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Role of Renewable Energy and Financial Innovation in Environmental Protection: Empirical Evidence from UAE and Saudi Arabia

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Abstract: In modern times, many countries are committed to achieving climate neutrality and environmental sustainability. Without financial innovation and green financing, switching to clean energy, reducing carbon emissions, and mitigating climate change will be impossible. The main objective of this study is to obtain zero carbon to protect the environment. To analyze sustainable development pathways, this research examines the impact of renewable energy and financial innovation on the environmental protection of the United Arab Emirates and Saudi Arabia from 2010 to 2021. The use of renewable energy sources, pollution, and climate change are all significant elements. Innovation can help slow the rate of global warming by lowering carbon emissions and expanding the usage of renewable energy sources. Green financing and innovation are powerful tools for environmental safety and deterioration. The acceleration of renewable energy growth is the primary driver of sustainable development. Moreover, green financing balances the innovation–energy–environment–climate nexus. Similarly, green finance amplifies the positive effects of innovation on using renewable energy. This study provides valuable insights into achieving zero carbon by producing renewable energy sources and modern green technology. Further research is possible by adding more dimensions of renewable energy sources.

Keywords: renewable energy; financial innovation; environmental protection; green finance

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1. Introduction

Climate change and environmental protection are both significantly impacted by energy use. An urgent global problem is increased CO_2 emissions [1]. World statistics show that carbon emissions from fossil fuels increased threefold, from 11,190 billion tons in 1965 to 34,356 billion tons in 2019 [2]. By 2030, energy-related carbon dioxide emissions are expected to rise by 40–100%, according to the Intergovernmental Panel on Climate Change (IPCC) [3]. Numerous countries actively seek strategies to lower greenhouse gas emissions due to environmental degradation and climate change severity. The "quick zero" and "net zero" schemes, which can ease the transition to a new energy system, protect the environment, and lessen the climate change catastrophe, have grown to depend heavily on renewable energy (RE) [4,5]. Both fossil fuels and RE must be considered when assessing how energy use affects carbon emissions and climate change [6,7]. As a result, the new viewpoint on RE enables the construction of an established theoretical framework for the energy–environment–climate nexus.

The Financial Revolution is critical in boosting energy efficiency and lowering energy intensity [8]. Innovative technology can provide high-value products with less energy utilization. A low-carbon economy is propelled internally by energy innovation, which optimizes how energy is used and hastens the uptake of RE sources [9]. Financial innovation

(FI) can help control pollution and energy conservation [10,11]. Both large-scale, low-cost use of RE and low-carbon traditional fossil energy use heavily depends on technological development. A well-planned program to minimize CO_2 emissions is also necessary to tackle global warming and other environmental issues [12]. Investments in technical innovation are required as an effective method to achieve long-term gains in energy security [13], mitigate carbon emissions, and reduce climate change concerns [14,15].

The industry of renewable energy is expanding at a rapid rate, which is causing the country's financial sector to undergo significant change. In spite of the fact that research into renewable energy has been increasingly popular over the past several years, fundamental questions still need to be answered. The term "renewable energy" refers to monetary contributions that are made to support projects that safeguard the environment. There are three primary groups that fall under the umbrella of renewable energy, and they are green asset financing, lending, and investments [2].

Green bonds and technology may make it easier for firms to finance environmentally friendly operations, encourage them to reallocate resources, and help them reach the goal of sustainable development [16,17]. In conclusion, innovation and green financing now play a more prominent role in environmental protection. Innovation frequently faces financial restrictions due to technical uncertainty and long R&D cycles [18]. Green economic development might offer enough funding for green technological innovation projects, improving energy efficiency, cutting carbon emissions, and reducing the likelihood of extreme weather events. Technological innovation can encourage an ecologically friendly industrial scale, leading to environmental sustainability, with the proper financial support [19,20]. Hence, this study examines the impact of RE sources and FI on the ecological protection of the UAE and Saudi Arabia from 2010 to 2022.

