Unfolding FDI, Renewable Energy Consumption, and Income Inequality Nexus: Heterogeneous Panel Analysis

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Abstract: We aim to examine the nexus between Foreign Direct Investment (FDI), Renewable Energy Consumption (REC), and income inequality across selected High-Income Countries (HIC), Upper Middle-Income Countries (UMIC), Lower Middle-Income Countries (LMIC), and Low-Income Countries (LIC). Given the cross-sectional dependency, slope homogeneity, and stationarity properties, we find that the aforementioned variables across all the regions are cointegrated in the long run (LR). For LR estimation, we use the Cross-Sectional-Autoregressive Distributed Lag (CS-ARDL) approach. For the HIC and the UMIC, an increase in FDI increases REC, which in turn causes income inequality to decrease. In the case of LMIC, an increase in REC causes an increase in FDI and decreases income inequality. However, we could not establish a significant relationship with the LIC. We also provide some useful recommendations, such as increased institutional efficiency and promotion of renewable energy investments through higher access to finance.

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1. Introduction

Energy is the lifeblood of the economy, providing daily sustenance and propelling economic growth by facilitating almost all economic operations, including the activities of businesses, social spheres, and households. Many studies such as [1,2] argue that for any economy to evolve from a subsistence level of consumption, a minimum level of energy is required. Over the last decade, the global energy demand has soared due to an increase in population, changing lifestyles, advancements in production, home compliances, and economic development. Around 84.30 percent of the world's primary energy mix consists of oil, gas, and coal, and there are imminent adverse environmental consequences of consuming such large amounts of fossil energy to fulfill our everyday demands [3]. Existing literature shows that excessive use of fossil fuels pollutes the air and water, impedes wildlife and habitat, harms public health, and raises concerns about global warming due to high greenhouse gas emissions. Global Carbon Dioxide (CO_2) emissions have been increasing consistently for the past decade in both developed and developing economies around the world, as shown in Figure 1.
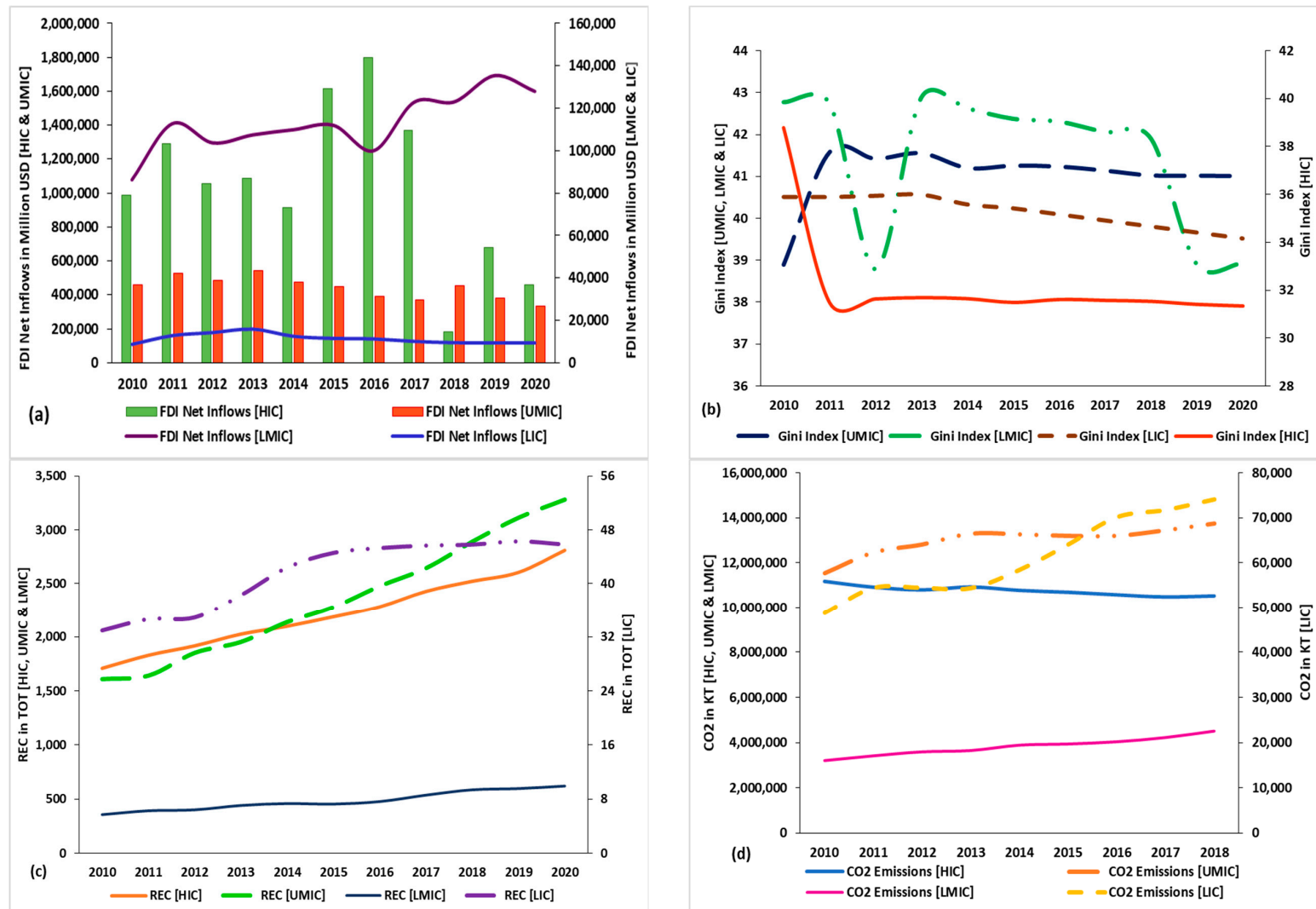
Figure 1. Trends in (**a**) FDI Net Inflows, (**b**) Gini Index, (**c**) REC, and (**d**) CO$_2$ Emissions across Regions. Source: [3,4].

The need for energy diversification has thus become essential since non-renewable resources will deplete over time and long-term environmental sustainability is crucial. This created the need to improve Renewable Energy (RE) development, as it improves global energy security [5]. Moreover, RE can create sustainable development through the integration of energy-saving and energy efficiency measures [6]. The share of RE in the primary energy mix has been increasing rapidly in the past few years as nations around the world are realizing the importance of RE in environmental conservation and the overall improvement of wellbeing [6–9]. This has resulted in higher RE consumption (REC) in countries across the globe, as shown in Figure 1.

The impacts of REC have further implications on wellbeing as it focuses not only on environmental sustainability but also on the overall development of nations. REC paves a path towards an increase in access to electricity by providing off-grid electricity access to remote areas and creating new jobs, which decreases income inequality and improves the overall standard of living in areas with high RE investments. Ref. [10] argues that since the RE industry (in some aspects) is relatively labor-intensive, it can employ more workers per unit of energy produced to create not only higher employment but also a more equal distribution of income, thereby increasing the overall wellbeing.

