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STEPPING INTO ISLAMIC ENVIRONMENTAL SUSTAINABILITY IN INDONESIA: DEVELOPING A FRAMEWORK FOR BALANCING ECONOMIC GROWTH, RENEWABLE ENERGY, AND CARBON EMISSIONS

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Abstrak

Ancaman perubahan iklim dan degradasi lingkungan yang semakin meningkat telah memperkuat minat dalam memahami peran energi terbarukan dalam mendorong pertumbuhan ekonomi sambil mengurangi emisi karbon dioksida (CO_2). Studi ini menganalisis hubungan timbal balik antara risiko politik, risiko keuangan, inovasi teknologi, konsumsi energi terbarukan, polusi lingkungan, dan emisi CO_2 dalam konteks Indonesia. Data sekunder diperoleh dari sumber-sumber terpercaya, termasuk Bloomberg dan World Development Indicators (WDI). Untuk memastikan analisis empiris yang kokoh, studi ini menggunakan analisis Wavelet dan pendekatan Autoregressive Distributed Lag (ARDL) untuk menangkap dinamika jangka pendek dan jangka panjang. Temuan empiris menunjukkan adanya hubungan kointegrasi jangka panjang di antara variabel yang diteliti, menunjukkan bahwa energi terbarukan, kondisi keuangan, dan faktor lingkungan bergerak bersama menuju keseimbangan jangka panjang. Hasil jangka panjang menunjukkan bahwa kondisi keuangan memiliki dampak positif dan secara statistik signifikan terhadap emisi karbon, menyarankan bahwa ekspansi keuangan dapat memperburuk tekanan lingkungan jika tidak sejalan dengan kebijakan berkelanjutan. Temuan ini memberikan implikasi kebijakan yang penting, menyoroti perlunya memperkuat mekanisme keuangan hijau, mendukung investasi energi terbarukan, dan mempromosikan inovasi teknologi bersih untuk mencapai pembangunan ekonomi berkelanjutan. Studi ini memberikan wawasan berharga bagi pembuat kebijakan dalam merancang strategi efektif untuk menyeimbangkan pertumbuhan ekonomi dengan keberlanjutan lingkungan di Indonesia.

Abstract

The growing threat of climate change and environmental degradation has intensified interest in understanding the role of renewable energy in promoting economic growth while reducing carbon dioxide (CO_2) emissions. This study examines the interrelationships among political risk, financial risk, technological innovation, renewable energy consumption, environmental pollution, and CO_2 emissions in the Indonesian context. Secondary data were obtained from reputable sources, including Bloomberg and the World Development Indicators (WDI). To ensure robust empirical analysis, this study employs Wavelet analysis and the Autoregressive Distributed Lag (ARDL) approach to capture both short-run and long-run dynamics. The empirical findings reveal the existence of a long-run cointegrating relationship among the studied variables, indicating that renewable energy, financial conditions, and environmental factors move together toward long-term equilibrium. The long-run results show that financial conditions have a positive and statistically significant impact on carbon emissions, suggesting that financial expansion may intensify environmental pressures if not aligned with sustainable policies. These findings provide important policy implications, highlighting the need to strengthen green finance mechanisms, support renewable energy investments, and promote clean technological innovation to achieve sustainable economic development. The study offers valuable insights for policymakers in designing effective strategies to balance economic growth with environmental sustainability in Indonesia

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INTRODUCTION

The global economy has witnessed substantial expansion and integration in recent times, prompting elevated concerns regarding environmental sustainability (Raihan et al., 2024). This surge has incurred a price, as environmental degradation and resource depletion have emerged as significant hurdles. As economies persist in their growth trajectory, the demand for energy and natural resources has skyrocketed. Consequently, there have been substantial issues in air pollution caused by the industry, and also greenhouse gas emissions, which both contribute to climate change and global warming (Khan et al., 2024). The relentless increase in CO2 emissions, in reality, is predicted to have an impact on the global climatic system and also on facets of society (Sarkar et al., 2020). Hence, the agenda for reducing Carbon emissions and enhancing the quality of the environmental become a worldwide program to ensure sustainable development (Raihan & Said, 2021). The Paris Agreement, which represents a United Nations Framework Convention on Climate Change (UNFCCC), aims to enhance the global commitment to climate change risks reduction within the framework of Sustainable Development Goals. Upon Indonesia's endorsement of the Paris Agreement, it became part of worldwide endeavors to keep global warming well below 2 °C, striving to limit it to 1.5 °C.