The following are some of this study's contributions: the study variables' relationship has not been studied before in the context of the UAE and Saudi Arabia; hence, this is a contextual and empirical contribution. Second, the energy–environment–climate models used in our research include FI and green financing as defining elements. Lastly, from the viewpoint of an energy structure shift, this study emphasizes the RE and FI, which may help clarify the effects of RE on reducing carbon emissions, mitigating climate change, and protecting the environment. Understanding how RE contributes to environmental protection and how much it reduces CO_2 emissions is crucial, given the rapid economic growth of these countries. The findings of this analysis will be essential for decision makers and government representatives to take the necessary actions to meet the increased demand for energy while also reducing the increase in CO_2 emissions brought on by intense economic activity. The scheme of the study is as follows; the next section discusses the literature review. After that, the research methodology is presented, and the results are given. In the end, the conclusion and policy implications of the study are described.

2. Literature Review

Energy use, pollution, and global warming are intricately linked [21,22]. Greenhouse gas emissions are a significant contributor to global warming, which in turn is caused by the extensive use of fossil fuels to power the world's economy, polluting the environment [23,24]. People everywhere are banding together to research and develop RE sources to ensure our planet's and economy's long-term health. By investing in RE, Wang et al. [25] mentioned that the 10 most recently industrialized nations between 1990 and 2019 might reduce their ecological footprint and avoid climate-related catastrophes. Udeagha and Ngepah [26] applied the mean group estimator to study CO_2 emissions from RE sources. If RE and natural gas consumption grow by 1% in BRICS countries, CO_2 emissions will decrease by 0.211 and 0.1641%, respectively. Between 1990 and 2008, Budiman et al. [27] studied greenhouse gas emissions from sustainable energy generation in 16 European Union member states and found that it was about half as high as those from fossil fuels.

The goal of renewable energy is to get the private sector involved in the funding of environmental initiatives so as to fill the financial gap that is left by public budgets that are not adequate. Because of the numerous financing constraints that developing countries experience, the possibility of poor environmental performance is increased; as a result, there is a necessity for active regulations regarding renewable energy. The formulation and execution of policies that encourage the use of renewable energy sources fall squarely within the purview of the governments that govern emerging nations. To ensure that environmental protection systems are supported in a manner that is both sustainable and responsible, financial mechanisms such as green bonds are now being utilized. Green bonds are a form of fixed-income investment and are issued with the intention of supporting environmental initiatives [15]. These bonds frequently come with a number of tax benefits tied to them, with the goal of increasing take-up and closing the renewable energy gap.

The use of RE to combat climate change was also shown to be feasible by Odugbasen and Aghazadeh [28] through a dynamic development model, and, as a result of varying energy consumption patterns, Tu et al. [29] and another researcher, Gheami and Rashidi [30], assessed the emissions of greenhouse gases and the costs of investments caused by meeting the electricity demand. Clean energy is an essential tool in the fight against global warming and environmental safety, and it is also cheaper than traditional power sources.

Other companies in the financial technology sector are actively implementing "green financial system" solutions, which are designed to make use of technology to facilitate more effective resource utilization and reduce carbon emissions. Fintech is attributed to supporting the adoption of environmentally friendly agricultural practices in China by ensuring credit availability, addressing information asymmetry, and developing trust among farming communities [22]. This was accomplished by addressing information asymmetry and increasing trust. The accumulation of empirical information demonstrates that the expansion of the internet in China has resulted in a discernible increase in the country's overall energy consumption [11]. This has been accomplished through the promotion of financial development and industrial upgrading. Environmental pollution issues have been increasingly prominent during the process of economic development; as a result, governments all over the world devote a significant amount of attention to environmental protection and put into place rules that regulate the industry. Credible environmental rules may enhance energy efficiency and more effectively reduce pollution, but they may not be helpful for the development of sectors that produce a lot of pollution. Enterprises typically incur additional compliance expenses as a result of stringent environmental legislation, and they face an intensifying level of scrutiny for engaging in activities that are harmful to the environment. The new Environmental Protection Law of China, which went into effect on 1 January 2015, elucidates the legal duties of both the Chinese government and private businesses with regard to the prevention of pollution and the preservation of the natural environment [4]. It is widely considered to be the most rigorous environmental law ever enacted in China. Therefore, enterprises with a high level of pollution need to adjust their approaches to development in order to compensate for these increased costs.

