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Forecasting the Contribution of Renewable Energy to the Indonesian Economy: A Vector Error Correction Model Approach

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A B S T R A C T

This study aims to evaluate the causal relationship between Renewable Energy Consumption, Non-Renewable Energy Consumption, and Economic Growth. This study uses quantitative methods and analyzes data using a Granger Causality Test, Vector Error Correction Model (VECM), Impulse Response Function (IRF), and Variance Decomposition (VDC). The study was conducted in Indonesia, with data ranging from 1993 to 2022 obtained from the World Bank database and Our World in Data. The results of the study based on the Granger test show that renewable energy has a significantly positive impact on economic growth in Indonesia. According to the VECM test, renewable energy consumption contributes to increasing economic growth as a result of construction and manufacturing sector activities in the development of renewable energy in Indonesia. The government should focus on energy availability, with an emphasis on increasing the production of renewable natural resources.

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INTRODUCTION

The economic impact of the War in Ukraine remains a significant issue in 2024. The two years since the start of the aggression between Russia and Ukraine have led to far-reaching economic impacts involving the European Union and the rest of the world (Papunen, 2024). Russia has a significant influence on the global oil market because it is the third largest crude oil exporter in the world (Duho et al., 2022). Countries in Southeast Asia rely on Russia for their oil supply. Russia also has economic and military ties with several countries in Southeast Asia, including Vietnam, Indonesia, and Thailand (Ilman & Anam, 2023). Ukraine, which is the main producer and exporter of food supplies, especially wheat, corn, vegetable oil, and others, has an impact on Indonesia because Ukraine is the second largest supplier in Indonesia after Australia. Despite being a non-traditional trading partner, Ukraine has significant commercial relations with Indonesia; therefore, the conflict caused by the Russia-Ukraine war will lead to inflation and increased shipping costs in Indonesia (Priyanto et al., 2022).

The impact of the war has become very felt due to the surge in energy and food prices, which has resulted in the disruption of the trade chain. A surge in energy prices has resulted in high inflation rates, creating a difficult framework for some countries (Papunen, 2024). The surge in energy prices also affects the condition of Indonesia, considering that the composition of its primary energy is still dominated by fossil energy, which accounts for approximately 90% of the total energy production (International Renewable Energy Agency, 2022). Energy use in Indonesia is still highly dependent on non-renewable resources, which are higher than renewable energy. Overall, fossil fuels (coal and natural gas) account for 92% and 94% of the electricity supply by 2025 and 2050, respectively (Handayani et al., 2019). Therefore, the transition from fossil fuels to renewable energy is becoming an increasingly important focus in response to climate change given the ever-increasing consumption of petroleum, coal, natural gas, and other fossil fuels (Aswadi et al., 2023).

Indonesia is a country with abundant natural resources and a capacity of more than 3,000 GW, most of which comes from solar, wind, hydro, bioenergy, marine, and geothermal power, and has great potential to produce renewable energy independently (Handayani et al., 2019; International Renewable Energy Agency, 2023). According to the Planned Energy Scenario (PES), Indonesia's wealth of renewable energy resources is predicted to nearly quadruple the country's overall energy consumption by 2050. By 2050, demand for electricity is predicted to have increased at least fivefold, making it the most prevalent energy source. By 2050, 47% of the final energy demand is anticipated to be met by electricity, which is mostly produced by renewable energy (International Renewable Energy Agency, 2022). One of the factors that causes an increase in electricity consumption in Indonesia is the increase in the use of electric cars, which has become increasingly popular since they were introduced to the automotive market in Indonesia.

Energy plays an important role in supporting economic activities in Indonesia, both for consumption needs and the production process in various economic sectors. The demand for renewable energy is increasing in line with significant growth in global energy consumption. The abundant potential of renewable resources offers an economical alternative to fossil fuels. Renewable energy produces less or even no greenhouse gas emissions, and its use is expected to increase in line with high fossil energy prices, rising inflation, high living standards, and increasing difficulties faced by some parties (Madaleno & Nogueira, 2023). However, the application of renewable energy in Indonesia is still limited because Indonesia's geographical conditions have created technical obstacles for renewable energy. Price caps are also a serious obstacle to the development of renewable energy, especially in the Java-Bali region, where most of the energy is generated and consumed (Bridle et al., 2018).