The impressive growth of Islamic economy also has responsibilty to cover the issue of environmental sustainability, such us intergarting ESG factors with Islamic screening procedures. It is essential because it strengthens the ethical substance of Islamic equity investment and aligns it more consistently with the higher objectives of Islamic law (*maqasid al-shari'a*). The ultimate aim of Islamic finance is not merely formal compliance, but the realization of socioeconomic justice, poverty alleviation, equitable income distribution, and productive economic development. In this regard, Al—Ghazali famously defined the purpose of sharia as safeguarding religion, life, intellect, progeny, and wealth, implying that Islamic financial practices should actively promote human welfare rather than rely solely on technical legal filters. Consequently, embedding ESG criteria into Islamic equity screening can enhance the capacity of Islamic indices to reflect substantive ethical commitments, addressing critiques that current screening mechanisms resemble "mathematical formalism" rather than genuine moral evaluation.

Indonesia has a strong commitment to diminish the level of GHG emission intensity of GDP by 45% by 2030, compared to its level in 2005, under the Paris Agreement (Raihan et al., 2022). Off course, this encompasses a 35% unconditional foundation and a 10% conditional foundation depending on developed nations' furnishing climate—based financing, such as via green financing, technological transfer, and capacity development. An eminent quandary that arises is how Indonesia can curtail CO_2 emissions, and this quandary may be tackled by scrutinizing the potential repercussions of Indonesia's emission reduction components. Comprehensive comprehension of Indonesia's potential to curtail emissions is increasingly imperative for policymakers to strike a balance between policies intended to mitigate climate change and accomplish sustainable development, and execute both.

From an Islamic perspective, Islamic environmental sustainability is very important to ensure that Islamic economic practice is also in line with shariah point of view. Hence, it also supports the achievement of SDGs. Financial intermediation is not value—neutral; it is expected to serve the *Maqasid al-shari'a* by promoting public welfare (*Maslahah*), preventing harm (*Dharar*), and ensuring justice (*adl*), including intergenerational responsibility as embedded in the concept of khalifah (stewardship). Therefore, the significant positive effect of financial conditions suggests that if financial deepening is

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not guided by ethical and environmental constraints, it may accelerate environmentally harmful production and resource exploitation, contradicting Islamic principles of balance (*mizan*) and the prohibition of corruption and destruction on earth (*Fasad fi al-ard*). In contrast, the significant negative effect of renewable energy provides strong empirical support for Islamic policy instruments such as green sukuk, waqf—based renewable energy projects, and Sharia—compliant sustainable finance frameworks, which can channel capital toward clean energy transitions while maintaining ethical legitimacy. Overall, the findings imply that Islamic finance can play a strategic role in environmental sustainability not merely through compliance—based screening, but through purposeful financial engineering that internalizes environmental responsibility, strengthens climate—oriented investment, and aligns development outcomes with both sustainability goals and Islamic moral economy.

Nevertheless, certain financial and institutional factors may significantly influence clean energy utilization (Wang et al., 2023). The integration of a greater share of green energy into the economy requires sustained financial support from both governments and banking institutions. Financial instability arising from heightened financial risks can hinder investment in clean energy. Moreover, increased financial risk may generate economic volatility that weakens the enforcement of environmental regulations. Additionally, during economic recessions, public and institutional support for environmental sustainability may decline (Xue et al., 2022). Consequently, these conditions can increase the ecological footprint (EF) and ultimately deteriorate environmental quality. However, effective financial risk control and achievement of economic stabilization may be necessary under this framework that supports tough environmental legislation and funds on going environment friendly work. Consequently, this would lead to better climatic conditions and a smaller EF.

Additionally, political risks can influence renewable energy (RE) adoption and environmental footprints (EF) reduction (Wang et al., 2023). Twelve institutional variables measure political risks. The development of green energy technologies and improvement of environmental parameters is closely related to institutions. However, since it involves institutional consideration in formulating and putting into practice policies on energy and environment. Assert that democracy which is a major institutional variable severely lowers down EF (Ahmed et al., 2022). Corruption is an inevitable companion that results in increased pollution caused by the depletion of natural resources through the mining activities for minerals and precious stones that lead to further loss of natural wealth and destruction of the land base. In addition, economic growth comes at a low cost if a country is endowed with strong institutions that make up institutions are important in ensuring success. Therefore, countries may experience higher rates of economic growth with lesser associated environmental problems in the longer—term period (Rizk & Slimane, 2018). Strong institutions curb corruption in the country and this makes it easy to implement hard ecological legislation, which contributes positively to the state of environment. Effective institutes provide more environmental information to the public which increases environmental awareness by the general public and subsequent pressures for good ecological quality. Free of political interference, institutions can implement policies effectively towards improvement of environmental standards and economic growth. On the contrary, less developed countries whose institutions are weak have their administration dysfunctional, corruption, and little environmental controls (Danish & Ulucak, 2020).

