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Empirical Analysis of Non-Renewable Energy, Renewable Energy, Foreign Direct Investment, and Economic Growth on Environmental Sustainability

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ABSTRACT

The study mainly focuses on checking the dynamic impact of nonrenewable energy, renewable energy, foreign direct investment, and economic growth on environmental sustainability by the newly developed bootstrap autoregressive distributed lag (ARDL) testing technique. ARDL being a dynamic model incorporates the capacity of giving both short and long runs series by the help of the first and second differences of the series. To this effect, the annual data covers a timeframe from the year 2000 up to 2023. On the other hand, Granger's causality analysis indicates that there is a one-way causative relationship between consumption of renewable and non-re renewable energies and environmental sustainability in relation to GDP in the United Arab Emirates. Moreover, the ARDL findings revealed that the coefficients of GDP showed positive values, whereas the quadratic GDP exhibited negative values. These findings support the validity of the EKC theory in the UAE, the negative relationship between FDI and environmental sustainability. Moreover, policymakers in the UAE must dedicate substantial financial resources towards the advancement of sustainable energy sources, while concurrently decreasing dependence on non-renewable fuels.

Keywords: Renewable Energy, Bootstrap ARDL, FDI, Environmental Kuznets Curve, Sustainability, UAE
JEL Classifications: O13, Q18, Q56

1. INTRODUCTION

The IPCC report (Brini et al., 2024) stressed the importance of cutting greenhouse gas emissions by 50-85% by 2050, compared to 2000 levels, to avert an environmental disaster. These reductions closely link to temperature increases; they should lean towards 85% rather than 50% to cap the temperature rise at 2°C. To meet this target, various studies indicate that individual emissions need to drop to between 0.8 and 2.5 tons of CO_2 equivalents per person annually. Even with just a 2°C increase, significant and unavoidable climate changes will impact many regions. In reaction to these threats, certain countries, including the USA, the European Union, and China, have enacted a variety of strategies to lower emissions. These approaches have been applied in developed and developing nations globally. Consequently, efforts are underway to boost the share of renewable energy sources to tackle climate change on a global scale. The Energy-Environment connection has received attention from governments and scholars. Researchers highlight the negative impact on the environment mainly from non-renewable energy sources. Substituting nonrenewable energy with renewable sources can offer benefits like reducing global warming emissions, diversifying energy sources, and decreasing dependence on non-renewable energy.

The interplay between climate and the economy, often termed the climate-economy nexus, has gained significant attention in recent literature (Dolge et al., 2022; Al-Kasasbeh et al., 2022; Jiang et al., 2022; Sarkodie et al., 2020; Dolge and Blumberga, 2022). These studies underscore the substantial impact of climate change on economic activities, with variations influenced by national policies and sustainability frameworks (Fan and Hao, 2020; Djellouli et al., 2022; Karaki et al., 2023; Almasria et al. 2024). While some research focuses on the economic repercussions, others examine climate change's effects on areas such as cyclone frequency, migration, and tourism. Despite these comprehensive analyses, specific research gaps remain. Notably, the role of foreign direct investment (FDI) in influencing both renewable and non-renewable energy sectors and its broader environmental implications is underexplored, particularly in the context of the UAE. Elheddad et al. (2022) highlight FDI's dual impact on energy sectors, while Ogbuabor and Egwuchukwu (2017) show the detrimental effects of carbon emissions on productivity growth, yet these studies lack a region-specific focus on the UAE.

Our focus shall be on UAE due to its large foreign reserves and the country's ability to attract foreign direct investment. Also, it portrays a high opportunity in the investment of renewable energy sources. In the UAE, the need for energy consumption is increasing due to extensive industrialization. The importance of renewable energy inspires us to investigate the impacts of non-renewable energy, renewable energy, foreign direct investment, and economic growth on sustainability quality in the UAE from 2000 to 2023. Policymakers consider the priorities included in the regulatory framework that encompasses UAE Economic Vision 2030 and UAE Energy Strategy 2050. The UAE has implemented numerous policies and initiatives to enhance sustainability and embrace renewable energy. To achieve these objectives, it is argued that innovative solutions in sustainable economic development and clean energy transition are essential. Researchers encounter an exciting opportunity to develop expertise on the complex process of a transition to a sustainable and resilient economy through exploring challenges and opportunities in sustainability and energy transition. The primary contributions and originality of this paper are as follows: First of all, we believe that this is the first study of its kind on the UAE with the latest data that will provide an important policy for this country. Secondly, this study examines the EKC Pollution Haven/Halo hypothesis for the UAE. Thirdly, we apply the comprehensive analysis by examining the variables under investigation utilizing updated the bootstrap ARDL approach.