2.1. Renewable Energy and Environment Protection

Many studies [4,31–34] in the field of RE have examined the correlation between CO_2 emission and energy consumption. Researchers [35–37] have looked into the link between using RE sources and CO_2 emission levels concerning environmental cleaning in recent years. The G20 has established the term "green finance (GF)" to describe the funding and investment in environmentally sustainable development [38,39]. GF encourages people to use fewer fossil fuels and more renewable energy sources by rewarding those who invest in projects that do just that [40]. Limiting the amount of money banks can lend to industries that use fossil fuels would be a more direct way to solve the problem. GF can decrease global warming and ease constraints on company finances by supporting projects that are good for the environment [41]. Over the period between 2010 and 2014, Nguyen et al. [42] analyzed 290 Chinese towns using the indifferences technique to show that GF considerably

reduced gas emissions [43,44]. Governments should move more quickly to facilitate green bonds and technology [45].

According to [46], carbon intensity is the most critical factor influencing the use of RE sources. However, this sector's growth is constrained by a shortage of autonomous driving capacity and strongly relies on long-term green financial support. Gu et al. [47] found that the sale of green bonds generates positive environmental externalities that aid in the international deployment and diffusion of RE solutions. Chen et al. [48] studied the correlation between green bonds and the RE from 2011 to 2019. Conclusions showed that energy efficiency per unit of RE might increase by 9.4% if OECD countries were to grow 29% of green bond financing to create the RE index. Other countries are beginning to distinguish the potential of GF to address environmental pollution [49,50].

Climate financing aims to provide financial support for initiatives aiming to reduce environmental pollution and adapt to the effects of climate change. Bag and Pretorios [23] said that the increasing claim for environmental quality is a critical factor in the demand for green bonds. Liu et al. [51] examined how green bonds fit into the market's system for funding ecological stability. The findings highlighted the value of green bonds in creating environmentally conscious enterprises. Hence, based on the above discussion, the study hypothesis is as follows:

H1: *There is a significant relationship between renewable energy sources and the environmental protection of the UAE and Saudi Arabian economies.*

2.2. Financial Innovation and Environment Protection

Changes in energy use and the spread of low-carbon economies are being propelled by financial and technological advancements on a worldwide scale [52]. Innovation aids in cutting down on energy consumption and improving the overall efficiency of the energy system. One way in which technology has helped curb emissions is by improving energy efficiency. By decarbonizing the manufacturing process, technological advancements can make conventional fossil fuels more efficient, thereby meeting the objectives of energy conservation and emission reduction [53]. It has the potential to speed up the development of the clean energy sector. Technology advancement can reduce carbon footprints and environmental damage by increasing energy efficiency, as Udeagha and Ngepah [26] found in 73 developing countries between 1990 and 2016. Yet, innovation may inspire a transition from carbon-intensive fossil fuels to RE sources, aiding in mitigating greenhouse gas emissions. The capacity of RE supply can be increased, and the energy mix optimized through technical advancements.

According to Guild [54], the critical factor in the decrease in fossil fuel consumption is innovations in RE leading toward environmental safety. Energy innovations boost the use of RE sources in countries with limited oil reserves. Between 1980 and 2010, Hsu et al. [4] studied the association between technological development and the use of RE in the United States and Germany. The growth of RE sources in China was boosted by technological progress, as discovered by [55]. They found that for every percentage point increase in research and development for RE sources, power generation in the province will increase by 0.411% [53].

