Unlocking Renewable Energy Potential: The Nexus Between Financial Inclusion and Renewable Energy in Indonesia

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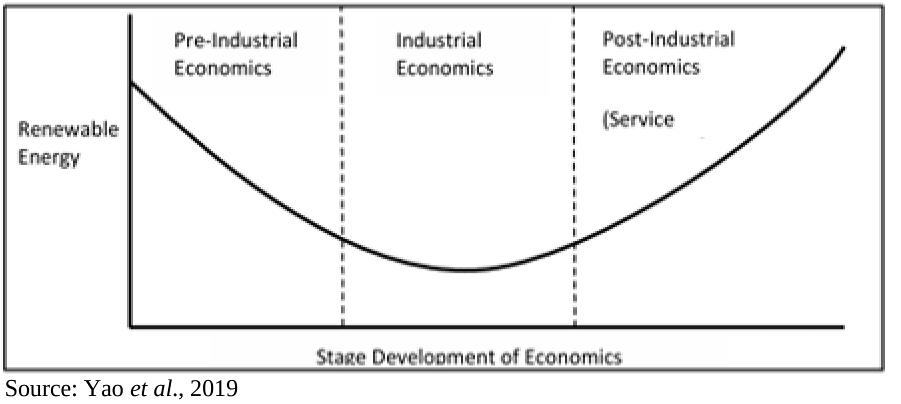
Abstract. Indonesia has pledged to achieve net-zero emissions in 2060. The energy transition can be achieved through financial inclusion. Based on the Environmental Kuznets Curve (EKC) theory, financial inclusion can be a catalyst in reducing environmental impacts if a country has reached the EKC turning point. This study investigates the impact of financial inclusion on the consumption of renewable energy in Indonesia. The data used in this study will be the percentage of renewable energy consumption and the financial inclusion index from the International Monetary Fund 2004 to 2021. Additionally, economic growth and the number of internet users are included as control variables. This study utilizes the Error Correction Model and finds that financial inclusion and internet usage have a negative significant effect on the percentage of renewable energy consumption in the long run. Based on these findings, it can be concluded that according to EKC theory, Indonesia is still in an early stage of development, where increasing financial inclusion and technology still have a negative impact on the environment. Policymakers are encouraged to develop targeted financial inclusion strategies to enhance environmental sustainability. Green finance and green investment are critical solutions to support Indonesia's energy transition.
Keyword: Climate Change, Error Correction Model, Financial Inclusion, Investment, Renewable Energy.

1. Introduction

Climate change has become a global issue that needs to be addressed immediately in almost every part of the world [1]. Climate change refers to long-term changes in temperature and weather patterns. Climate change occurs naturally, but since the 1800s, climate change has been caused by human activities, primarily due to the burning of fossil fuels [2]. Climate change is a significant challenge for the environmental sustainability of a country. In recent decades, the importance of environmental sustainability has continued to increase due to the growing awareness of the risks posed by climate change among entrepreneurs, businesses, and policymakers [3]. Environmental sustainability is crucial in economic development because when environmental degradation and climate change occur, economic growth will slow down and cause infrastructure losses in a country. However, it cannot be denied that economic growth also harms the environment. There are several studies use the Environmental Kuznets Curve (EKC) to try understand how economic growth and environmental pollution are related [4].

The relationship between economic growth and environmental degradation can be explained by the Environmental Kuznets Curve (EKC) hypothesis, which has an inverted U-shaped relationship [5]

However, the EKC theory does not explicitly explain the relationship between economic growth and renewable energy. Yao et al. (2019) proposed a hypothesis called the renewable energy environmental Kuznets curve (RKC), which describes a U-shaped relationship between economic growth and renewable energy as shown in figure 1, detailing the stages of economic structural changes that occur starting from the pre-industrial era. In the pre-industrial era, economic growth will affect the renewable energy consumption. The shift in economic activities from pre-industrial to industrial has influenced the decrease in renewable energy consumption, as many companies strive to increase their productivity. Next, when the economy reaches the post-industrial stage, there is a gradual increase in renewable energy consumption [6]. So, finding a balance between economic growth and environmental sustainability becomes very important because if left unchecked, it will impact the depletion of natural resources.