Moreover, existent literature, including [11,12], suggests that an increase in REC, by shifting consumption from fossil fuels to renewables, can stabilize energy prices due to the declining cost of RE technologies. Since poor households use a considerable amount of income on energy sources, the declining cost of RE technologies and the subsequent fall in energy prices can significantly improve their living standards. This can lead to a decrease in income inequality. Additionally, ref. [13] postulates that cheaper RE technologies disproportionately help the poor since environmental degradation hurts them significantly more than the relatively affluent, who have more avenues to protect themselves from environmental pollution. The available literature, such as [11,14,15], provides compelling evidence of a positive relationship between REC and economic wellbeing in the long run (LR), consisting of higher employment and growth, stable energy prices, and reduced CO_2 emissions.

Foreign Direct Investment (FDI) is a form of direct investment in another country which includes the transfer of knowledge, management practices, and technology. This creates overarching impacts on the economic development of nations. Ref. [16] argues that FDI positively impacts the wellbeing of developing nations directly by contributing toward job creation, capital inflows, increased wages, and tax revenues while indirectly stimulating growth and competition through knowledge and technology spillovers to local businesses. However, there is existing literature, such as [17–20], that proposes a negative effect on the host country due to crowding out of domestic investors and a large technology gap, leading to inequality. Nevertheless, FDI contributes to the wellbeing of nations as it increases the level of education, improves life expectancy, raises the purchasing power of consumers, and improves infrastructure [21].

FDI can also potentially increase investments in RE production and dissemination since higher social cognizance and environmental awareness in foreign firms can create a paradigm shift in the host country to increase the use of RE, as discussed in many studies [22,23]. This spillover effect can also occur through higher REC since there are increased abilities, acceptance, and awareness of RE with increased FDI [5]. There are also theoretical underpinnings to the relationship between FDI and REC. The pollution halo hypothesis suggests that FDI creates better environmental regulations and limits environmental degradation through the transfer of energy-saving technologies, promoting REC [24].

Since the existing literature points out numerous shreds of evidence of FDI increasing REC and vice-versa, and REC, in turn, decreasing income inequality, the motivation of this paper is to find whether there is a triangular relationship between FDI, REC, and income inequality. This can be from higher FDI to higher REC to lower income inequality to again higher FDI, or from lower-income inequality to higher REC to higher FDI to lower income inequality, and vice versa. Thus, the main objective of this paper is to find

the nexus between the variables FDI, REC, and income inequality. The intrinsic benefit of analyzing the underlying relationship between FDI, REC, and income inequality is numerous. Among others, we argue that the benefits associated with the socio-economic factors are immense due to each variable's impact on social and economic factors at the aggregate level. Therefore, it is expected that the outcome of this paper will be useful for the strategic policy formulation in terms of achieving Sustainable Development Goals (SDG) and beyond.

Therefore, given the motivation, the novelty of this paper is twofold. Firstly, the paper states a novel idea (both theoretically and empirically) that links all three variables concerning FDI, REC, and income inequality. There are many strands of literature that discuss the bivariate relationships between the concerned variables, but no previous attempt has been made to empirically check the nexus between these three variables. Thus, we contribute to this gap in the literature. We investigate this interconnected triangular relationship by taking data from 123 countries and dividing them into different income groups according to the World Bank classifications of High-Income Countries (HIC), Upper Middle-Income Countries (UMIC), Lower Middle-Income Countries (LMIC), and Low-Income Countries (LIC). Secondly, since we investigate this nexus in different income cohorts (regions) in countries across the world, we can find how these variables respond to each other depending on the income status of the country and whether there are any significant differences between them.

The rest of the paper is organized as follows: Section 2 presents a brief review of the literature; Section 3 highlights the theoretical framework, models, methodology, and data. Section 4 discusses the results and provides an analysis, and Section 5 concludes the paper with a few policy recommendations.

2. A Review of Literature

The existing literature shows numerous pieces of evidence of empirical analysis that explore the relationship between FDI and REC, FDI and income inequality, and REC and income inequality with or without other variables from the perspective of macroeconomics, finance, environment, sustainability, institution, governance, etc. In this section, we aim to provide a brief review of the existing literature.

2.1. Literature on FDI and REC

Ref. [25] examined the factors that influence FDI in BRICS (Brazil, Russia, India, China, and South Africa) countries with a special emphasis on how energy impacts FDI between the years 1990 and 2018. The empirical results revealed that REC has a statistically significant positive effect on FDI. LR results from CS-ARDL and other estimators revealed that both RE and non-renewable energy utilization have positive contributions to FDI, but the magnitude of the effect of RE utilization is larger. CS-ARDL results revealed that improvement in REC by one percent stimulates FDI by 0.485 percent. It is implied that BRICS nations could increase RE capacity through increased FDI in green energy projects. Since non-renewable energy attracts FDI, policies must be devised to channel FDI from the non-renewable sector to the RE sector.

Ref. [26] used panel data to investigate the cointegration and causal relationship between FDI and REC in 43 countries from 2005 to 2017. The results of Granger causality revealed that unidirectional causality runs from REC to FDI. The results from Pedroni residual cointegration test further provided evidence of a LR relationship between FDI and REC.

On the other hand, ref. [5] examined the nexus between FDI and REC in Bangladesh using Granger Causality and Vector Error Correction Model (VECM). The results revealed that a LR bidirectional causality runs between REC and FDI. However, results concluded no causality between REC and FDI in the short-run (SR). Since bidirectional causality runs between REC and FDI, ref. [5] recommended that policymakers should take policies so that an environment is created for FDI to develop the RE sector, which can then boost the

economy of Bangladesh in the LR. This can also help to protect economic activities in case of any sudden international risks that could cause energy price fluctuation.

Ref. [27] used Granger causality to examine the relationship between FDI, economic growth, and REC in Kazakhstan and Uzbekistan from 1992 to 2018, and the results showed a two-way linkage between the variables of REC and FDI in the LR. Considering the relationship between REC and economic growth, results suggested that Uzbekistan follows neutrality while Kazakhstan follows a negative growth hypothesis. It was recommended that the governments of Uzbekistan and Kazakhstan should stimulate FDI flow in RE using the experience of other countries which have advantages in RE sources.

Ref. [28] examined the LR equilibrium nexus between CO2 emissions, urban population, trade openness, GDP, FDI, and RE in South Asia from 1990 to 2019. Estimation results of Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) revealed that there is a significant negative relationship between FDI and RE in South Asia. An increase in FDI by one percent would decrease RE by 3.36 percent. Ref. [28] recommended that the economic policies in South Asia should focus more on the removal of trade barriers and it should promote global international commerce. As trade openness can impede the use of RE, policymakers must ensure that RE technologies are being transferred in the trade that takes place between South Asian countries and their trading partners.

