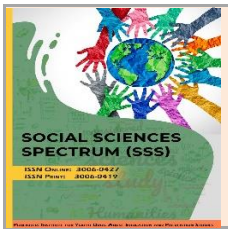

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Financial Development Stages and Energy Efficiency: Mediating Roles of Renewable Energy and Moderating Effect of Green Finance and FDI

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Abstract

The study about modelling aims to comprehend how renewable energy use mediates the effects of foreign direct investment, green finance, economic growth, natural resources rent, international trade, and urbanization on energy efficiency while examining the moderation of financial development by employing a two-stage moderated mediation model in the particular case of 79 nations, covering the twenty-one years 1999-2019. We obtained data from the World Bank (2022) and the OECD (2022). The findings show that Difference GMM proves the presence of a conditional effect of FD on countries. The result of the second stage moderated mediation has a strongly significant impact. The study suggests that policymakers should concentrate their focus on Urbanization's adaptation to support the use of clean, renewable energy. Specific environmental rules may encourage associated businesses in economies to spend more on R&D to advance technology.

Keywords: Green Finance, Energy Efficiency, Financial Development, Foreign Direct Investment, Economic Growth, Renewable Energy Use.

1. Introduction

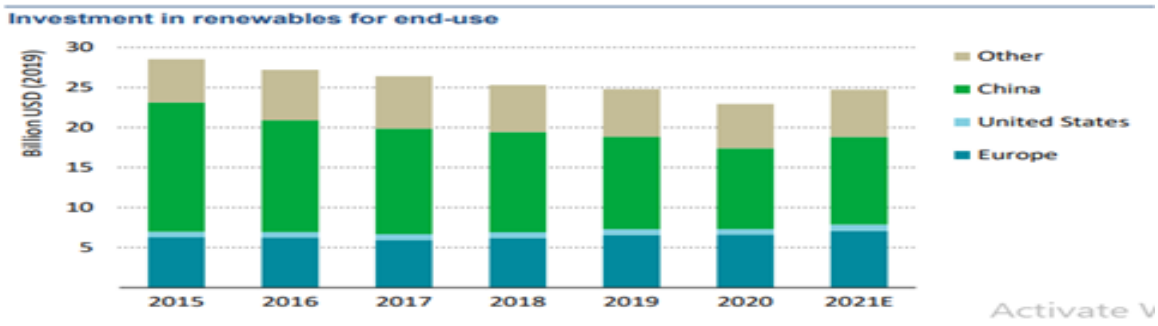
The Sustainable Development Goals (SDGs)' fundamental tenets are to support economic and financial growth, uphold resource management that demonstrates sustainable development, and positively advance social advancement. Fossil fuel use has increased as a result of industrialization and economic prosperity. Global warming, air pollution, and elevated health hazards are just a few of the negative environmental effects of growing non-renewable energy production and usage by various nations. The Organization for Economic Co-operation and Development (OECD) contends that, due to their higher energy density and slow rate of innovation, fossil fuels will likely continue to dominate the world's energy supply in the near future (Paramati et al., 2022). Longer-term advantages of energy efficiency include increased sustainable competitiveness and decreased emissions. The change of energy structure is speeding up in relation to achieving global carbon neutrality. More and more countries are actively introducing laws and programs to stimulate the expansion of the renewable energy sector, which has bright possibilities. Since there has been increasing agreement regarding the need for worldwide climate change action and low-carbon energy because of the devastating results of world climate degradation, it is a major challenge of the 21st century (Umar et al., 2022; Liu et al., 2021). Since 1995, the "International Energy Agency" (IEA) has observed energy consumption of 50% in worldwide energy consumption (IEA, 2013). Fossil fuels (FF) supply 80% in energy consumption of the world that makes energy sector an important contributor to greenhouse gas (GHG) emissions (IEA, 2013), which account for almost two-thirds of all emissions globally (Umar et al., 2021). Improving energy efficiency is one of the top priorities on the global agenda today for economies. Numerous emerging economies are expanding very quickly, and as a result, energy demand is rising. Since practically all commodities and services require energy in their production process, it is important to comprehend the factors that influence the demand for energy. This study adds to many previously published literary works. In this analysis, the following research issues were prioritized: Does FD moderate the conditional indirect effect of green finance and other economic factors on Energy efficiency through renewable energy use? Do green finance, FDI, and other economic variables provide a viable policy tool for enhancing Energy Efficiency? How much did moderating and mediating factors, like FD and REU, influence GFN, FDI, and other economic variables to have an impact on energy efficiency? There is no easy solution, but there are hints and cues we can use to build a plausible story about how this will pan out.

First, solar, wind, biofuels, nuclear, and hydro-power are some of the REU sources. So, after the industrial revolution, it has been noted that every country is striving for high economic growth by using its sources of energy. Second, the vast use of fossil fuels has created an urgent issue due to excessive widespread carbon emissions, which end up causing the sea level to rise by an additional 10–20 cm than anticipated. Third, in the 21st century, the world's air temperature increased from 1.0° to 3.5°. This worrying situation has led nations to focus on REU sources, which are essential to achieving sustainable development worldwide (Nnaji et al., 2013; Naz, S. et al., 2019).