Governments and international organizations have highlighted the need for sustainable development and the shift towards a low carbon—based economy in order to

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address these issues (Bekhet & Othman, 2018). The use of technology advancements and increased reliance on renewable energy are considered key drivers towards environmental sustainability and economic growth. Sustainable forestry practices also play a key role in mitigating carbon emissions and protecting ecologies. It is important for economic growth to be balanced with environmental protection in order to achieve sustainable economic development. Implementing sustainable production and consumption practices, developing renewable energy infrastructure, encouraging of Circular Economy principles is required. Apart from this, it is important that developed and developing world, inculcate a culture for sustainable environment. Economies need to practice sustainability and curb use of primary resources so as to reduce environmental degradation. The rightly made environmental policy supported by people's backing can lead to innovations improving the production processes with due regard to environment. Achieving optimal balance between macro−economic growth, full employment and environmental preservation leads to sustainable development (Raihan et al., 2022). Therefore, economic policies that result in sustainable economic development should consider environmental protection and ecosystem preservation.

The significance of this research lies in its ability to address critical gaps in the existing literature and enhance understanding across several intersecting fields, namely environmental policy, economic growth, and sustainable development. Some other research on government interventions in environmental sustainability focuses on developed economies (Adebayo & Odugbesan, 2021; Danish & Ulucak, 2020; Kirikkaleli & Kalmaz, 2020; Xue et al., 2022). Our study shifts the focus to Indonesia, an emerging economy with distinct challenges and opportunities in implementing sustainable policies. This helps fill a geographical research gap by providing insights applicable to other similar economies in Southeast Asia and beyond. While previous studies may have examined isolated aspects of government interventions, such as the impact of specific subsidies or regulations, our research proposes a more holistic approach. By examining a combination of interventions including economic incentives, regulatory measures, and public investments in renewable energy our study offers a more specific understanding of how these policies interact and their collective impact on economic growth and carbon emissions. Additionally, our research also integrates the analysis of financial and political risks, which are often overlooked in conventional environmental economics studies. Understanding how these risks moderate the effectiveness of government policies provides a deeper theoretical and practical insight into the barriers and enablers of sustainable development.

Furthermore, by exploring the relationship between government interventions and sustainability within the Indonesian context, our research could contribute to or challenge theories like the Environmental Kuznets Curve (EKC), which posits that environmental degradation initially increases with economic growth but decreases after reaching a certain income level. Our findings may support, refute or suggest modifications to the EKC in the context of an emerging economy. On top of that, our study employs advanced statistical methods like ARDL and Wavelet analysis, which allows for a more detailed understanding of the short−term and long−term dynamics between economic growth, government policies and environmental outcomes. These methods can reveal how the impacts of policies evolve over time and across different frequencies, offering a richer and more complex picture as compared to standard econometric approaches. What's more, by identifying which types of government interventions are most effective at promoting environmental sustainability without compromising economic growth, our study offers actionable insights for policymakers. These can directly influence policy design and

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implementation, not only within Indonesia but also in other nations with similar economic and environmental profiles.

Our research bridges gaps between finance, public policy, and environmental science, encouraging a multidisciplinary approach to tackling environmental issues. This can foster greater collaboration across academic and professional fields, leading to more integrated solutions to complex problems. Lastly, as global attention increases on sustainable development goals and the Paris Agreement, our research contributes to the global discourse on how countries can balance economic development with environmental sustainability. The insights from our study are particularly timely and relevant, given the urgent need for effective strategies to mitigate climate change. Basically, the importance of our research lies in its potential to fill significant gaps in the literature by providing a comprehensive and empirically grounded analysis of the effectiveness of various government interventions within the specific context of Indonesia. This contributes both to academic theory and practical policy−making, advancing understanding and offering guidelines which are crucial for sustainable development. Based on the research background, the objective of this study is to determine the impact of economic growth, renewable energy, forest conservation, and environmental degradation on carbon emission.

LITERATURE REVIEW

Environmental Kuznets Curve Theory

The Environmental Kuznets Curve (EKC) theory provides a fundamental framework for understanding how environmental degradation and economic growth are linked. According to the EKC hypothesis, which was first put forward by Grossman and Krueger (1991) and then formalized by Panayotou (1993), there is an inverse U−shaped relationship between environmental degradation and per capita income. This theory states that the industrialization and economic growth of a country initially lead to an increase in environmental destruction, but that once a certain income threshold is reached, additional economic development leads to a better environmental quality. This turning point is attributed to technological developments, increased environmental awareness and the advent of clean energy sources.