Therefore, the contributions of this study are threefold. First, this study leverages the latest data, offering a comprehensive policy framework specifically tailored for the UAE. This ensures that the analysis is grounded in the most current and relevant information, enhancing the accuracy and applicability of the findings. Second, we delve into hypothesis testing by examining the Environmental Kuznets Curve (EKC) and Pollution Haven/Halo hypotheses within the unique context of the UAE. This exploration provides valuable insights into how these environmental-economic relationships manifest in a rapidly developing nation with significant energy demands and environmental considerations. Third, the study employs the bootstrap ARDL approach, a methodological advancement that enables a more robust and nuanced analysis of the variables under investigation. This approach enhances the reliability of the results and offers deeper insights into the complex dynamics of energy consumption, FDI, and economic growth. By addressing these aspects, the research not only enriches the understanding of the climate-economy nexus in the UAE but also delivers practical implications for policymakers aiming to promote sustainable economic growth and environmental resilience.

2. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Numerous studies have been undertaken on the relationship. between economic growth and the environment through the EKC context. The EKC model illustrates a non-linear link between growth and environmental decline. According to the EKC hypothesis, in the early stages of economic development, there is a positive association between economic growth and environmental damage. However, once a certain level of economic growth is attained (referred to as the turning point), environmental deterioration begins to decrease. This trend showcases an inverted U-shaped correlation between the two factors. Several empirical studies have affirmed this core concept. Authors like Pata (2018), Bekun et al. (2020), and Wasti and Zaidi (2020) have published their respective works on this topic. While some empirical research has not supported this idea, it has proposed alternative non-linear relationships such as U-shaped and N-shaped correlations. Notable studies in this regard include those by Sarkodie (2018), Halliru et al. (2020), and Leal and Marques (2020). The association between the climate-economy nexus was highlighted in the latest literature (Mei et al., 2020; Wei et al., 2022; Sarkodie et al., 2020; Dolge and Blumberga, 2022; Bhuiyan et al., 2022; Dolge et al., 2022). Several recent studies have emphasized that climate change has a substantial effect on the economy but varies from country to country based on economic and Sustainability policies (Fan and Hao, 2020; Djellouli et al., 2022). Another direction in studying climate change took a different way by impacting climate change on cyclone frequency, migration, tourism, and many other issues, as presented in the assessment Report of the Climate Change Panel (Intergovernmental Panel on Climate Change on Climate Change, 2023 Elheddad et al. (2022) research indicates that FDI influences both renewable and non-renewable energy sectors significantly. Ogbuabor and Egwuchukwu (2017) illustrate that long- and short-term carbon emissions negatively impact productivity growth in Nigeria while deforestation negatively impacts the short-term economy on the development of Several lines of evidence point to the economic costs of climate change. For the UAE, increased exports lead to lower greenhouse gas emissions eventually (Xu and Lin, 2015). Expected to be key factors of climate change policy mitigation are green energy and energy efficiency. (Awan et al., 2022; Yu and Liu, 2024). In Bangladesh, for example, FDI has been linked with higher CO_2 emissions due to increased non-renewable energy usage, while also discouraging renewable energy consumption.

Previous research on the relationship between carbon emissions, energy consumption, and economic growth has been inconsistent,

with some finding a strong association (Dissanayake et al., 2023). Dissanayake et al. (2023) established this empirically, where they established that, indeed, there were firm Granger causal relationships between GDP and energy consumption in transitional economies. In brief, their findings were such that the increase in energy was further propelled by economic growth. The literature review emphasizes that industrialized countries have to shift their policy emphasis regarding renewable energy and take on the approaches of cutting CO_2 emissions for sustainable economic growth (Fan and Hao, 2020; Alkasasbeh et al., 2023). It would mean that the developed nations should preferably adopt renewable energy. It will give preference to the ways of CO_2 emission reduction, achieving the ambition for sustainable long-term economic prosperity (Fang et al., 2022; Iqbal et al., 2023). This will result in policy changes within economies in transition to the bidirectional causality between GDP and CO_2, which has to be included in the transitional economies together with the first instance. Every nation should, therefore, take the issue of switching to renewable energy with all the seriousness for a sustainable future perspective. (Vandaele and Porter, 2015; Prasad et al., 2021; Khan et al., 2021). The study, however, does not examine the social implications of using renewable energy sources, such as job creation, enhanced rural living quality, public health, and awareness, because it is primarily focused on renewable energy, environmental sustainability, and economic growth.

