emissions to hydropower energy consumption and also hydropower energy consumption to carbon dioxide emissions.

Dilec (2019) made a study that aims to investigate the causal relationship between renewable energy production, total energy consumption and economic growth in Turkey. This causal relationship will be sought in both the long and short term. The analytical method used some test there are the Johansen cointegration test, VECM, Granger causality, impulse response function and variance decomposition for turkey in the period 1980–2016. The result of this analyze that the causal relationship between renewable energy and economic growth shows a two way relationship in both the short and long term, and also shows a causal relationship that flowing from energy consumption to economic growth in both the short and long term. However, no consistent results were obtained for the short-term relationship from economic growth to energy consumption.

Edwin (2022) analyze the relationship between Energy Used and CO2. The data used were collected from 1971 to 2018 with method namely the correlation between multivariate time series variables can also be explained by the VECM model, and can explain the effect of a variable or set of variables on other variables using Granger Causality, Impulse Response Function (IRF), and Forecasting. This study focuses on the findings of the best model to see the relationship between variables.

Methods

The research method used in this study is the Granger Causality test dan Vector Error Correction Model (VECM) for long run and short run causality. Other methods used in this study such as unit root test and the co-integration test.

The data used in this study is secondary data with the research location of the State of Indonesia. The data used are annual data and time series from 1990 to 2020. Secondary data obtained from World Development Indicators World Bank (WDI World Bank) and BP Statistic Review of World Energy 2021.

The function can explain behavior between renewable consumption from hydropower, geothermal, biomass, and other sources, carbon dioxide emission to economic growth can write as follow:

$$GDP = f(CDE, RCH, RCO) \quad (1)$$

The dependent variable in this study is GDP which represents the current Gross Domestic Product per capita in US$ as an indicator of economic growth. Sedangkan yang di tetapkan sebagai varibel independent yaitu Carbon Dioxide Emission (CDE) dalam satuan Million Tonnes sebagai indicator bagian enviromental, kemudian ada juga Renewable Energy Consumption-Hydropower (RCH) dan Renewable Energy Consumption-Geothermal, Biomass and Others (RCO) dalam satuan exajoules sebagai indicator bagian renewable energy.

Research Process Models

This research was tested in several stages. First, test the degree of integration and stationarity on each variable. Second, use the cointegration test to examine the long-term relationship between variables. Third, look at the long-order criteria and test the stability of the VAR before starting the long-term and short-term analysis. Fourth, analyze the long-term and short-term regression using the Error Correction Model by determining GDP as the dependent variable and others as independent variables. Finally, using the Granger Causality Test to see long-term co-integration and directional causality variables, then using the Vector Error Correction Model (VECM) to compare short-term causality between variables.

Unit Root Test

Econometric theory based on the assumption of stationarity of data evidenced by the mean value, variance and covariance are constant for all values of t. When the regression performed on non-stationary series data it is feared will generate spurious regression. Spurious regression characterized by high R-squared value and low value Durbin Watson (Insurkindro, 1998). The impact of the linear regression is spurious regression coefficient estimator is inefficient, forecasting based on the regression will be missed and a common standard test for related coefficients become authentic.

According to Gujarati (2003), stationarity test data can be done in several ways, namely perform plotting the data, seeing the autocorrelation correlogram fuction, and test unit roots to see stationary data. The degree of integration test will be performed if the data is not stationary at the degree level. Stationarity test, whether the time series data contains a unit root. For this reason, the method used is Augmented Dickey-Fuller Test (ADF), Phillips-Peron Test (PP) or Im Pesaran and Shin W-Stat (IPS).

Unit root testing using the Phillips-Peron Test or Augmented Dickey-Fuller is most commonly used. The unit root test improves the high-order serial correlation by adding the time difference on the right-hand side. Several simulation studies show that the Phillips and Peron nonparametric test has more serious distortions in sample size when the data generally have a negative autocorrelation advantage over the first difference.(Schwert, 1989; Phillips and Peron 1988; Dejong, 1992 in Mandala and Kim , 2004).

The probability of the t-statistic is smaller than the level of alpha 5 percent or 10 percent its mean data stationary. But the desired result test, all variables are not stationary at level, the probability value of each variable must be greater than the specified alpha to get unit root. All variables that no stationary at Level so that the application of ECM method should be continued. If it has been ascertained that no stationary in Level, repeat steps with unit root test but with a data of 1st difference, and 2nd difference to produce probability values are stationary.