Ref. [29] examined the relationship between Financial Development (FD), GDP growth, and REC in five South Asian countries from 1990 to 2018. By applying panel ARDL (linear and non-linear), DOLS, and FMOLS models, it was found that in the LR, an increase in FD was found to reduce the propensity of REC by 0.07–0.15 percent. Moreover, it was found that GDP growth increases REC by around 0.50–1.56 percent until certain thresholds, after which it reduces REC by 0.01–0.03 percent. The authors suggested that countries strengthen RE development by restructuring RE policies and focusing on institutional reforms.

Using linear and non-linear ARDL methods, ref. [30] inspected the relation between economic policy uncertainty and REC with the intervening role of FDI and FD in BRIC countries (Brazil, Russia, India, and China) from 1997 to 2018. The statistically significant and positive relationship that was found for FDI and FD to REC gives a signal that renewable energy integration could be augmented with continuous FDI and financial sector development. Study findings postulated that the role of FDI and FD are critically significant because technological advancement and capital investment augment clean energy integration through the application of renewable energy.

Ref. [31] studied the effect of different factors on REC in Iran, with a special focus on the role of FDI, FD, and the stock market, between 1978 and 2016 using ARDL. Findings revealed that a causal relationship exists between FDI, stock market, and REC in Iran. Both in the short-run (SR) and LR, an increase in FDI would result in higher energy consumption in Iran. According to the estimation results, if FDI increases by one percent, the consumption of RE increases by 0.02 percent. The results also implied that if FDI is increased through clean and environmentally friendly technology, replacing pollutant and destructive technology, it will cause an increase in clean energy. Furthermore, if CO_2 emissions are decreased by one percent, REC will increase by 0.192 percent in the LR. Furthermore, results suggested that if CO_2 emissions are decreased by one percent, the GDP of Iran will increase by 0.428 percent.

Using CS-ARDL, ref. [32] examined the impacts of RE, economic growth, government effectiveness, and FDI on carbon emissions in India, Bangladesh, Sri Lanka, and Pakistan from 1996 to 2019. Results revealed that there is cross-sectional dependence among all variables at a one percent significance level. If REC is increased by 1 percent, CO_2 emissions will decrease by 13.95 percent. The results further revealed that an increase in governance (government effectiveness) by 1 percent would reduce CO_2 emissions by 7.68 percent. Therefore, Mehmood (2021) suggests that governments must integrate FDI with RE considering the context of strict environmental policies.

Ref. [33] used panel ARDL to examine the nexus between FDI and RE production in Turkey and BRICS countries from 1996 to 2015. Results revealed that, although there

was no SR impact of FDI found on RE production, a LR nexus was found to exist between the two variables in the aforementioned nations. LR estimation results revealed that a rise in FDI by one percent led to a decrease in RE production by 0.147 percent. Ref. [33] mentioned that these results might be an indication that FDIs are not directed towards the RE sector and recommends that policymakers should find suitable incentives for FDIs from the non-renewable energy sector to be channeled to the RE sector so that more RE investments can be achieved.

Using Panel Vector Autoregressive (PVAR) Granger causality and static panel data, ref. [34] examined the cointegration and causality relationship between FDI in the renewable electricity industry (FDIREI), renewable electricity production (REP), and GDP in 32 African countries between 2002 and 2019. Results provided evidence that unidirectional causality runs from RE production to GDP, so it supports the growth hypothesis. For the remaining variables, the neutrality hypothesis is confirmed. Ref. [34] recommended that African policymakers should give more priority to RE production, which could be achieved through both promotion and expansion of RE production. Moreover, policymakers should revitalize the financial and regulatory policies of RE production. It is recommended in the paper that energy banks in African countries augment RE production as a prime component. In order to enhance green FDI, effective attractive policies should be taken.

Using a dynamic heterogeneous estimation technique, ref. [35] examined the impact of growth in income, RE, FDI, and governance on emissions of Green House Gas (GHG) in 47 Sub-Saharan African countries between 1990 and 2017. From the decoupling effect, it is revealed that income level, FDI, and governance exacerbate climate change. However, REC lessens the impact of climate change. Empirical results revealed that if the share of RE is increased by one percent, emissions of GHGs will decline by 35.32 percent, but an increase in the interactive effect of REC and FDI by one percent would worsen climate change by 34.33 percent. To decrease GHG emissions, ref. [35] recommended that governments should take actions to change the economic structure through energy efficiency and decarbonization. To improve the environment quality, diversification of energy mix by replacing fossil fuels with RE technologies is essential.

2.2. Literature on FDI and Inequality

Studies have also been conducted looking into the relationship between FDI and income inequality. Ref. [36] analyzed the impact that FDI has on income inequality in 16 African countries from 1980 to 2013 using a pooled mean group estimator. The findings of this paper showed that although FDI initially improves income distribution, a further increase in FDI causes a diminishing effect to take place. This is due to the fact that the relationship between the variables is non-linear, and the effect is U-shaped, where income inequality decreases before rising again. The authors suggested that FDI in these countries must be restructured since FDI-induced growth may not necessarily reduce inequality, even though it can enhance growth. It was also suggested that FDI should target both ends of the labor market to address the existing inequality.

Other studies also support the idea of FDI increasing inequality. Ref. [37] examined the impact of FDI on income inequality by taking small and large samples from Latin America and data from different periods of time, ranging from 1982 to 2011. Using DOLS, panel cointegration techniques, and unbalanced panel regression analysis, it was found that a significant positive effect on income inequality exists due to inward FDI. No evidence was found for reverse causality from income inequality to FDI. The authors addressed conflicting goals of the governments regarding FDI and suggested avoiding FDI-induced demand for skilled workers, containing social conflicts to improve basic education, and focusing on strong economic growth, which has previously contributed to the decline in income inequality in recent years.

Ref. [38] conducted a study that supported similar findings. They examined the interactions between FDI, inequality, and growth in 119 developing countries from 1970 to 1999. Using the System-GMM (Generalized Method of Moments) estimator and fixed-

effects estimator, it was found that FDI promotes inequality and growth and is likely to reduce the share of agriculture to GDP in the recipient country. A growth model of a dual economy (traditional and modern) was then developed, and the predictions of the model were found to be consistent with the stylized facts previously observed, one of the predictions being that FDI and inequality are positively correlated. FDI can especially exacerbate inequality where, due to lower initial human capital, the poor have a lack of access to the FDI-based technology.