In order to promote efficient economic growth, non-renewable energy sources including coal, natural gas, and petroleum have been more popular in recent decades due to constraints on the use of renewable energy (Aslan et al., 2014; Mohammadi et al., 2023). According to the majority of research, both developed and developing nations have experienced notable economic growth as a result of the usage of non-renewable energy (Aswadi et al., 2023; Pegkas, 2020). Although energy transition has been implemented in several countries, non-renewable energy consumption is still widely used, even though it has produced a source of carbon emissions and environmental degradation (Adewuyi, 2020). The use of non-renewable energy has become increasingly crucial over time because it shows a diverse increasing trend. This increase occurs because fossil fuel energy is one of the most basic components used worldwide and contributes significantly to economic growth (Pegkas, 2020). As an energy-exporting country, non-renewable energy sources in the form of petroleum are still the most widely used energy sources in the household sector in Indonesia. Most industrial sectors also produce certain products or outputs that use gas as the main fuel; thus, gas consumption remains high because the supply is abundant in almost every country.

The use of nonrenewable energy has become the main consumption of society, although some countries face a dilemma over priority policies for pollution reduction or economic growth. On the other hand, renewable energy can be an alternative to fossil fuels and reduce CO2 emissions. However, the transition from non-renewable energy consumption to renewable energy will take a lot of time and money. Countries must strive to maintain their growth, development, and economic prosperity (Adewuyi, 2020). Countries also need to ensure sustainable economic growth that needs to be achieved and need to ensure lower pollution levels so that climate change goals can be met (Madaleno & Nogueira, 2023). Therefore, a transition to renewable energy needs to be made to achieve better energy sustainability, which can support energy sustainability and economic growth (Aswadi et al., 2023). Indonesia, with considerable renewable energy potential, needs to be optimized in the future.

Extensive research has been conducted on the causal relationship between energy consumption and economic growth, although definite results have not

been reported. Previous research has shown an important correlation between energy consumption and energy growth by using the Pesaran Cross-section Dependence test to test data dependence and found that increasing the total portion of renewable energy will reduce the use of fossil fuels, thereby affecting energy prices (Pesaran, 2004). Through regression of Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) cointegration, this study tests the strength of the results that show that only non-renewable energy consumption affects economic growth by showing that Indonesia is still heavily dependent on fossil energy consumption (Aswadi et al., 2023).

Therefore, this study aims to achieve three main objectives: to examine the impact of renewable energy consumption on economic growth in Indonesia; to explore the influence of non-renewable energy consumption, especially natural gas, on economic growth in Indonesia; and to investigate the short- and long-term effects of renewable energy consumption, non-renewable energy consumption, and economic growth in Indonesia. This study links the use of energy, including renewable and non-renewable energy, with economic issues. In addition, this study focuses on Indonesia because natural gas and energy will increase in 2023 by 3% and 13.8%, respectively, compared with the previous year (Kementerian Energi dan Sumber Daya Mineral, 2024).

LITERATURE REVIEW

Economic growth is significantly influenced by energy use. A wealthier economy can be achieved through the efficient use of energy. Making the switch to renewable energy can boost economic growth by lowering carbon emissions and improving people's quality of life. There are advantages and disadvantages to the transition to sustainable energy sources. The requirement to invest in the shift to renewable energy is one of the most common challenges. Investing in renewable energy can boost industrial growth, diversify the economy, lessen dependency on non-renewable energy, and create jobs. The economy may become more resilient to changes in the price of energy globally as a result of this diversification.