Co-Integration Test

After conducting the stationary test data characteristics can we know whether the data will be used for this research is the data are stationary or not. Cointegration can be interpreted as a long-term relationship (long term relations/equilibrium) between variables are not stationary. The existence of cointegration relationships provide opportunities for data that individually are not stationary to generate a linear combination of the data between the stretcher so as to create conditions that are stationary. Cointegration regression intends to prove that occur conformity with the theory of the long-term. Cointegration test is a continuation of the unit root test and test the degree of integration.

The purpose is to test the cointegration regression of stasionaritas residuals. Stationary residuals is very important if you want to develop a dynamic model, especially ECM which includes key variables in the cointegrating regression related. In principle, the error correction model (ECM) there is a balance between the long-term fixed economic variables. if in the short term there is an imbalance in one period, it will correct the error correction model itself an error in the next period. This error correction mechanism can be interpreted as aligning the behavior of short term and long term. Thus the error correction model is consistent with the concept of cointegration. Johansen's test is a cointegration test for several time series I(1) data. "Cointegration" is a property of two time series data in which they share the same stochastic deviation. Stochastic drift is the change in the average value of a random or stochastic process. Empirical model for equation as follows:

$$GDP_t = a_0 + a_1 CDE + a_2 RCH + a_3 RCO \quad (2)$$

The advantage of the Johansen test stems from its ability to handle several time series variables; on the other hand, the Engle-Granger test can only handle one cointegration relationship. The Johansen test relies on two types of tests: (i) the trace test and (ii) the maximum eigenvalue test.

Error Correction Model

Short term and long term relationship in this study using a frame Error Correction Model (ECM). In order to obtain an accurate estimation result, the preliminary test of Error Correction Model framework that unit root test and cointegration test. The error correction model can be used to explain why economic actors face imbalances in the context of phenomena that are desired by economic actors, which are not necessarily the same as what actually are and need to be adjusted as a result of differences in the actual phenomena faced so far time. Furthermore, using ECM can be analyzed theoretically and empirically whether the resulting model is in accordance with the theory or not (Sri Isnowati, 2002).

In analyzing the long-term effects of economic growth as changes GDP, CDE, RCH and RCO, equation (2) can be transformed into another form of equation, as follows:

$$DGDP_t = \alpha_0 + \alpha_1 DCDE_t + \alpha_2 DRCH_t + \alpha_3 DRCO_t + \alpha_4 CDE_{t-1} + \alpha_5 RCH_{t-1} + \alpha_6 RCO_{t-1} + \alpha_7 ECT_{t-1} \quad (3)$$

Where $ECT = CDE_{t-1} + RCH_{t-1} + RCO_{t-1} + GDP_{t-1}$ (4)

Of the equation (3) will be able to put forward the hallmark of the model ECM, where to get an accurate estimate of the results should be worth negative estimation ECT in order to get a positive value in the long-term equation (Pandej dan Jindapon, 2012).

Granger-Causality

The right direction of causality between variables helps policy makers to sustain growth and achieve beneficial impacts of renewable energy consumption. Granger VECM causality can be applied when the variables are integrated with the same order of integration. To determine the direction of causality between variables, VECM is presented with the following equation:

$$DGDP_t = \delta_{10} + \sum_{i=1}^{q} \delta_{11}\, DGDP_{t-i} + \sum_{i=1}^{r} \delta_{12}\, DCDE_{t-i} + \sum_{i=1}^{s} \delta_{13}\, DRCH_{t-i} + \sum_{i=1}^{t} \delta_{14}\, DRCO_{t-i} + \mu_1 ECT_{t-i} + \varepsilon_{1t} \quad (5)$$

$$DCDE_t = \delta_{20} + \sum_{i=1}^{q} \delta_{21}\, DCDE_{t-i} + \sum_{i=1}^{r} \delta_{22}\, DGDP_{t-i} + \sum_{i=1}^{s} \delta_{23}\, DRCH_{t-i} + \sum_{i=1}^{t} \delta_{24}\, DRCO_{t-i} + \mu_2 ECT_{t-i} + \varepsilon_{2t} \quad (6)$$

$$DRCH_t = \delta_{30} + \sum_{i=1}^{q} \delta_{31}\, DRCH_{t-i} + \sum_{i=1}^{r} \delta_{32}\, DGDP_{t-i} + \sum_{i=1}^{s} \delta_{33}\, DCDE_{t-i} + \sum_{i=1}^{t} \delta_{34}\, DRCO_{t-i} + \mu_3 ECT_{t-i} + \varepsilon_{3t} \quad (7)$$

$$DRCO_t = \delta_{40} + \sum_{i=1}^{q} \delta_{41}\, DRCO_{t-i} + \sum_{i=1}^{r} \delta_{42}\, DGDP_{t-i} + \sum_{i=1}^{s} \delta_{43}\, DCDE_{t-i} + \sum_{i=1}^{t} \delta_{44}\, DRCH_{t-i} + \mu_4 ECT_{t-i} + \varepsilon_{4t} \quad (8)$$