Fourth, increasing the use of energy becomes a crucial part of smooth growth that would address poverty. For businesses in energy-intensive industries, the productivity benefit of the low-carbon city pilot strategy is influenced. The LCCP approach encourages businesses to use more energy through the benefits of energy-saving and green innovation, which improves businesses' long-term attitudes towards energy conservation and energy efficiency (S Yang et al.,2023). The main focus of the economies is on the development of the economy, irrespective of environmental

degradation and energy demand. It is not possible to ignore the energy use as all human and economic activities highly depend on the energy sector.

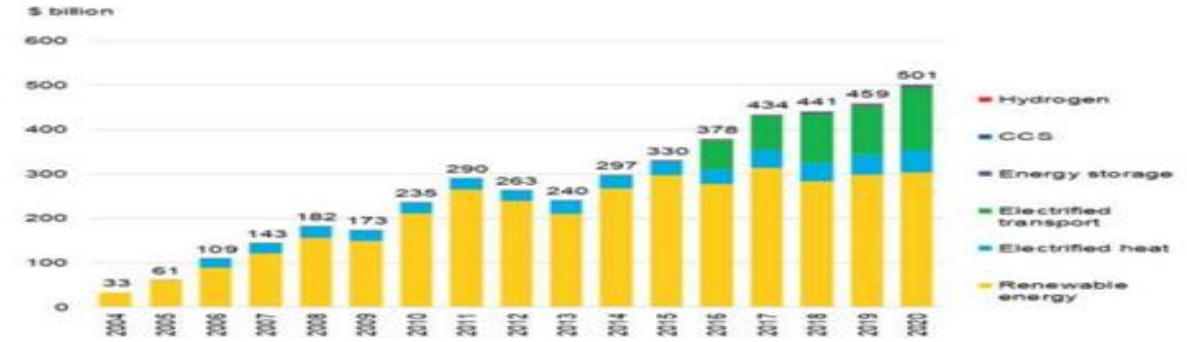
Figure 1.2: *Investment in renewable end-use*



(Source: World Energy Investment, 2021)

Fifth, Transitions in energy have greatly improved human well-being. Consumers may profit from the saturation effects of the demand for energy services, upcoming technology advancements, and energy transitions (R Fouquet, 2018). The shift to low-carbon energy has become more dependent on the financial industry (Chenet et al., 2019). The total amount of investment needed globally has been estimated at $100 billion for fulfilling the SDGs stated by the UN and the goals to overcome climate challenges outlined in the "Paris Climate Agreement." But the rate and scope of advancement are not encouraging. According to IRENA (2020), the world will need to invest $2 trillion in green projects between 2021 and 2023.

Figure: 1.3: *Energy Transition Investment*



(Source: Energy Transition Investment Hit $500 Billion, 2020)

Sixth, the price is thought to have been affected thus far by the switch from coal to natural gas in the production of energy. Urbanization and deforestation have a serious impact on the environment. We need to switch towards non-fossil fuels, which include renewable energy, in this term, renewable energy to increase the energy efficiency, that's what we are striving for.

Finally, utilizing renewable energy has a number of advantages, including increased energy security, continued economic growth, and a considerable decrease in greenhouse gas emissions. Variations in solar radiation and wind speed have an impact on solar and wind power, respectively, which hinders the stable operation of these systems and increases output volatility. Contrarily, due to their highly renewable and sustainable character, biofuels are attracting substantial interest and have become recognized as a viable alternative to conventional fuels.

Additionally, biofuels are carbon neutral, easily produced from biomass and other waste, biodegradable, and environmentally benign.

Therefore, the excess use of non-renewable resources like fossil fuels leads to a decrease in environmental quality and its negatively effect on the development of a green economy. Academics stress the importance of achieving sustainable economic growth and putting sustainable environmental policies in place. Little research has connected economics and ecology until now. According to Wang and Zhi (2016), creating financing for solar energy can help achieve environmental sustainability. Clearly, the discussion above contains a lot of assumptions. The amount of area available for renewable energy generation is anticipated to have a substantial impact on how quickly the decarburization of renewable energy will progress. It is envisaged that new targets would assist a low-carbon economy and eventually lead to the removal of CO2 from the environment in the future. Emerging serious ecological issues and energy crises pose a threat to human society's ability to evolve sustainably (Wu et al., 2021). Countries have not made considerable economic progress despite having a wealth of natural resources. Therefore, policymakers, governments, and researchers are becoming concerned about urbanization (URB) activities because of the environmental problems they pose. This study examines how urbanization, financial development, green finance, renewable energy use, foreign direct investment, economic growth, and natural resource rent interact with energy efficiency. The investment needed to achieve the climate goal is huge, but green finance has the power, and also shares responsibility for other economic factors to make that happen.

1.1. Aim, Scope and Paper Organization

The objective of our study is that by using a moderated mediation technique, to investigate whether a sound financial system can manage energy intensity and CO2 emissions by looking at the effects of GFN and other economic factors through REU. Another objective is to promote a green economy and determine the costs and advantages of a quick energy transition.

