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The Interplay of Financial Development, Oil Prices, and CO_2 Emissions in Shaping Renewable Energy Consumption in Emerging Nations: An Evidence from Panel Quantile Regression

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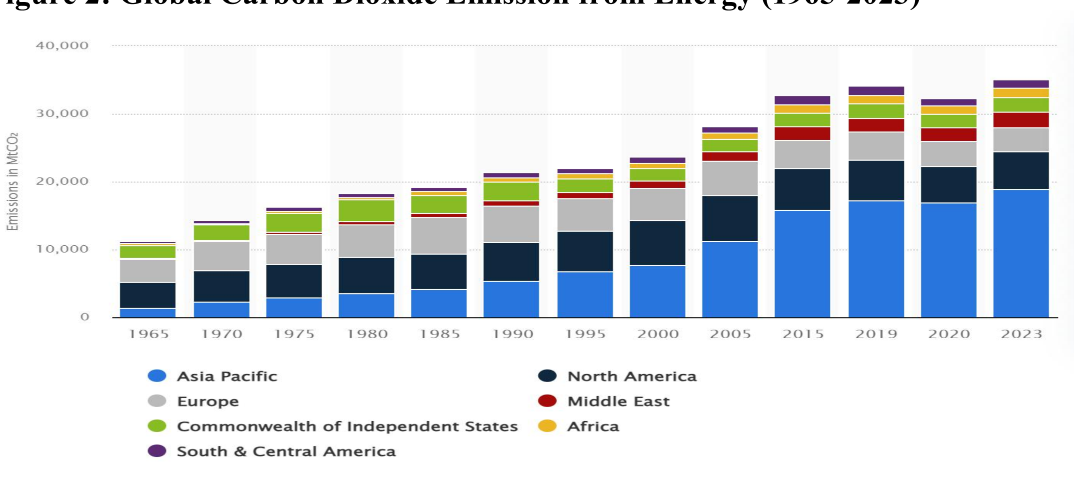
ABSTRACT

Using the panel dataset of 22 emerging economies from 2005 to 2021, this study investigates the impact of financial development, CO_2 emission, oil prices, trade openness, and FDI on renewable energy consumption. To this end, we employ panel quantile regression (PQR) by Powell (2016) and Methods of moment quantile regression (MMQR) by Machado and Silva (2019). In addition, we employ POLS, OLS with Driscoll and Kraay (1998) standard errors, and FMOLS. The results confirm that all the variables significantly influence renewable energy consumption in the sample region. Specifically, financial development has a positive influence on renewable energy use while oil prices exert contrasting effects on renewable energy consumption. It diminishes renewable energy use in the lower quantile range and has a positive increasing effect in the upper quantile range. Moreover, foreign direct investment has a positive effect on renewable energy consumption while CO_2 impedes the consumption of renewable energy in higher quantities. In light of these outcomes, this study contributes substantially to the empirical literature and will help practitioners and policymakers to design environmentally and economically friendly energy systems for emerging nations.

1. Introduction

The problem of climate change is growing day by day, leading to a challenging obstacle to global sustainable development. The Intergovernmental Panel on Climate Change (IPCC) states that climate change is mainly caused by human activity, specifically the excessive combustion of fossil fuels and the release of greenhouse gases (GHGs). Consequently, by implementing the energy transition and thereby diminishing greenhouse gas (GHG) emissions, it is possible to mitigate or potentially prevent the consequences of climate change. Consequently, numerous nations have participated in the competition to achieve a "zero-carbon" status (Agarwal et al., 2017). Fossil energy such as coal, oil, and natural gas has been essential in pushing for economic development. However, with these resources becoming scarce and global energy needs rising constantly, Primary energy consumption globally recorded an uptick of 1.8% in 2012 (Ellabban et al., 2014). The Intergovernmental Panel on Climate Change (IPCC) states that by 2050, renewable energy has to account for 70-85% of the global electrical supply. To restrict global warming to 1.5 °C, the amount of money invested in various energy technologies and energy efficiency needs to be increased by a ratio of 4–10 compared to the investments made in 2015. Currently, the transformation is occurring at a pace that is slower than what is necessary. According to an IPCC Special Report, the existing policies to reduce carbon emissions and counteract climate change are projected to cause a global temperature increase of around 3 °C by the year 2100, with additional warming expected in the future. Economic, socio-cultural, and institutional obstacles have hindered the widespread use of renewable energy technologies (IPCC, 2018). Figure 1 shows the global split of CO_2 emissions from fossil fuel consumption by regions for the years 1965 to 2023. This shows that emissions had a gradual increase, and in the recent past, the Asia Pacific, represented by the blue portion of the graph, had more inclination towards enhancing the aspect. The emissions from other countries, such as North America, Europe, and the Middle East, also reveal a steady but less pronounced increase. Emissions mobilized in relation to economic growth and modernization, especially in developing countries, due to its postindustrial nature. Figure 1 illustrates the need for global emission reductions to meet the climate targets as the consumption of energy and the use of fossil fuels continues to be high globally (Statista, 2024). CO_2 emissions trend corresponds to the increased ability necessary for a shift to green energy to mitigate the cost and effects of conventional use of fossil energy sources. This paper analyses the position of renewable energy and the effect of financial advancement, oil price, carbon footprint, trade liberalization, and FDI on emerging economies from 2005 to 2021.

Figure 2: Global Carbon Dioxide Emission from Energy (1965-2023)



Source: www.statista.com

There is an established correlation between growth and energy. Economic growth positively correlates with energy consumption, particularly the need for fossil fuels. Renewable sources refer to energy sources that are both ecologically beneficial and have low carbon emissions. Solar, wind, geothermal, and hydroelectric power sources are GHG-free (Rasheed, et al., 2025; Shahzadi, et al., 2025; Naz, et al., 2022). Recently, numerous nations have embraced renewable energy technologies as a means of safeguarding the environment. Emerging economies have been motivated to consume renewable energy sources due to several factors, including energy dependency, energy supply security, energy price volatility, climate change, health concerns, and environmental calamities. Governments, economists, researchers, and policymakers are currently seeking strategies to guarantee a sustainable and thriving environment (Chaabouni and Saidi, 2017). The decreasing expenses of environmentally-friendly energy technologies, for example, solar and wind power (UN, 2015a), along with the impetus generated by the Paris Climate Agreement and the SDGs[1] (UN, 2015b), are propelling swift transformation towards a future reliant on renewable energy. As previously said, wind and solar energy are the fundamental pillars of this transition.

Energy consumption represents the whole quantity of energy utilized by the final consumer. This encompasses both domestic production and imports, among other factors (Shukla et al., 2015). Consumers of India and Pakistan mainly depend on fossil fuels. However, a considerable portion of energy consumption in Nepal and Sri Lanka is attributed to combustible renewable sources and waste, such as firewood and solid fuels. It is crucial to acknowledge that in numerous nations, the proportion of energy derived from renewable sources is below 5% (Kumar and Sudhakar, 2015; Shukla et al., 2016b). Developing countries such as India, Pakistan, Thailand, China, and others are exploring sustainable and renewable energy means, such as solar, hydro, wind, and biomass. Energy consumption has risen due to the rapid population expansion and economic development in South Asian countries (Shukla et al., 2016a).

Developing nations are progressively acknowledging the necessity to shift towards sustainable energy solutions in order to tackle environmental issues, promote economic advancement, and guarantee social welfare (Bertaglio, 2017; UN, 2023). The B.N.E.F. documented that the reason behind the dominant status of green energy in emerging nations is not just the availability of these sources but also a significant fall in the cost of producing renewable energy in the current era (Bertaglio, 2017). Emerging nations are increasingly allocating more resources to generate and develop renewable energy, mainly concentrating on wind technologies and solar photovoltaics (Cantarero, 2020).