D before the variable representing the difference operator, δ_{it} is a constant term and ECT represents the error correction term derived from the long-run cointegration relationship. ε_{1t}, ε_{2t}, ε_{3t}, and ε_{4t}, are error terms and are assumed to be normally distributed. Long-term causality between variables was estimated with t-statistical significance relating the error term coefficient (ECT_{t-1}). However, causality between variables in the short term was determined by the chi-squared significance in the first difference of the variables in equations 5 to 8. Wald's test was used to estimate the chi-squared. The null hypothesis is whether the coefficients of the lagging independent variables are equal to zero.

In addition, the joint significance of long-term and short-term causality is denoted by the joint significance of the two independent variables estimated lagging and ECT. The rejection of the null hypothesis indicates the existence of causality. For example, when $\delta_{12} \neq 0$ and significant for every I(1), it indicates that Granger's renewable energy consumption causes economic growth. That is, there is a one-way causality flowing from renewable energy consumption to economic growth. Again when $\delta_{21} \neq 0$, this indicates that there is a unidirectional causality flowing from economic growth to renewable energy consumption.

Results and Discussion

The null hypothesis for testing in the ADF, PP and IPS unit root tests indicates that the data series under consideration has a unit root and is tested against the alternative hypothesis that the series has no unit root (ie is stationary). As can be seen in Table 1, the ADF, PP and IPS tests show that GDP, CDE, RCH and RCO at the level have unit roots. This is because we fail to reject the null hypothesis of the unit root at the 10% and 5% significance levels. On the other hand, when the first difference of GDP, CDE, RCH and RCO is considered, the variable becomes stationary.

The variables GDP, CDE, RCH, and RCO are simultaneously non-stationary when the Unit Root Test is level. In the Unit Root integration test of order 1 or first defference there are several different results, namely GDP, CDE, RCH, and RCO variables are stationary at 5% simultaneously under PP, while the ADF and IPS tests get the same results, namely GDP, RCH and RCO stationary at 5%, while the CDE variable in ADF and IPS is stationary at 10%. The results of this unit root test can be seen in Table 1 below.

Table 1.

Unit Root Tests

	Level			**1st Difference**		
Variabel	**ADF**	**PP**	**IPS**	**ADF**	**PP**	**IPS**
GDP	0.9439	0.9309	0.9439	0.0075*	0.0075*	0.0075*
CDE	0.8852	0.9230	0.8852	0.0876**	0.0000*	0.0876**
RCH	0.9462	0.4357	0.9462	0.0000*	0.0000*	0.0000*
RCO	0.9970	0.9970	0.9970	0.0536*	0.0104*	0.0536*

Source: the results of data processing using Eviews12

Thus, it is concluded that all variables are not stationary at the level and are integrated in the first order simultaneously across all types of unit root tests. The unique integration sequence suggests that cointegration tests can be explored. However, it is necessary to first determine the maximum lag length. Therefore, the selection order criteria test was carried out. The results of the selection order criteria presented in Table 2 show that the optimal lag length p*= 5 was chosen, according to the results below:

Table 2.

Selection Order Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-195.0424	NA	52.43633	15.31096	15.50451	15.36669
1	-105.3811	144.8375*	0.184998	9.644700	10.61247	9.923382
2	-91.01269	18.78946	0.231774	9.770207	11.51219	10.27183
3	-75.61316	15.39953	0.319607	9.816397	12.33259	10.54097
4	-40.06604	24.60954	0.133507	8.312773	11.60318	9.260291
5	24.56560	24.85833	0.013866*	4.571877*	8.636496*	5.742340*

Source: the results of data processing using Eviews12

After performing the selection order criteria test, a VAR Stability Test is carried out to see if the data is in a stable condition or not in the VAR model.

Table 3.

VAR Stability Test

Lag Specification : 1 2	
Root	**Modulus**
-0.451077 – 0.704226i	0.836305
-0.451077 + 0.704226i	0.836305
0.438685 – 0.579752i	0.727019
0.438685 + 0.579752i	0.727019
-0.315764 – 0.605319i	0.682728
-0.315764 + 0.605319i	0.682728
0.351612	0.351612
0.264697	0.264697
VAR satisfies the stability condition	

Source: the results of data processing using Eviews12

From Table 3, it can be seen that there is no characteristic root value and modulus more than 1. This shows that the VAR (4) model was obtained in a stable condition.