Dissanayake et al. (2023) study spanning 1990-2019 across 152 nations analyzed the relationships between energy consumption, CO_2 emissions, and economic growth. The results underscore the complex interactions between these variables, suggesting that the type of energy consumption significantly influences the environmental and economic outcomes of nations. Jia et al. 2023 study covering countries along the Belt and Road initiative found that renewable energy consumption not only supports economic growth but also has a considerable impact on sustainable economic development by influencing gross capital formation and trade. This suggests that increased usage of renewable energy lessens the environmental repercussions of an economy. This is because while the early stages of financial expansion may cause higher pollutants, alternative, and cleaner technology frequently reverses the trajectory, underscoring the impact of investing in renewable energy and technological development to achieve environmental effectiveness in the long run. There has been growing public opinion across international society in recent years about the critical worth of sustainability guarantees on economic upturn sustainability for living existence and prospect generations, which raises necessities without reducing the atmosphere. Sustainability, as the capability to meet present demands without compromising the capacity of future eras to do the same, has in recent years emerged as a quality of corporate development demolition policy agendas and the focal point of academic economic inquiry. Energy treatment, developing economy, and environmental monitoring have been three major, intricate considerations in debates concerning sustainability. The socioeconomic concern has become through which these three considerations are connected manifestations taken. The theoretical framework grounded on sustainable development grasps energy uptake mechanization. This theoretical foundation permits an appreciative understanding of the interface or heterogeneity between non-renewable energy, and renewable energy while operational as investors moderately than economists, and it is reliant upon the lasting draw inferences multipliers. This paper intends to carry out the time series autoregressive distributed lag assessments to discover the long-term and short-term dimensions of modification and should reappearance applicable to the growth. Currently, the carbon footprint measures the usage of non-renewable energy surpassing worldwide recycles and waste absorption abilities, these ecological upshots eradicated the EKC mean as the Asian economy develops, accumulates, and eventually improved pollutant expulsion occurs.

The selection of variables in this study reflects the important role they play in sustainability outcomes. The use of non-renewable energy generated by coal, oil, and natural gas has been a major source of energy for industrial and economic growth throughout history but with negative environmental impacts including greenhouse gases and air pollution to clean, sustainable energy sources underscores the urgency of the need for change (Abban et al., 2020; Yu and Li, 2020; Kumari et al., 2023; Ullah et al., 2024). In contrast, renewable energy, derived from sources such as wind, solar, hydroelectric, and biomass, offers promising alternatives that reduce environmental impact while promoting energy security and resilience (Kim, 2020; Awan et al., 2022).

FDI plays an imperative part in driving economic growth and technological innovation ((Doytch and Narayan, 2016 and Mohamed et al., 2021), which can determine the outcome of sustainable development FDI inflows can lead to non-productive technologies facilitating the environment, encouraging resource efficiency, and facilitating sustainable development policies in host countries (Kang et al., 2021; Wei et al., 2022; Bilalli et al., 2024). It depends on various factors including legal framework, organization types of power, and corporate governance practices applied.

Economic growth is often considered the cornerstone of development policies aimed at improving social and environmental outcomes and reducing poverty (Gurbuz, 2024), but it must balance the pursuit of sustainability strategies with environmental sustainability considerations and social equity (Kumar et al., 2024). Sustainable economic development includes promoting economic expansion away from environmental degradation, promoting inclusive growth, and tackling global challenges such as climate change and resource scarcity is and to be encouraged (Awan et al., 2022; Grabara et al., 2021).

In this context, the projected theoretical framework pursues to clarify the intricate interconnections between non-renewable energy, renewable energy, FDI, economic growth, and sustainable development Period using a time series ARDL analysis, the purpose of the research is to provide empirical insights that drive systemic implementation, sustainable business strategies - through a detailed examination of these relationships as well as possible for informing academic issues related to development and energy transition, the research seeks to contribute to knowledge development and sustainability goals in a rapidly changing global environment.