Chen et al. in Ref. [48] showed that technological advancements are positively correlated with shorter lead times and lower total emissions of carbon dioxide in the United States. Ref. [14] stressed the need to decarbonize the power industry in the worldwide shift away from fossil fuels and towards renewables. They used data from 35 OECD countries and five BRICS countries between 2001 and 2018 to show that adopting a technical innovation strategy can improve the efficiency with which carbon emissions are reduced when using wind power. Zhou et al. in Ref. [56] examined whether technological progress can slow down pollution. Utilizing information from 70 countries, they concluded that new technology positively reacts to environmental deterioration [57].

Financial and technological advancement is the most helpful tool in the fight against global warming. Greenhouse gas emission reduction programs are just one of several technology innovation initiatives launched to tackle climate change and other ecological pressures [58]. The goals of the Climate Change Conference can be more effectively met by promoting technological innovation. A proven strategy for cutting emissions is to invest in R&D; this will encourage creativity and progress toward a greener future, which will help lower emissions. High levels of greenhouse gas emissions drive governments to stimulate technological innovation in RE, suggesting that innovation processes respond favorably to climate change. Hence, the study hypothesis is as follows:

H2: *There is a significant relationship between the financial innovation and environmental protection of the UAE and Saudi Arabian economies*.

3. Research Methodology

This section defines the study's parameters, including the kind of data and measurements used and the set of countries considered. Using annual data from 2010 to 2022, this study builds a panel data set on the UAE and Saudi Arabia. RE sources can be found through green financing activities and bonds [59]. FI is measured through investing in Research and Development activities. Environmental Protection is the mitigation of CO_2 emissions in the environment [25]. Data are extracted from World Development Indicators (WDI) and Energy Information Administration (EIA) database. All of the above variables are measured in different units, so before beginning any empirical research, they must be converted into a standard measurement.

To avoid issues related to the distributional features of the data series, we followed recent research and transformed all of the variables into natural logarithms [60]. The empirical analysis begins with a look at the variables' order of integration. This is crucial in deciding the models to use in an empirical study. For instance, the LLC test developed by [61] analyzes the shared unit root process.

In contrast, the IPS test Tenzin (2019) developed analyzes the standalone unit root process. Because of this, these variables may share a long-term cointegration connection. We use a panel cointegration method to examine the long-term equilibrium relationship between the variables. Because of this benefit, the panel cointegration method has become increasingly popular among researchers investigating long-run symmetry between variables. Johansen's method is used in the Fisher-type panel cointegration technique. Hence, based on the above methodology, the study framework is as follows:

$$CO2_{i,t} = \beta_0 + \beta_1 RE_{i,t} + \beta_2 FI_{i,t} + e$$

4. Results

The data are analyzed through different statistical techniques, and the results are presented in this section. The sequence of variable integration is investigated using two various panel unit root tests. This suggests that a cointegration relationship may exist between the variables. Table 1 presents the panel correlation matrix results showing that RE and FI significantly negatively impact CO_2 emissions in the UAE and Saudi Arabia. Hence, these two factors are prominent elements through which environmental protection and safety are possible (Table 2).

Table 1. Panel correlation matrix.

Variables CDE	CO_2	RE	FI
CO_2	1.000		
RE	−0.544	1.000	
FI	−0.233	−0.221	1.000

Table 2. Panel unit root test.

	LLC Test				IPS Test			
	Level		First Difference		Level		First Difference	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
CO_2	0.507	0.751	8.558 ***	0.000	1.870	0.771	8.585 ***	0.000
RE	−0.558	0.787	−5.855 ***	0.000	−5.185	0.777	−5.585 ***	0.000
FI	−1.555	0.108	−7.877 ***	0.000	−1.758	0.750	−8.575 ***	0.000

Note: *** are significance at 0.001.

We employ the Fisher-type Johansen panel cointegration test to investigate the long-run equilibrium connection between the variables. Table 3 displays the outcomes of this test. The results indicate a significant long-term equilibrium relationship between CO_2 emission and RE sources in the form of green bonds. The results validate the long-term equilibrium between CO_2 emissions and FI of the UAE and Saudi Arabia.

Table 3. Johansen–Fisher panel cointegration test.