In Table 4. Shows that the cointegration between the variables that will be used in this study. It can be proven through a significance value of probability that is smaller than the critical value of 5 percent. Another way that can be used is to look at the value of the Trace stat is greater than the Critical Values in Trace Test, and the value of the Max-Eigen stat is greater than the Critical Values in Maximum Eigenvalue Test.

Table 4.

Johanson Co-Intergration Test

Trace Test				
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.655010	50.27457	47.85613	0.0291
At most 1	0.413364	21.54012	29.79707	0.3248
At most 2	0.186968	7.139637	15.49471	0.5615

At most 3	0.055827	1.551051	3.841465	0.2130
Maximum Eigenvalue Test				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.655010	28.73445	27.58431	0.0355
At most 1	0.413364	14.40048	21.13162	0.3331
At most 2	0.186968	5.588586	14.26460	0.6664
At most 3	0.055827	1.551051	3.841465	0.2130
Trace & Maximum Eigenvalue tests indicates 1 cointegration eqn(s) at the 0.05 level				

Source: the results of data processing using Eviews12

So that the data cointegrated in Trace Test and Maximum Eigenvalue Test. It can be concluded that the variables used in this study mutually cointegrated. Therefore this model passes from the test cointegration, Error Correction Model for regression analysis and VECM causality test can be used in the study.

Table 5.

Long Run Results

Dependent Variable : GDP			
Variabel	**Coefficients**	**Standard Error**	**T-Statistics**
Constant	-2154.413	391.0089	-5.509881*
CDE	12.73118	2.132596	5.969803*
RCH	8187.555	4460.230	1.835680**
RCO	-21445.33	8183.845	-2.620447*
R-Squared : 0.921844			
D.W. Statistics : 0.812970			

Source: the results of data processing using Eviews12

After confirming the existence of a long-term relationship between the variables, the study estimates the long-term effects of carbon dioxide emissions, consumption of renewable energy-hydropower, and renewable energy geothermal, biomass, and others on economic growth. The estimated long-term relationship coefficients are presented in Table 5.

Based on the results presented in Table 5, the long-term equation can be written as follows GDPt = –2154.41 + 12.73CDE + 8187.56RCH - 21445.33RCO. The estimated coefficients suggest that carbon dioxide emission and renewable energy consumption–hydropower positive significant impact on economic growth, which is in line with theoretical argument that carbon dioxide emission and renewable energy consumption-hydropower enhance economic growth. However, renewable energy geothermal, biomass, and others have negative significant impact on economic growth.

Table 6.

Short Run Results

Dependent Variable : GDP			
Variabel	**Coefficients**	**Standard Error**	**T-Statistics**
Constant	-1039.735	464.6811	-2.237523*
CDE	4.551995	2.300646	1.978573**
RCH	6590.045	2666.103	2.471789*
RCO	-16457.67	8898.811	-1.849424**
ECT-1	0.310800	0.122035	2.546813*
R-Squared : 0.540467			
D.W. Statistics : 1.645107			

Source: the results of data processing using Eviews12

After estimating the long-term coefficient, the next step is to estimate the short-term dynamic growth model. The results for the short term are shown in Table 6. It can be seen that ECTt-1 (0.3108) is positive and significant, which confirms the existence of a long-term relationship between economic growth, carbon dioxide emissions, renewable energy consumption–hydropower and renewable energy consumption–geothermal, biomass, and others. Based on the results shown in Table 5, the short-term growth dynamics equation can be formed as follows: GDPt = -1039.74 + 4.55CDE + 6590.05RCH – 16457.67RCO. Output elasticity with respect to carbon dioxide emissions and consumption of renewable energy - hydropower is positive and significant for economic growth at a significance level of 10 percent.

This implies that carbon dioxide emission and renewable energy consumption-hydropower to economic growth in the short run. However, renewable energy consumption–geothermal, biomass, and others has a negative effect on economic growth but it is significant at 5% level of significance effect on economic growth in the short run. This condition can be seen from the Adjusted R-squared 54.05%. In table 6 also shows significant ECT with a probability value of less than alpha 0,05. ECT value in ECM explains whether the model can be used as a long-term analysis. In addition to the value of ECT must be positive and less than 1 (Syon Syarid, 2004).

Granger Causality

A causal relationship is one in which the variables have a long-term relationship. The Granger VECM causality method was used to determine the direction of causality between variables.Tables 7 and 8 present the long-term and short-term Granger causality results.