The contribution of the study consists of the integration of the moderating impact of the financial system and the mediator (REU) in the analysis of the effects of FDI, GFN, ECG, NRR, IT, and URB on energy intensity. Second, most studies have included financial development as a stimulant factor for several purposes. In this model, financial development is included as a conditional factor. By using a moderated mediation technique, our study was able to investigate whether a sound financial system can manage energy intensity by looking at the effects of REU, GFN, ECG, NRR, IT, and URB on energy intensity. There are conflicting findings regarding how these variables affect energy efficiency. This flaw is filled with sample selection as well as the methodology used in the modelling that linked the GFN, FDI, URB, EG, IT, and NRR, with energy efficiency. Third, there haven't been many studies that examine how financial development affects REU and energy efficiency, as well as green economic aspects. Prior research ignored the impacts of FD on REU and focused only on the moderating effects of financial development between these factors and energy efficiency. The scope of this study is to improve the understanding of the damaging effects of these chosen variables on the ecosystem for the Researcher. The findings will assist policymakers in boosting energy efficiency in promoting financial and economic development and trade with the least amount of environmental damage.

With the insights gained from our study, government agencies, institutions, policymakers, and other organizations could implement more sensible, suitable, and effective measures to increase energy efficiency. The government can provide funds and concessions to promote the

development of REU technologies. Governments, on the other hand, play a crucial role in energy usage by assisting citizens in changing their lifestyles and behavior towards lowering energy demand through policy guidance.

The structure of our study is as follows: first, we gave a theoretical background, objectives, and problem statement. Second, Literature has focused particularly on the connections between the variable and research questions. Third, we described our research methodology, framework, empirical model and analysis. Finally, we presented our findings together with the analysis and conclusions.

2. Literature Review

In this section, the literature of past studies related to the study variables shows the relationship between energy efficiency, urbanization, financial development, economic growth, international trade, green finance, natural resource rent, financial direct investment, and renewable energy use.

2.1. Environmental Factors-Energy Efficiency Nexus

2.1.1. Sustainable economic-energy efficiency nexus

Countries might choose energy efficiency measures to lessen environmental harm. The economic production and energy intensity, particularly in developing nations, had an impact on changes in economic consumption. Energy consumption and energy efficiency could significantly drop as a result of environmental technology advancement. In 134 nations from 1990 to 2014, Deichmann et al. (2018) examined the link between economic expansion and energy use. They used a regression model to identify a minimal influence of income development on variations in energy intensity. According to Mahmood and Ahmad (2018), economic growth and energy intensity are mutually exclusive in European nations. The effect of industrialization and trade openness on energy intensity was studied by Pan et al. (2019). Li et al. (2022) studied RES on the environment at the expense of economic expansion. The findings demonstrate that RES steadily reduces the ecological footprint. Additionally, RES keeps up global growth-promoting behavior. However, we were unable to locate any specific papers discussing the sustainability and energy efficiency with the moderation factor of "financial development". Since there is a research void in this area, our study fills it and offers a unique and creative research approach. According to global evidence that has emerged in recent years, the technological ability to boost energy efficiency by a large margin improves sustainable economic performance, especially in seasons of uncertainty in geopolitical matters, with institutional quality mediating efficiency gains across income groups (Bento and Okafor, 2025).

2.1.2. Green finance and energy efficiency nexus

Several empirical studies have been done to show how green money affects energy efficiency. For instance, according to Hesary, T. et al. (2019), based their claim on theoretical investment models, green money can help to lower the risks associated with green finance while enhancing profits on GEP. Pavlyk (2020) discovered that green investments improve renewable energy and energy efficiency by using bibliometric analysis. Peng and Zheng (2021) determined that the promotional effect of the green money on energy has been determined. All of this research has shown how green cash can encourage consumers to use less energy. Therefore, the study investigates green finance and energy with the mediating role of renewable energy and the moderating role of FD. The empirical evidence supports the fact that the instruments of green finance, such as environmental taxes and green investment flows, enhance energy efficiency most

notably through supporting the realization of cleaner technologies and energy-saving innovations, especially in those developing economies (Yeboah et al., 2025).

2.1.3. Natural resource rent-energy efficiency nexus

Resource-rich nations produce renewable energy from their resources, which reduces their reliance on energy imports and aids in the prevention of environmental degradation (Balsalobre-Lorente et al., 2018). The failure of resource-poor nations, or the "resource curse," is mostly due to energy imports (fossil fuels), which hasten the deterioration of the environment. Additionally, poor environmental quality is caused by overuse of resources brought on by industrialization, deforestation, and mining (Baloach et al., 2019).

In order to attain an environment and development, the study offers factual information demonstrating the necessity for effective and long-term resource utilization, as well as the rising percentage of renewable energy in the energy mix (Recep Ulucak et al., 2020). Countries with less natural resources, known as resource curses, primarily rely on imported fossil fuels for energy and harm the environment. As a result, the study investigates the NRR and energy with the mediating role of renewable energy and the moderating role of FD. Recent research indicates that rents on natural resources generate nonlinear impacts on energy efficiency, with moderate rents leading to clean investment, and high reliance disheartens efforts to improve efficiency as well as strengthen the production U-shape system (Smith & Nguyen, 2025).