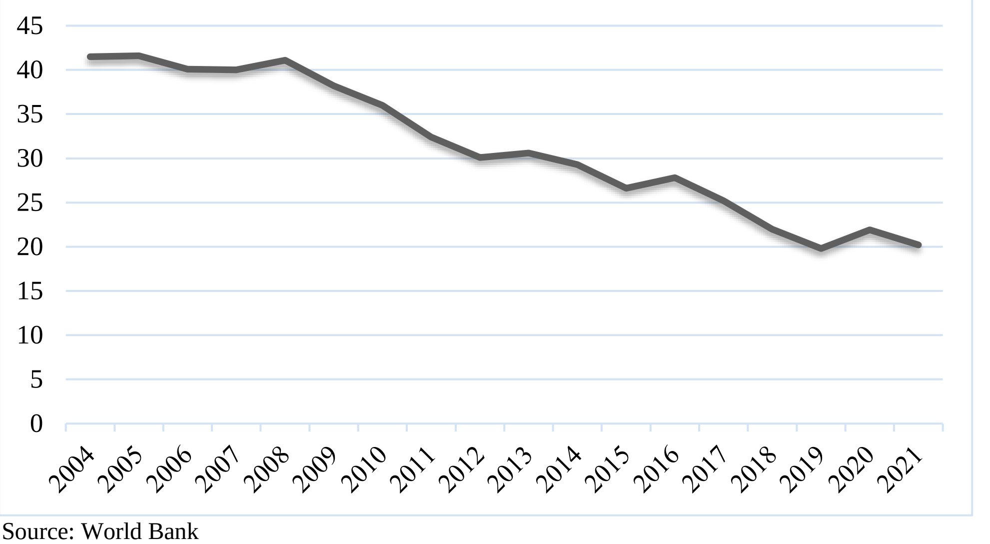


Source: Yao *et al.*, 2019

Figure 1. Renewable Energy Environmental Kuznets Curve

Indonesia, as a nation with a vast variety of ecosystems, ranks among the countries significantly impacted by climate change. The consumption of non-renewable energy in Indonesia remains relatively high, according to the BP Statistical Review of World Energy (2022) non-renewable energy accounted for 88.86 percent of Indonesia's energy use in 2021. The significant consumption of non-renewable energy in Indonesia risks depleting key resources such as petroleum, natural gas, and coal, which are finite and may eventually run out if current usage trends continue. This ongoing reliance on fossil fuels poses challenges for sustainable energy security and highlights the urgency for accelerating the transition to renewable energy sources to prevent resource exhaustion in the future. The high consumption of non-renewable energy in Indonesia is also evidenced by the decreasing percentage of renewable energy consumption in Indonesia from 2004 to 2021, as shown in figure 2.

The decreasing consumption of renewable energy in Indonesia will result in environmental damage. The consumption of renewable energy can be influenced, among other things, by the use of financial services. The use of financial services that enhance financial inclusion can promote environmental sustainability by enabling more efficient and environmentally friendly resource management practices and transactions [3]. Financial inclusion is crucial for the collaborative reduction of pollutants and carbon emissions. Financial inclusion is a process that ensures ease of access, availability, and use of the formal financial system for all members of the economy in a country [8]. Financial inclusion contributes to emission reduction, resource conservation, and sustainable development. Financial services have the potential to significantly lower carbon emissions in poor nations. Based on research by Usman, Makhdum, and Kousar [9] in a country with the highest level of financial inclusion, the more it will attract foreign direct investment, which will ultimately reduce environmental damage caused by climate change. However, research by Omri [10] found that financial inclusion actually reduces the consumption of renewable energy. This is because in countries with high financial inclusion, industrialization actually increases, leading to environmental degradation.



Source: World Bank

Figure 2. Percentage of Consumption Renewable Energy in Indonesia From 2004 to 2021

Until now, the relationship between renewable energy and financial inclusion remains a controversial issue and is not yet fully agreed upon. Based on previous research, it is still uncertain whether financial inclusion increases renewable energy consumption, has no impact, or even slows down renewable energy consumption. Therefore, in this study, financial inclusion is examined to see if it increases renewable energy consumption in Indonesia using a time series method from 2004 to 2021. In this study, the variable of the percentage of renewable energy consumption will be used, along with the financial inclusion index measured using Sarma [8] approach, which involves the formation of a financial inclusion index based on three dimensions: the dimension penetration, the availability services, and the usage of banking services.

2. Research Method

2.1. Renewable Energy

Renewable energy is energy that can be utilized sustainably and sourced from nature. In line with the definition according to the International Energy Agency (IEA), renewable energy is energy sourced from nature that can be used continuously [11]. Renewable energy can also be defined as environmentally friendly energy, meaning it does not pollute the environment and does not contribute to climate change and global warming. This is because the energy obtained from natural processes such as sunlight, water, bioenergy, geothermal, wind, etc., is naturally available from the sustainable climate energy flow [12].

2.2. Investment Renewable Energy

Investment in renewable energy is part of green investment, which leads to an increase in capital dedicated to the development of renewable energy with the hope of reducing environmental pollution [27]. Investment in renewable energy can also be defined as investing capital in energy projects sourced from nature and that can be continuously renewed [29]. Investment in renewable energy has an impact on renewable energy consumption. When investment in renewable energy increases, it will drive an increase in renewable energy consumption, simultaneously supporting green economic growth and energy efficiency [28].

2.3. Financial Inclusion

Financial inclusion as a process that ensure ease of access, availability, and use of the formal financial system for all members of the economy [8]. Financial inclusion provides easy access to various quality and affordable financial products and services for everyone around the world [13]. The goal of financial inclusion is to eliminate barriers and address the inability of certain groups in society and individuals, including the poor and less privileged, to access and use financial services [14].

This study measured financial inclusion variables using the index and following the method developed by Sarma [8]. This method incorporated three dimensions namely banking penetration, availability, and usage. The process of constructing Financial Inclusion Index (FII) started with determining the upper (M_i) and lower limits (m_i) for each dimension. In this study, m_i was set to zero (0) and M_i was determined for each dimension. Furthermore, banking penetration dimension for the number of deposit accounts in commercial banks was 2,500. The availability dimension for the number of commercial bank branch offices was 60 and the number of ATMs was 120 while banking usage aspect for the ratio of the volume of loans and deposits was 300. Subsequently, weights were applied to calculate the index of each dimension. The weight for the first dimension was 1 while the second and third signified 0.5. The next step was to calculate the index value of each dimension with the formula.

$$d_i = w_i \frac{A_i - m_i}{M_i - m_i} \tag{1}$$

where d_i represented the index of the i-th dimension, w_i signified weight for the i-th dimension ($0 \leq w_i < 1$), A_i denoted indicator value of the i-th dimension, m_i suggested the lower limit of the i-th dimension value, and M_i showed the upper limit of the i-th dimension value.