The Government of Indonesia, through the National Energy Council (DEN), has a renewable energy target that will increase from 2025 to 2060. Despite Indonesia's increasing renewable energy potential, the country's utilization of this energy is still very low, with only a 0.55 percent increase per year (Wahyudi et al., 2024). This is because of the obstacles that arise, including the lack of efficient technology and the high cost of renewable energy, as well as the country's dependence on non-renewable energy sources such as coal, oil, and natural gas. In addition, the transition to renewable energy requires large investments that can affect economic growth in the short term (Purnomo et al., 2023). Although Indonesia has great potential for renewable energy sources such as hydropower, solar, and wind, challenges in processing and utilizing these resources optimally will remain. Until now, there have been many studies that have discussed the two-way relationship between energy consumption and economic growth in various countries. Four hypotheses have been developed in several studies that explore the relationship between energy consumption and

economic growth: growth, conservation, feedback, and neutrality. The difference between these four hypotheses is that the policy recommendations differ according to the definition of their respective relationships (Kahia et al., 2017).

Energy is an important input in the relationship between energy consumption and economic growth (Rahman & Velayutham, 2020). When a country's economy is heavily influenced by energy use, its use of technology is not as advanced, and policy recommendations are needed for greater energy use efficiency (Kahia et al., 2017). REC has a significant unidirectional influence on Economic Growth, both in the short and long terms (Amri, 2017). Meanwhile, the NREC and Economic Growth have asymmetrical unidirectional relationships. This means that the NREC has a positive and negative influence on economic growth, depending on the use of energy sources in each country (Awodumi & Adewuyi, 2020). The REC has a significant negative impact on economic growth in Indonesia (Aswadi et al., 2023). This is due to the fact that renewable energy production is still limited and expensive, making this energy production still unable to shift non-renewable energy in Indonesia, in addition to increasing consumption demand. In G7 countries, the increase in investment in renewable energy sources is much greater than the cost of non-renewable energy (Okumus et al., 2021). This causes the influence of REC on economic growth to be lower than that of NREC.

The ongoing relationship between economic growth and energy consumption states that economic growth is not too dependent on energy consumption. Thus, policies to reduce energy use can be recommended and do not have a negative impact on economic growth (Kahia et al., 2017). Increased Economic Growth has a positive influence on REC (Rahman & Velayutham, 2020). In addition, the one-way relationship that runs from Economic Growth to NREC depends on the treatment of nonrenewable energy as a normal or inferior good. Another finding states that some countries are experiencing a dilemma between reducing pollution owing to increased NREC and maintaining economic growth (Bhuiyan et al., 2022).

Energy consumption and economic growth have been found to have an asymmetric two-way causal relationship in which economic growth causes REC to rise, and REC causes economic growth to fall (Kahia et al., 2017). Accordingly, RECs can boost economic growth and lessen reliance on NRECs. Energy consumption was determined to be a driving element for economic growth after a two-way causal association between NREC and economic growth was also discovered (Amri, 2017). Furthermore, surprising findings were obtained in 17 developing countries, stating that all the markets studied had no significant positive or negative relationship between energy consumption and economic growth, except for Poland, where there was a one-way relationship between renewable energy consumption and economic growth (Ozcan & Ozturk, 2019).

METHODOLOGY

This study predicts the impact of the use of Renewable Energy (REC) and Non-Renewable Energy (NREC) on increasing Economic Growth in Indonesia by involving control variables such as Foreign Direct Investment, Poverty,

Education, and Unemployment. This research model is tested in Indonesia with GDP per capita (GDP) as a proxy for calculating Economic Growth in Indonesia.

Table 1. Variable Definition

Variable		Description	Status	Source
Economic Growth	GDP	GDP per capita (current US$)	Eksogen	World Bank
Renewable Energy Consumption	REC	Primary energy consumption from renewables	Endogen	Our World in Data
Non-renewable Energy Consumption	NREC	Gas consumption	Endogen	Our World in Data
Foreign Direct Investment	FDI	Foreign direct investment, net inflows (% of GDP)	Control	World Bank
Poverty	POV	Poverty Data Explorer	Control	Our World in Data
Education	EDU	Education	Control	World Bank
Unemployment	UMP	Unemployment	Control	World Bank