No.of CE(s)	Trace Test	Prob.	Max-Eigen Test
None	200.800 ***	0.000	86.840 ***
At most 1	124.400 ***	0.000	66.640 ***
At most 2	56.210 ***	0.000	42.400 ***
At most 3	62.760 ***	0.000	44.800 ***
At most 4	46.850 **	0.025	46.850 **

** and *** indicate the rejection of no cointegration at the 5 and 1% significance, respectively.

Table 4 shows the results of country-specific long-run estimates. Firstly, it gives the findings of the UAE and then gives Saudi Arabia's results. RE has a significant negative impact on CO_2 emission with a beta value of −0.665 ***; in the case of FI, the beta coefficient is −0.553 **. If we move toward the Saudi Arabia case, the RE and FI beta coefficients are −0.445 *** and −0.342 ***, respectively. These two factors also have a significant negative relationship with CO_2 emission. Hence, if countries want to save their environment, they should boost the RE sources and FI. Another technique, a fully modified ordinary least square (FMOLS), is performed in Table 5. The results also showed the negative relationship of RE and FI with the CO_2 emissions of the UAE and Saudi Arabia.

Table 4. Country-specific long-run estimates.

Country	Variable	Constant	RE	FI	R2	Adj R2
UAE	Coefficient	7.886 ***	−0.665 ***	−0.553 **	0.776	0.665
	Prob.	0.000	0.000	0.023		
Saudi Arabia	Coefficient	7.554 ***	−0.445 ***	−0.342 ***	0.775	0.654
	Prob.	0.000	0.000	0.000		

Note: ***, **, are significance at 0.001, 0.005, respectively.

Table 5. FMOLS and DOLS results.

FMOLS			DOLS		
Variables	**Coefficients**	***p*-Value**	**Variables**	**Coefficients**	***p*-Value**
RE	−0.221 ***	0.001	RE	−0.332 **	0.005
FI	−0.331 **	0.002	FI	−0.231 **	0.004

***, **, are significance at 0.001, 0.005, respectively.

5. Discussion

Environmental protection is a significant need for sustainable development, which is possible through green bonds and FI. This study was performed to check the impact of RE sources and FI on the environmental protection of the UAE and Saudi Arabia from

2010 to 2022. The results were analyzed using panel unit root test, cointegration, and FMOLS. The findings indicated that RE sources in the form of green bonds negatively impact the CO_2 emissions of the UAE and Saudi Arabia. Both factors were found to have a negative correlation because the enhancement of one aspect will lead to a decrease in the other facet. RE sources are a significant element in mitigating CO_2 emission; hence, this is environmental protection.

On the other hand, FI significantly negatively impacts the CO_2 emissions of the UAE and Saudi Arabia. If the countries want to increase environmental protection and safety, ultimately, they should boost innovation so that the best sources for CO_2 mitigation should produce energy. FMOLS results showed that RE negatively impacts CO_2 emission with a beta value of −0.221 ***. Conversely, FI has a significant negative relationship with CO_2 emission with a beta value of −0.331 **. If the UAE and Saudi Arabia want to be safe and make a pollution-free environment, they should enhance the RE sources and promote the FI. These results are consistent with the study of Udeagha and Ngepah [26] while contradicting the study of [62]. This study is limited to the UAE and Saudi Arabia from 2010 to 2022 concerning renewable energy sources, financial innovation, and environmental protection.

The topic of discussion among those who create policy and scientists who study the environment right now is how to slow or stop the increase in CO_2 emissions around the world. The developed economies have made substantial strides in reducing their CO_2 emissions by elevating the proportion of their overall energy consumption that is derived from renewable sources. Despite this, there is a growing concern about it among individuals and policy leaders in developing economies as a result of the increased growth of CO_2 emissions. This is mostly because of the increasing demand for energy from a variety of economic activities. The consumption of non-renewable energy sources, which is the predominant form of energy utilized in developing nations, results in an increased amount of carbon dioxide emissions. As a consequence of this, in the most recent past, policy makers and government officials have been working towards the goal of promoting the generation and use of renewable energy across the board in terms of economic activity and protecting the environment.