EKC theory has been frequently applied in studies that examine the dynamics between economic growth and environmental sustainability, particularly in the context of CO_2 emissions and energy consumption. Studies by Dinda (2004) and Stern (2004), for example, have shown that the EKC framework is particularly relevant for developing countries, where industrialization and urbanization often lead to increased CO_2 emissions and scarcity of resources. However, the applicability of EKC theory varies by country and environmental indicators, with some studies suggesting that the link may not apply to all pollutants or in all economic contexts (Kaika & Zervas, 2013). In Indonesia, a rapidly developing economy that is heavily dependent on fossil fuels, EKC theory provides a valuable perspective for analyzing trade−offs between economic growth and environmental sustainability. Indonesia's economic expansion in recent decades has been accompanied by rising CO_2 emissions and deforestation, raising concerns about the long−term ecological consequences of its development. However, the country's recent efforts to switch to renewable energy sources and implement measures to reduce CO_2 emissions suggest the potential to balance economic growth and environmental sustainability in line with the EKC framework.

EKC theory also underscores the crucial role of the introduction of renewable energy in reaching the turning point where economic growth leads to an improvement in the environment. When nations invest in cleaner technologies and turn away from fossil fuels,

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the negative environmental effects of economic activity can be mitigated. For Indonesia, this means that integrating renewable energy into its energy mix is essential not only to reduce CO_2 emissions, but also to ensure sustainable economic growth in the long term. While EKC theory provides a useful framework, it is not without limitations. Critics argue that the theory assumes a linear course of economic development and improvements in environmental conditions, which may not take into account the complexity of global supply chains, resource dependency, and the unequal distribution of environmental costs (Arrow et al., 1995). Furthermore, the theory does not explicitly address the role of institutional frameworks, political interventions, and social factors in shaping the relationship between economic growth and environmental consequences. These restrictions underscore the need for complementary theories and frameworks to fully grasp the dynamics of environmental sustainability in Indonesia.

The EKC theory serves as a fundamental grand theory for understanding the interplay between economic growth, renewable energy and CO_2 emissions in Indonesia. By identifying the conditions under which economic development can lead to an improvement in the environment, the EKC framework provides a basis for developing policies and strategies that balance economic growth with environmental sustainability. However, its application must be contextualized with Indonesia's unique economic, social, and environmental realities and supplemented with additional theoretical perspectives to account for Indonesia's inherent limits.

Previous Studies

It's no secret that Indonesia's predicament on CO_2 emission has been a global issue recently due to being an 'emerging country' (Bekhet & Othman, 2018). A major source of CO_2 emission in Indonesia results from the use of these non−renewal resources as the main energy provider. Such a dependence on fossil fuels for generation of electricity also affects the long−term availability of such resources. The emissions of carbon dioxide and other greenhouse gases like nitrous oxides enter in the air environment (Raihan, 2023). Additionally, deforestation as well as the conversion of forests and grasslands contribute immensely towards CO_2 emissions in Indonesia (Raihan et al., 2022). Most notably, the rising consumer use of energy, unhealthy dependence on fossils, poor waste disposal techniques as well as growth in the industrial and motor manufacturing industries contribute significantly to increased carbon emissions in Indonesia.

Some empirical studies have revealed the relationship between economic growth and CO_2 emissions in different factors, approaches, and countries. Employing ARDL, FMOL, and DOLS (Odugbesan & Adebayo, 2020) proved that there is a significant impact of economic growth on carbon emission in Nigeria. The same result was also evidenced in Mexico, in which, according to a study from (Adebayo, 2020), there is a positive effect of economic growth on carbon emissions. Teng et al. (2021) used data spanning from 1985−2018 and discovered through an ARDL model that economic development boosts CO_2 emissions, particularly among OCED countries. The same result also documented by Kirikkaleli and Kalmaz (2020), in case of Turkey, and Liu and Bae (2018), for China's case. Alternative energy sources are taking up a leading role in ensuring both biodiversity conservation and economic expansion into the future as our planet realizes that we need sustainable solutions now (Adebayo et al., 2020). For example, it is possible to increase economic growth and address environmental problems by using renewable energy technologies such as wind or solar power. Investments in renewable energy would foster economic growth through creation of employment opportunities in the renewable energy sector.

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Transition to renewable energy sources may help produce a cleaner and greener atmosphere that could be aimed in addressing the global warming problem and pollution (Li et al., 2024). This is in addition to increasing a country's energy security through diversification that comes with including renewable energy in the national grid (Berradia et al., 2023). The diversification helps in reducing vulnerabilities of price fluctuations as well as supply interruptions linked to fossil fuels. In addition, renewable energy promotes economic development as it creates jobs and investment in this sector (Ahmed et al., 2022). Further, it mitigates degradation of the environment by minimizing dependency on non−renewable products and reducing carbon dioxide levels, thus enhancing a cleaner and more habitable atmosphere.

Numerous renewable energy supplies are available in Indonesia, including landfill fumes, rice husk, hydropower, forest leftovers, oil palm leftovers, mill leftovers, solar heat, and solar photovoltaic (Sarkar et al., 2020). In 2001, the Indonesian government labelled renewable energy as the nation's fifth fuel source as part of their endeavors to ensure a long−term energy supply and meet the mounting demand. Since then, efforts have commenced to establish the legal, regulatory, and financial framework required to achieve the set objectives for renewable energy generation (Mohd Chachuli et al., 2021).