This study analyzes the short- and long-term using time series data collected from 1993 to 2022, which are grouped quarterly for each year. In the initial stage, a data causality test was carried out using the Stationer Test at the level of first difference with Phillips–Perron (PP) based on a significance value of 5% (Derouez et al., 2024; Wicaksono et al., 2023). After the Stationer Test, the next step is to determine the Lag Criteria Test based on the results of the likelihood ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Criterion (SC), and Hannan-Quin Criterion (HQ) (Alshami, 2023; Bunnag, 2023). The researcher then conducts Johansen's Co-Integration Test when all the data are stationary at the first difference. This test was carried out to calculate several cointegration equations and provide evidence of long-term relationships between variables using Trace Statistics and Max-Eigen Statistics based on significance at the level of 0.05 and comparison with critical values (Iyer & Mahajan, 2021). The next stage is to conduct the Granger Causality test, which is used to test the relationship between the direction and determine the current condition of each variable (Panait et al., 2022) and is divided into two stages. First, the test only involves exogenous (Renewable Energy and Non-Renewable) and endogenous (Economic Growth) variables. Second, we add control variables (Foreign direct investment, poverty, education, unemployment) to ensure the relationship between variables in the short-term and not long-term approach with the equation estimation model (Khasanah et al., 2021).

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \cdots + \alpha_i Y_{t-i} + \beta_1 X_{t-1} + \cdots + \beta_i X_{t-i} + \mu_t \quad (1)$$
$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \cdots + \alpha_i X_{t-i} + \beta_1 Y_{t-1} + \cdots + \beta_i Y_{t-i} + \mu_t \quad (2)$$

The estimation model shows that the period and μ are white noise errors. Parameter 0 represents the constant growth rate of Y and X, meaning that the General Movement of Cointegration between X and Y refers to the process of the Root Unit. This analysis investigates the causality relationship between variables based on the results of hypothesis tests, if the estimation results show that only X is not a significant Granger-Cause Y, it means that there is only Unidirectional Causality between variables, but if the two affect each other, it means that there is Bidirectional Causality between variables. Furthermore, the Vector Error Correction Model (VECM) analysis process was carried out in the previous two stages to estimate the volatility of Economic Growth based on long-term analysis with the following estimation model (Wicaksono et al., 2023).

$$\Delta Y_t = \alpha_1 + p_1\, e_1 + \sum_{i=0}^{n} .\beta_i\, \Delta Y_{t-i} + \sum_{i=0}^{n} .\delta_i\, \Delta X_{t-i} + \sum_{i=0}^{n} .Y_i\, Z_{t-i} \quad (3)$$
$$\Delta Y_t = \alpha_2 + p_2\, e_1 + \sum_{i=0}^{n} .\beta_i\, \Delta Y_{t-i} + \sum_{i=0}^{n} .\delta_i\, \Delta X_{t-i} + \sum_{i=0}^{n} .Y_i\, Z_{t-i} \quad (4)$$

The equation shows that any short-term relationship that fluctuates has an impact on the stability of the relationship between variables. In addition, this study conducted an Impulse Response Function (IRF) analysis to predict the response of Economic Growth to shocks caused by all exogenous variables in the long term through deviation and alternative shocks. A Variance Decomposition analysis was then conducted to evaluate the interaction of relationships between variables and to describe the role and composition of each exogenous variable on endogenous variables in the long term (Wicaksono et al., 2023).

RESEARCH RESULT

The data used in this study were analyzed by first transforming them into a natural logarithm (LN) (Sun et al., 2024). This transformation was carried out to reduce heteroscedasticity, make the distribution of data closer to normal, and improve the linearity of the relationship between the variables analyzed. This process is important for producing more accurate and reliable analysis results, especially in the context of regression analysis or other statistical models.