Equation (1) produced dimensional index value range $0 \leq d_i \leq w_i$. In a three-dimensional space, point $X = (d_1, d_2, d_3)$ represented a country's financial inclusion achievement. The point $O = (0,0,0)$ showed the worst condition while point $W = (w_1, w_2, w_3)$ signified the ideal point with the highest achievement in all dimensions. The next step included calculating X_1 (the normalized Euclidean distance between points X and O) and X_2 (inverse normalized Euclidean distance between points X and W) using the following equations

$$X_1 = \frac{\sqrt{d_1^2 + d_2^2 + d_3^2}}{\sqrt{w_1^2 + w_2^2 + w_3^2}} \tag{2}$$

$$X_2 = 1 - \frac{\sqrt{(w_1 - d_1)^2 + (w_2 - d_2)^2 + (w_3 - d_3)^2}}{\sqrt{w_1^2 + w_2^2 + w_3^2}} \tag{3}$$

FII was obtained by averaging X_1 and X_2 with the following formula

$$IFI = \frac{1}{2}[X_1 + X_2] \tag{4}$$

Equation (4) produced FII value ranging from 0 to 1 where a higher value showed greater financial inclusion. In the grouping of FII values, there were three categories namely (1) high FII having a value of more than 0.6, (2) medium FII having a value in the range of 0.3 to 0.6, and (3) low FII showing a value of less than 0.3 [8].

The development of the financial sector, which in this study is represented by financial inclusion, has a complex relationship with renewable energy consumption. On the one hand, financial inclusion can increase the consumption of renewable energy and can reduce environmental degradation by promoting financing for more environmentally friendly production technologies [30]. Financial inclusion can also reduce production and energy costs and can accelerate economic growth, which in turn improves environmental quality [31]. However, on the other hand, financial inclusion can increase environmental degradation and be one of the factors driving increased carbon emissions. This is illustrated by the ease with which companies can access finance, such as obtaining low-cost loan capital, which leads to the expansion of production scale and subsequently increases environmental damage [30]. Additionally, the ease with which companies can access finance also encourages consumers to purchase energy-intensive durable goods, leading to environmental problems.

2.4. Economic Growth

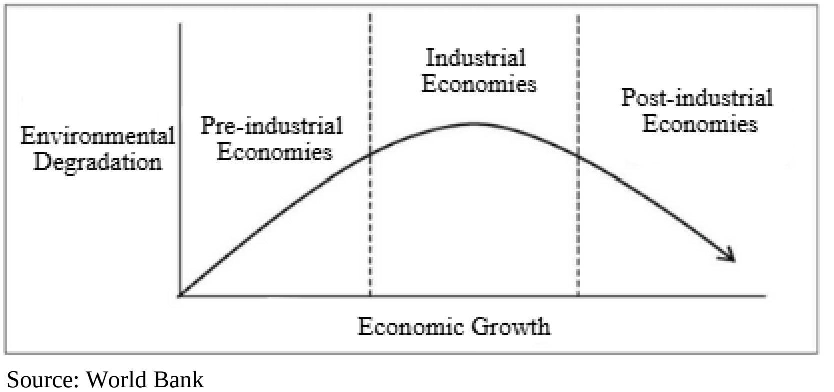
Economic growth is one of the indicators used in analyzing the economic development of a country. Economic growth can be used as a criterion for the success of a country's development. The higher of economic growth of a country, the more successful the development in that country. Economic growth can be defined as the development of the production of goods and services in a specific economic area over a certain period compared to the previous year [15]

2.5. Internet User

Internet, or interconnected network, is a global communication network system that connects computers and computer networks worldwide. Internet facilities provide access to a variety of communication services including web pages, email, news, entertainment, and data. Internet access facilities are not assumed to be limited to computers; they can also be accessed through mobile phones, PDAs, electronic gaming devices, etc. [16].

2.6. Environmental Kuznets Curve (EKC)

Environmental Kuznets Curve (EKC) is a curve often used to describe the relationship between economic growth and environmental quality. In the EKC, there is an inverted U-shaped relationship between the economy and the environment.



Source: World Bank

Figure 3. Environmental Kuznets Curve

In figure 3, it is shown that when there is a change in economic growth, the economic structure also undergoes a change. The inverted U-shaped relationship explains that the stages of economic growth go through several phases of structural economic change. The stages of economic structure change that occur are from pre-industrial, industrial, to post-industrial. Environmental degradation increases when there is an economic growth spurt due to the shift in economic structure from pre-industrial to industrial. This occurs because, during the industrialization phase, society focuses solely on maximizing work to earn income, leading to an increase in pollution. Next, at the stage of economic structure transition from industry to post-industry, environmental degradation experiences a decline. This is because the production processes that are taking place have started to consider their impact on the environment [17].