There is an increasing trend and interest in incorporating renewable energy sources into the energy framework of developing countries, encouraging low-carbon use (Kayani, et al., 2023; Khan, et al., 2021). Numerous emerging nations, such as China, Brazil, Thailand, and Indonesia, have moved to implement biofuels as the main source to cut down on the environmental impact of the respective transportation industries (Ahlgren et al., 2017; Fulton et al., 2015). Though emerging nations have a lower number of per-person vehicles relative to developed nations, the rate of increasing ownership of vehicles is high in the Global South. Developing countries represented 63% of the total worldwide investment in renewable energy in 2017. Investment in developing countries is mainly focused on China, India, and Brazil, which collectively accounted for slightly more than 50% of worldwide investment in renewable energy (excluding major hydropower) in 2017. China alone represented 45% of this investment (McCrone et al., 2018). Between 1990 and 2017, the average annual growth rates of vehicle ownership were 18.5% in

[1] Sustainable Development Goals

China, 9.6% in Indonesia, and 7.5% in Malaysia. In contrast, developed countries like the UK, Germany, and the U.S. experienced much lower growth rates of 1.6%, 1%, and -0.5%, respectively (Davis and Boundy, 2020).

Developing nations encounter obstacles in effectively handling end-of-life renewable resources, such as minimal or nonexistent expenses for disposal, the cost of gathering and transporting them to recycling facilities, competition from the informal waste sector and enterprises engaged in salvaging electronic components, as well as a general absence of incentives or enforcement mechanisms to encourage reusing and recycling instead of resorting to landfilling and open burning (Bronstein, 2020). The relationship between energy use and sustainable development has been a contentious subject due to its impact on crucial policy determinations. Traditional fossil energy, being a vital natural resource, presents numerous ecological challenges due to its significant contribution to greenhouse gas (GHG) emissions (Dogan et al., 2020).

Based on the World Energy Outlook 2020 (Agency, 2020), around 55% of the total carbon emissions worldwide can be attributed to the power industry, with coal-fired generation contributing to over 80% of these emissions. Hence, the adoption of an energy transition has become an unavoidable decision in order to attain the 2.0 °C target outlined in the Paris Agreement. Renewable energy development (REN.) is vital for two reasons (Zhang, et al., 2023). Initially, with global industrialization, there is a persistent increase in the need for energy. Renewable energy is abundantly available and holds significant potential for growth, guaranteeing the security of energy supply and mitigating energy scarcity (UNFCCC, 2021).

Furthermore, the extraction and consumption of fossil energy not only releases greenhouse gases (GHGs) but also poses a threat to ecological resources such as land, water, and air, hence jeopardizing human health (Ahmad, et al., 2021; Ali, et al., 2020; Ahmad, 2018). Renewable energy, despite using the same amount of energy, releases a smaller amount of pollutants and greenhouse gases (GHGs). Renewable energy development has emerged as a crucial tool in tackling climate change, enhancing energy security, and enhancing environmental quality (Dong et al., 2022).

The decentralized nature of renewable energy, particularly solar power, has long been acknowledged for its capacity to cater to scattered rural communities (Azhar, 2024; Azhar & Imran, 2024; Azhar, et al., 2022). Due to the poverty prevalent among rural populations in developing countries who do not have access to electricity grids, clean energy solutions, such as solar and wind energy, have proven to be highly effective in promoting inclusive growth for those at the lower end of the socioeconomic spectrum (Bhattacharya et al., 2016; McCollum et al., 2018).

There is growing evidence that VRE (variable renewable energy) will be recognized and utilized as a catalyst for economic development. The following items are included (Arndt et al., 2019):

- The swift reduction in costs since the cost of all power technology options has been influenced by advancements in technologies and fluctuations in fuel costs.
- The emerging regions possess significant endowments of renewable energy, particularly solar energy, which are relatively abundant.
- The developed world's increasing familiarity with renewable energy, even in cases where the available resources are not as advantageous (e.g., solar electricity in Germany), along with successful experiences from other advanced technologies like cellular phones and
- The inherent benefits of renewable energy for rural electrification.

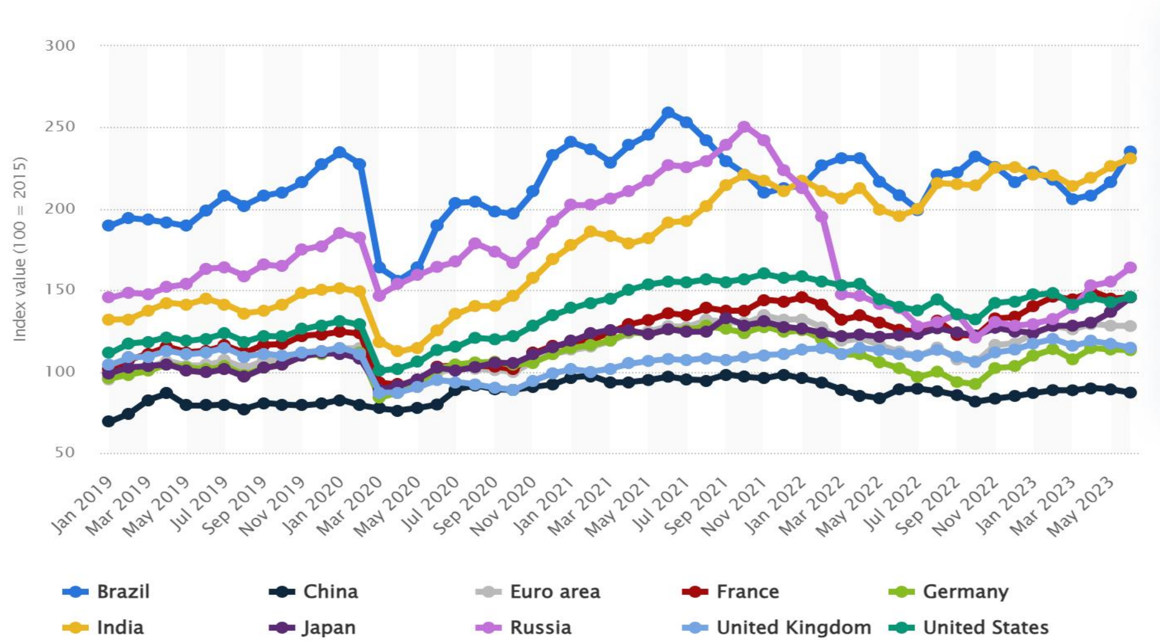
This research makes several contributions to existing literature. *First*, the research underscores the utilization of renewable energy use and its potential in achieving Sustainable Development Goals (SDGs). The study focuses on the interaction of renewable energy use and key factors such as financial development, oil price, and carbon emission, which are focal points in our global search for a sustainable future (Hsu et al., 2024; Hsu & Huynh, 2023; Hsu et al., 2023). Thus, this research aims to examine the complexities, looking into the possible conflicts and opportunities, with the primary goal of shedding light on factors affecting renewable energy use with the goals of sustainable development. This research examines the effect of financial development, oil price, carbon emission, trade openness, and FDI on renewable energy use in 22[2] Emerging economies over 2005-2021.

Secondly, the majority of the previous research has estimated the aforementioned link using conventional regression models such as NARDL. and GMM (Mary Adenrajo and Sade Akintunde, 2022; Deka et al., 2024). We have employed the latest PQR by Powell (2016) and MMQR by Machado and Silva (2019) along with several other techniques, namely, OLS, OLS with robust standard errors, OLS with Driscoll and Kraay standard errors, fully modified OLS PQR is particularly effective at handling outliers and heterogeneity, providing an advantage over traditional regression techniques, which often overlook these issues and lead to inconsistent and biased results (Ummalla et al., 2019). This approach bridges the gap in the literature on renewable energy consumption, which has primarily relied on the conventional linear regression approaches that may not adequately capture the heterogeneous effect of financial development, oil prices, and carbon emission levels on renewable energy use across the diverse segments of the population. This study bridges all these gaps; the study adds to the literature on renewable energy use and offers practitioners and policymakers advice on how to advance renewable energy use in emerging economies. The empirical evidence furnished by a study enables policymakers to frame economically and environmentally friendly energy infrastructure in developing nations.