Table 2. Descriptive Variable

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Obs.
GDP	2284.994	1992.350	4788.0000	459.20000	1363.796	117
REC	81.16312	54.14000	277.06000	25.090000	63.02257	117
NREC	376.4231	372.0000	458.00000	229.00000	58.40998	117
FDI**	2.582051	2.550000	5.3000000	0.9000000	1.015759	117
POV**	26.59611	24.87500	69.120000	2.4700000	19.68080	117
EDU**	110.3974	11.75000	116.00000	101.00000	3.903628	117
UMP**	5.344872	4.850000	8.1000000	2.8000000	1.365636	117

Table 2 presents the mean, median, maximum, minimum, and standard deviation of the variables used in this study. Based on the table, it is known that Economic Growth has a vulnerable GDP gap of 4,328.80, and a vulnerable gap in Renewable Energy Consumption of 251.97, while the vulnerable gap in Non-renewable Energy Consumption is not too far away, with a value of 229.00.

Table 3. Uji Stationer

Variable	Phillip Perron (PP)	
	Level	First Difference
GDP	0.8978	0.0006*
REC	0.9994	0.0007*
NREC	0.0099*	0.0035*
FDI**	0.1212	0.0014*
POV**	0.9999	0.0127*
EDU**	0.9929	0.0258*
UMP**	0.2878	0.0001*

The model equation used to test the variables in this study was the Phillips–Perron test (PP). In this test, the probability level set is 5%, which means that if the probability value is below that level, the data will be declared stationary (Derouez et al., 2024; Wicaksono et al., 2023). Table 3 shows that in the PP test, the six variables did not pass the test at the level stage, but were declared to have

passed the 1st difference stage with a significant score of less than 5%. Because the data used are stationary, VECM estimation is performed, where the optimal lag length is obtained from 0 to 9. The Lag criteria were determined based on the order of the most lag selected.

Table 4. Johansen Cointegration Test

Hypothesized No. of CE(s)		Cointegration Rank Test (Trace)			Cointegration Rank Test (Maximum Eigenvalue)		
		Trace Statistic	0.05 Critical Value	Prob	Max-Eigen Statistic	0.05 Critical Value	Prob
First Stage	r = 0*	80.77218	29.79707	0.0000*	37.07215	21.13162	0.0001*
	r ≤ 1*	43.70003	15.49471	0.0000*	25.77359	14.26460	0.0005*
	r ≤ 2*	17.92644	3.841465	0.0000*	17.92644	3.841465	0.0000*
Second Stage	r = 0*	318.3025	125.6154	0.0000*	88.69512	46.23142	0.0000*
	r ≤ 1*	43.70003	15.49471	0.0000*	25.77359	14.26460	0.0005*
	r ≤ 2*	17.92644	3.841465	0.0000*	17.92644	3.841465	0.0000*
	r ≤ 3*	97.97878	47.85613	0.0000*	41.17165	27.58434	0.0005*

VECM estimation can be performed if the equation model has a cointegration relationship, such that the Johansen cointegration test is used to determine the long-term relationship between variables. This research model has a significance value below 0.05, in model one involving GDP, REC, and NREC, and in model two involving control variables, including FDI, POV, EDU, and UMP (Iyer & Mahajan, 2021). These results show that there is a relationship between variables, thus establishing VECM as the best model in this study (Wicaksono et al., 2023). All variables in this study had direct long-term relationships with each other. Therefore, the VECM estimation can be continued in the next stage.

Table 5. Granger Causality

First Stage					
GDP		REC		NREC	
REC	0.0004*	GDP	0.0538	GDP	0.8463
NREC	0.8410	NREC	0.1587	REC	0.9864

Second Stage						
GDP	**REC**	**NREC**	**FDI****	**EDU****	**POV****	**UMP****

REC	0.0004*	GDP	0.0538	GDP	0.8463	GDP	0.5591	GDP	0.8197	GDP	0.1777	GDP	3.E-05
NREC	0.8410	NREC	0.9864	REC	0.1587	REC	0.2597	REC	0.1766	REC	0.0082*	REC	0.0438*
FDI**	0.662	FDI**	0.9991	FDI**	3.E-05	NREC	0.6501	NREC	0.5348	NREC	0.7899	NREC	0.0482*
POV**	0.5588	POV**	0.1902	POV**	0.0149*	POV**	0.5709	FDI**	0.9953	FDI**	0.4744	FDI**	0.0032*
EDU**	0.5906	EDU**	0.7149	EDU**	0.1096	EDU**	0.6183	POV*	0.0061*	EDU**	0.6092	POV**	0.0060*
UMP**	0.0307	UMP**	0.7795	UMP**	0.5734	UMP**	0.0279*	UMP**	0.6803	UMP**	0.6948	EDU**	0.9511

Note: * Significant at 0.05 alpha, ** Control Variable; Source: Author's analysis.