Several previous studies conducted by researchers have also shown that increasing the use of renewable energy can lead to a reduction in CO_2 emissions. Liu et al. (2021) in his study found that the application of renewable energy will reduce CO_2 emissions in China. Meanwhile, (Baek, 2016) revealed that in the case of America, the use of renewable energy was also able to significantly reduce CO_2 emissions in the United States. Meanwhile, the results of research conducted by Dogan and Seker (2016) also proved that increasing renewable energy consumption can effectively reduce carbon emissions in leading renewable energy countries. Zoundi (2017) found on the contrary, that the use of renewable energy actually had a negative impact on CO_2 emissions for 25 African countries. Aeknarajindawat et al. (2020) documented that CO_2 emissions were mitigated by increased renewable energy consumption in Indonesia. Bekhet and Othman (2018) analyzed Malaysian data and concluded that renewable energy can improve environmental quality.

Financial risk, on the other hand, can trigger financial instability, which can ultimately affect investments related to the environment, and this will lead to a decline in environmental quality. Although significant, this aspect is largely ignored in the existing literature. However, research conducted by Zhao et al. (2021) found that reducing financial hazards can actually strengthen CO_2 levels in OECD countries. Political hazards also turn out to be important as factors that influence carbon emissions. This is because political hazards are evaluated based on institutional variables, that play a role in shaping energy and environmental policies and their practical implementation, both of which affect the production, utilization, and quality of green energy. According to Ahmad et al. (2021) , institutional quality (INSQ) not only reduces carbon emissions but also functions as a moderator in supporting complex goods that reduce carbon emissions in developing countries. Zallй (2019) suggests that increasing INSQ helps accelerate the use of natural resources to achieve better economic growth. Increasing renewable energy consumption is a valuable strategy to prevent environmental pollution. However, INSQ can either amplify environmental pollution or help control it. Previous studies on the relationship between INSQ and environmental pollution have presented conflicting findings. Furthermore, the relationship between environmental degradation and financial hazards has been largely ignored. Thus, this study uncovers the relationship between economic growth, renewable energy, forest conservation, environmental degradation, and carbon

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emissions in Indonesia to inform better energy and environmental policies. Based on the Environmental Kuznets Curve theory and the previous research, therefore, the hypotheses development on this research:

H1: Economic growth has an impact on carbon emissions.

H2: Renewable energy use and forest conservation have an impact on carbon emissions.

H3: Forest conservation and environmental degradation have an impact on carbon emissions.

METHOD

Autoregressive Distributed Lag (ARDL)

The objective of this study is to examine the impact of economic growth (EG), renewable energy (RE), forest conservation (FC), and environmental degradation (ED) on carbon emissions (CE). ARDL techniques are used to investigate this relationship. The study also makes use of the wavelet coherence technique to look into the causality and correlation between variables. Before looking at any connections between the time series, it is crucial to understand the stationarity property of the series. The Phillips—Perron test and the Augmented Dickey−Fuller test are used in the study to investigate these variables' stationarity. The ARDL bound test is used in a subsequent stage of this analysis to examine the long−term cointegration between CE and EG, RE, FC, and ED. The ability to jointly analyze short−term and long−term relationships with different integration orders is one of the benefits of the ARDL approach. G. It doesn't work with I (2) variables, but it does when the series is either I (0), I (1), or both I (0) and I (1).

Equation 1 draws the economic function and econometric model, respectively:

$$CE_t = \vartheta_0 + \vartheta_1 EG + \vartheta_2 RE + \vartheta_3 FC + \vartheta_4 ED + \epsilon_t \quad (1)$$

The ARDL framework for the model is depicted in Eq. 2 as follows:

$$\Delta CE_t = \vartheta_0 + \sum_{i=1}^{t} \vartheta_1 \Delta CE_{t-1} + \sum_{i=1}^{t} \vartheta_2 \Delta EG_{t-1} + \sum_{i=1}^{t} \vartheta_3 \Delta RE_{t-1} + \sum_{i=1}^{t} \vartheta_4 \Delta FC_{t-1} + \sum_{i=1}^{t} \vartheta_5 \Delta ED_{t-1} + \beta_1 \Delta CE_{t-1} + \beta_2 \Delta EG_{t-1} + \beta_3 \Delta RE_{t-1} + \beta_4 \Delta FC_{t-1} + \beta_5 \Delta ED_{t-1} + \epsilon_t \quad (2)$$