Figure 2 shows the index of financial development in significant developing and developed economies during 2019-2023. As of June 2023, Brazilian and Indian stock markets emerged as the top performers among major developed and emerging economies, with index values of 235.25 and 230.91, respectively. In contrast, China and Germany had the lowest-performing markets, with index values of 86.98 and 113.04, respectively. The index values are based on 2015 as the baseline year (2015 = 100).

Figure 2: Trend of **Financial Development in major developed and emerging economies 2019-2023**

[2]In Appendix, Table A-4.



Source: www.statista.com

The subsequent sections of this study are outlined as follows: Section 2 shall furnish a comprehensive review of the literature. The third section will focus on outlining the data and sources, models, and methods used in the study. Section 4 will present the estimated results. The final section, section 5, will provide the conclusion and discuss the policy implication of the findings.

2. Literature review

2.1. Financial Development and Renewable Energy Consumption

Anton and Nucu (2020) analyzed the effect of financial development on the use of renewable energy in the 28 EU nations during 1990-2015. They focused on the three dimensions of financial development, namely, the banking sector, the bond market, and the capital market. The empirical analysis using fixed effect showed that all three measurements of financial development positively affect the consumption of renewable energy. Similarly, Shahbaz et al. (2021) studied the effect of financial development on renewable energy use in 34 upper-middle-income developing nations. The study used FMOLS, and findings revealed that financial development is found to increase demand for renewable energy. Mukhtarov et al. (2020a) in Azerbaijan and Mukhtarov et al. (2022a) in Turkey also identified that financial development has a positive effect on renewable energy use.

On the contrary, Mary Adenrajo and Sade Akintunde (2022), using NARDL, found a negative effect of financial development (domestic private credit) on renewable energy consumption in Nigeria from 1990 to 2020. At the same time, changes in domestic credit have a significant and positive impact on renewable energy consumption in Nigeria. Deka et al. (2024) aim to identify the factors that promote renewable energy (RE) consumption, with a focus on financial development and oil prices in emerging nations (Turkey, Russia, India, Indonesia, Mexico, Brazil, and China) over the period 1990–2019. Employing fixed effect and GMM methods, the findings highlight the significance of financial development in promoting renewable energy consumption development.

Prempeh (2023) examined the impact of financial development on renewable energy consumption in Ghana in the long run. The study employs VECM, ARDL, DOLS, CCR, and FMOLS. The outcomes of the study signify that financial development positively affects the consumption of renewable energy in Ghana (Janjua, et al., 2025; Shah, et al., 2024; Naseer, et al., 2018). Moreover, Vatamanu and Zugravu (2023) investigate the nexus between renewable energy use and financial development in 27 EU member nations for the period spanning 2000-2020. Employing fixed effect, they discovered that increased financial development increases renewable energy use. In their study, Wu et al. (2023) explored financialization concerning the two targets of the Nordic states: clean energy (SDG 7) and climate action (SDG 13), manifesting that the identified states experience problems with both financialization and renewable energy integration. Applying wavelet analysis for the period 1980–2020, the paper identified a negative short-run and long-run link between financial development and CO_2 emissions, as well as for renewable energy.

Athari (2024) examined the possible factors that influenced the REN in developing markets with special reference to BRICS countries covering the period between 2000 and 2021. Through fixed effects and quantile panel data techniques, the authors determined that while economic openness increases REN, benefiting the formulation of environmental sustainability policies, financial development also improves the environment. In their paper, Alam et al. (2024) looked at the macroeconomic determinants of India's RE and NRE, where they identified the financial account and technology as essential influencers. The short-run effect of technology on per capita non-renewable energy consumption is positive, while in the long run, this effect is negative. Yadav et al., (2024) examine renewable energy consumption in BRICS economies, finding positive correlations with economic growth, consumer price index, and domestic credit, but a negative relationship with foreign direct investment (FDI).

2.2. CO_2 and Renewable Energy Consumption

Mitigation of carbon emissions to cater to the challenges of global climate change has attracted nations to adopt renewable energy sources and campaign for environmental prevention (Azhar, 2024; Azhar & Imran, 2024; Azhar, et al., 2022). As a result, earlier research that concentrated on the factors affecting renewable energy adoption has integrated carbon emission as an element of the predictor variable. Literature has established that higher per capita carbon emission is crucial to driving renewable energy consumption across G7 and emerging economies (Ali, et al., 2020; Ali, et al., 2020; Xu, et al., 2019). For example, carbon emission has been reported by Salim and Rafiq (2012) to be a substantial factor in determining renewable energy consumption in nations such as the Philippines, China, Brazil, Indonesia, Turkey, and India. Finally, Omri and Nguyen (2014) added to the literature that increasing carbon emissions primarily increases the utilization of renewable energy sources.

Additionally, Apergis and Payn (2014) examined the association among Central American countries. The study found a direct association between the utilization of renewable energy and carbon emissions. Similarly, evidence was produced by Mac Domhnaill and Ryan (2020) demonstrating that the European Union embraced a higher percentage of renewable energy in the power sector owing to increasing greenhouse gas emissions between 2000 and 2015. In contrast, Nguyen and Kakinaka (2019) detected varying relations between renewable energy use and carbon emission. Research outcomes indicated a positive link between renewable energy consumption and carbon emission in low-income nations; however, high-income nations exhibit an inverse relation between renewable energy consumption and carbon emission. Karacan et al. (2021) found a negative effect of carbon emission on renewable energy use.

2.3. Oil Price and Renewable Energy Consumption

Mukhtarov et al. (2020b) examined how oil prices affected renewable energy usage in Azerbaijan from 1992 to 2015 using structural time series analysis. The study found that oil prices have negative effects on renewable energy usage in Azerbaijan in the long term. Comfort from higher oil prices may impede the shift from conventional to renewable energy in the analyzed country. Chen et al. (2021) documented that actual oil price hikes contribute to higher utilization of clean energy in less democratic nations but have no substantial effect in democratic nations. Higher trade openness reduces clean energy consumption in relatively less democratic nations. Karacan et al. (2021) delved into the effect of carbon emissions and oil prices in Russia during 1990-2015. Using VECM, outcomes demonstrated that higher oil prices affect renewable energy consumption negatively, thereby impeding the transition to renewable energy.

Tambari et al. (2023) observed the international oil price effect on the development of renewable energy in oil-exporting and oil-importing countries in Africa. They found that higher oil prices have a positive effect on renewable energy consumption in oil-importing nations, thereby making these countries economically more competitive (Nisar, et al., 2025; Basharat, et al., 2023; Naz, et al., 2020). In contrast, Prempeh (2023) established a negative effect of oil prices on renewable energy consumption in their study in Ghana. In the same vein, Kareem et al. (2023) evaluated the effect of oil prices on the consumption of renewable energy in South Africa using the bootstrap ARDL model (Masih, et al., 2025s; Masih, Saher & Raju, 2022). They discovered that the oil price shocks bear a substantial adverse effect on energy usage, indicating that higher oil price slashes energy consumption in South Africa. Mukhtarov et al. (2022b) also reported a negative effect of energy prices on renewable energy utilization. Deka et al., (2024) analyze the factors promoting renewable energy (RE) consumption in seven emerging economies, highlighting the positive impact of financial development and economic growth. The study finds that oil prices negatively affect RE development, while foreign direct investment shows no significant effect.

2.4. Research Gap

It is in this section that the current study pinpoints a major research hole that is yet to be filled in the current literature and reveals how the present analysis will fill this void. Though LREN has become an essential area of research interest in achieving Sustainable Development Goals (SDGs), the literature mainly considers how financial development, FDI, and renewable energy interrelate in the context of the EU (Anton and Nucu, 2019). Likewise, previous research has reviewed how oil prices, financial development, and renewal of energy consumption relationships in the G7 nations, Russia, India, Indonesia, Mexico, Brazil, as well as China (Cetin and Barkitas, 2018; Deka et al., 2024, inter alia).