To determine the causal relationship between variables, a Granger causality test was carried out using a level of 0.05 (Wicaksono et al., 2023). Table 5 shows the results of the first phase of the variable test, which shows a unidirectional relationship between REC and GDP with a probability value below 0.05. This is in line with previous research showing that renewable energy affects economic output in Indonesia, because economic growth depends on the amount of renewable energy used (Amri, 2017). In the second stage, control variables were added to test the feasibility of the model. The results in the second stage are not significantly different from the findings in the first stage, and there is a unidirectional relationship that occurs from REC to GDP so that the model can be declared robust.

Table 7. VECM in Short Term

Model	Variabel	Koefisien	T-Statistic	T-Table	Prob.*
First Stage	D(LN_GDP(-4),2)	0.12427	-2.26670*	1.9084	Significant
	D(LN_REC(-8),2)	0.16073	2.34835*	1.9084	Significant
Second Stage	D(LN_GDP(-4),2)	0.22898	-2.56615*	1.9084	Significant
	D(LN_REC(-4),2)	0.30588	2.30683*	1.9084	Significant
	D(LN_REC(-8),2)	0.25298	2.28508*	1.9084	Significant
	D(LN_NREC(-4),2)	0.96104	1.98236*	1.9084	Significant
	D(LN_NREC(-8),2)	0.64751	2.01715*	1.9084	Significant
	D(LN_EDU(-4),2)	3.45684*	2.02056*	1.9084	Significant

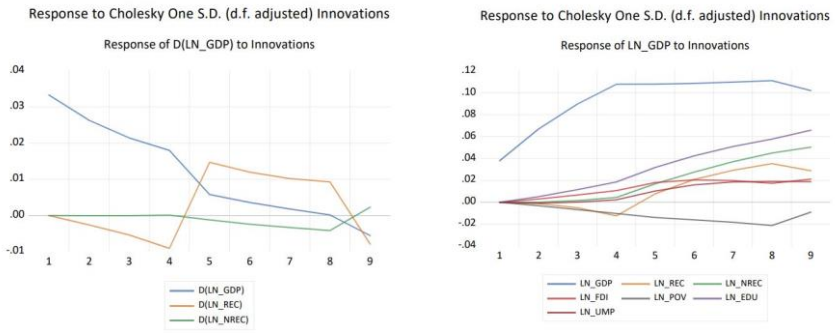
The use of VECM explains the short- and long-term effects between variables. Based on the results of the Lag Length Criteria test, the optimal lag in the forecast is 9. Therefore, the VECM estimation test process uses a lag of 9 with a significance level of 0.05 and a table value of 1.9804. Table 7 presents the results of the short-term VECM tests. The results of the VECM test on short-term estimates based on lag 9 show that the REC variable equation in lags 4 and 8 has a positive and significant influence on GDP at the level of 0.05. Suppose the REC variable increases by 1% in the previous four and eight years; then, GDP increases by 0.174% and 0.160%, respectively (Luqman et al., 2019).

Table 9. VECM in Long Term

Model	Variable	GDP	T-Table
First Stage	REC	0.83230 2.61040*	1.9804
	NREC	1.65938 2.24337*	
Second Stage	REC	0.50357 4.56933*	1.9804
	NREC	1.07103 1.79572	
	FDI**	0.22325 4.85634*	
	POV**	0.64391 -2.20780*	
	EDU**	4.57467* 0.95514	
	UMP**	0.48564 0.83785	

Note: * Significant; Source: Author's analysis.