2.7. Error Correction Model (ECM)

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The initial stage in the ECM method is to conduct a stationarity test on all variables using the Augmented Dickey-Fuller (ADF) unit root test with trend and intercept at the level. If there is a difference in stationarity at the level, then the next step is to conduct an integration degree test to determine at which differencing degree the data will be stationary. The next step is to form the long-term equation by regressing the variables at the level using the OLS method. Here is the long-term equation in this study.

$$REC_t = \beta_0 + \beta_1 FII_t + \beta_2 EG_t + \beta_3 ICT_t + u_t \quad (5)$$

The next step is to determine the long-term equilibrium among the variables being studied using the cointegration test. In this study, the cointegration test uses the residual values from the long-term model (u_t) known as the Error Correction Term (ECT). The ECT variable that is stationary at the level indicates the presence of cointegration. The presence of cointegration indicates that there is a long-term equilibrium relationship in the formed model. Value of ECT must be significant and negative. This aims to adjust from short-term imbalances towards long-term equilibrium. The short-term regression equation is as follows.

$$\Delta REC_t = \beta_0 + \beta_1 \Delta FII_t + \beta_2 \Delta EG_t + \beta_3 \Delta ICT_t + \gamma u_{t-1} + \varepsilon_t \quad (6)$$

Short-term modeling on ECM can be considered valid if the speed of adjustment (γ) has a value within the range of 0 to 1 and has a negative sign and significantly affects the dependent variable. This means that the model is valid in correcting short-term imbalances towards long-term equilibrium. After obtaining the ECM model, the next step is to test the significance of the model, namely the coefficient of determination using the Adjusted r-square value, followed by the simultaneous test (F-test) which aims to determine the effect of independent variables on the dependent variable simultaneously, and the partial-t test which aims to see the effect of each independent variable on the dependent variable.

2.8. Data and Variables

In this study, line graphs are used to provide an overview of the dimensions composing the financial inclusion index and an overview of the financial inclusion index and other variables affecting the percentage of renewable energy consumption in Indonesia from 2004 to 2021. In this study, the Error Correction Model (ECM) method is also used to determine the impact of financial inclusion and other variables on the percentage of renewable energy consumption in Indonesia from 2004 to 2021. For the variables used in this study, please refer to table 1.

Table 1. Summary variables

Data	Notation	Unit	Source
Dependent variable			
Renewable energy consumption	REC	Percent	World Bank
Financial inclusion complication indicators			
Banking penetration dimension			
Number of deposit accounts with commercial banks per 1,000 adults	DCA	Proportion	Financial Acces Survey IMF
Availability of banking services dimension			
Number of ATMs per 100,000 adults	ATMA	Unit	Financial Acces Survey IMF
Number of commercial bank branches per 100,000 adults	BANKA	Unit	Financial Acces Survey IMF
Dimension of banking utilization			

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Data	Notation	Unit	Source
Dependent variable			
Ratio of loans and deposits at commercial banks to GDP	CDEPOSIT	%GDP	Financial Acces Survey IMF
Independent variable			
Financial inclusion index	FII	Score	-
Economic growth	EG	Percent	World Bank
Percent of internet users	ICT	Percent	World Bank
Investation Renewable Energy	IRE	Juta USD (2021)	IRENA

3. Result and Discussion

3.1. Financial Inclusion Index

The financial inclusion index created in this study is based on [8] and consists of three financial dimensions: banking penetration, banking service availability, and banking usage. Based on the graph in figure 4, it can be seen that the three dimensions experienced different trends from 2004-2021. The penetration dimension experienced the most significant increase compared to other dimensions. This dimension experienced a significant increase in 2010 and continues to increase until 2021. This illustrates that there is an increase in the adoption of financial services by the community. The availability dimension shows a relatively increasing trend throughout the period although it tends to stagnate after 2015. Meanwhile, the usage dimension shows a relatively increasing and stable trend throughout the period. The increase in access and penetration did not create a significant spike in the utilization of financial services.