Ref. [39] analyzed the relationship between FDI and income inequality and came to more specific conclusions. A meta-analysis was conducted by using 543 empirical studies with time periods ranging from 1995 to 2019, following MAER-NET guidelines and using meta-regression analysis (MRA) models. It was revealed that literature regarding this relationship is inconclusive due to the fact that it depends on how developed the countries in question are. When grouped into three income groups, FDI was found to be associated with higher inequality for the low-income group and had no statistically significant effect on the middle-income group. It was found to be associated with reduced inequality only for the high-income group. Therefore, it was concluded that FDI is likely to increase income inequality in a country during its initial development stage and lower it with higher development.

2.3. Literature on REC and Inequality

Ref. [40] found a moderating relationship of inequality between REC on CO_2 emissions using a fixed-effects panel regression model for a sample of 175 countries with data covering from 1990 to 2014. The results suggested that income inequality increases REC which reduces emissions, but when the use of fossil fuels is controlled in the model, the reduction in emissions was more significant. Hence, the analysis argued that national income inequality dictates the way in which REC proliferates and affects a reduction in CO_2 emissions. This is because in places with increasing inequality, RE displaces more fossil fuels compared to places with decreasing inequality, where RE displaces less fossil fuels.

Ref. [41] studied the disparity in RE generation in the OECD countries using Theil's second measure using data ranging from 1980 to 2011. The analysis found that countries exhibit inequality in RE generation, but with increasing RE generation, the inequality is decreasing. This relationship exists between groups and within groups, with the between-group inequality being higher.

Ref. [42] used a panel ARDL method to find the relationship between income inequality on REC between 43 countries (2000–2015) by controlling for economic, environmental, and institutional variables. The results revealed a negative relationship between the Gini coefficient and REC, both in the SR and LR, meaning countries with an equal distribution of income had more REC. The study also found a unidirectional causal relationship between income inequality and REC.

Ref. [43] found the link between income inequality and REC using Quantile Regressions (QR) and GMM for 39 Sub-Saharan African countries. For the analysis, they used data covering from 2004–2014. It was argued that financial development promotes REC, but income inequality has a counter effect on this promotion. The QR also concluded that countries with relatively high REC could not depend on financial development for further increase in REC but rather have to decrease income inequality to offset the negative impact it has on REC.

Ref. [11] investigated the relationship REC has on income inequality for 23 developed countries with data covering from 1990–2014. The SR and LR estimations are done by using panel system-GMM and Dynamic Common Correlated Effects (DCCE) estimators. Their estimations suggested a negative relationship between REC and income inequality, meaning that an increase in REC decreases income inequality. The system-GMM results revealed that a 1 percent increase in REC reduces income inequality by 0.014 percent in the SR and 0.246 in the LR. The DCCE results indicated that a 1 percent increase in REC

reduces income inequality by 0.120 percent in the SR and 0.197 percent in the LR. The analysis suggested that the LR impact of REC on income inequality is larger.

2.4. Summary

Overall, the discussion provides a clear picture of the existing contribution pattern in the body of literature. According to the reviewed studies, there is evidence of inter-connection between FDI and REC, FDI and Inequality, and REC and inequality, even though results are relatively heterogeneous across countries and regions. The observed heterogeneity in the results is certainly plausible due to the observed and unobserved dynamics across the countries and regions, which evolve from numerous aspects ranging from social and cultural norms, government targets, political agendas, institutional aspects, etc. Turning back to the pattern of contribution, it is indeed perceptible that there persists a gap in creating an empirical framework for investigating inter-linkages among FDI, REC, and income inequality together based on theoretical foundations. Therefore, in the next section, we develop an empirical framework from explicit theoretical underpinnings as well as discuss the required econometric methodology and data for the panel analysis.

3. Theoretical Foundations, Model, Methodology, and Data

3.1. Theoretical Foundations

The theoretical underpinnings of this paper come from both an economic perspective and a psychological perspective. The theoretical foundation for the dynamics of REC with respect to FDI and inequality is supported by ecological economics and the rational optimization of consumption levels. Ecological economics argues that energy commodities should be incorporated into the consumption modeling framework. Following the argument, households and other economic agents focus on optimizing the consumption pattern based on the rational expectation assumption. In doing so, all the economic agents maximize their respective utility (U_t) given a constraint. Utility depends on non-energy consumption (C_t), non-renewable energy consumption (NEC_t), and renewable energy (REC_t). At the aggregate level, this constraint is nothing but the national income or GDP (Y_t), which is a function of C_t, government expenditure and net exports (X_t), and cost of energy (Z_t) [44].

National income also depends on investment. The investment is assumed to be divided into two components, namely domestic investment and FDI, respectively (DI_t and FDI_t) so that FDI dynamics (given its exogenous interest rate r) can be explicitly captured. Following the arrangements of [45], an additional component is assumed in the constraint that captures the dynamics of REC and inequality (W_t) through income distribution. Assuming X_t, C_t, NEC_t, and DI_t exogenous, the optimization process leads to a REC pattern where its dynamics in the LR can be modeled by FDI and inequality given prices are normalized and λ as a mathematical constant.

$$U_t = f(C_t, NEC_t, REC_t) \tag{1}$$

subject to

$$Y_t = f(C_t, X_t, Z_t, FDI_t, DI_t, W_t) \tag{2}$$

Therefore, the Lagrangian for this planning problem is as follows:

$$L = U_t + \lambda[Y_t - f(C_t, X_t, Z_t, FDI_t, DI_t, W_t)] \tag{3}$$

Solving the first-order condition given the above exogeneity assumption, we can write optimal REC by Equation (4).

$$REC_t = f(FDI_t, W_t, Y_t) \tag{4}$$

The dynamic response of FDI with respect to REC and inequality can be explained by the underlying notions of the Theory of Planned Behaviour (TPB) and the Social Exchange Theory (SET) [46,47]. The TPB and the SET are recognized as popular theoretical frameworks in order to investigate human behaviors in different disciplines. It should be worth mentioning that the use of these theoretical frameworks has been significantly increased in the field of economics, renewable energy, environment, wellbeing, and sustainability [48].

"Intention to act" is the main aspect of the TPB. This phenomenon is characterized by the motivational factors or pure willingness of the economic agents due to their attitude. It also depends on subjective norms, thus making it very heterogeneous. The literature argues that given that subjective norms shape the individual attitude, the perceived social pressure also becomes a determinant for explaining human behavior [46]. Lastly, how individual attitude is influenced by the perceived social pressure is captured by the SET. According to the SET, economic agents tend to accept or be attracted to certain activities when the potential benefit is greater than the cost. However, the degree of acceptance or attraction to certain activities tends to be governed by perceived social pressure. Positive social pressure increases the degree of acceptance or attraction and vice-versa.