The utilization of non-renewable energy contributes to environmental degradation and resource depletion (Ali et al., 2021) thereby negatively impacting energy sustainability; Non-renewable energy such as fossil fuels are finite, and pollutants like greenhouse gases when burned for energy (Amin et al., 2022; Ali et al., 2021). Environmental pollution increases due to increased consumption but beyond a certain threshold of income, environmental awareness and technological advances drive the shift towards different sources of energy sustainable cleaning is easier, thereby reducing the impact on the environment (Ullah et al., 2024). Moreover, another study conducted by Şanlı et al. (2023) focusing on OECD countries used a non-linear panel ARDL model to explore the asymmetric effects of energy supply shocks on CO_2 emissions. This research emphasized that non-renewable energy consumption is one of the primary sources of greenhouse gases, thereby affecting environmental quality. In contrast, renewable energy use has been acknowledged as crucial for combating global climate change and reducing greenhouse gas emissions (Owusu and Asumadu-Sarkodie, 2016).

Renewable energy consumption promotes cleaner and sustainable energy sources, leading to improved environmental quality and enhanced sustainability. The utilization of renewable energy promotes sustainable clean energy, improves the environment, and increases sustainability (Zafar et al., 2020; Ibrahim et al., 2024), Renewable energy, solar, wind, hydropower, and geothermal, offer significant advantages over non-renewable alternatives in terms of environmental sustainability. Renewable energy technologies that generate pollution-free electricity, thereby reducing air and water pollution and vindicating climate change, are aligned with the principles of sustainable development by guaranteeing that energy availability for future generations is compatible with environmental decrease. Replacing non-renewable sources with renewable energy contributes to a more sustainable energy mix and advances the transition to a low-carbon economy (Gurbuz, 2024). Renewable energy consumption is increasingly being recognized for its role in promoting cleaner and more sustainable energy sources, which leads to improved environmental quality (Chen et al., 2023). A study conducted by Chen et al. (2023) examining the G7 countries has highlighted that renewable energy consumption and advancements in digital technology are significantly reducing greenhouse gas emissions, they have found that the long-lasting positive effects of digitalization on lowering emissions, thereby contributing to sustainability goals.

Additionally, research on the nexus between carbon emissions, energy consumption, and economic growth across a broad range of countries has identified the critical role of renewable energy in mitigating carbon footprints (Dissanayake et al., 2023).

The UNEP report suggests a critical rethinking of the relationship between consumption and economic prosperity to achieve sustainable growth, especially since demand for resources will triple by 2050 as current levels of exploitation continue a (Bernhard et al., 2023). The World Economic Forum also noted that there was a significant increase in renewable energy capacity, with the year 2023 accounting for 50% growth from the previous year (WEF Forum, 2024). This is part of the growing trajectory globally towards decarbonization and is expected to lead to the fast growth of renewable energy in the next five years (WEF Forum, 2024). What is more, the United Nations Environment Programme has also taken up the issue, acknowledging the need for a global move in resource productivity to be able to achieve economic growth without corresponding increases in environmental impact.

FDI can also help improve sustainability through enabling technology transfer in green, improved energy efficiency, and sustainable best practices in production processes. FDI has increasingly come under the limelight as a mechanism of driving sustainability, more especially through the transfer of green technologies. According to research, FDI positively influences how environmental sustainability takes place and is done, which is done by promoting improved or better energy sources and sustained practice in the production process (Rauf et al., 2023; Abueid et al., 2018).

However, past research works disclose the fact that while FDI inflows ignite potential economic growth, they may represent a damaging influence on environmental sustainability without proper synchronization of technological innovation (Rauf et al., 2023). Technological innovations depicted a positive relationship with economic growth and a negative one with CO_2 emissions, thus depicting an improvement in environmental sustainability for the region (Rauf et al., 2023). Green finance has also been directly linked with FDI since it is a financial instrument that tries to motivate investment through the development and implementation of green innovation and technology. Investments in green techniques and innovations from renewable energy result in a positive impact on the environment (Qadri et al., 2023). Furthermore, an earlier study demonstrated that FDI can highly enhance green innovation, especially if it is combined with favorable policy environments and high levels of marketization. The findings suggest that FDI could serve as a useful mechanism for local governments in the full realization of foreign capital for green innovation activities (Chen et al., 2023). If decoupled from environmental degradation, then positive impacts of economic growth on sustainability occur through encouraging innovation and investment in clean technologies, to minimize the wastage of resources.