However, these studies either consider these variables individually or, at best, cover them in a limited number of geographical areas, missing the impact of a set of factors that consist of financial development, oil price, carbon dioxide emission, trade openness, FDI, and GDP on the consumption of renewable energy in emerging nations simultaneously. This research fills this gap through an examination of the effects of these variables on renewable energy consumption for 22 emerging economies for the period 2005-2021. This is a good approach because, as the previously mentioned statistics show, new economy countries have a different economic structure and relationships that require a more extensive and open investigation.

Nevertheless, previous methodologies may not adequately capture the problem of outliers and heteroscedasticity of panel data. To overcome this limitation, this study adopts two methodological innovations, i.e., the latest Panel Quantile Regression (PQR) by Powell (2016) as well as the Method of Moments Quantile Regression (MM-QR) by Machado and Silva (2019). These methodologies are particularly appropriate to identify how the effects of the analyzed variables vary across different quantiles, providing richer and more accurate information. The use of PQR and MM-QR is a methodological contribution because it further generalizes the results, showing that statistical rigor is higher under conditions of heterogeneity and non-normality.

Summary of literature review is provided in Tbale 1.

Table 1: Summary of Literature Review

Author	Period	Region	DV	IV	Techniques	Results
Carbon Emissions and Renewable Energy Consumption						
Salim and Rafiq (2012)	1980-2006	Turkey, Brazil, India, China, Philippines, Indonesia	Renewable energy use	carbon emission	FMOLS, DOLS	Significant, positive
Omri and Nguyen (2014)	1990-2011	64 Emerging nations	Renewable energy use	carbon emission	GMM	Significant, positive
Apergis and Payn (2014)	1080-2010	Central America	Renewable energy use	carbon emission	Nonlinear panel smooth transition VECM	Significant, positive
Mac Domhnaill and Ryan (2020)	2000-2015	European Union	Carbon emission	Renewable energy use	Fixed Effect Vector Decomposition	Significant, positive
Nguyen and Kakinaka (2019)	1990-2013	107 Low-income and High-income nations	Carbon emission	Renewable energy use	FMOLS, DOLS	Significant, positive effect in low-income and a negative effect in high-income nations.
Karacan et al. (2021)	1990-2015	Russia	Renewable energy use	carbon emission, Oil prices	VECM	Significant, negative
Oil Prices and Renewable Energy Consumption						
Mukhtarov et al. (2020b)	1992-2015	Azerbaijan	Renewable energy use	Oil prices		Significant, negative
Tambari et al. (2023)	1990-2021	Africa	Renewable energy use	Oil prices	Panel VECM	Significant, positive
Prempeh (2023)	1990-2019	Ghana	Renewable energy use	Oil prices	VECM, FMOLS, DOLS, CCR	Significant, negative
Kareem et al. (2023)	1990-2019	South Africa	Renewable energy use	Oil prices	Bootstrap ARDL	Significant, negative

Mukhtarov et al. (2022b)	1980-2019	Iran	Renewable energy use	Oil prices	General to Specific (Gets) modeling approach	Significant, negative
Deka et al., (2024)	1990-2019	Developed nations	Renewable energy use	Oil prices	Fixed Effect, GMM	Significant, negative
Financial Development and Renewable Energy Consumption						
Anton and Nucu (2020)	1990-2015	28 EU nations	Renewable energy use	Financial development	Fixed Effect	Significant, positive
Shahbaz et al. (2021)	1994-2015	34 upper-middle-income nations	Renewable energy use	Financial development	FMOLS	Significant, positive
Mukhtarov et al. (2020a)	1993-2015	Azerbaijan	Renewable energy use	Financial development	ARDL	Significant, positive
Mukhtarov et al. (2022a)	1980-2019	Turkey	Renewable energy use	Financial development	VECM, ARDL	Significant, positive
Mary Adenrajo and Sade Akintunde (2022)	1990-2020	Nigeria	Renewable energy use	Financial development	NARDL	Significant, negative
Deka et al. (2024)	1990-2019	Turkey, Russia, India, Indonesia, Mexico, Brazil, and China	Renewable energy use	Financial development	Fixed Effect, GMM	Significant, positive
Prempeh (2023)	1990-2019	Ghana	Renewable energy use	Financial development	VECM, DOLS, CCR	Significant, positive
Vatamanu and Zugravu (2023)	2000-2020	27 EU nations	Renewable energy use	Financial development	Fixed effect (FE) model	Significant, positive
Wu et al. (2023)	1980–2020	Nordic states	Renewable energy use	Financial development, CO_2	Wavelet Analysis	Significant, negative
Athari (2024)	2000-2021	BRICS	Renewable energy use,	Financial development, economic growth	Fixed Effect, Quantile Regression	Significant, positive
Alam et al..	2009-2019	India	Renewable	Financial	Multiple	Significant, positive in

(2024)			energy use	development, technology	regression model	the short run, negative in the long run
Yadav et al. (2024)	1995-2022	BRICS	Renewable energy use	Financial development, economic growth, consumer price index, FDI	Fixed Effect	Economic growth, CPI, and domestic credit have significant positive effects. FDI has a negative effect

Note: DV represents the dependent variable and IV represents the independent variable.

3. Data and Methods

The objective of the study is to examine the effect of financial development, carbon emission, oil prices, trade openness, per capita GDP, and FDI on renewable energy use in 22 emerging economies from 2005 to 2021. We have gathered the data from World Development Indicators, and countries are chosen based on the availability of data. Table 1. Provides the details of the variables.

Following the studies of Anton and Nucu (2019) and Cheng et al. (2021), we have developed the following model;

3.1. Model

$$LREN_{it} = \beta_0 + \beta_1 LFD_{it} + \beta_2 LOP_{it} + \beta_3 LCO2_{it} + \beta_4 LGDP_{it} + \beta_5 LTRADE_{it} + \beta_6 LFDI_{it} + \varepsilon_{it} \text{.......(1)}$$

Where i = 1,2,3,…,10 t = 2007, 2008,…, 2021

LREN (renewable energy consumption) is the dependent variable. While LFD (financial development), LOP (accurate oil price), LCO_2 (carbon dioxide emission), LGDP (gross domestic product), LTRADE (trade), and LFDI (foreign direct investment) are independent variables. $\beta_1 \rangle 0$, financial development can offer tax breaks, subsidies, and other forms of financial incentives that can uplift the usage of renewable energy (Pata et al., 2022; Anton and Nucu, 2020). The association between oil prices and the use of renewable energy is complex and dependent on several variables. Some studies contend that heightened oil prices could lead to increased use of LREN (Wang et al., 2020; Chen et al., 2021). Thus, $\beta_2 \rangle 0$ as well. Renewable energy efforts may face limited resources, attention, and political will due to competing agendas, which could affect their growth and use. In this way, $\beta_3 \rangle 0$

$\beta_4 \rangle 0$ a higher GDP per capita results in a more ecologically friendly energy mix with a greater proportion of renewable energy sources (Ergun and Rivas, 2023). $\beta_5 \rangle 0$, trade openness has an adverse effect on renewable energy use, and Tiwari et al. (2022) support this finding. A rise in foreign direct investment (FDI) is likely to have a favorable knock-on effect, making renewable energy sources more adaptable domestically. Therefore, $\beta_6 \rangle 0$ by deterring the use of conventional energy sources like fossil fuels in the host nation, the inflow of FDI could encourage the use of renewable energy (Doytch and Narayan, 2016; Navas, 2019). The description, units, and data source of the variables are presented in Table 2.

Table-2. Data description

Variable	Measure	Unit	Source
LREN	Renewable energy consumption	% of total final energy consumption	WDI
LFD	Financial development	Index	IMF
LOP	Oil prices	U.S. $ per barrel	FRED
LCO_2	LCO_2 emission	Metric tons per capita	WDI
LTRADE	Trade openness	Trade (% of GDP)	WDI
LGDP	Gross domestic product	Constant 2015 US$	WDI
LFDI	Foreign direct investment	Net inflows (% of GDP)	WDI

Note: W.D.I., I.M.F., and F.R.E.D. stand for World Development Indicators, International Monetary Fund, and Federal Reserve Economic Data, respectively.