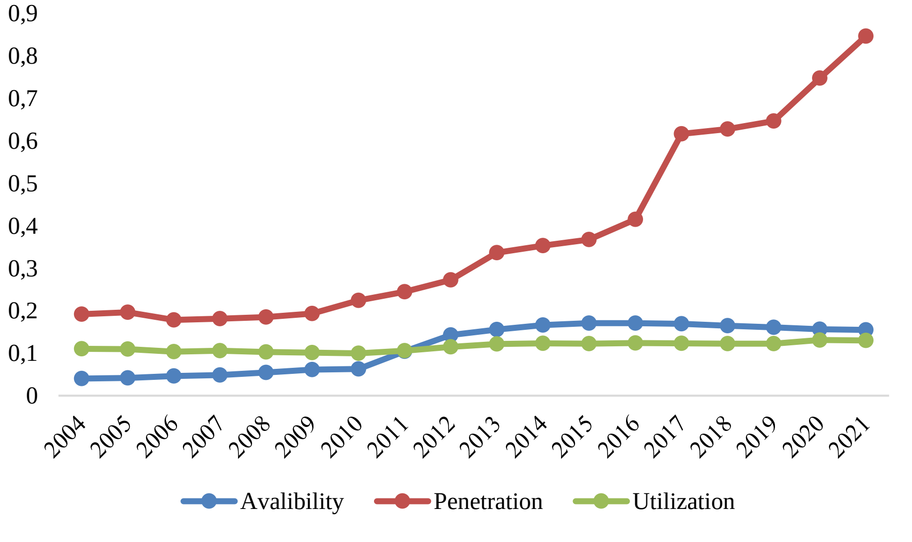

Figure 4. Dimensions That Make Up the Financial Inclusion Index 2004-2021

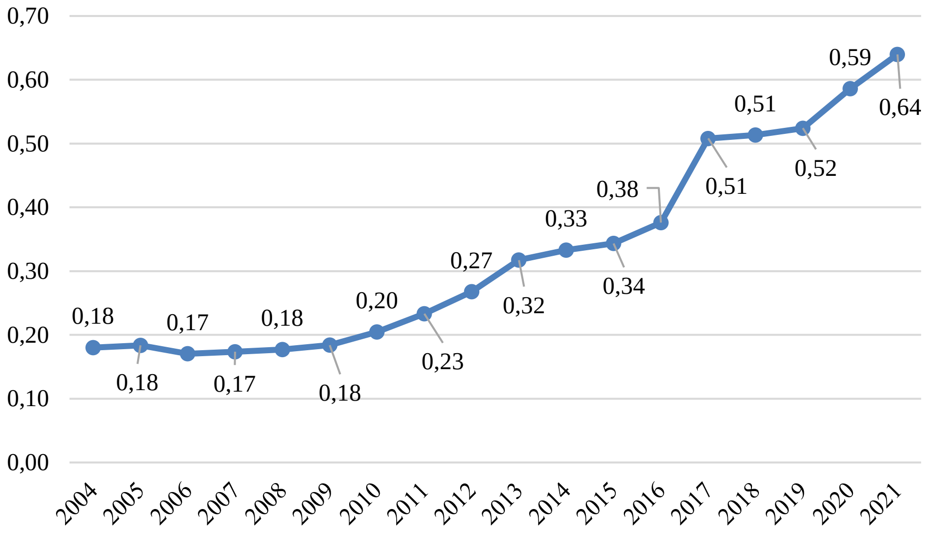

Figure 5. Financial Inclusion Index in Indonesia From 2004 to 2021

The next step is the calculation of the X_1 value, which is the normalized Euclidean distance between point X and reference point O, and the X_2 value, which is the inverse of the normalized Euclidean distance between points X and O. Subsequently, the financial inclusion index is calculated by taking the simple average of the X_1 and X_2 values. Graph in figure 5 illustrates the development of the financial inclusion index from 2004 to 2021. Based on the graph, it can be seen that the financial inclusion index almost always increases every year with a peak in 2021 of 0,64. This shows that public access to financial services has become easier in Indonesia.

3.2. Descriptive Statistics and Correlation Matrix

The descriptive statistics of the entire data are represented in table 2. Based on table 2, it can be seen that the variable percentage of renewable energy consumption has an average value of 31.36 percent with a standard deviation of 7.81 percent. The minimum value of 19.8 percent and a maximum of 41.6 percent indicate a fairly large range. The Financial Inclusion Index (FII) shows an average of 0.3286 with a standard deviation of 0.1599, illustrating the high variation in values ranging from 0.1704 to 0.6398. The Ln (ICT) variable, which represents the natural logarithm of the number of internet users, has an average value of 2.6748 with a standard deviation of 0.9528. The maximum value of 4.1288 and the minimum value of 0.9556 reflect the rapid growth of digitization in Indonesia.

Table 2. Descriptive Statistics

Variable	Meaning	Mean	Standard Deviation	Minimum	Maximum
REC	Renewable energy consumption	31.3556	7.81	19.8	41.6
FII	Financial inclusion index	0.3286	0.1599	0.17038	0.6398
Ln (ICT)	Logaritma natural internet users	2.6748	0.9528	0.9556	4.1288
IRE	Investation renewable energy	22.12	33.6838	0.06	113.82
EG	Economic growth	4.9449	1.8715	-2.0655	6.3450

The Investment in Renewable Energy (IRE) variable shows an average value of 22.12 with a very high standard deviation of 33.68. The maximum of 113.82 and the minimum value of 0.06 indicates an extreme level of volatility in renewable energy investment over the study period. Meanwhile, Economic Growth (EG) recorded an average of 4.94 percent with a standard deviation of 1.87%. The range of values between 2.07 percent to 6.35 percent shows significant economic fluctuations, especially in 2008 when the global financial crisis occurred and in 2020 when the COVID-19 pandemic occurred.

3.3. Unit Root Test

The unit root feature of the data is checked before performing regression analysis. According to the ADF, the unit root test is used to accomplish this job.

Table 3. Unit root tests.

Variables	Augmented Dickey Fuller (ADF)			
	Levels		First Difference	
	T-statistics	P-value	T-statistics	P-value
REC	-0.23508	0.9163	-3.47084*	0.0247
FII	1.63044	0.9989	-3.29487*	0.0328
LN_ICT	-1.24456	0.6276	-6.45337*	0.0001
EG	-2.9906	0.0560	-6.628743*	0.0001
IRE	-1.2384	0.1887	-9.417799*	0.0000

Note: *): significant at 5 percent significance level

Table 3 are shown the coefficient estimates for both unit root tests. The results of the ADF test indicate the percentage of renewable energy consumption, FII, IRE, LN_ICT, and EG are variables that are not stationary at the first level. Based on table 3, it can be seen that all variables used in the study are not stationary at the level. This can be seen from the p-value which is greater than 0.05. Then, the stationarity test is continued at the first difference and it is found that all variables are stationary at first difference. Therefore, we can proceed with cointegration analysis to see the short-term and long-term relationship.

3.4. Estimation Results

The long-term equation is obtained by regressing the independent variables with all dependent variables when they are not stationary at level. Based on table 4, it is known that at a significance level of 0.05, it can be concluded that the financial inclusion index variable and Ln_ICT have a negative significant effect on the percentage of renewable energy consumption.

Table 4. Long Run Approximation.