Conversely, economic growth, if detached from environmental degradation, may hold the potential to make positive contributions toward sustainability through development in innovation, investment in clean technologies, and materials conservation (Raihan and Tuspekova 2022; Ahmed et al., 2022); the ancient that economic growth is related to increased consumption and environmental degradation. Recent academic research supports the notion that it is feasible to decouple economic growth from environmental degradation. Several small-scale and broad international-focused studies have been carried out on this relationship. For instance, Conrad and Cassar, (2014) in explored the progress made in Malta, a small island state, towards decoupling economic growth from several environmental pressures, including energy intensity and water use.

Nonetheless, the model of fragmentation indicates that economic growth can be realized without a corresponding expansion in

environmental effect. Sustainable development emphasizes the reputation of generating economic growth from environmental degradation and environmental degradation through innovation, technological development, and independent policy. Economic development can be used as a force for sustainability through investment in research and development, promotion of environmentally friendly business practices, and regulatory policy objectives controlling the use to achieve economic prosperity, so now -The long-term prosperity of future generations is ensured.

3. METHODOLOGY

We obtain annual data for the United Arab Emirates spanning from 2000 to 2023. This paper employs the dependent variable of total CO_2 emissions from fuel combustion as a measure of environmental degradation. Past studies by Quadrelli and Peterson (2007) and Greer et al. (2019) have extensively employed this indicator. Energy sources are divided into two categories: non-renewable and renewable. This study investigates the proportion of power generation from non-renewable sources like oil, gas, and coal. Renewable energy's percentage of total final energy consumption is used as an indicator, a metric previously utilized by Inglesi and Dogan (2018) and Furlan and Mortarino (2018) and Pérez-Lombard et al. (2008). Economic growth is measured using the annual GDP growth rate, while Foreign Direct Investment (FDI) is evaluated as the net FDI inflow percentage of GDP. The data used in the analysis are sourced from the International Energy Agency (IEA) and the World Bank Development Indicators (WDI).

The study's current model is built upon the theoretical framework and purpose of the study. As a result, the study's model specification is determined by the application of Foreign Direct Investment (FDI) about the Environmental Kuznets Curve (EKC) and the Pollution Haven/Halo Hypothesis (PHH). The EKC theory suggests a curvilinear relationship between economic performance (GDP) and environmental performance (good or bad quality), characterized by an inverted U-shaped pattern. On the other hand, the PHH theory suggests that FDI hurts environmental performance in emerging nations. The present study employs the following variables: non-renewable energy, renewable energy, economic growth, and FDI as the explanatory variables. Therefore, the model specification, based on the Environmental Kuznets Curve (EKC) and the Polluting Heterogeneity Hypothesis (PHH), can be represented by the following equation:

$$CO_2 = (NREC, REC, GDP, GDP2, FDI, FDI2) \quad (1)$$

As indicated in Eq. (1), CO_2 is an index to account for environmental degradation while GDP is the growth in economic growth and GDP2, respectively; NREC is non-renewable energy, FDI is foreign direct investment and FDI2 is squared, REC denotes renewable energy. Equation (1) is remodeled in the following estimable econometric model:

$$CO_{2t} = \beta_0 + \beta_1 NREC_t + \beta_2 REC_t + \beta_3 GDP_t + \beta_4 GDp^2_t + \beta_5 FDI_t + \beta_6 FDI^2_t + \varepsilon_{it} \quad (2)$$

Where β_0 is the constant term; Δ is the operator of the first difference; α_1, α_2, α_3, α_4, α_5 and α_6 are coefficients that measure short-run relationships; ρ_1, ρ_2, ρ_3, ρ_4, ρ_5 and ρ_6 refer to the long-term coefficients of the tested variables; $LNNREC_t$, $LNREC_t$, $LNGDP_t$, $LNGDP^2_t$, $LNEFDI^2_t$, $LNFDI_t$ describe the selected variables of the examination; ε_t is an error term; m is the optimal of the lags.