3.2. Methods

At first, we test for cross-sectional dependency; cross-sectional dependence commonly exists in the panel dataset. Cross-sectional dependence arises due to unobserved standard shocks and significant interlinks between socioeconomic variables. Therefore, the panel estimators lead to inconsistent and unreliable results. Thus, it is crucial to check its presence empirically; neglecting to do so could lead to significant penalties (De Hoyos and Sarafdis, 2006). The study investigates the dependencies among various cross sections with the help of the Pesaran parametric test, presented by Pesaran (2007). The test statistic is defined as follows:

$$\text{CDT}=\sqrt{\frac{2T}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{g=i+1}^{N}\hat{\rho}_{ig}\text{.......(2)}$$

If cross sections are interdependent mutually, then the conventional first-generation unit root test becomes invalid. Thus, this study employs a modern second-generation CADF test introduced by Pesaran (2007), which considers the issue of cross-sectional dependence among datasets.

We utilize the Westerlund cointegration test by Westerlund (2008) to confirm the long-run association between the concerned variables.

3.2.1. Panel Quantile Regression

Due to the diverse array of panel data types, several estimation techniques and empirical models are utilized to examine how explanatory variables affect the mean of the dependent variable. Nevertheless, these methods commonly overlook the overall effect of explanatory variables across the distribution. Economic variables commonly encounter issues such as outliers and non-normal distributions, which potentially lead to misleading regression outcomes (Lin and Xu, 2018). Therefore, it is necessary to employ a suitable estimation method; panel quantile regression (PQR) is the best method to address these issues (Koenker and Bassett, 1978). According to Lin and Xu (2018), PQR residuals are not bound to meet the standard classical assumptions of linear regression models, i.e., zero mean, constant variance, and normal distribution. In quantile regression, the objective is to minimize the absolute value of residuals, diverging from the conventional OLS estimator that minimizes the sum of squared residuals.

PQR effectively handles unobserved heterogeneity and outliers. This study utilizes panel quantile regression (PQR) to investigate how financial development, oil price, carbon emission, trade openness, and real income affect renewable energy use across various distributions of the dependent variable. In PQR, the conditional distribution of the dependent variable is divided into various quantiles, with the median marked as the 50th quantile (Ummalla et al., 2019).

Koenker (2004) proposed a concise approach for estimating the individual effect coefficients. Nevertheless, it may not capture the influence of unobserved factors. Based on the framework of Koenker (2004), Canay (2011) introduced a two-step fixed effect PQR In the first step, the additive fixed effects are estimated from the expected mean and unobserved variable coefficients. In the second step, the difference between the fixed effects and the original dependent variable is then estimated, and finally, PQR is applied. However, incorporating these steps could change the model's structure. To resolve this problem, Powell (2016) presented PQR, integrating nonadditive fixed effects to address the ambiguous impact of policy variables in the A.F.E.[3] model. Powell (2016) yields more reliable estimates, particularly within the small timeframe (T).

This study goes further by employing MMQR, as proposed by Machado and Silva (2019). MMQR is a valuable tool for computing quantile regression, mainly when the estimation of parameters is problematic, yielding consistent and robust results essential for policy formulation. It is advantageous because of simplified calculations, particularly in nonlinear models and when dealing with multiple endogenous variables. Thus, we assessed the impact of financial

[3] Additive fixed effect

development, oil price, carbon emission, trade openness, and real income on renewable energy consumption by augmenting descriptive statistics.

Ike et al. (2020) argue that conventional quantile regression methods overlook the individual-specific unobserved heterogeneity. In addition to addressing this concern, MMQR effectively deals with the models with endogenous independent variables or identifies the conditional heterogeneous effects of these variables.

The description of the MM-QR technique is derived from the works of Ike et al. (2020), Anwar et al. (2021), and Pradhan et al. (2020)

$$Y_{it}=\gamma_i+X_{it}^{'}\beta+(Z_{it}^{'}\alpha+\theta_i)\,U_{it} \text{ (3)}$$

In which (γ_i, θ_{it}) represents individual fixed effects, Z is a k-vector of transformable identified components, X_{it} is independent across time, as well as independently and identically distributed (i.i.d) with any individual i. At the same time, U_{it} is i.i.d across both time t and individual i. It is assumed that X_{it} and U_{it} are orthogonal to each other. Lastly, the probability $P\left(Z_{it}^{'}\alpha+\theta_{it}>0\right)=1.(\gamma,\beta^{'},\theta,\alpha^{'})$' denotes the parameters to be estimated.

Equation (1) can be expressed as:

$$Q_Y(\varphi|X_{it})=\left(\gamma_i+\ \theta_i q(\varphi)\right)+X_{it}^{'}\beta+Z_{it}^{'}\alpha^{*}q(\varphi) \text{ (4)}$$

In Equation (3), $Q_Y(\varphi|X_{it})$ represents the quantile distribution of the dependent variable Y_{it} . The position of the independent variable Xit influences the quantile distribution of $_{Yit}$. $X_{it}^{'}$ is a vector of explanatory variables, which includes $\left(\gamma_i+\ \theta_i q(\varphi)\right)$, a scalar coefficient that represents the quantile- φ fixed-effect for individual i^{th}. Finally, $q(\varphi)$ indicates the φ^{th} sample quantile estimated through solving the optimization exercise:

$min_q \sum_i \sum_t \rho_\varphi[R_{it}\text{-}(Z_{it}^{'}\alpha+\theta_i)\ q(\varphi)]$

In which $\rho_\varphi(A)=(\varphi\text{-}1)AI\{A\leq 0\}+TAI\{A>0\}$ is the check function.

4. Results and Discussion

4.1. Primary Results

Based upon the analysis presented in this work, Table 3 contains summary statistics regarding the data employed in the study. The variables, expressed in terms of logarithm, indicate a relatively intermediate central tendency and differential variability. LREN, the log of renewable energy consumption, has an average value of 2.087, S.D. of 1.967, and varies from a minimum of -4.605 to a maximum of 3.925. Mean of LFD is 0.866, displaying. Low S.D. of 0.315, and the range is -1.981 and -0.305, hence portraying little volatility compared to the other ones. Similar to GDP (A.L.I.), oil prices (LOP) have small fluctuations, with an average of 4.221 and an S.D. of 0.308. The CO_2 emissions average levels (LCO_2) analysis yields slightly above average values, specifically a mean of 1.291 and a standard deviation of 0.987, which varies between - 1.460 and 3.303. Temperatures (TRADE) have a mean of 4.059 with a standard deviation of 0.524, and the range is as follows: min = 3.095, max = 5.317.

At the same time, LGDP has a high mean of 8.744 (Table 3) and S.D. of 0.896 and varies greatly between the minimum and maximum values of 0.896 to 10.979 in terms of GDP LFDI stands at a moderate mean (mean = 0.782) but high volatility (S. D = 0.886) and an extent of dispersion between a minimum of -2.870 and a maximum of 4.669. In total, further analysis of the data shows that most of the sound variables of LREN, LCO_2, and LFDI have significant volatility during the period under consideration. In contrast, the LFD and LOP have lower volatility. VIF test and correlation matrix are given in the appendix (see Table- A. 1 and Table-A. 2).