6. Conclusions and Policy Implications

In today's era, there is an immense need to protect the environment and mitigate CO_2 emissions. Hence, in this case, RE sources and FI play a vital role in environmental safety and sustainable development goals. However, energy consumption in growing nations has been a significant cause of two major issues: the exhaustion of non-renewable natural resources and CO_2 emission. A switch to RE sources, including solar, wind, tidal, waste, and others, is necessary due to these worsening environmental conditions. RE sources are preferable to traditional, non-renewable ones since they are better for the environment and cannot be used up [63]. Energy consumption from renewable sources is increasing as countries worldwide recognize the benefits of switching to them.

The UAE and Saudi Arabia economies found that the connection between using RE and environmental damage is crucial. There is a discussion among environmentalists and policymakers about how to slow the rise in CO_2 emissions around the world. This study's robust panel econometric models were applied to annual data collected between 2010 and 2021. Evidence from cointegration models shows a long-term equilibrium relationship between RE and environmental protection, as well as between FI and mitigation of CO_2 emissions. With these results, our study contributes significantly to the existing body of information and the policy. Our findings also revealed that the beneficial impact on environmental protection from using RE sources was more significant than that from using non-renewable sources. That is why we recommend that those economies' policymakers and government officials implement additional effective policies to boost RE output and use across the economy.

In addition to boosting FI, this will also help reduce carbon dioxide production. Large-scale adoption of renewable energy sources guarantees a shift to a low-carbon economy

and paves the way for long-term sustainable development. Our findings additionally demonstrate that transitioning to renewable energy sources resulted in lower levels of CO_2 emissions in those economies. Consequently, at least in the case of the UAE and Saudi Arabia, it is worthwhile to promote the use of RE to increase economic development while decreasing CO_2 emissions [64]. Governments should support the growth of RE sources and create an energy infrastructure more grounded in science and reason. To lessen worldwide CO_2 emissions, governments should prioritize the transition to RE sources over fossil fuels. To attain carbon neutrality, nations must make deliberate changes to their energy infrastructure.

It is essential, in light of the tremendous economic expansion taking place in these nations, to have an understanding of the role that renewable energy plays in economic expansion and the degree to which it contributes to a reduction in CO_2 emissions in these nations. The findings that were produced from this research will be essential for policymakers and government officials in order for them to be able to take suitable actions to meet the growing demand for energy while also limiting the growth of CO_2 emissions caused by substantial economic activities.

When it comes to environmental protection, policymakers frequently have to choose from a variety of different policy instruments. The effect that differing regulations have on the incentives that companies have to create cleaner production methods is an important factor that plays a role in this option. In the short term, it may appear that there is a substantial conflict between economic activity and environmental quality; nevertheless, in the long run, the accumulative effect of technological innovation may significantly reduce the severity of these conflicts. This effect is notably relevant in the context of global climate change, where governments have, up to this point, been unable to implement measures to considerably cut emissions of greenhouse gases due to the possible economic consequences of these actions.

Energy conservation, and environmental preservation, are just a few examples of green industries that need government support to thrive. Removing obstacles to entry for RE sources is essential, as is ensuring their goods have competitive access to the market for generating electricity. Second, environmental technology development should be a top priority for government agencies. They must collaborate more effectively worldwide to raise ecological standards everywhere and boost government funding for eco-friendly research and development and decarbonization strategies. To speed up the commercialization of breakthrough technologies and encourage their improvement, nations should establish inter-regional platforms for innovation cooperation. Third, there needs to be a unified green financing structure put in place. Governments should employ asset securitization to boost the vitality of carbon assets since it can improve the allocative efficiency of these assets. As an additional means of providing monetary backing for sustainable growth, the development of green financial products and solutions should be actively promoted. Financial services that can adjust to the needs of the sustainable energy industry are essential. This study is limited to the UAE and Saudi Arabia; further research can be possible by considering the emerging economies through other factors such as environment decentralization, financial development, geopolitical risks, etc.

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