Following the arguments, it is expected that changes in REC may bring changes in FDI. For instance, given the national income structure, an increase in REC in one country may give market signals to foreign investors to invest in projects that are profitable and promote the use of renewable energy and environmental sustainability [5]. On the other hand, since foreign investors tend to engage with Corporate Social Responsibilities (CSRs), prevailing inequality may attract FDI in targeted areas through Non-Government Organisations (NGOs). Hence, we can formulate the following Equation for our analysis:

$$FDI_t = f(REC_t, W_t, Y_t) \tag{5}$$

The theoretical linkage between inequality and FDI is closely associated with the theoretical framework of [38]. The economy is considered to have two sectors: industrial and traditional. The traditional sector produces agricultural commodities (Y_{at}) and the industrial sector produces manufacturing and intermediate commodities (Y_{mt}). Apart from labor and capital (both physical and human) ($L_{at}, H_{at}, L_{mt}, H_{mt}, K_{at}, K_{mt}$), energy ($TEC_t$) (both non-renewable and renewable) is considered as an extra factor of production following [49]. Summation of the outputs produced by both the sectors yields national output (Y_t). It is further assumed that given that the land supply is fixed, the agricultural sector faces greater diminishing returns. In this framework, economic agents are divided into rich and poor categories. The distribution of the resources is arranged in a way so that the rich agents have access to both production technology; however, the poor agents only have access to one production technology (agriculture). This indicates that the rich agents have human capital (H_{mt}) that is above or equal to the minimum human capital (H_{min}) needed to start industrial production at a given time. Such distinction is also important because it helps the rich agents attract FDIs in the industrial sector.

Since the selected countries are mostly open economies, they receive FDI in the industrial sector at an exogenously fixed world interest rate apart from domestic investment in both sectors. Finally, if the preferences are assumed to follow [50], then once the subsistence level of agricultural commodities is consumed, agents start giving more weight to manufacturing commodities so that inequality persists in the economy. Therefore, FDI tends to provide an upward push to income inequality. However, FDI may reduce inequality if poor agents could achieve minimum human capital, as mentioned earlier. On the other hand, if the energy-income (i.e., output) nexus confirms the presence of the growth hypothesis, then inequality could be reduced since energy is considered a necessity good and improves socio-economic aspects [51].

$$Y_t = Y_{at}(L_{at}, K_{at}, H_{at}, TEC_t) + Y_{mt}(L_{mt}, K_{mt}, H_{mt}, FDI_t, TEC_t); \; H_{mt} \geq H_{min} \tag{6}$$

$$FDI_t = f(FDI_{t-1}, r) \tag{7}$$

$$TEC_t = f(REC_t, NEC_t) \tag{8}$$

$$K_{jt} = f(\theta K_{jt-1}, v_{jt}); \; v_{jt} = \text{physical capital investment} \tag{9}$$

$$H_{jt} = f(\mu H_{jt-1}, n_{jt}); \; n_{jt} = \text{human capital investment} \tag{10}$$

$$U_t = f(C_{at}, C_{mt}, TEC_t) \tag{11}$$

Given the arguments of production and preferences above, we can express an inequality Equation as described by [38,42] after allowing exogenous dynamics in capital, labor, consumption, and non-renewable energy.

$$W_t = f(FDI_t, REC_t, Y_t) \tag{12}$$

3.2. Econometric Modeling

Since our objective is to check whether there is any LR relationship between the variables of interest, the following models are used. It is worth mentioning that the models are selected following the argument and intuition of [5,27,30,31].

$$REC_{it} = f\left(REC_{i,t-1}, \sum_{i=0}^{p} FDI_{i,t-i}, \sum_{i=0}^{q} W_{i,t-i}, \theta\right) \tag{13}$$

$$FDI_{it} = f\left(FDI_{i,t-1}, \sum_{i=0}^{p} REC_{i,t-i}, \sum_{i=0}^{q} W_{i,t-i}, \theta\right) \tag{14}$$

$$W_{it} = f\left(W_{i,t-1}, \sum_{i=0}^{p} REC_{i,t-i}, \sum_{i=0}^{q} FDI_{i,t-i}, \theta\right) \tag{15}$$

From Equations (13)–(15), $REC_{i,t-1}$ represents the value of a one-period lag (Lag is used in autoregressive dynamic panel models, and it reduces the issue of endogeneity. A lag of one period is used as it is standard practice in empirical econometrics, and it shows the annual dynamic relationship within a variable) of consumption of renewable energy, $W_{i,t-1}$ represents a one-period lag value of income inequality. $FDI_{i,t-1}$ represents a one-period lag value of FDI inflows. Here, θ is the control variable which incorporates the effect of GDP, country fixed effects, and cross-sectional adjustment effects.

3.3. Cross-Sectional Dependency and Slope Homogeneity

Recent empirical investigations show panel data are frequently interlinked. The cross-sectional dependence method proposed by [52] has been applied to investigate the cross-dependency in the concerned variables. On the other hand, earlier, it was assumed there is complete slope homogeneity. Recent literature has rejected the assumption and advocated the existence of heterogeneous slopes across the sections. In this paper, the Pesaran-Yamagata test [53] has been incorporated to study the concern of slope homogeneity.

3.4. CADF and CIPS Tests

The stationarity property of variables is checked by two tests, namely Cross-Sectional Augmented Dickey Fuller (CADF) and Cross-Sectional IPS (CIPS) tests which were suggested by [54]. Both of the tests take the assumption of cross-sectional dependence into consideration. Although CIPS, as well as CADF test mechanisms, are similar in nature, there is only one exception—CIPS uses the CADF test's cross-sectional average. Assume that x_{it} is the objective variable and ε_{it} is the error term. Therefore, based on the standard ADF framework, the following Equation can be written:

$$\Delta x_{it} = \alpha_i + \beta_i x_{i,\,t-1} + \rho_i T + \sum_{j=1}^{n} \theta_{ij} x_{i,j-1} + \varepsilon_{it} \tag{16}$$

In Equation (16), the first differenced operator is indicated by Δ. The intercept (or constant) is denoted by α and the time trend by T. The null hypothesis for both of the tests is that the individuals within the panel dataset are not stationary, and the alternative hypothesis, again for both of the tests, is that at least one individual within the dataset is stationary.