2.1.4. Urbanization-energy efficiency nexus

Sheng et al. (2017) explore the effect of urbanization on energy efficiency and consumption. According to empirical results from system-GMM, urbanization worsens the prospects for energy efficiency and increases energy consumption. Rapid urbanization puts sustainability at risk by spiking energy use and CO2 emissions. However, the use of residential and industrial energy, second, the building industry's energy use to upgrade infrastructure, public transit, and housing, and third, the clearing of forests for urban growth. (A. Raihan et al, 2022). Therefore, the study investigates that URB and energy with the mediating role of renewable energy and the moderating role of FD. Urbanization has been seen to lead to increased energy, but higher energy efficiency is obtained in cities with developed infrastructure, regulation frameworks, and clean energy policy, which would reduce the negative effects on the environment imposed by the rapid urbanization (World Economic Forum, 2025).

2.1.5. FDI and energy efficiency nexus

The word "FDI" refers to the transfer of capital from the countries where multinational firms are headquartered to those where they have established operations. This typically involves the transmission of learning, technology, and management practices and systems. It is also considered to be the main reason why energy intensity has decreased in developing market economies. Consequently, decision-makers must comprehend how FDI influences energy intensity. (Doytch and Narayan, 2016; Wang, 2017; Cao et al., 2020).

Investment in green capital spillovers, which boost FDI flow to the country's overall energy consumption, improves efficiency (Doytch and Narayan, 2016). The findings of Petrovi et al. (2018) were quite solid and suggested that foreign direct investment had little impact. The results of the investigation conclusively show that FDI reduces emissions intensity (Predrag Petrovi et al., 2022). The link between FDI and energy is still being debated on a worldwide level because of the conflicting empirical findings. This study examines that renewable energy use is associated with foreign direct investment to enhance energy intensity, with the conditional effect of FD. The

evidence of the panel supports the idea that foreign direct investment improves energy efficiency because of technology transfer and capital flows as well, but these are strengthened by financial inclusion and fintech growth in emerging markets (Soni & Manogna, 2026).

2.1.6. International trade and energy intensity

According to Zhao et al. (2019), industrial sectors also improve by imposing the conditions that are environmentally friendly on trade, specifically on imports. Trade boosts overall productivity due to the efficient utilization of inputs and resource reallocation brought on by liberalization (Yao et al., 2021). Another study conducted by Shah, W.U.H et al. (2022) on the relationship of trade-energy nexus shows that two important points were established by the investigation. First off, innovations resulting from research and development boost commerce but do not promote energy efficiency. Second, while governance benefits trade, it places less of an emphasis on enhancing energy efficiency. Therefore, the study investigates IT and energy with the mediating role of renewable energy and the moderating role of financial development. As per recent studies, international trade may be less intensive with cleaner standards of production and technology transfer, but trade openness that is not accompanied by environmental regulations is likely to increase the nature of energy consumption (Wang, 2024).

2.1.7. Renewable energy use-energy efficiency nexus

Past studies have very few literatures on the "relationship between renewable energy use and energy efficiency". Li et al. (2020) stated that the enhancement in the energy could improve the renewable shares for long and short periods, but only in those countries that are members of OECD. They select the variable energy productivity, which improves efficiency and reduces the level of CO2. Muntasir Murshed et al. (2022) they found that important macro factors like renewable energy are missing in the past literature. Renewable energy initiative has the power to improve efficiency in energy sectors and achieve the SDGs. Therefore, the study investigates the mediating role of renewable energy on this model. Current research supports that the further implementation of renewable energy has a great positive impact on energy efficiency, as it does not require the use of fossil fuel and promotes the development of energy-efficient technologies and storage methods (Becchetti et al., 2025).

2.1.8. Financial Development-Energy efficiency nexus

The financial industry offers subsidies for green technology that uses less energy and produces more (Ouyang et al.,2018). The long-term environmental efficiency increases as a result of investors being encouraged to make investments in energy-saving machinery by an established and sophisticated finance structure (Shah et al., 2019). To properly implement financial policy, a robust financial system is necessary. Similar to this, more capital mobility depends on a sound financial system (Yao et al., 2021). This study looks at the connections between G7 economies' energy efficiency, commerce, financial development, and political stability from 1996 to 2015. The Data Envelopment Analysis is used to calculate these nations' energy efficiency. The Driscoll & Kraay approach was used in the study, which discovered that trading is a useful way to boost energy efficiency. The study did, however, make two very important points.

First off, innovations resulting from research and development boost commerce but do not promote energy efficiency. Second, while governance benefits trade, it places less of an emphasis on enhancing energy efficiency. Moreover, financial progress improves energy efficiency (Shah et al., 2022). As a result, the financial industry has devised less expensive environmental protection initiatives. Financial institutions can help maintain the energy sector and

environmental standards over time. According to Adom et al. (2023), technical energy efficiency is fueled by all facets of financial institutions, but the access component is more crucial. Therefore, the study investigates the conditional role of FD in the model. Finance development is also demonstrated to enhance energy efficiency through reducing financing limits to clean technologies, green credit expansion, and encouraging fintech-facilitated investments in infrastructure that is energy efficient (Soni & Manogna, 2026).