Table-3. Summary Statistics

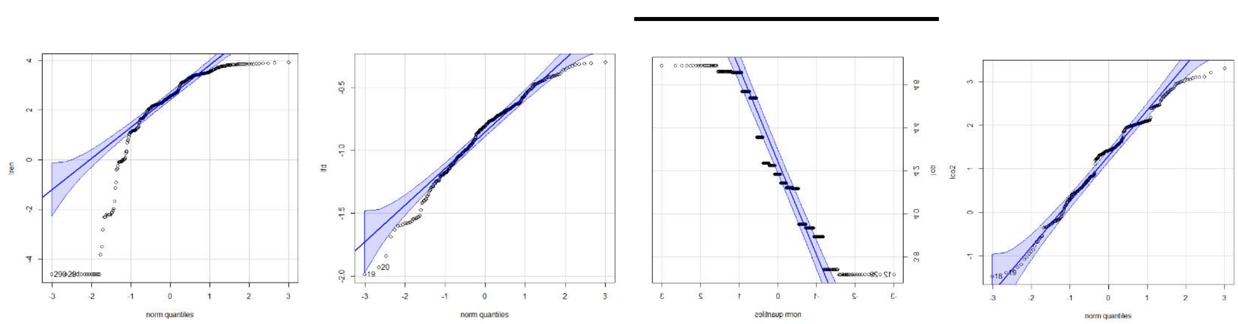
Variable	Mean	S.D	Min	Max
LREN	2.087	1.967	-4.605	3.925
LFD	0.866	0.315	-1.981	-0.305
LOP	4.221	0.308	3.719	3.303
LCO_2	1.291	0.987	-1.460	3.303
LTRADE	4.059	0.524	3.095	5.317
LGDP	8.744	0.896	0.896	10.979
LFDI	0.782	0.886	-2.870	4.669

Source: Author.

Note: All the variables are in log form. Min, Max, and S.D. are minimum, maximum, and standard deviation, respectively.

The conditional mean regression model employs an assumption of normal distribution of variables. However, when this condition is met, the model can adequately capture the implications of financial development, oil prices, carbon emissions, trade, GDP, and FDI on LREN Nevertheless if the variables are not normally distributed, the results might be inaccurate, which is why using this approach is not suitable (Nasreen et al., 2023). In such circumstances, the PQR model may be more beneficial in assessing the strategic importance of a particular activity. To determine the normality of each data, we used Q-Q plots based on the following findings shown in Figure 3. Since the plots did not form a diagonal line, there remained an indication that tests were non-normal.

For renewable energy consumption (LREN), the graph indicates that, although the data is relatively well approximated by a straight line over the middle portion of the range, there are some inconsistencies, especially at the lower end of the scale. This may mean that the distribution of LREN is actually leptokurtic or skewed, which, in effect, is an indication of outliers. The Linear Financial Development (LFD) data also has linear characteristics, which suggest that variables approximate a normal distribution, but variations at the lower tail and upper tail suggest skewness or the availability of outliers. As with other variables, similar outcomes exhibit different values in the tails. As can be observed in Table 3, and specifically from LREN and LFD, T.E. remains non-normal in the tail area. More details are presented in Table 4. We find no evidence to support the use of conditional means regression, which leads us to prefer the PQR model for our analysis (Belaid et al., 2021).



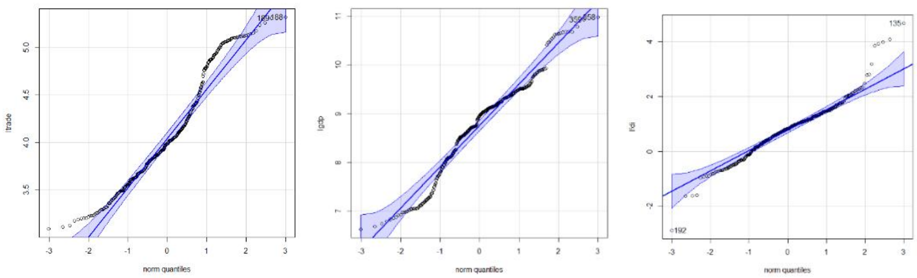


Figure 3: QQ-Plots.

First, we checked for the normality of data using the Shapiro-Wilk W test, Shapiro-Francia W' test, and Jarque Bera test of normality. Table 4 provides evidence against the normality of data since probability values are quite significant. In all variables, the tests perform well in rejecting the null hypothesis of normality; all the p-values generated are more significant than 0.05. This indicates that all the variables are not normally distributed (Moral-De La Rubia, 2023). When it comes to the LREN, LFD, LOP, and LTRADE formula, all the evidence pointed towards the fact that the significance level deviated highly from normality, and this was confirmed by both the Shapiro-Wilk and Shapiro-Francia statistics and also of J.B. highly significant results. Similarly, LCO_2 and LGDP both fail the normality test, but in this case, LGDP has a slightly lower value of J.B. p-value than the other variables. Third, LFDI has a significantly high level of non-normality, and all three tests utilized in the analysis output a p <0.05. Altogether, the normality tests reveal that the data for all the variables under analysis goes against the normal distribution, and some variables are even more vital, for example, LREN and LFDI

Table 4: Normality Tests

Variable	Shapiro-Wilk W test	Shapiro-Francia W' test	J.B. test
LREN	62.38 (0.000)	69.42 (0.001)	477.7 (0.000)
LFD	8.658 (0.000)	9.126 (0.000)	29.76 (0.000)
LOP	12.95 (0.000)	13.66 (0.000)	20.08 (0.000)
LCO_2	5.909 (0.000)	5.968 (0.000)	10.86 (0.004)
LTRADE	13.09 (0.000)	13.49 (0.000)	22.41 (0.000)
LGDP	9.243 (0.000)	9.587 (0.000)	6.44 (0.04)
LFDI	9.747 (0.000)	11.41 (0.000)	104.9 (0.000)

Note: Parentheses show probability values. Source: Author.

Table 5 reports the statistical outcomes for cross-sectional dependence and unit root tests. Table 4 presents the CSD and unit root to explore the characteristics of the variables used in the study, which include LREN (Renewable Energy), LFD (Financial development), LOP (oil prices), LCO_2 (Carbon Dioxide Emissions), LTRADE (Trade), LGDP (Gross Domestic Product) and LFDI (Foreign Direct Investment) among others. Starting with the Pesaran CD test, all variables exhibit significant cross-sectional dependence, as indicated by their respective test statistics and p-values. For instance, LFD shows a statistic of 13.00 with a p-value of 0.000, demonstrating a solid rejection of the null hypothesis of no cross-sectional dependence. Similar patterns are observed across other variables, highlighting that these factors are interrelated within the data set. Since the presence of CSD in the panel data makes the use of conventional unit root test powerless, therefore, we utilize the second-generation cross-sectional augmented dickey fuller test by Pesaran (2007).

Concerning CADF unit root test results, the research finds that at their level, most of the variables fail to reject the null, which means that they are non-stationary. For instance, LREN and LFD = -0.937 and = -1.544, and the corresponding p-values are 1.000 and 0.816. However, when comparing the first difference, the value of all variables is negative, and the test statistic value of $p < 0.05$ suggests that the variables turn stationary after the first difference. Interestingly, the analysis shows that variables are stationary once the first differences are taken into account.

Table 5: Results of CSD and Unit Root Test

Variable	LREN	LFD	LOP	LCO_2	LTRADE	LGDP	LFDI
Pesaran CD test							
Statistic P- value	4.22 0.000	13.00 0.000	62.67 0.000	14.34 0.000	7.74 0.000	38.72 0.000	4.09 0.000
CADF unit root test (At level)							
Statistic P-value	-0.937 1.000	-1.544 0.816	2.610 1.000	-1.832 0.983	-1.489 0.875	-2.072 0.844	1.110 0.867
CADF test (At First Difference)							
Statistic P-value	-2.457 0.000	-2.898 0.000	2.610 0.09	-2.238 0.011	-2.314 0.004	-2.274 0.007	-10.01 0.000

Source: Author.

In the next step, this study determined the cointegration between the study variables using Westerlund cointegration tests (Westerlund, 2007). Table 6 reports the Westerlund cointegration test. The value of the variance ratio statistic is 2.8657 with a strongly significant probability value (0.0021), rejecting the null hypothesis of no cointegration at a 1% level of significance. This result provides strong evidence of a long-run co-movement between study variables. This low p-value is good and reaffirms the fact that, eventually, all the variables are synchronized. Thus, the outcomes of the test support the occurrence of cointegration among the concerned variables.

Table 6: Westrlund Cointegration

	t-statistic	Probability
Variance ratio	2.8657	0.0021

Source: Author.

Table 7: OLS Results (Dependent variable: LREN).