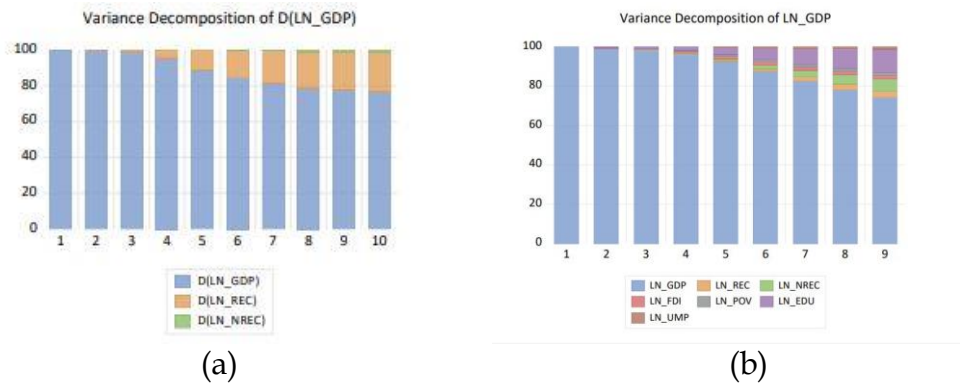
The results of the long-term estimates show that REC and NREC have a positive and significant relationship with GDP at a probability level of 0.05. This can be proven by comparing the t-statistical values (2.61040) and (2.24337) with the t-table values (1.9084). If the t-statistic value is greater than the t-table value, there is a significant relationship between the two variables. Furthermore, the REC and NREC coefficients were 0.83230 and 1.65938, respectively. This means that a 1% increase in REC and NREC leads to an increase in GDP by 0.832% and 1.659%, respectively. The results of the second stage, shown in table 10 in the long-term test, show that there is a significant positive relationship between REC and GDP, with a coefficient of 0.50357. This means that if there is a 1% increase in REC in the long term, GDP will increase by 0.503% (Rahman & Velayutham, 2020; Wahyudi et al., 2024).



(a) (b)

Figure 2. Impulse Response Combined Graph

The influence of GDP, REC, and NREC through the Impulse Response Function (IRF) was examined to observe the movement of variables that have the potential to have an impact on other variables. Before the IRF test, a VAR Stability Condition Check test was first carried out. The result was a modulus value of <1 with an optimal lag length of 9, which means that the equation used in the study can be considered stable.



(a) (b)

Figure 3. Variance Decomposition Stacked Graph

The Variance Decomposition Value analysis aims to test the most influential Economic Growth index value among the REC, NREC, and control variables, as shown in Figure 3. It can be seen that in the first stage the REC variable dominated the Economic Growth index in Indonesia. In addition, in the second stage, the dominance of the REC variable continues, even though the control variable is involved. This further strengthens the influence of the REC on Economic Growth.

DISCUSSION

These results show that there is a relationship between variables in the Johansen cointegration test, thus establishing VECM as the best model in this study (Wicaksono et al., 2023). All variables in this study had direct long-term relationships with each other. The findings in the first and second stages of the Granger causality tests show a unidirectional relationship between REC and GDP. This means that the rise and fall of the REC value will affect the GDP level in Indonesia but not the other way around, suggesting that the relationship between REC and economic growth depends on the amount of renewable energy used in Indonesia. Renewable energy consumption improves energy efficiency, drives growth through technology transfer, and improves resource distribution.

The results of the VECM test on short-term estimates based on lag 9 show that the REC variable equation in lags 4 and 8 has a positive and significant influence on GDP at the level of 0.05. Suppose the REC variable increases by 1% in the previous four and eight years; then, GDP increases by 0.174% and 0.160%, respectively (Luqman et al., 2019). Hydropower has been the largest contributor to renewable energy for more than two decades in Indonesia in the total primary energy supply mix. After the COVID-19 pandemic, the government continued to

strive to build a sustainable, inclusive, and resilient economy by laying the foundation for financial, economic, and social recovery. Investments that drive employment and economic activity, protect biodiversity and ecosystem services, strengthen resilience, and advance economic decarbonization are top priorities in the short- and long-term recovery phases (International Renewable Energy Agency, 2023).