3. Research Methodology

3..1. Variables, Data Collection and Measurement Units

The study about modelling aims to comprehend how REU mediates the effects of FDI, GFN, EG, NRR, IT, and URB on energy efficiency while examining the moderation of financial development by employing a moderated mediation model in the particular case of 79 countries. The availability of annual data was the main reason to choose the sample period and nations for the entire study. The study uses a quantitative approach and secondary data covering the years 1999-2019. The dataset for the variables is taken from the World Bank (2022) and the OECD (2022). The following factors are included in the data as independent variables: inflow of FDI (% of GDP), NRR (% of GDP), and URB was calculated against the total urban population (% of total population). The proportion of GDP that is exported and imported was used to gauge international trade, GDP growth (constant 2015 US$), and green finance (Environmental protection products by residents). Energy intensity (MJ/$2017 PPP GDP) is taken as the dependent variable. Financial development (% of GDP) serves as a moderator, and Renewable energy use, calculated as (percentage of energy consumption), serves as a mediator. Labor force, Merchandise trade, Infrastructure, fixed capital, and gross savings serve as control variables for this study. The total labor force of populations was used to calculate the labor force. Infrastructure was determined by the number of mobile subscriptions per 100 persons, while saving was calculated as a percentage of GDP. Trade goods were calculated as the sum of exports and imports of goods. The chosen variables are shown in Table 1.

Table 1: *Description of Variables*

Dependent Variables	Notation	Indicator	Database
Energy Efficiency	EE	Energy intensity	WDI
Independent Variables			
Green Finance	GFN	Environmental Protection Product by Resident	OECD
Natural Resourse Rent	NRR	Total Natural Resourse Rent % of GDP	WDI
Economic Growth	EG	% Annual Growth of GDP	WDI
Urbanization	URB	% of total Urban population	WDI
International Trade	IT	Exports, Imports	WDI
Foreign Direct Investment	FDI	FDI net flow	WDI
Control variables			
Merchandise Trade	MT	Amount of exports and imports of goods	WDI
Labour Force	LF	Total labour force of populations	WDI
Infrastructure	INF	Number of mobile subscriptions per 100 persons	WDI
Gross savings	GNS	% of GDP	WDI
Other Variables			
Renewable Energy Use	REU	Renewable energy consumption % total energy	WDI
Financial Development	FD	Domestic & foreign loan to private sector	WDI

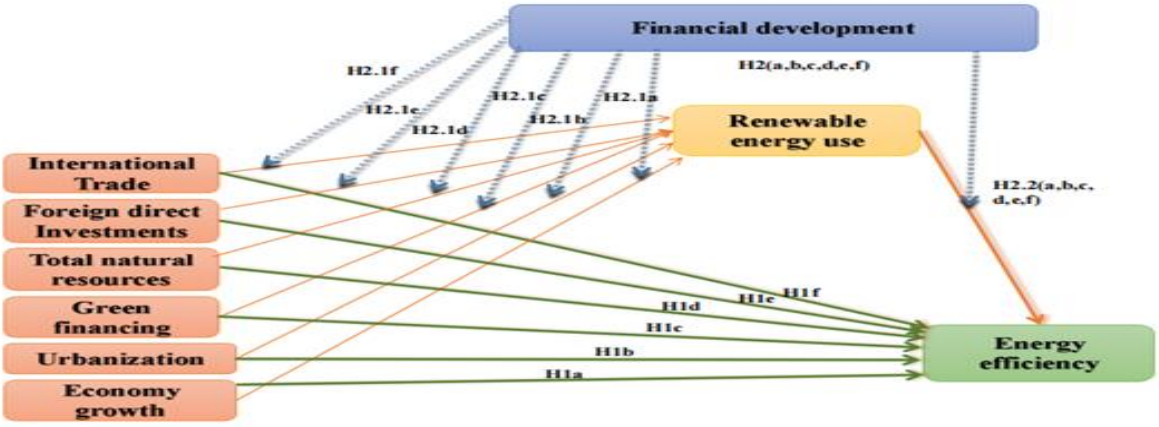
Foreign direct inflows, natural resource rents, urbanization, international trade, Economic growth, and green finance are explanatory variables in the study (Li et al., 2022). Energy efficiency has been taken into consideration as a dependent variable to ascertain its interactions. Financial development serves as a moderator, and Renewable energy use serves as a mediator.

The labor force, trade in goods, infrastructure, and savings served as the study's control variables (Sher Khan et al., 2020).

3.2. Theoretical Framework

In Fig. 3.1, which depicts the study's conceptual model of moderated mediation, these conditional impacts of GFN, FDI, URB, ECG, IT, and NRR on Energy Efficiency through REU are illustrated.

Figure 3.1: *Conceptual model: both side moderated mediation of FD between GFN, IT, FDI, URB, ECG, and NRR on Energy Efficiency through REU.*



(Source: Adapted from Tarek Bel Had, 2021)

3.3. Hypotheses

These hypotheses are constructed using the data presented above and go as follows:

H1: NRR, IT, EG, URB, FDI, and GFN have a direct relation with energy efficiency.

H2: REU mediates the effects of NRR, IT, EG, URB, FDI, and GFN on energy efficiency.

H3: The conditional effect of FD moderates the REU mediation on NRR, IT, EG, URB, FDI, and GFN on energy efficiency.