Variable	OLS	OLS with Robust St. Error	Pooled OLS with Driscoll and Kraay St.Error	FMOLS
LFD	2.607*** (0.251)	2.607*** (0.231)	2.6073 (0.106)	0.417*** (0.037)
LOP	0.028 (0.196)	0.028 (0.192)	0.028* (0.072)	0.338*** (0.055)

LCO_2	-1.842 (0.136)	-1.842*** (0.133)	-1.842** (0.051)	-1.791*** (0.039)
LTRADE	-1.572*** (0.144)	-1.572*** (0.095)	-0.572* (0.084)	-0.058*** (0.017)
LGDP	0.013 (0.138)	0.013 (0.111)	0.013* (0.060)	0.421*** (0.009)
LFDI	0.288*** (0.080)	0.288*** (0.096)	0.288* (0.090)	0.057*** (0.015)

Note: S.E. are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Author

Initially, we employed OLS and OLS with robust standard error and FMOLS. In simple OLS, LFD, LTRADE, and LFDI are significant (see Table 7). In pooled OLS with Driscoll and Kraay standard error, all are significant except LFD Finally, in FMOLS, results show that all the variables are highly significant and positively influence LREN except LCO_2 and LTRADE, which have a negative impact on LREN Regarding the positive effect of LFD, LOP, LTRADE, there is support from previous literature (Wang et al., 2020; Cheng et al., 2021; Tiwari et al., 2022).

4.1. Results of PQR

As noted earlier, our variables do not follow a normal distribution. We have employed the non-parametric approach, the PQR by Powell (2016). Table 8 shows the results of PQR, with LREN as the dependent variable, while the three renewable energy resources are the independent variables. The Table provides the robust result of the independent variables by using the quantile regression analysis with a specified band of quantiles (from 0.05 to 0.95) to analyze the impact of the independent variables on renewable energy consumption at any point of the distribution of the dependent variable.

The quantile regression results show that LFD affects the entire quantile range positively and significantly on renewable energy usage. The size of the coefficient reduces as we subdivide the sample into higher quantiles of the dependent variable, indicating some form of nonlinear relationship between financial development and renewable energy consumption in the sample country. It shows the direct relation between LFD and LREN and is supported by Anton and Nucu (2020). LOP is also significant in most of the quantiles and has a positive effect on LREN in the entire quantile range, as indicated by the positive coefficient. The prior work of Wang et al. (2020); and Cheng et al. (2021) supports the positive impact of oil prices. LCO_2 and LTRADE are also significant and have a reducing effect on LREN in the entire quantile range (5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th, and 95th). This is evident from significant probability values and negative coefficients. It implies that an increase in LCO_2 and LTRADE leads to a decrease in LREN This is in line with Tiwari et al. (2022). LGDP and LFDI are significant and have a positive effect on LREN in the case of selected emerging economies, as evidenced by significant p values and positive coefficients. An increase in LGDP and LFDI encourages renewable energy use in the sample region and is supported by literature (Tiwari et al., 2022). Increased FDI leads to increased corporate business behavior in countries, which brings technological innovations and thus increases renewable energy use. Salim et al. (2017) and Anton and Nucu (2020) support this conclusion.

4.3. Results of MMQR

In an attempt to build the reliability of our findings, we further go a notch higher by implementing the MMQR method proposed by Machado and Silva (2019), which accounts for unobserved heterogeneity and endogeneity. Many of our results are statistically significant. In

Table 9, if we consider the figures, it can be seen that LFD, with all its quantile figures, is greater than zero and statistically significant, with LREN confirming the hypothesis that higher financial development results in increased renewable energy consumption. However, it gradually fades off at higher quantiles from 4.148 at the 0.05 quantile to 0.019 at the highest 0.95 quantile.

On the other hand, LCO_2 is negative and significant for almost all the quantiles, and higher carbon emissions reduce renewable energy with a decline in coefficients from -2.860 at 5% to 0.008 at 95%. Similarly, the coefficient of the trade variable (LTRADE) indicates a pessimistic, albeit insignificant, impact on the RE consumption extent at all the quantiles in the range of 0.05 to 0.9.

Last, LGDP and LFDI have different significant, both of which have positive and significant coefficients. In contrast, the coefficients of LFDI are positive at lower quantiles but decline with higher quantiles, meaning that FDI initially has a positive impact on renewable energy consumption but decreases over time. The explanations for these results are comparable to those from the PQR (Powell, 2016) method mentioned earlier. Results indicate that all the variables are significant (except LGDP in MM-QR) determinants of renewable energy consumption in emerging economies.

4.5. Discussion

This Section focuses on the complex relationships between all explanatory variables (i.e. financial development, oil prices, the economic growth rate (LGDP), carbon emissions (LCO_2), trade openness) and the explained variable (i.e. LREN) in the sample region of the study. Thoughtfully, the analysis of these factors shows how specifically and generally, each variable supports or hinders the transition to renewable energy. The following analysis offers deeper insight into the detailed impacts of each of the factors under consideration, supported by empirical evidence and aligned with prior research outcomes.

Financial development plays a significant role in promoting renewable energy transition. Financial development can offer tax breaks, subsidies, and other forms of financial incentives to encourage the use of renewable energy. Research findings reveal that a 1% increase in LFD corresponds to a 0.41% (FMOLS) increase in the use of LREN Finding is quite similar to studies in previous literature (Anton and Nucu, 2020; Mukhtarov et al., 2022a; Pata et al., 2022). There is a complex relationship between oil prices and the usage of renewable energy, and it depends on a number of variables. According to a few studies, heightened oil prices could lead to intense use of renewable energy (LREN) (Wang et al., 2020; Chen et al., 2021; Sahu et al., 2022). At the same time, some studies pointed to a more nuanced link that may change depending on the circumstances (Mukhtarov et al., 2022b).

LGDP affects the utilization of renewable energy positively, but the link is complex and dependent on a number of factors. A higher level of economic growth encourages more investment in renewable energy, which can improve well-being and spur further economic growth while lowering greenhouse gas emissions and raising natural resource productivity. A higher level of income could initially lower the renewable energy proportion in the energy mix in relatively poorer economies as fossil fuel meets the increased energy demand. Higher GDP per capita, however, could eventually result in a more ecologically friendly energy mix, with a more significant proportion of renewable energy sources, as countries develop (Ergun and Rivas, 2023).

According to the findings of this study, LCO_2 emissions have an adverse effect on LREN Besides the efforts to reduce carbon emissions, governments and politicians must strike a balance between several factors, such as social welfare, economic development, and national security. Efforts to achieve renewable energy may face limited attention, resources, and political will due to competing agendas, which in turn affect their growth adversely. This outcome is supported by Karacan et al. (2021). Finally, trade openness has an adverse effect on renewable energy use, and Tiwari et al. (2022) support this finding. The scale effect and the technical impact are two distinct phenomena that can be used to explain the relation between energy demand and trade openness. Removing trade barriers can boost national output and economic activity, which will accelerate economic growth. Because of an increase in domestic demand, the upsurge in national output is reshaping the energy market. We call this phenomenon scale effect. Trade restrictions have been removed, allowing emerging economies to import advanced technologies. Adopting new technologies will reduce energy density. This cutting-edge technology will create more with less energy consumption—a process known as the "technical effect." (Zeren and Akkus, 2020).