4. RESULTS AND DISCUSSION

The findings displayed in Table 1 show that the variables CO_2, NREC, REC, GDP, and FDI demonstrate stationarity and are integrated at the first difference (Δ). Therefore, the selected variables have a (1) order of integration level. The outcomes from the B-ARDL analysis of the cointegration method are displayed in

Table 1: The Zivot–Andrews test results

	Level		First differences	
Tested variable	t–STAT	Structural break date	t–STAT	Structural break date
$LNCO_2$	−1.556	2006	−6.336**	2012
LNNREC	−1.714	1996	−5.324**	2016
LNREC	−1.911	1999	−6.536**	2014
LNGDP	−2.006	2009	−5.656**	2017
LNFDI	−1.129	1991	−6.011**	2007

**Denotes 5% level of significance

Table 2: The bootstrap ARDL cointegration analysis

	Bootstrap ARDL results		
ARDL (1,1,1,0,1,1,1)	F-Pesaran	T-dependent	F-independent
(CO_2, NREC, REC, GDP, GDP2, FDI, FDI2)	6.91***	-3.11***	6.89***
Bootstrap-based table critical values 1%	4.11	4.11	7.01

***Statistical significance at the 1%, level

Table 3: Long run and short run estimates

Variable	Coefficient	T-statistic
Δ (LN NREC)	0.925***	0.745
Δ (LN REC)	−0.212*	−0.356
Δ (LN GDP)	1.024**	1.224
Δ (LN GDP2)	−0.822*	−0.397
Δ (LN FDI)	−0.121*	−0.824
Δ (LN FDI2)	−0.054*	−2.067
ECTt-1	−0.152**	−2.591
LN NREC	0.925***	0.745
LN REC	−0.212*	−0.356
LN GDP	1.024**	1.224
LN GDP^2	−0.822*	−0.397
LN FDI	−0.121*	−0.824
LN FDI2	−0.055*	−2.067

*, ** and ***denote levels of significance at 10%, 5% and 1% respectively

Table 4: Diagnostic test results for ARDL

P-value	
Serial correlation (LM)	0.391 (1.221)
Heteroscedasticity	1.451 (0.431)
Normality	1.113 (0.791)
ARCH	1.011 (0.673)
Stability Ramsey	1.070 (0.311)

Table 5: Results of the Granger causality testing approach.

Variable	Δ LNCO$_2$	Δ LNNREC	Δ LNREC	Δ LNGDP	Δ LNFDI	ECTt-1
Δ LNCO$_2$	-	7.36**	7.19**	8.01**	7.02**	−0.078
Δ LNNREC	1.11	-	2.82	5.91	6.35**	−0.004
Δ LNREC	2.06	1.76	-	5.75*	8.53**	−0.633
Δ LNGDP	2.38	3.25	3.26	-	6.15**	−0.026
Δ LNFDI	3.11	3.07	2.47	2.85	-	−0.018

Table 2. It is evident from the results that FPesaran, Findependent, and tdependent values exceed the critical values of B-ARDL, indicating co-integration among the variables (CO_2, NREC, REC, GDP, GDP2, FDI, and FDI2).

The ARDL model was estimated to compute the long-term coefficients, as outlined in Table 3. The statistical significance of both the positive GDP coefficient and the negative GDP2 coefficient was confirmed. The outcomes of this research align with the inverted U-shaped EKC hypothesis. Consequently, it can be concluded that the EKC holds in the UAE, indicating that environmental degradation will occur as production levels surpass a specific threshold. These findings are in line with the study conducted by (Bilgili et al., 2016). Nonrenewable energy sources showed a positive correlation, indicating that further reliance on non-renewable energy sources will lead to increased environmental pollution in the UAE. These findings are consistent with previous studies conducted by Charfeddine and Khediri (2016); Dogan and Ozturk (2017); Gill et al. (2018) and Samour et al. (2022); Almasria et al. (2024). On the other hand, renewable energy had a negative and statistically significant coefficient, aligning with the research conducted by Magazzino (2016) and Al-Kasasbeh et al. (2023). This suggests that increasing the use of alternative energy sources can help mitigate climate change and reduce environmental contamination. A negative but insignificant relationship exists between FDI and environmental sustainability both in the short run and long run in the first stage. Quantitatively, a percentage point change in FDI causes a −0.121% decrease in environmental sustainability. A percentage point change in FDI2 causes a −0.054% decrease in environmental sustainability. This does not follow an inverted U-shaped relationship between the environmental performance and FDI rather, a flat pattern of relationship is uncovered between the environmental sustainability and FDI. The impact of squared FDI on environmental sustainability at 1%. These findings are consistent with previous studies conducted by Sbia et al. (2014); Khan and Agha (2015). The results from the ECM model can be found in Table 3, showing a coefficient of −0.152 at a 5% significance level. This suggests that short-term shocks are adjusted by 15.2% towards long-term equilibrium. Moreover, deviations from the equilibrium level of economic growth are corrected by over 15%, supporting the presence of a long-term relationship between the variables.