Where the first difference is denoted by Δ and the coefficients of the long−run variables are denoted by P1−6. Once the long−run linkages are ascertained, the short−run linkages are examined using the error correction model (ECM) created by Engle and Granger (2015) to analyze the short−run coefficients and the error correction term (ECT). This is done by incorporating the ECM into the ARDL framework for the following model:

$$\Delta CE_t = \vartheta_0 + \sum_{i=1}^{t} \vartheta_1 \Delta EG_{t-1} + \sum_{i=1}^{t} \vartheta_2 \Delta RE_{t-1} + \sum_{i=1}^{t} \vartheta_3 \Delta FC_{t-1} + \sum_{i=1}^{t} \vartheta_4 \Delta ED_{t-1} + \rho ECT_{t-1} + \epsilon_{t-1} \quad (3)$$

Where the speed of adjustment is depicted by Δ and the error correction term is depicted by ECTt−1. The objective of this study is to examine the impact of economic growth (EG), renewable energy (RE), forest conservation (FC), and environmental degradation (ED) on carbon emissions (CE).

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RESULTS AND DISCUSSIONS

Result

Table 1. Descriptive Statistics

Variable	Mean	SD	Min	Max
CE	1,878	0,388	1,302	2,643
EG	3,696	1,520	−2,894	4,950
RE	33,727	8,724	19,8	45,6
FC	51,655	2,080	47,722	53,944
ED	9,119	1,386	7,204	12,312

Table 1. presents the descriptive statistics of five key variables: CE, EG, RE, FC, and ED. The mean value of CE is 1.878, with a relatively low standard deviation of 0.388, suggesting that the data for CE are tightly clustered around the mean and exhibit low variability. The minimum and maximum values (1.302 and 2.643) indicate a moderate range, implying stable behavior of this variable across observations. The EG variable shows a mean of 3.696 with a higher standard deviation of 1.520, indicating greater dispersion compared to CE. The wide range from −2.894 to 4.950 suggests substantial fluctuation, including periods of contraction (negative values) and expansion, which reflects volatility in economic growth.

The RE variable has a relatively high mean of 33.727 and a standard deviation of 8.724, showing moderate variability. The observed range (19.8 to 45.6) suggests that renewable energy utilization is relatively elevated but varies noticeably across periods or entities. For FC, the mean is 51.655 and the standard deviation is only 2.080, indicating strong stability and low variation. The narrow range (47.722 to 53.944) further supports that financial conditions remain relatively consistent throughout the observations. Finally, ED shows a mean of 9.119 with a standard deviation of 1.386, indicating moderate dispersion. The minimum and maximum values (7.204 and 12.312) suggest some variation, but not extreme, implying that education−related indicators are relatively stable. Overall, the results indicate that CE and FC are the most stable variables, while EG exhibits the highest volatility, and RE and ED demonstrate moderate variability. This pattern suggests that economic growth is the most dynamic factor in the model, while financial conditions and carbon emissions remain relatively stable over the observed period.

The correlation matrix indicates a very strong correlation between renewable energy (RE) and carbon emissions (CE). This pattern is not unusual in annual macroeconomic time−series data, where variables often share common long−run trends. Therefore, the correlation may reflect trend−driven comovement rather than problematic multicollinearity. To ensure model reliability, additional multicollinearity and stability diagnostics were conducted, and the ARDL specification remained stable and statistically valid. As below:

Table 2. Correlation Matrix

Variable	CE	EG	RE	FC	ED
CE	1				
EG	−0,1525	1			
RE	−0,9814	0,2102	1		
FC	−0,9237	0,3284	0,9722	1	
ED	0,9677	−0,0932	−0,9696	−0,9237	1

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Table 2. presents the pairwise correlations among the variables CE, EG, RE, FC, and ED, revealing several strong and statistically meaningful relationships. CE (Carbon Emissions) shows a strong negative correlation with RE (−0.9814) and FC (−0.9237), indicating that higher levels of renewable energy utilization and stronger financial conditions are associated with lower carbon emissions. Conversely, CE has a very strong positive correlation with ED (0.9677), suggesting that higher energy demand or education−related development is closely linked with increased carbon emissions. The correlation between CE and EG (−0.1525) is weak, indicating a very limited linear relationship.

Economic Growth (EG) shows weak correlations with most variables. Its relationship with CE (−0.1525) and ED (−0.0932) is weakly negative, while it has low to moderate positive correlations with RE (0.2102) and FC (0.3284). These results suggest that economic growth is relatively independent of the other variables in this model, or that its effects are more complex and not purely linear. Renewable Energy (RE) is very strongly and positively correlated with FC (0.9722), implying that improvements in financial conditions are closely associated with higher renewable energy adoption. At the same time, RE is strongly negatively correlated with CE (−0.9814) and ED (−0.9696), which indicates that increased renewable energy use is linked to reduced carbon emissions and lower energy demand/education−related pressures. Forest conservation (FC) exhibit a very strong negative relationship with CE (−0.9237) and ED (−0.9237), and a very strong positive relationship with RE (0.9722). This pattern suggests that stronger financial systems may facilitate renewable energy investments and contribute to lower emissions and energy−related pressures. Energy Degradation (ED) shows a very strong positive correlation with CE (0.9677) and strong negative correlations with RE (−0.9696) and FC (−0.9237), indicating that increases in ED are associated with higher emissions but lower renewable energy use and weaker forest conservation.