Table 8: Results of Powell (2016)
(LREN is the dependent variable)

Variables	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
LFD	5.094*** (0.001)	4.062*** (0.000)	2.579*** (0.004)	2.717*** (0.006)	1.800*** (0.000)	1.556*** (0.001)	1.582*** (0.000)	1.193*** (0.002)	0.886*** (0.000)	0.428*** (0.035)	0.422*** (0.004)
LOP	0.418*** (0.000)	0.078*** (0.019)	0.059*** (0.001)	0.050*** (0.002)	0.043*** (0.000)	0.063*** (0.000)	0.105*** (0.001)	0.023*** (0.001)	0.0009*** (0.000)	0.036 (0.036)	0.0009 (0.005)
LCO_2	-3.641*** (0.000)	-2.747*** (0.032)	-1.652*** (0.000)	-1.957*** (0.004)	-1.466*** (0.000)	-1.280*** (0.001)	-1.201*** (0.000)	-1.026*** (0.001)	-1.094*** (0.000)	-1.095*** (0.011)	-1.022*** (0.004)
LTRADE	0.537*** (0.000)	0.146*** (0.016)	-1.597*** (0.001)	-1.560*** (0.000)	-0.537** (0.000)	-0.408*** (0.001)	-0.205*** (0.000)	-1.205*** (0.001)	-0.095*** (0.000)	0.076*** (0.016)	0.077*** (0.003)
LGDP	0.517*** (0.000)	0.442*** (0.006)	-1.285*** (0.002)	1.120*** (0.001)	0.210*** (0.000)	0.083*** (0.000)	0.021*** (0.000)	0.015*** (0.002)	0.007*** (0.000)	0.289*** (0.009)	0.263*** (0.005)
LFDI	0.180*** (0.000)	0.229*** (0.006)	1.449*** (0.000)	0.347*** (0.000)	0.211*** (0.000)	0.138*** (0.000)	0.128*** (0.000)	0.106*** (0.001)	0.100*** (0.000)	0.107*** (0.005)	0.078*** (0.004)

Note: S.E are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Author

Table 9: Results of MMQR
(LREN is the dependent variable)

Variables	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
LFD	4.148* (0.089)	3.791* (0.074)	3.203** (0.034)	2.891** (0.0348)	2.627** (0.027)	2.437** (0.021)	2.304** (0.020)	2.204** (0.020)	2.103** (0.022)	1.979** (0.025)	0.019** (0.013)

LOP	-	-	-	-	-	-	-	-	-	-	-
LCO_2	-2.860*** (0.053)	-2.622** (0.044)	-2.229** (0.028)	-2.02** (0.020)	-1.874** (0.016)	-1.717** (0.012)	-1.629 (0.012)	-1.562** (0.012)	-1.495** (0.013)	-1.412** (0.015)	0.008** (0.020)
LTRADE	-0.227 (0.542)	-0.305 (0.443)	-0.432** (0.028)	-0.500** (0.020)	-0.547** (0.015)	-0.598** (0.012)	-0.627** (0.012)	-0.649** (0.012)	-0.671** (0.013)	-0.698** (0.015)	0.687 (0.112)
LGDP	0.258*** (0.005)	0.204** (0.047)	0.116* (0.060)	0.069 (0.217)	0.037 (0.167)	0.001 (0.132)	0.017** (0.012)	0.032* (0.093)	0.048* (0.074)	0.066* (0. 066)	0.156* (0.060)
LFDI	0.497 (0.342)	0.455 (0.280)	0.386 (0.178)	0.349** (0.012)	0.324* (0.099)	0.296* (0.079)	0.280* (0.075)	0.269* (0.078)	0.257* (0.085)	0.242* (0.097)	-0.002** (0.011)

Note: S.E. are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Author.

5. Conclusion and Policy Insights

The main objective of this study is to examine how financial development, oil prices, and carbon emissions affect renewable energy consumption along with other control variables, including trade openness and economic growth, in 22 emerging nations. We have employed a panel dataset from 2005 to 2021. For empirical analysis, we employed various versions of quantile regression introduced by Powell (2016) and Machado and Silva (2019) to get reliable estimates of our study. Due to its effective handling of heterogeneity and outliers, the estimates from panel quantile regression (PQR) are more reliable relative to those from simple ordinary least square (OLS) regression. Moreover, conventional regression techniques overlook these problems, leading to biased and inconsistent results (Ummalla et al., 2019; Nasreen et al., 2023). Finally, PQR is resilient to outliers in exogenous variables as well.

The findings confirm the positive effect of financial development on renewable energy use in emerging economies. The oil prices have a notable adverse effect on renewable energy use in the lower quantile range, whereas favorable effects are in the upper quantile range. Additionally, foreign direct investment in the financial sector and real income per capita encourage the use of renewable energy. Conversely, trade openness and LCO_2 levels hinder the use of renewable energy, as higher LCO_2 levels reduce consumption when countries surpass a certain threshold. Trade openness, however, enables developing nations to import advanced technology from industrialized nations, which are known for being less energy-consuming and yielding higher output.

In light of current research findings, developing economies may choose to implement the following policy recommendations. (i) Our research suggests a significant association between financial development and renewable energy in selected emerging economies. The growth of financial markets offers a range of loan options available to the real sector for investments in environmentally friendly technologies and renewable energy projects. Thus, it is necessary to monitor the growth of the financial markets by enacting new legislation and establishing a shared ownership and transparency structure. (ii) Since oil price has a substantial positive effect on renewable energy usage, the governments of emerging economies should introduce subsidies in order to make renewable energy projects more competitive than traditional energy sources. This will encourage businesses and consumers to invest in and use renewable technologies as a result. (iii) The results also emphasize the need for emerging economies to draw in more foreign direct investment (FDI) as it enhances managerial abilities and promotes the use of cutting-edge, energy-efficient technologies.

Limitations and Suggestions for Future Research

A significant limitation of the study is that we have analyzed the effect of environmental quality on renewable energy use by using carbon emission levels; further studies may use Sulphur dioxide and ecological footprint to examine the effect of environmental quality on renewable energy use. Secondly, the study described the threshold effect for CO_2 levels but did not explicitly investigate or model these thresholds in detail. Understanding the precise points at which this effect change could offer more actionable insights.

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Declaration

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Appendix

The VIF test (variance inflating factor test) is employed to examine the issue of collinearity. The results of the VIF test are shown in Table A.1, which demonstrates that TOL[4] values are greater than 0.2, and values of VIF are less than 5, demonstrating that multicollinearity does not exist in data.

Table-A. 1
Multicollinearity test results

Model (Dependendt variable: LREN)		
Variable.	**VIF**	**TOL =1/VIF**
LFD	1.74	0.574
LOP	1.01	0.986
LCO_2	4.99	0.200
LTRADE	1.58	0.634
LGDP	4.28	0.233
FDI	1.42	0.702
Mean VIF value	2.50	

Source: Author.

Table-A. 2
Analysis of correlation

	LREN	LFD	LOP	LCO_2	LTRADE	LGDP	LFDI
LREN	1						

[4] Tolerance

LFD	0.166	1					
LOP	0.013	0.020	1				
LCO_2	0.725	0.603	0.000	1			
LTRADE	0.385	0.451	0.077	0.511	1		
LGDP	0.591	0.525	0.020	0.751	0.470	1	
FDI	0.061	0.307	0.026	0.154	0.369	0.325	1

Source: Author.

Table-A.3: Abbreviations

LFDI	Financial Development
LOP	Oil Price
LCO_2	Carbon Emission
LTRADE	Trade Openness
LGDP	Gross Domestic Product (Real Income)
LREN	Renewable Energy Use
FDI	Foreign Direct Investment
PQR	Panel Quantile Regression
MMQR	Methods Of Moment Quantile
OLS	Ordinary Least Square
POLS	Pooled Ordinary Least Square
ARDL	Autoregressive Distributive Lag Model
NARDL	Non-linear Autoregressive Distributive Lag Model
VECM	Vector Error Correction Model
DOLS	Dynamic Ordinary Least Square
FMOLS	Fully Modified Ordinary Least Square
CCR	Canonical Cointegrating Regression
CSD	Cross-Sectional Dependence
VRE	Variable Renewable Energy

Table-A.4: Sampled Countries

Sr No.	Country	Sr No.	Country
1	Argentina	12	Malaysia
2	Bangladesh	13	Mexico
3	Brazil	14	Pakistan
4	Chile	15	Philippines
5	China	16	Poland
6	Colombia	17	Russia
7	Egypt	18	Saudi Arabia
8	Hungary	19	South Africa
9	India	20	Thailand
10	Indonesia	21	Turkey
11	Iran	22	United Arab Emirates