Starting with a long-term causal relationship, the results validate that there is a long-term causality flowing from renewable energy consumption–hydropower to economic growth, but there is no long-term causality from economic growth to renewable energy consumption–hydropower which explains that there is only a one-way relationship. Then there is a long-term causality that flows from carbon dioxide emission to renewable energy consumption–hydropower, but there is no long-term causality from renewable energy consumption–hydropower to carbon dioxide emission. Next, there is a long-term causality that flows from carbon dioxide emission to renewable energy consumption–geothermal, biomass, and others, but there is no opposite case. And lastly, there is a long-term causality that flows from renewable energy consumption–hydropower to renewable energy consumption–geothermal, biomass, and others, but there is no long-term causality otherwise.

Table 7.

Granger Causality Test

Long Run

Dependent Variable	**Independent Variable**			
	GDP	**CDE**	**RCH**	**RCO**
GDP	….	1.67551	7.05648*	0.13326
CDE	0.57473	….	6.70617	1.03352
RCH	1,98814	3.73943*	….	1.02070
RCO	1.62987	6.39469*	4.72828*	….

Source: the results of data processing using Eviews12

While the results of the causality test using the VECM model to obtain short-term causality produce several numbers that indicate causality between variables. There is an alternating short-term causality between carbon dioxide emissions and economic growth, and there is also a short-term alternating causality between renewable energy consumption – geothermal, biomass, and others and economic growth.

Table 8.

Vector Error Correction Model

Short Run

Dependent Variable	**Independent Variable**			
	D(GDP)	**D(CDE)**	**D(RCH)**	**D(RCO)**
D(GDP)	….	13.93177*	3.634749	5.101691*
D(CDE)	7.846430*	….	1.301665	4.383998
D(RCH)	4.077615	3.334958	….	2.819829
D(RCO)	6.125449*	2.915273	0.833832	….

Source: the results of data processing using Eviews12

Conclusion

This study seeks a causal relationship between renewable energy consumption, carbon dioxide emissions and economic growth by using econometric analysis with annual time series data and focusing on Indonesian data for the period 1990-2020. To determine the long-term relationship and determine the short-term causality relationship, cointegration test, VECM and Granger causality analysis were used. The cointegration test results conclude that there is a long-term relationship between the variables of economic growth, carbon dioxide emissions, renewable energy consumption-hydropower, renewable energy consumption-geothermal, biomass, and other sources.

The results obtained are that there is a long-term causality that flows from renewable energy consumption-hydropower to economic growth, but there is no long-term causality from economic growth to renewable energy consumption-hydropower which explains that there is only a one-way relationship. Then there is the long-term causality that flows from carbon dioxide emissions to renewable energy consumption-hydropower, but there is no long-term causality from renewable energy consumption-hydropower to carbon dioxide emissions. Furthermore, there is long-term causality flowing from carbon dioxide emissions to renewable energy consumption–geothermal, biomass, and other sources, but there is no opposite case. And lastly, there is a long-term causality that flows from renewable energy consumption-hydropower to renewable energy consumption-geothermal, biomass, and other sources, but there is no long-term causality otherwise.

While the results of the causality test using the VECM model to obtain short-term causality produce several numbers that indicate causality between variables. There is alternating short-term causality between carbon dioxide emissions and economic growth, and there is also alternating short-term causality between renewable energy consumption–geothermal, biomass, and other sources and economic growth.

The estimated coefficients show that carbon dioxide emissions and renewable energy consumption-hydropower have a significant positive impact on economic growth, which is in line with the theoretical argument that carbon dioxide emissions and renewable energy consumption-hydropower increase economic growth. However, renewable energy consumption – geothermal, biomass, and other sources have a significant negative impact on economic growth.

Results for the long-term relationship between economic growth, carbon dioxide emissions, renewable energy consumption-hydropower, and renewable energy consumption–geothermal, biomass, and other sources. The output elasticity with respect to carbon dioxide emissions and renewable energy consumption-hydropower is positive and significant at the 10 percent significance level.

This implies that carbon dioxide emissions and consumption of renewable energy-hydropower economic growth in the short term. However, renewable energy consumption – geothermal, biomass, and other sources have a negative effect on economic growth but significant on economic growth in the short term.

For now, renewable energy consumption-hydropower can be an alternative to substitute non-renewable energy because renewable energy has a significant positive to economic growth. In the other side carbon dioxide emission also has positive significant to economic growth. But for carbon dioxide, not a good environment, where we know about the issue of global warming which is currently in the world's spotlight. Of course, the positive effect for the economy is because more and more energy is used which is one of the productive factors of a country. Indonesia still dominates the use of non-renewable energy sources that are not environmentally friendly, while energy demand is increasing. So that carbon dioxide emission will increase. The government is expected to provide policies to reduce carbon dioxide emissions by changing alternative renewable energy sources, especially hydropower energy.

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