3.4. Empirical Model

3.4.1. Mediation model

The indirect influence of REU on NRR, IT, EG, URB, FDI, and GFN's effect on CO2 emissions was examined using the SEM. According to Su. W et al. (2022), this model made it possible to analyze both indirect and direct effects. Equations (1) through (3) are drawn from Model 1, where CO2 emissions are the outcome variable, renewable energy use is the mediator, and NRR, IT, EG, URB, FDI, and GFN are the exposure variables.

$$EE_{it} = \beta_0 + \beta_1 GFN_{it} + \beta_2 NRR_{it} + \beta_3 FDI_{it} + \beta_4 IT_{it} + \beta_5 EG_{it} + \beta_6 URB_{it} + \mu_{it} \dots\dots\dots\dots\dots\dots (1)$$

$$EE_{it} = \beta_0 + \beta_1 GFN_{it} + \beta_2 NRR_{it} + \beta_3 FDI_{it} + \beta_4 IT_{it} + \beta_5 EG_{it} + \beta_6 URB_{it} + MV_{it}\partial_1 REU_{it} \dots\dots (2)$$

Where I and t stand for individual nations and eras, respectively. The erroneous term is (μit). Equation (1) shows the overall effect of the independent variables on the energy efficiency.

Equation (2) shows the indirect/Mediating effect of the exposure factors on the energy efficiency through the mediator (REU). The variables GFN stands for green financing, FDI for foreign direct investment flows, URB for urbanization, EG for economic growth, IT for international trade, NRR for natural resources rent, FD for Financial development, REU for usage of renewable energy sources, and EE is energy efficiency in Equations (1) and (2).

3.4.2. Moderated mediation model

This study aims to determine the relationship between urbanization, green financing, economic growth, foreign direct inflows, international trade, and natural resources on energy efficiency through REU in such a way that these effects are moderated by financial development. Equation (3) shows the conditional effect of FD on this model, where I and t stand for individual nations and eras, respectively. The erroneous term is (μit). The variables GFN stands for green financing, FDI for foreign direct investment flows, URB for urbanization, EG for economic growth, IT for international trade, NRR for natural resources rent, FD for Financial development, REU for usage of renewable energy sources, and EE for energy efficiency. Where MV is used with mediator, and MO is used with moderator.

$$EE_{it} = \beta_0 + \beta_1 GFN_{it} + \beta_2 NRR_{it} + \beta_3 FDI_{it} + \beta_4 IT_{it} + \beta_5 EG_{it} + \beta_6 URB_{it} + MV_{it}\partial_1 REU_{it} + MO_{it}\partial_1 FD_{it} \quad \text{.....(3)}$$

$$EE_{it} = \beta_0 + \beta_1 REU_{it} + MO_{it}\partial_1 FD_{it} + C_1 GNS_{it} + C_2 INF_{it} + C_3 MT_{it} + C_4 LF_{it} \quad \text{.....(4)}$$

4. Result and Discussions

4.1. Descriptive Statistics

Table 2 shows the findings of the mean, observation, and standard deviation, etc. The standard deviation of the variables used in the study is fairly high. So, according to the average statistics for the variables, EE (2.457), NRR (9.148), IT (.739), EG (1.515), URB (20.478), FDI (22.931), GFN (7.416), REU (19.756), and FD are the variables (46.105). The average figures demonstrate that the highest average values are for URB, FDI, and FD. The statistical finding in Table 2 shows for the panel data from 1999 to 2019, statistical descriptive profile details about the countries.

Table 2: *Descriptive Statistics*

Variable	Obs	Mean	Std. Dev.	Min	Max
ID	1659	40	22.81	1	79
Years	1659	2009	6.057	1999	2019
EE	1659	4.817	2.457	1.32	28.2
NNR	1659	5.131	9.148	.001	58.92
IT	1659	.673	.739	-.365	5.701
EG	1659	9.103	1.515	.673	11.63
URB	1659	66.443	20.478	9.056	100
FDI	1659	6.982	22.931	-37.712	449.083
GFN	1659	12.41	7.416	.84	92.59
REU	1659	20.524	19.756	.009	91.31
FD	1659	70.04	46.185	.186	255.31
LF	1659	15.856	1.586	11.941	20.5
GNS	1659	23.722	9.276	-16.359	66.884
INF	1659	86.686	45.712	.021	212.639
MT	1659	68.19	42.097	15.695	343.481

4.2. Correlation Matrix

We first verify the correlations of all the variables, and the findings are shown in Table 2. At the 5% level of significance, except for NRR, all tests related to the correlation between the independent factors and the energy efficiency are significant, proving the validity of the variables used in this study. Further evidence that international green finance may have a detrimental impact on IT, EG, URB, and FDI comes from the fact that GFN has negative correlations with these independent variables. IT also has a negatively correlation with NRR. However, further estimate is necessary for more precise results. Additionally, the majority of the results of the correlation tests between these factors are lower than 0.8, which indicates that there isn't a significant Multicollinearity problem between the variables.