Table 3. Stationarity Test

Variable	Level	First Difference
CE	0,4948	0,0317
EG	0,0055	0,0000
RE	0,9423	0,0014
FC	0,9999	0,0160
ED	0,9922	0,0003

The table reports probability (p−value) results for unit root tests at level and first difference for the variables CE, EG, RE, FC, and ED. Using the common 5% significance level ($\alpha = 0.05$), variables are considered stationary when the p−value is less than 0.05. At the level form, only EG ($p = 0.0055$) is stationary, indicating that it does not contain a unit root in its original form. In contrast, CE (0.4948), RE (0.9423), FC (0.9999), and ED (0.9922) all have p−values much greater than 0.05, meaning they are non−stationary at level. After taking the first difference, all variables become stationary. The p−values drop significantly for CE (0.0317), EG (0.0000), RE (0.0014), FC (0.0160), and ED (0.0003), all of which are below the 5% threshold. This indicates that these variables are integrated of order one, I(1).

Table 4. Cointegration Test (Bound Test)

F-Bounds Test	Value	Significant Value	I(0)	I(1)
F−Statistics	5,695	10%	2,525	3,560
K	4	5%	3,058	4,223
		1%	4,280	5,840

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The ARDL Bounds Test is used to examine the presence of a long−run (cointegrating) relationship among the variables. The decision rule is based on comparing the F−statistic with the lower bound (I(0)) and upper bound (I(1)) critical values. In this study, the calculated F−statistic is 5.695. This value is higher than the upper bound critical values (I(1)) at the 10% level (3.560) and the 5% level (4.223). Additionally, the F−statistic also exceeds the 1% lower bound (4.280) but is slightly below the 1% upper bound (5.840). The optimal lag length for the ARDL model was selected using the Akaike Information Criterion (AIC) within EViews. Based on the selection results, the study employs the ARDL(1,2,1,2,2), where 1 is the lag order for CE, and 2, 1, 2, and 2 are the lag orders for EG, RE, FC, and ED, respectively.

Table 5. Results of ARDL Estimation (Long−Run)

Variable	Coefficient	SE	t	Prob.
CE(−1)	−0,078	0,160	−0,491	0.630
ED	0,295	0,444	0,665	0.515
EG	0,007	0,012	0,626	0.540
FC	0,055	0,002	27,825	0.000
RE	−0,020	0,006	−3,675	0.002
c	0,023	0,024	0,967	0.347
F-statistic		*171,930*		
Prob(F-statistic)		*0,000*		
R-squared		*0,981*		

The empirical results reveal a strong overall model performance, as indicated by a high R−squared value (0.981) and a highly significant F−statistic ($p < 0.01$). This suggests that the selected macroeconomic and environmental variables jointly provide a strong explanation of variations in the dependent variable. Similar findings have been reported in previous studies, which argue that integrated financial and energy−related indicators tend to produce highly explanatory models when environmental variables are included (Apergis & Payne, 2014; Shahbaz et al., 2013). The robustness of the model further confirms the relevance of financial and renewable energy factors in environmental−economic frameworks.

The results show that financial conditions (FC) have a strong and statistically significant positive effect on the dependent variable in the long−run. This finding is consistent with the literature suggesting that financial development can accelerate economic and industrial activities, which in turn influence environmental outcomes (Sadorsky, 2010; Shahbaz et al., 2016). Strong financial systems tend to ease access to credit and capital, encouraging investments and production expansion, which may intensify resource use and emissions if not accompanied by green regulations. Thus, the positive and significant role of FC reflects the growth of financial environment nexus highlighted in earlier empirical work.

Conversely, renewable energy (RE) exhibits a significant negative effect, indicating its role in reducing environmental pressure or emissions in the long−run. This result strongly aligns with previous findings that renewable energy adoption contributes to environmental sustainability by lowering carbon emissions and dependence on fossil fuels (Farhani & Shahbaz, 2014; Shahbaz et al., 2016). The negative coefficient supports the argument that clean energy transitions are effective policy tools for mitigating environmental degradation, especially in emerging and developing economies.

On the other hand, variables such as economic growth (EG) and education/energy demand (ED) are found to be statistically insignificant in the long−run. This is consistent with studies emphasizing that the environmental impact of economic growth often manifests in the long run rather than immediately (Dinda, 2004; Grossman & Krueger,

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1991). Moreover, the insignificance of the lagged dependent variable CE(−1) suggests weak long−run persistence, indicating that current changes are more responsive to contemporaneous financial and energy factors than past environmental conditions.