Variables	Coefficient	P-value
IFI	-18.57513*	0.0409
LN_ICT	-5.05786*	0.0020
IRE	-0.01643	0.2703
EG	-0.26349	0.3805

Note: *) : significant at 5 percent significance level

The next step involves conducting a cointegration test by examining whether the residuals from the long-run model are stationary at level. The cointegrated regression of Y_t and X_t indicates that short-term shocks to variable and X_t will lead $Y_t$back to its long-term relationship value, even though in some moments the regression equation exits the long-term relationship (equilibrium). Testing the cointegration of long-term residuals is done with the ADF test and can be seen in table 5. Table 5 shows that the residuals are stationary at the level indicated by a p-value of less than 0.05. This means that it is evident that there is a cointegration relationship in the variables in the model or the variables have equilibrium in the long run.

Short-term equation is done by regressing the variables on the first difference and adding lags of the long-term residuals. In the short run there is a difference between what is desired and what actually

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happens, so an adjustment is needed. The short-term model includes the adjustment to correct the short-term imbalance towards the long-term. Based on the results in table 6, only the IRE variable has a significant negative effect on renewable energy consumption in the short term.

Table 5. Cointegration Test in Level

Variables	P-value	Decision
ECT	0.0489*	Stationer

Note: *) : significant at 5 percent significance level

The Error Correction Model (ECM) estimation results show that the Error Correction Term (ECT) variable has a coefficient of -0.549 and is significant at the 5 percent significance level. This coefficient indicates that about 54.9 percent of the long-term deviation between the percentage of renewable energy consumption and the independent variables can be corrected in one period. This means that the variables in the model are appropriate in correcting short-term imbalances towards long-term equilibrium with an adjustment of 54.9 percent in the first year and the rest occurs in subsequent years. This finding reinforces the existence of a cointegrative relationship between the percentage of renewable energy consumption and the independent variables used. The negative value of the ECT is in line with theoretical expectations and confirms the existence of a self-correcting mechanism in the short-term dynamics of the percentage of renewable energy consumption in Indonesia during the period 2004-2021.

Table 6. Short Run Approximation.

Variables	Coefficient	P-value
C	-1.479804	0.0782
D(IFI)	-3.744865	0.7358
D(Ln_ICT)	1.452523	0.6443
D(IRE)	-0.016814*	0.0400
D(EG)	-0.224080	0.1806
ECT(-1)	-0.549832*	0.0498

Note: *) : significant at 5 percent significance level

Based on the theoretical standpoint, financial inclusion could both negatively and positively influence the environment. This empirical finding is in accordance with the U-shaped RKC hypothesis which states that in the early stages of development it will result in a decrease in the percentage of renewable energy consumption, but after reaching a certain level it will increase the percentage of renewable energy consumption. This study shows that in the long run, an increase in the financial inclusion index actually decreases the percentage of renewable energy consumption in Indonesia, contradicting earlier positive effect evidence reported by Usman *et al.* [9]. This indicates that Indonesia is still at an early stage of development as greater access to finance is still used for fossil-based energy consumption. As financial inclusion increases, so does economic activity and increases demand for non-renewable energy sources ([18];[4]). In the context of Tunisia, the relationship between financial development and renewable energy consumption during 1984–2017 was investigated using both symmetric and asymmetric ARDL approaches. The analysis indicated that financial development significantly and adversely affects renewable energy consumption [19].

Amin *et al.* [20] investigated the relationship between financial development and renewable energy consumption using panel data from 1990 to 2018 in a few South Asian countries. They discovered that, over the long run, financial development has a negative effect on the propensity to consume renewable energy by 0.07 percent to 0.15 percent. The use of renewable energy is negatively impacted by financial development, according to research by Prempeh *et al.* [21]. This implies that expanding access to financial services may actually make it more difficult for the area to employ renewable energy. Green finance, which aims for sustainable energy and environmental quality, has recently gained international attention. Increased financial inclusion makes money available to households and businesses, which leads to the purchase of energy-intensive products and higher energy consumption. Green financing focuses on this by paying attention to the funds that will be channeled into environmentally friendly activities. The finding that financial inclusion negatively affects renewable energy consumption implies that advancements in the financial sector may not directly support the shift toward cleaner energy sources [22].

The results also show that in the long run, increasing in the number of internet users has a significant negative effect on the percentage of renewable energy consumption. This is in line with the rebound effect theory, where technological advances improve energy efficiency but ultimately trigger higher consumption [23]. In Indonesia, internet use is still dependent on fossil energy, so technological improvements have not yet had a positive impact on the energy transition. ICT production, use and disposal can directly increase energy demand and exacerbate environmental damage [24]. This shows that Indonesia is still in the early stages of the EKC where technological growth has yet to contribute to environmental sustainability.

Renewable energy investment (IRE) variable has no significant effect in the long run. While in the short term, the IRE variable has a significant negative effect on the percentage of renewable energy consumption. Similar to the previous variable, this indicates that investment is still at an early stage so that the impact actually reduces the percentage of renewable energy consumption in the short term. The development of renewable energy power plants such as geothermal and wind, can increase fossil energy consumption. This is due to the material requirements of the energy-intensive manufacturing sector [25]. Research conducted by Li *et al.* [26] revealed that although investment in green energy can reduce carbon emissions in the long term, in the short term, increased investment in renewable energy can lead to increased carbon emissions, mainly due to the initial dependence on fossil energy sources during the transition.