Table 3: *Matrix of Correlations*

Variables	EE	NRR	IT	EG	URB	FDI	GFN
EE	1.000						
NRR	-0.037	1.000					
IT	0.068*	-0.074*	1.000				
EG	0.097*	0.000	0.161*	1.000			
URB	0.061*	0.101*	0.161*	0.466*	1.000		
FDI	0.059*	0.098*	0.143*	0.452*	0.997*	1.000	
GFN	0.118*	0.336*	-0.091*	-0.083*	-0.026	-0.024	1.000

**** p<0.01, ** p<0.05, * p<0.1*

4.3.GMM

The null hypothesis for the Hausman test is in favor of random effect and the alternative is in favor of fixed effect, but the value of p in this test is significant, which means we rejected the null hypothesis, and for this study, we use the fixed effect model as our base model. So, we will do further analysis by taking a fixed-effect model as our base model. NRR, IT, EG, URB, FDI, and GFN were tested for their impact on EE using the Difference GMM - two-step technique. At a significance level of 1%, the results demonstrate that NRR, IT, EG, URB, FDI, and GFN values indicate a positive connection with EE.

4.3. Panel Root Test

In order to analyze our econometric model, this part first calculated the SHT and tested for unit roots for the variables. Table 5 shows the slope of heterogeneity, in which the results show that we have variation in the economies because the SHT H0 is rejected. Additionally, the result shows that our research's following steps will use a valid method for calculating the Difference GMM. The unit root test was examined using CADF and CIPS tests in the study. As shown in Table 6, none of the series (NRR, IT, EG, URB, FDI, and GFN) was stationary at the level. In light of this, following the initial difference, all of the candidates' series are represented as stationary (1). This technique can be used to check for long-run counteraction in the series used in this investigation.

Table 4: *GMM*

EE	FE	RE	GMM
L			1***
			(0)
NRR	-.000***	0**	0***
	(0)	(0)	(0)
IT	.001***	0**	0***
	(0)	(0)	(0)
EG	.010***	0***	0***
	(0)	(0)	(0)
URB	.007***	0	0*
	(.001)	(.001)	(0)
FDI	-.033***	.001	0***
	(.007)	(.003)	(0)
GFN	0**	0***	0***
	(0)	(0)	(0)
REU	0***	0***	
	(0)	(0)	
FD	0***	0*	
	(0)	(0)	
Constant	7.544***	7.601***	
	(.009)	(.004)	
LF			0**
			(0)
GNS			0***
			(0)
INF			0***
			(0)
MT			0***
			(0)
Hausman test	2544.294***	*** p<0.01, ** p<0.05, * p<0.1	

Table 5: *Slope of Heterogeneity Result*

H0: slope coefficients are heterogeneity			
adj.	**p-value**	**adj.**	**p-value**
30.013	0.000	38.146	0.000

Table 6: *Panel: Second Generation Test for Unit Root*

Series	CIPS		CADF		Order of Integration
	Level	**First difference**	**Level**	**First difference**	**I (1)**
EE	2.610	-6.190 ***	2.610	-6.190***	**I (1)**
NRR	-1.853	-3.929***	-1.930	-2.814***	**I (1)**
IT	-2.398	-3.687***	-2.630	-3.133***	**I (1)**
EG	-1.978	-3.126***	-1.917	-2.153***	**I (1)**
URB	-4.738	-4.349***	-1.315	-2.092***	**I (1)**
FDI	-3.259	-5.534***	-2.488	-4.114***	**I (1)**
GFN	-3.628	-5.702***	-2.965	-3.986***	**I (1)**

4.4. Cointegration Test

We utilized these methodologies introduced by Westerlund in 2007 to investigate the existence of long-term cointegration interaction among the research variables. The outcomes represent that the variables interact via cointegration. Additionally, the two criteria and two-panel statistics used for this study are used to evaluate their possible consequences. With a very significant level of 1%, Table 6 demonstrates that one class (Gt) and (Ga) are statistically significant.

Table 7: *Cointegration Test (Westerlund 2007)*

Statistic	Z-value	P-value
Gt	-3.7e+04	0.000
Ga	-1.8e+03	0.000
Pt	12.871	1.000
Pa	2.342	0.990

4.5. Mediation Model Findings

The correlation matrix and VIF statistics are used to test for the presence of Multicollinearity, and the results show that these phenomena are not of concern. To save space, the findings are not shown, but they are available to the authors upon request. The Sobel (1982) test is shown in Table 8 along with the direct, indirect, and overall effects. This was carried out by Baron and Kenny's (1986) method, which uses the "ratio of indirect to total effect" to test for mediation.

To check the reliability of results, the Sobel (1982) test was used. According to Baron and Kenny (1986), a few prerequisites must be met to create a mediated relationship: The dependent variable and the mediator must both be considerably influenced by the independent variable in order for there to be a meaningful relationship between them.

Table 8: *Direct, Indirect, and Total Effects, and Sobel Test Results*

Variables	Direct effect *(NRR, IT, EG, URB, FDI, GFN → CO_2 emissions)*	Indirect effect *(NRR, IT, EG, URB, FDI, GFN influences CO_2 emissions via REU)*	Total effect *(NRR, IT, EG, URB, FDI, GFN → REU → CO_2 emissions)*	Sobel test
NRR	0.000	-0.000**	-0.000	0.097
	(0.003)	(0.000)	(0.003)	
IT	0.232	0.000*	0.000	0.113
	(0.001)	(0.000)	(0.001)	
EG	0.000***	-0.000*	0.000***	0.044
	(0.000)	(0.000)	(0.000)	
URB	0.000**	-0.001**	0.000**	0.931
	(0.000)	(0.000)	(0.000)	
FDI	-0.000**	-0.000**	-0.000***	2.310
	(0.000)	(0.000)	(0.000)	
GFN	0.000***	0.000	0.000***	0.021
	(0.000)	(0.000)	(0.000)	

Notes: *** means statistical significance at the 1% level.