The consumption of renewable and non-renewable energy has increased economic growth in Indonesia. Indonesia has abundant renewable energy potential, but its exploitation remains minimal, with an annual increase of only 0.55% (Wahyudi et al., 2024). By increasing the attractiveness of investment and the development of renewable energy, Indonesia can accelerate its transition to green energy and meet its climate targets. The development of renewable energy plays an important role in encouraging economic prosperity through construction and manufacturing sector activities that can guarantee energy supply and increase job opportunities. Therefore, renewable energy sources contribute significantly to economic growth.

The IRF test provides an overview of the response of a variable to shocks caused by other variables over a long period of time (Wicaksono et al., 2023). Figure 2 shows the results of the positive correlation between REC movements and Economic Growth in Indonesia during the first period. However, in the second to fourth periods, shocks to Economic Growth gave a negative response, as shown by the decline in Figure 2. The positive response then occurred in the fifth to tenth periods, although it decreased in the eighth to tenth periods. This is in contrast to NREC, which always gives a negative correlation and decreases in the fifth to tenth periods.

Figure 2 of the IRF in the second stage shows the change in response to Economic Growth. The presence of control variables included in the data test yielded different results for the NREC response, showing a change in response from positive to negative. It can be seen in Figure 2 that the NREC responded positively to Economic Growth and experienced an increase in the fifth to tenth period.

Data from the government shows that the percentage of renewable energy mix in 2021 is 11%, and will increase by 23% in 2025 and is predicted to increase by 31% in 2050 (Tambunan et al., 2020). Highlighting the importance of renewable energy in economic growth, there is a need to expand and update policies related to investment in renewable energy in Indonesia (Amri, 2017). The accuracy of this analysis depends on the current and future uses of renewable energy in Indonesia. If the use of renewable energy increases from year to year, the predictions of this study will have a stronger influence on the Economic Growth index.

CONCLUSIONS AND RECOMMENDATIONS

This study aims to evaluate the causal relationship between renewable energy (REC) and non-renewable energy (NREC) on economic growth in Indonesia by including control variables such as Foreign Direct Investment (FDI), Poverty, Education, and Unemployment. The analysis methods used include the Johansen cointegration test, Granger causality test, and VECM model to measure the long-term and short-term relationships between these variables.

The results show that REC has a significant and positive relationship with Indonesia's GDP in both the short and long term. The use of renewable energy contributes to improved economic growth, while non-renewable energy also shows a positive impact but with greater dependence on specific contexts. Renewable energy consumption not only improves energy efficiency, but also contributes to economic growth through increased technology transfer and better distribution of resources. Meanwhile, non-renewable energy drives economic growth because energy sources still dominate energy consumption in Indonesia and many other developing countries. Non-renewable energies, such as petroleum, coal, and natural gas, have well-established infrastructures, are more efficient in producing large amounts of energy, and support economic sectors such as manufacturing and transportation that rely heavily on fossil fuel-based energy.

The implications of this study show that the development of renewable energy must be prioritized to achieve sustainable economic growth and reduce dependence on fossil fuels. However, this study has limitations, such as data that are limited to a certain period and potential for external variables that are not observed. Policy recommendations include increased investment in renewable energy and the development of policies that support energy transition to strengthen positive impacts on economic growth.

In general, this study confirms that renewable energy has great potential to improve economic growth in Indonesia. Although non-renewable energy still plays an important role in today's economy, the transition to renewable energy not only supports economic growth, but also contributes to environmental sustainability. Policies that support the development of and investment in renewable energy are strongly encouraged to maximize economic and environmental benefits, while technical and price challenges associated with the energy transition must be addressed to ensure optimal outcomes.

ADVANCED RESEARCH

This study still has limitations, so future researchers interested in discussing the relationship between economic growth and energy consumption can expand the research by adding variable indices such as non-renewable energy consumption other than gas to reveal the overall short-term and long-term relationship of energy consumption to economic growth. Also, future research can expand the period and multiply the country as the population is used.

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