Finally, these findings have important policy implications. The strong influence of financial conditions and renewable energy implies that policymakers should focus on green finance mechanisms and renewable energy investments to ensure sustainable development. This supports the growing consensus in the literature that environmental sustainability can be strengthened through environmentally oriented financial systems and clean energy policies (Ahmad et al. 2021). At the same time, the insignificance of some macroeconomic variables highlights the importance of long−run structural reforms and cointegration−based policy frameworks rather than long−term growth−driven interventions.

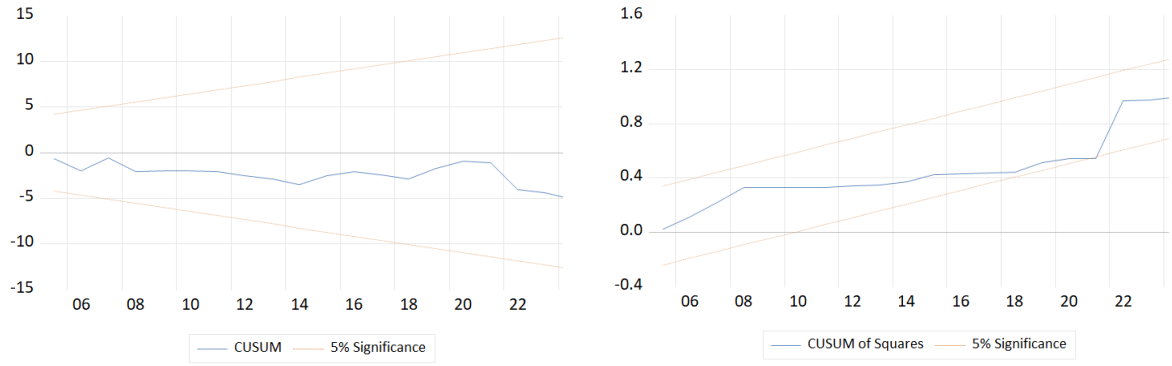

Figure 1. Model Stability Test

CONCLUSION

This study provides robust empirical evidence of the dynamic relationship between financial conditions, renewable energy, and environmental outcomes. The results from the ARDL bounds testing confirm the existence of a long−run cointegrating relationship among the variables, indicating that they move together toward a stable long−term equilibrium. The overall model exhibits strong explanatory power, as reflected by the high R−squared value and highly significant F−statistic, confirming the reliability of the estimated framework. The short−run estimations reveal that financial conditions exert a positive and statistically significant effect, suggesting that financial development can intensify economic and production activities, which may increase environmental pressure if not guided by sustainable policies. In contrast, renewable energy consumption demonstrates a significant negative effect, confirming its critical role in reducing environmental degradation and supporting environmental sustainability. These findings are consistent with the environmental economics literature that emphasizes the importance of green energy transitions and sustainable finance.

Meanwhile, economic growth, education/energy demand, and the lagged environmental variable appear to be statistically insignificant in the short run, indicating that their impacts are more structural and long−term in nature. This suggests that environmental outcomes are more sensitive to financial and energy−related shocks in the short run, while broader macroeconomic and social factors tend to influence environmental quality over longer horizons. Overall, the study highlights the importance of aligning financial system development with environmental sustainability goals. Policies that promote green finance instruments, renewable energy investment, and environmentally responsible credit allocation are essential to ensure that financial

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progress does not come at the cost of environmental degradation. These findings offer valuable policy insights for governments and stakeholders seeking to balance economic development with climate and environmental targets. Future research is recommended to incorporate broader variables, longer time horizons, and country−specific institutional factors to further validate and extend these findings. Additional methodological approaches, such as structural break tests and nonlinear models, could also provide deeper insights into the complex dynamics between finance, energy, and the environment. Islam is also very much concerned about the issue of the environment. Hence, some policy must be developed in line with the development of the Islamic economy.

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Declarations

Author Contribution Statement

All authors have a contribution in conceptualization, data collection, analysis, and other element of the study.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Declaration of Interests Statement

There is no conflict of Interest

AI Use Statement

[1] During the preparation of this manuscript, the authors used **ChatGPT version 5.2** solely for **language editing (grammar, clarity, and readability)**. The authors **reviewed, revised, and verified** the final text and **take full responsibility** for the content of the publication.

[2] The authors used ChatGPT version 5.2 to support initial drafting and/or structuring of parts of the manuscript. All AI−assisted outputs were critically reviewed, rewritten where necessary, and verified against the study data and cited sources. The authors remain fully accountable for the accuracy, originality, and integrity of the manuscript.

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