3.5. Durbin-Hausman Panel Cointegration Test

The Durbin-Hausman [55] panel cointegration test is a second-generation cointegration test that takes into consideration cross-sectional dependence. Moreover, the Durbin-Hausman test does not require any priori information about the integration order of the variables of interest. In other words, this test can be carried out without the knowledge of the variables being I(0), I(1), or even mutually integrated. This test can be categorized into the Durbin-Hausman Panel (DH_p) test and the Durbin-Hausman Group (DH_g) test, which can be defined as follows:

$$DH_p = \hat{S}_n \left(\tilde{\vartheta} - \hat{\vartheta} \right)^2 \sum_{i=1}^{N} \sum_{t=2}^{T} \hat{e}_{i,t-1} \tag{17}$$

$$DH_g = \sum_{i=1}^{N} \hat{S}_i \left(\tilde{\vartheta}_i - \hat{\vartheta}_i \right)^2 \sum_{t=2}^{T} \hat{e}_{i,t-1} \tag{18}$$

DH_p tests $H_o : \vartheta_i = \vartheta = 1$ for all cross-sections against $H_1 : \vartheta_i = \vartheta < 1$ for all cross-sections in the panel dataset. In Equation (17), $\hat{\vartheta}$ is considered as pooled OLS and $\tilde{\vartheta}$ is considered as Pooled IV estimator. Moreover, $\hat{S}_n = \frac{\hat{\omega}^2{}_N}{\left(\sigma_N^2\right)^2}$ with $\hat{\omega}_N^2 = \frac{1}{N} \sum_{i=1}^{N} \hat{\omega}_i^2$ and finally, $\hat{\sigma}_N^2 = \frac{1}{N} \sum_{i=1}^{N} \sigma_i^2$. On the other hand, DH_g test's $H_o : \vartheta_i = 1$ for all cross-sections against $H_1 : \vartheta_i < 1$ for at least one cross-section within the panel dataset. Similar to Equation (8), in Equation (18) $\hat{\vartheta}_i$ is considered as pooled OLS and $\tilde{\vartheta}_i$ is considered as Pooled IV estimator. $\hat{S}_i = \frac{\hat{\omega}^2{}_i}{\left(\sigma_i^2\right)^2}$ is the LR consistent estimator variance.

3.6. CS-ARDL

The CS-ARDL approach controls the common factors by augmenting the individual ARDL regressions competently with some additional lags of cross-sectional averages [56]. The CS-ARDL approach, after adding cross-sectional lag terms, can be presented as:

$$y_{i,t} = \omega_i + \sum_{j=1}^{p_y} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{p_x} \beta'{}_{ij} x_{i,t-j} + \sum_{j=0}^{p_T} \gamma'{}_{ij} \bar{z}_{t-j} + u_{i,t} \tag{19}$$

Here, $\bar{z}_{t-j} = \left(\bar{y}_{i,t-j} , \bar{x}_{i,t-j} \right)$ and p_T, which is not always equal to p_y or p_x, represents the number of lags of the cross-sectional averages which are to be considered for inclusion. Moreover, different lag orders can be allowed for $\bar{y}_{i,t}$ and $\bar{x}_{i,t}$ [57]. Computation of the LR unit-specific estimates and the mean group estimates in CS-ARDL is done in the following manner:

$$\hat{\theta}_{CS-ARDL,i} = \frac{\Sigma_{j=0}^{p_x} \hat{\beta}_{ij}}{1 - \Sigma_{j=1}^{p_y} \hat{\lambda}_{ij}} \tag{20}$$

As mentioned in [57], in order to achieve the LR estimates $\hat{\theta}_{CS-ARDL,i}$ the above-mentioned CS-ARDL approach depends on the SR estimates $\hat{\beta}_{ij}$. The calculation of the LR estimates is likely to be considered sensitive to outlier estimates if the AR coefficients $\Sigma_{j=1}^{p_y} \hat{\lambda}_{ij}$ are close to 1. Moreover, satisfactory small sample performance demands a relatively large time dimension in cases where there are many lagged terms of the explanatory variable [57,58]. This estimator has been chosen for LR estimation due to its numerous advantages. One of the main advantages of CS-ARDL over traditional estimators (fixed-effects, random-effects, GMM, etc.) is that it can properly address the issue of cross-sectional dependency. Moreover, compared to other traditional estimators, CS-ARDL can give robust estimates even if the sample size is relatively small. Furthermore, CS-ARDL gives a heterogeneous slope for better policy implications.

3.7. Data

The empirical analysis of this paper is based on data covering from 2010 to 2020. Data for the concerned variables of 34 HIC, 38 UMIC, 27 LMIC, and 15 LIC are extracted from

three sources, namely the World Development Indicators (WDI), the Standardized World Income Inequality Database (SWIID), and the International Energy Agency (IEA). GDP (in million USD) and FDI (in million USD) are collected from the WDI. On the other hand, disposable income-based Gini coefficient (index) data is obtained from the SWIID. REC data was collected from IEA. Other control variables such as country fixed effects and cross-sectional averages are prepared manually from the exiting data of the above-mentioned variables. A snapshot of the key variables is shown in Table 1.

Table 1. Descriptive Statistics of the Concerned Variables.

Variable	Mean	Std. Dev.	Min.	Max.	N	Countries
FDI	21.55	2.17	10.92	26.96	1117	123
W	3.64	0.22	2.97	4.15	1117	123
REC	8.59	2.30	1.20	14.60	1117	123
GDP	25.17	1.99	20.31	30.70	1117	123

Note: data in the table went through natural logarithmic transformation.

4. Results and Discussion

4.1. Cross-Sectional Dependency Test

Determining the presence of cross-sectional dependence is crucial for panel empirical investigations. As the panel empirical investigation strategies started to develop, it was assumed that the errors were uncorrelated across the sections (i.e., country, region, industry, villages, and communities). However, as the theoretical literature on panel econometric analysis developed over time, it is now clear that such an assumption is not entirely valid (i.e., errors may be correlated across the sections for selected variables) and may lead to spurious policy implications if cross-sectional relations are not taken into account [52].

Table 2 depicts the Pesaran CD test results as discussed in the previous section. Looking at the results, we cannot directly conclude that there is cross-sectional dependence in all variables across the countries of the regions. For the UMIC, all the key concerned variables have cross-sectional dependence (i.e., the null hypothesis is rejected). This indicates there is a presence of common unobserved patterns within the variables that should be addressed when analyzing stationarity properties, cointegration, and LR estimations. On the other hand, we find that for the HIC, LMIC, and LIC, the Gini coefficient has cross-sectional independence since we cannot reject the null hypothesis of no cross-sectional dependence. Such a result indicates that within these regions, inequality due to income differentials is strongly determined by unique patterns (such as sectoral distribution in GDP, tax base, and consumption pattern) that do not vary across the sections. We also find evidence of cross-sectional independence in FDI for the LIC, indicating that FDI dynamics do not portray a common pattern across the countries of this region. The outcome is also relatively plausible because foreign investment in the LIC is subject to unique risks, uncertainties, and government mandates and regulations. Therefore, a sudden shock may not change the FDI pattern in a similar way across the countries of this region.

4.2. Slope Homogeneity Test

Slope homogeneity in panel analysis indicates that the slope of the regression line is the same across the sections. However, even if there is some degree of uniformity within the cross-sections, it does not always mean the slope of the regression line will be the same. Therefore, if the sample is relatively large and slope homogeneity is assumed even if heterogeneity prevails, then there will be a loss of valuable information that may lead to sub-optimal policy implications.