This mediation analysis shows the direct effect of NRR, IT, EG, URB, FDI, and GFN. The results show that, except the NRR and IT, all other variables have a significant direct relationship with energy efficiency. EG, URB, and GFN has positively significantly impact on energy efficiency, which means any change in NRR will bring a change in EE as well. The results of FDI have a significant negative impact on energy efficiency, which means an inverse link is found with energy efficiency. This test verifies H1 for all the variables except for NRR and IT because NRR and IT do not have a direct relationship with energy efficiency. According to the Sobel test, REU mediates (0.097) of NRR-EE. REU mediates (0.113) of IT-EE. REU mediates (0.044) of EG-EE. REU mediates (0.931) of URB-EE. REU mediates (2.310) of FDI-EE. REU mediates (0.021) of GFN-EE, which means 2% of the effect of GFN on EE is mediated by REU. NRR, IT, EG, URB, and FDI influence country-level EE via REU in a statistically significant way, corroborating H2.

4.7 Moderated Mediation Model Findings

This moderated mediation model was employed in an effort to shed light on how financial development affects the mediating effect of NRR, IT, URB, FDI, and GFN on EE in various economies. Table 9 displays the Difference GMM-based moderated mediation effects. In the initial step of moderated mediation, the latter was produced by an interaction between all independent variables and the suggested moderator. We also created an interaction between the mediator and the moderator, REU and FD, in the second stage to examine the conditional effect of FD on this model.

The Difference GMM proves the presence of conditional effects on countries, contradicting the null hypothesis that there is no evidence of such an impact. This index shows the interaction of FD with EG, URB, and GFN on the renewable energy use in countries have positive significant impact. The interaction of FD with FDI on the renewable energy use in countries has a negative impact. The result of REU_FD interaction on EE has a positive and strongly significant impact.

Table 9: *Moderated Mediation Model Results*

REU	First stage GMM	Variables	Second stage GMM
L	.954***	**L**	1***
	(.028)		(0)
NRR_FD	0	**REU_FD**	0***
	(.001)		(0)
IT_FD	0		
	(.008)		
EG_FD	.014**		
	(.006)		
URB_FD	.032***		
	(.012)		
FDI_FD	-.143***		
	(.042)		
GFN_FD	0**		
	(0)		
LF	-.658		0***
	(.745)		(0)
GNS	.041**		0***
	(.02)		(0)
INF	-.062		0***
	(-1)		(0)
MT	-.859		0***
	(.543)		(0)
Mean dependent var	20.553		7.606
Number of obs		1501	

*** p<.01, ** p<.05, * p<.1

5. Conclusion

Increasing energy efficiency is one strategy to improve sustainable competitiveness and assist nations in getting ready for a low-carbon economy. Due to the depletion of energy supplies, many countries are currently experiencing severe issues with environmental degradation and financial development. Energy efficiency mixes economic growth with environmental protection as an example of green growth. It's a plan to carry out the 2030 policy agenda for sustainable development. By investigating the connections between natural resource rent, international trade, economic growth, foreign direct investment, green finance, renewable energy usage,

urbanization, financial development, and energy efficiency in the economies, this study enhances the existing literature. This study employed the difference GMM approach to assess moderated mediation after validating the direct and indirect relationship between the series. The results show that, except for the NRR and IT, all other variables have a significant direct relationship with energy efficiency. EG, URB, and GFN has positively significantly impact on energy efficiency, which means any change in NRR will bring a change in EE as well. The results of FDI have negatively significantly impact on energy efficiency. REU mediates all variables. Only 2% of the effect of GFN on EE is mediated by REU. NRR, IT, EG, URB, and FDI influence country-level EE via REU in a statistically significant way. The Difference GMM proves the presence of conditional effects on countries, contradicting the null hypothesis that there is no evidence of such an impact. The result of two stage moderated mediation model shows that the interaction of FD with EG, URB, and GFN on the renewable energy use in countries have positive and significant impact. The interaction of FD with FDI on the renewable energy use in countries has a negative impact. The result of REU_FD interaction on EE has a positive and strongly significant impact. The study suggests policymakers should concentrate their focus on the inefficient economies, especially developing nations, and should enhance the logical allocation and effective use of energy resources through workable solutions to achieve a shared increase in regional energy efficiency, local consumption, particularly for the developing sectors that employ energy's conventional sources to produce goods and services. Second, in order to reduce emissions, economies should support urbanization's adaptation. They should also push for changes to land use to support the use of clean, renewable energy. Third, having a stable and comprehensive financial system would encourage businesses to use cutting-edge, energy-efficient technologies. Similar to this, businesses and entrepreneurs should be encouraged to support green business and participate in green securities, green lending, and green investments. Also, Specific environmental rules may encourage associated businesses in economies to spend more on R&D to advance technology. Investors can use this study's competitive advantage to investigate economies before engaging in any kind of industrial cooperation or investment. The authors are hoping that by presenting actual evidence, other researchers will be inspired to look into the relationship between other carry-over variables and energy efficiency.

Conflict of Interest

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