4. Conclusion

Based on the results of the empirical research that has been conducted, it can be concluded that based on EKC theory, Indonesia is still at an early stage of development, where the increase in financial inclusion and technology still has a negative impact on the environment. It also shows that the financial system in Indonesia still has some shortcomings in terms of green finance. The negative effect of financial inclusion on the percentage of renewable energy consumption indicates that the development of the financial sector in Indonesia has not been effective in driving the energy transition. Policymakers need to pay attention to where funds will be channeled. In addition, it is essential for policymakers to formulate targeted financial inclusion strategies that promote both economic growth and environmental sustainability. Financial inclusion initiatives should prioritize support for enterprises and entrepreneurs involved in clean energy innovation. Green finance emerges as a key instrument for financial regulators to enhance awareness among stakeholders within financial institutions. Accordingly, relevant authorities are encouraged to strengthen education and capacity-building efforts to foster greater institutional support for renewable energy development and utilization.

During the initial phase of internet expansion, the deployment and use of internet-related infrastructure have been associated with a decline in the percentage of renewable energy consumption. The findings of this study indicate that greater internet penetration significantly reduces renewable energy usage in developing nations. This outcome is attributed to the insufficient alignment between the rapid growth of information and communication technologies (ICT) and the availability of renewable energy sources. Consequently, internet proliferation has led to increased reliance on conventional energy. These results are consistent with the Environmental Kuznets Curve (EKC) hypothesis, suggesting that Indonesia remains in an early development stage where technological advancement correlates with reduced renewable energy shares. To address this issue, the government should promote the integration of digital infrastructure with renewable energy systems, for instance by offering incentives for data centers powered by clean energy and for energy storage initiatives. A comprehensive national roadmap is necessary to synchronize the digital transformation with the expansion of renewable energy capacity, particularly in regions with high internet usage.

This study also reveals that, in the short term, investment in renewable energy has a significantly negative impact on the percentage of renewable energy consumption. Increased investment tends to stimulate overall production activity, which may inadvertently lead to higher fossil fuel usage. As a developing nation, Indonesia continues to face challenges such as limited access to advanced technology, insufficient capital, and inadequate infrastructure, all of which hinder a smooth energy transition. Therefore, it is crucial for policymakers to emphasize the expansion of renewable energy investments and implement strategic policies that offer specific incentives to accelerate this process. Such measures are essential to restructure the national energy mix and lessen dependency on fossil-based sources. Government support can be strengthened through fiscal incentives, tax relief mechanisms, and green financing programs aimed at promoting investment in the clean energy sector.

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References

[1] K. Abbass, M. Z. Qasim, H. Song, M. Murshed, M. H., and I. Younis, "A review of the global climate change impacts, adaptation, and sustainable mitigation measures," *Environ. Sci. Pollut. Res.*, vol. 29, no. 28, pp. 42539–42559, 2022, doi: https://doi.org/10.1007/s11356-022-19718-6.

[2] U. Nations, "What Is Climate Change?," 2024, [Online]. Available: https://www.un.org/en/climatechange/what-is-climate-change.

[3] M. A. A. Ansari, M. Sajid, S. N. Khan, V. M. Antohi, C. Fortea, and M. L. Zlati, "Unveiling the effect of renewable energy and financial inclusion towards sustainable environment: Does interaction of digital finance and institutional quality matter?," *Sustain. Futur.*, vol. 7, no. March, p. 100196, 2024, doi: 10.1016/j.sftr.2024.100196.

[4] R. Said and A. O. Acheampong, "Achieving Carbon-Neutrality in MENA Countries: Does Financial Inclusion Matter?," *J. Environ. Dev.*, vol. 33, no. 2, pp. 312–336, 2024, doi: 10.1177/10704965231225780.

[5] P. . Stern, "Individual and household interactions with energy systems: Toward integrated understanding," *Energy Res. Soc. Sci.*, vol. 1, pp. 41–48, 2014.

[6] S. Yao, S. Zhang, and X. (Zhang, "Renewable energy, carbon emission and economic growth: A revised environmental Kuznets Curve perspective.," *J. Clean. Prod.*, no. 235, pp. 1338–1352., 2019, [Online]. Available: https://doi.org/10.1016/j.jclepro.2019.07.069

[7] BP Statistical Review of World Energy, "BP Statistical Review of World Energy 2022," 2021. [Online]. Available: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf

[8] M. Sarma, "Index of Financial Inclusion - Ameasure of Financial Sector Inclusiveness," 2012.

[9] M. Usman, M. S. A. Makhdum, and R. Kousar, "Does financial inclusion, renewable and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries," *Sustain. Cities Soc.*, no. 65, p. 102590, 2021, [Online]. Available: https://doi.org/10.1016/j.scs.2020.102590

[10] A. Omri, S. Daly, C. Rault, and A. Chaibi, "Financial development, environmental quality, trade and economic growth: What causes what in MENA countries," *Energy Econ.*, vol. 48, pp. 242–252, 2015, doi: 10.1016/j.eneco.2015.01.008.