Table 3 shows the results of the slope homogeneity test of all four regions. Results indicate that in most of the cases, slope homogeneity is rejected since we can accept the alternative hypothesis of slope heterogeneity at different levels of statistical significance. So, for the LR estimation, it is imperative to account for slope heterogeneity. It is worth noting that in the cases where slope homogeneity prevails, accounting for slope heterogeneity will

not create any issue. The reason is that indirectly, it reveals where insignificant relations persist, which also determines the significance level of mean (i.e., group) LR estimates.

Table 2. Cross-Sectional Dependency Tests.

HIC				
Criteria	**FDI**	**GDP**	**W**	**REC**
Pesaran CD	1.39 *	31.11 ***	−1.56	50.09 ***
UMIC				
Criteria	**FDI**	**GDP**	**W**	**REC**
Pesaran CD	3.79 ***	30.42 ***	2.42 **	26.32 ***
LMIC				
Criteria	**FDI**	**GDP**	**W**	**REC**
Pesaran CD	8.20 ***	28.25 ***	−1.87	18.79 ***
LIC				
Criteria	**FDI**	**GDP**	**W**	**REC**
Pesaran CD	1.24	8.06 ***	−0.82	4.84 ***

Note: ***, **, and * refer to significance levels at 1%, 5%, and 10%, respectively.

Table 3. Pesaran-Yamagata Slope Homogeneity Test.

Model	**Pesaran-Yamagata Slope Homogeneity Test**			
	Delta Statistics	*p*-**Value**	**Delta adj. Statistics**	*p*-**Value**
HIC				
Model 1	0.821	0.411	1.537	0.104
Model 2	1.110	0.267	2.078	0.038
Model 3	2.013	0.044	3.766	0.000
UMIC				
Model 1	0.864	0.388	1.616	0.106
Model 2	0.581	0.561	1.087	0.277
Model 3	1.943	0.052	3.636	0.000
LMIC				
Model 1	−1.303	0.193	−2.437	0.015
Model 2	−0.286	0.775	−0.536	0.592
Model 3	1.531	0.126	2.864	0.004
LIC				
Model 1	−0.903	0.367	−1.689	0.091
Model 2	−0.990	0.322	−1.852	0.064
Model 3	−0.717	0.473	−1.341	0.180

4.3. CIPS and CADF Tests

The results of the cross-sectional dependency test and slope homogeneity test reveal that traditional unit root tests should not be used for checking the stationarity properties of the concerned variables.

Table 4 shows the summary results of the panel unit root tests (CIPS and CADF) for all four regions. (The detailed unit root test results are not presented due to brevity; however, they can be delivered upon request.) From the results, the mix order of integration is

evident (i.e., variables are I(0) and I(1)). In other words, across regions (other than the LMIC), some variables are augmented with high-degree stochastic patterns, and some show no or trivial evidence of the aforementioned patterns. The obtained results point out an important conclusion for choosing the appropriate approach for testing cointegrating relationships. Since we find evidence of mix order integration, cointegration tests that only allow strict I(1) patterns among the variables should not be considered. Rather, we need to consider a second-generation cointegration test that allows both mixed and strict orders of integration.

Table 4. Panel Unit Root Tests for HIC.

HIC	
Variable	**Order of Integration**
FDI	I(0)
GDP	I(1)
W	I(1)
REC	I(0)
UMIC	
Variable	**Order of Integration**
FDI	I(0)
GDP	I(1)
W	I(1)
REC	I(0)
LMIC	
Variable	**Order of Integration**
FDI	I(1)
GDP	I(1)
W	I(1)
REC	I(1)
LIC	
Variable	**Order of Integration**
FDI	I(0)
GDP	I(1)
W	I(1)
REC	I(1)

4.4. Panel Cointegration Test

Given the results of cross-section dependency, slope homogeneity, and unit root, we now analyze whether there is any LR relationship among the variables of interest. Table 5 shows the results of the panel cointegration tests of the three models using the Durbin-Hausman Test. Both the DH_Group and DH_Panel show a strong LR cointegrating relationship (at various significance levels) among the variables in each model across the regions. As cointegration is confirmed, we now can focus on LR estimation by applying a robust estimator that can account for cross-sectional dependency and slope heterogeneity, given the stationarity properties of the variables.

Table 5. Panel Cointegration Test.

Model	Durbin-Hausman Test	
	DH_Group	**DH_Panel**
HIC		
Model 1	12.55 ***	17.39 ***
Model 2	11.44 ***	3.01 ***
Model 3	4.07 ***	2.02 **
UMIC		
Model 1	10.23 ***	20.39 ***
Model 2	5.33 **	3.01 ***
Model 3	12.07 *	8.02 **
LMIC		
Model 1	15.15 ***	14.19 ***
Model 2	11.09 ***	3.01 *
Model 3	4.07 ***	2.02 **
LIC		
Model 1	9.14 **	11.43 ***
Model 2	17.02 ***	7.21 **
Model 3	6.01 *	3.11 **

Note: ***, **, and * refer significance level at 1%, 5%, and 10%, respectively.

4.5. Estimation of Cointegrating Factors

Table 6 shows the estimated coefficients of the cointegrating factors for all models and regions. We reveal that for the HIC, an increase in FDI by 1 percent causes a 0.31 percent increase in REC. This is because a portion of the direct investments is being utilized for renewable energy projects that give rise to REC, as suggested by the pollution halo hypothesis. Higher FDI, through increased acceptance, awareness, and abilities, increases REC. Such enhancement in the REC also reduces the propensity of CO_2 emissions across the countries of this region. Moreover, it has been found that an increase in REC by 1 percent causes a 0.54 percent decrease in the Gini coefficient. This occurs due to REC being a stabilizer of electricity prices and the fact that the RE industry is a different aspect labor-intensive industry, thus creating a large number of jobs. Lastly, if GDP increases by 1 percent, the Gini coefficient increases by 0.50 percent, thus decreasing wellbeing. This shows to be consistent with the idea that a higher GDP without proper distributional channels tends to concentrate wealth and income to the richer counterparts of the economy, thereby increasing income inequality.

For the UMIC, it is revealed that an increase in FDI by 1 percent causes a 0.15 percent increase in REC, and an increase in GDP by 1 percent causes a 0.47 percent increase in REC significantly. This is consistent with the findings of [30] in the cases of China, Brazil, and Russia (UMIC) but inconsistent with the findings of ref. [27] in the case of Kazakhstan and ref. [33] in the cases of Brazil, Russia, China, Turkey, and South Africa. Apart from the notion of RE as a normal good, an increase in GDP is an indicator of progressive development that leads to an increase in REC due to better environmental regulations, better technology, and better institutions to encourage the consumption and investment of RE. It is also found that an increase in REC by 1 percent pushes down the Gini coefficient by 0.05 percent at a 1 percent significance level, following similar intuitions explained for the HIC.