The diagnostic examinations results are outlined in Table 4. The normality test results show a P-value exceeded the 5% significance level, supporting the idea that the model in this article follows a normal distribution. Additionally, the LM test results reveal no autocorrelation and homoscedasticity in the model. Furthermore, the Ramsey-Reset test outcomes suggest that the model is appropriately specified.

The t-statistics computed for the lagged value of the ECT suggest that foreign direct investment, economic growth, consumption of renewable and non-renewable energy, and REC all contribute to long-term causality in the context of UAE's carbon emissions (FDI, GDP, NREC→CO_2). The (F)statistics values presented in Table 5 demonstrate that foreign direct investment, economic growth, non-renewable and renewable energy consumption, and UAE's carbon emissions (FDI, GDP, REC, NREC→CO_2) are causally related in a unidirectional manner. Besides, the uni-directional causality relationship can be observed between foreign direct investment, non-renewable energy consumption of the UAE (including oil, gas, and coal), renewable energy consumption (REC), and GDP. Hence, this result verifies the fact that carbon emits in the UAE from FDI.

5. CONCLUSION AND RECOMMENDATIONS

The relationship between energy consumption, economic growth, and FDI has received considerable attention in the ongoing debate on sustainable development. Achieving sustainable development, which is generally considered to meet current needs without compromising the ability of future generations to meet their own has emerged as an important goal for economies around the world. This is especially important in energy consumption, because the ratio of non-renewable resources to renewable resources is high environmental can be impacted.

Utilizing Granger causality analysis, the direction of the causal interaction between the examined variables was determined. Additionally, the Granger causality results indicated the presence of a unidirectional causal relationship between renewable and non-renewable energy consumption, environmental sustainability, and GDP in the United Arab Emirates. Furthermore, the ARDL results indicated that the GDP coefficients exhibited positive values, while the quadratic GDP demonstrated negative values. Based on these findings, the EKC hypothesis appears to be valid in the UAE. Statistically, the nonrenewable energy coefficient was positive. Consequently, an additional escalation in the utilization of non-renewable energy sources may potentially result in heightened levels of environmental contamination within the UAE. Nevertheless, the UAE exhibited a noteworthy renewable energy coefficient, indicating that augmenting the utilization of alternative energy sources would mitigate climate change and consequently safeguard against environmental contamination.

The UAE is the third-largest economy among Middle Eastern countries, boasting a GDP of USD 415 billion in 2022. From 2000 to 2023, the banking sector in the UAE witnessed favorable advancements. The UAE has made considerable strides in developing the renewable energy sector by diversifying its energy

sources to meet environmental concerns. The UAE has set a goal to achieve carbon neutrality by the year 2050. Based on the results of this research, the paper presents the following conclusions for policymakers in the UAE: It is imperative for authorities in the UAE to actively encourage the adoption of green financing and provide additional financial resources for investments in renewable energy.

The relationship that should exist between foreign direct investment (FDI) and green energy in the UAE should be such that it has to serve as an incentive for policymakers to know ways and have clear strategies through which the level of investment in this green sector can be raised. Maybe the issuing of tax incentives in terms of deductions for investment in green energy could be one such way. Furthermore, UAE officials owe it to their citizens to come up with innovative environmental policies aimed at curbing the adverse effects brought about by the use of non-renewable energy. This can be achieved by implementing financial incentives, such as tax breaks, to encourage investments in green energy.

The findings are fundamental in formulating investments that promote sustainable energy, attract FDI in sustainable areas, and stimulate economic growth, while promoting environmental sustainability.

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