[11] D. Prinz, "Contributor and Victim - Indonesia's Role in Global Climate Change with Special Reference to Kalimantan.," *J. Sains &Teknologi Lingkung.*, vol. 1, no. 2, pp. 138–153, 2009, [Online]. Available: https://doi.org/10.20885/jstl.vol1.iss2.art5

[12] Neha and J. Rambeer, "Renewable Energy Sources: A Review," *J. Phys. Conf. Ser.*, vol. 1979, no. 1, 2021, [Online]. Available: https://doi.org/10.1088/1742-6596/1979/1/012023

[13] A. Patwardhan, "Financial Inclusion in the Digital Age.," *Handb. Blockchain, Digit. Financ. Inclusion, Vol. 1 Cryptocurrency, FinTech, Insur. Regul.*, vol. 1st ed., V, 2018, [Online]. Available: https://doi.org/10.1016/B978-0-12-810441-5.00004-X

[14] S. R. Chakravarty and R. Pal, "Financial inclusion in India: An axiomatic approach.," *J. Policy Model.*, vol. 5, no. 35, pp. 813–837, 2013, [Online]. Available: https://doi.org/10.1016/j.jpolmod.2012.12.007

[15] Hendra Andy Mulia Panjaitan, Sri Mulatsih, and Wiwiek Rindayati, "Analisis Dampak Pembangunan Infrastruktur Terhadap Pertumbuhan Ekonomi Inklusif Provinsi Sumatera Utara," *J. Ekon. Dan Kebijak. Pembang.*, vol. 8, no. 1, pp. 43–61, 2020, doi: 10.29244/jekp.v8i1.29898.

[16] BPS, "Statistik Telekomunikasi Indonesia 2022," 2022.

[17] N. M. Katsoulakos, L.-M. Misthos, I. G. Doulos, and V. S. Kotsios, "Environment and Development. In Environment and Development.," *Elsevier B.V.*, 2016, [Online]. Available: https://doi.org/10.1016/B978-0-444-62733-9.00008-3

[18] R. Tao, C.-W. Su, B. Naqvi, and S. K. A. Rizvi, "Can Fintech development pave the way for a transition towards low-

carbon economy: a global perspective," *Technol. Forecast. Soc. Change*, vol. 174, p. 121278, 2022, [Online]. Available: https://doi.org/10.1016/j.techfore.2021.121278

[19] H. Saadaoui and N. Chtourou, "Do Institutional Quality, Financial Development, and Economic Growth Improve Renewable Energy Transition? Some Evidence from Tunisia," *J. Knowl. Econ.*, vol. 14, pp. 2927–2958, 2023, [Online]. Available: https://doi.org/10.1007/s13132-022-00999-8

[20] M. A.-A. Parvez, E. H. Katha, M. K. Shaeba, and M. S. Hossain, "Fintech and inclusive growth : Evidence from 25 Asian developing countries," Tokyo, 1358, 2023. [Online]. Available: https://doi.org/10.56506/QMHR3332

[21] K. B. Prempeh, C. Kyeremeh, F. K. Danso, and S. A. Yeboah, "Exploring the impact of financial development on renewable energy consumption within the renewable energy-environmental Kuznets curve framework in Sub-Saharan Africa," *Int. J. Renew. Energy Dev.*, vol. 13, no. 5, pp. 884–897, 2024, doi: 10.61435/ijred.2024.60339.

[22] P. A. Kwakwa, "What determines renewable energy consumption? Startling evidence from Ghana," *Int. J. Energy Sect. Manag.*, vol. 15, no. 1, pp. 101–118, 2021, doi: 10.1108/IJESM-12-2019-0019.

[23] T. T. Thanh, L. T. Ha, H. P. Dung, and T. T. L. Huong, *Impacts of digitalization on energy security: evidence from European countries*, vol. 25, no. 10. Springer Netherlands, 2023. doi: 10.1007/s10668-022-02545-7.

[24] S. Lange, J. Pohl, and T. Santarius, "Digitalization and energy consumption. Does ICT reduce energy demand?," *Ecol. Econ.*, vol. 176, p. 106760, 2020, [Online]. Available: https://doi.org/10.1016/j.ecolecon.2020.106760

[25] D. Hartono, S. H. Hastuti, A. Halimatussadiah, A. Saraswati, A. F. Mita, and V. Indriani, "Comparing the impacts of fossil and renewable energy investments in Indonesia: A simple general equilibrium analysis," *Heliyon*, vol. 6, no. 6, p. e04120, 2020, doi: 10.1016/j.heliyon.2020.e04120.

[26] Y. Li *et al.*, "Green energy investment, renewable energy consumption, and carbon neutrality in China," *Front. Environ. Sci.*, vol. 10, no. August, pp. 1–10, 2022, doi: 10.3389/fenvs.2022.960795.

[27] Eyraud, L., Clements, B., & Wane, A. (2013). Green investment: Trends and determinants. *Energy Policy*, *60*, 852–865. https://doi.org/10.1016/j.enpol.2013.04.039

[28] Listiani Sukmawati, M., & Febriana Hariyani, H. (2023). Dampak Investasi Energi Terbarukan Terhadap Emisi Karbon Di Negara Oecd. *Journal of Financial Economics*, *60*(3), 1–13

[29] Ningsih, M. M. (2024). Pembiayaan Ramah Lingkungan Terhadap Sub Sektor Energi Baru Dan Terbarukan Di Indonesia. *Jurnal Energi Baru Dan Terbarukan*, *5*(2), 12–29. https://doi.org/10.14710/jebt.2024.22805

[30] Charfeddine, L., & Ben Khediri, K. (2016). Financial development and environmental quality in UAE: Cointegration with structural breaks. *Renewable and Sustainable Energy Reviews*, *55*, 1322–1335. https://doi.org/10.1016/j.rser.2015.07.059

[30] Jiang, C., & Ma, X. (2019). The Impact of Financial Development on Carbon Emissions: A Global Perspective. *Sustainability*, *11*(19), 5241. https://doi.org/10.21098/jcli.v3i3.249