Table 6. Estimation of the Cointegrating Factors.

Variable	HIC			UMIC			LMIC			LIC		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
REC(t−1)	0.04 (0.31)			−0.06 (0.10)			−0.38 (0.55)			0.002 (0.15)		
FDI(t−1)		−0.38 ** (0.16)			−0.36 *** (0.08)			−0.20 ** (0.08)			−0.07 (0.15)	
W(t−1)			0.10 (0.15)			0.22 ** (0.09)			0.11 (0.18)			0.38 ** (0.17)
FDI	0.31 * (0.17)		−0.05 (0.03)	0.15 ** (0.08)		−0.002 (0.02)	0.40 (0.47)		0.26 (0.27)	0.004 (0.04)		0.18 (0.15)
W	−131.91 (136.90)	0.10 (5.53)		−1.40 (1.36)	26.28 (28.60)		0.25 (5.83)	8.08 (12.98)		0.48 (2.20)	−0.66 (11.55)	
REC		−2.06 (1.68)	−0.54 * (0.31)		−0.09 (0.387)	−0.05 * (0.03)		0.87 ** (0.50)	0.11 * (0.06)		1.21 (1.16)	0.13 (0.17)
GDP	39.31 (38.17)	−4.47 (3.69)	0.50 ** (0.25)	0.47 ** (0.24)	2.47 (1.60)	0.06 (0.05)	−0.65 (1.55)	−1.29 (1.63)	−0.12 (0.50)	0.43 (0.40)	2.42 (1.93)	0.08 (0.11)
CS Avg.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
P−CD	0.46	−0.74	−0.97	−0.85	2.18*	0.36	−0.17	−1.58	−0.51	0.57	−0.08	−1.21
CIPS	−4.87 ***	−4.17 ***	−3.73 ***	−3.56 ***	−3.85 ***	−3.15 ***	−5.05 ***	−3.70 ***	−4.71 ***	−3.62 ***	−3.62 ***	−3.52 ***
N	320	320	320	330	330	330	320	320	320	100	100	100

Note: ***, **, and * refer significance level at 1%, 5%, and 10%, respectively. Standard errors are in parenthesis.

Looking at the LMIC, if REC increases by 1 percent, FDI increases by 0.87 percent, and the Gini coefficient increases by 0.11 percent, respectively. This is inconsistent with the findings of [27] for the case of Uzbekistan and [31]. One of the possible reasons for such a result is that since the LMIC are less developed than the HIC and the UMIC, an increase in REC through development agendas and market signals may attract foreign investors. However, an increase in REC may not necessarily increase welfare (i.e., reduce inequality) due to multiple reasons. It may be the case for the LMIC that the costs of RE technologies are still high, leading to a one-dimensional expansion only (for example, use in urban and semi-urban areas more than in rural areas). Furthermore, institutional inefficiencies and fragmentations may deter the decrease in income inequality through increased REC if proper opportunities cannot be created. Since FDI rises as REC increases, the motivation of the LMIC for green transition is evident. Most of the countries in this region have completed the initial stages of development. Given decent and sustained economic growth coupled with improved, different socio-economic standards, these countries have now started to focus on achieving environmental standards that are in line with the Paris Agreement. Apart from adaptation and mitigation strategies, most of the countries from this region are focusing on increasing RE share in the primary as well as electricity generation mixes. As a result, REC is gradually increasing and creating positive environmental and further socio-economic externalities.

On the other hand, no significant relationship could be established between REC and FDI in the LIC. The results resonate with Rostow's five stages of economic development. Along with managing stability in vital macroeconomic conditions, LIC have some priority areas such as healthcare and education, food stability, access to water, and other socio-economic activities that need to be focused on. A possible reason for the lack of a significant relationship between FDI and REC could be that any FDI the LIC receives is likely to be diverted to those areas, leading to very slow RE augmentation. RE can only be given priority at an adequate level of development once the basic needs of the population are met. Without readily available skills and resources, RE cannot be prioritised. Moreover, the market signals from the LIC are not very strong to attract FDI from different parts of the world.

Lastly, in all of the regions, we do not find any significant dynamics in the Gini coefficient with respect to the changes in FDI. However, the sign of the coefficients of the HIC and the UMIC is in line with the theoretical framework of [38]. One intuitive explanation for such insignificancy is the result of a situation where restrictions of access to production technology and lack of minimum human capital for the poor economic agents are moderately eased, resulting in a near-neutral effect on the Gini coefficient from the changes in FDI. In terms of model diagnostics, residuals are found to be stationary at levels. It indicates that all the stochastic patterns are well-controlled by the proposed models in all regions. Furthermore, cross-sectional dependence tests in the residuals also indicate the absence of cross-sectional dependence (except model 2 from the UMIC with weak inter-linkage), meaning that most of the major unobserved common components are accounted for in the investigation.

5. Conclusions and Policy Recommendations

The objective of this paper was to empirically examine the nexus between FDI, REC, and income inequality using recent and robust econometric methods. We found that in the HIC, an increase in FDI increases REC, and an increase in REC decreases the Gini coefficient, decreasing income inequality. We found similar results in the UMIC that an increase in FDI increases REC, and an increase in REC decreases the Gini coefficient, but the relationship between the variables is more inelastic compared to the HIC. However, in the LMIC, we found that an increase in REC increases FDI, and an increase in REC increases the Gini coefficient, indicating higher income inequality. Lastly, we found no significant relationship between FDI, REC, and Gini coefficient for the LIC.

In conclusion, we could not find any uniform interconnected linkage between all three variables, and we argue that this might be the case as there are gaps between the transmission channels of the multiplier effects between these variables. These may be caused by high institutional inefficiency and fragmentation that most of the lower and middle-income countries exhibit, which limits RE investment through FDI and the subsequent increase in REC, potentially breaking the link that reduces inequality. In addition, the cost of RE in most lower-income countries is still very high, and in order to allow the transmission of FDI-induced inequality reduction through RE, there needs to be a gradual and persistent decrease in the cost of RE technologies. Furthermore, since the dataset used in this paper included a large number of countries, it was not possible to capture the subjective country-specific reasons for which there are breaks in the theoretical linkage that was hypothesized. The heterogeneity in investment decisions, FDI inclusiveness, and willingness to pay for RE in different countries could be the reason why the empirical analysis to find a triangular relationship was inconclusive. There are also the differentiated impacts of the REC and FDI on different communities and income groups within countries that need to be addressed for more robust results.

There are clear policy implications that this research, therefore, suggests. As previously highlighted by [52], this paper strongly emphasizes the institutional efficiency to improve the economic wellbeing of nations through increased REC and FDI. Among others, refs. [59–62] emphasize that the lack of administrative power in a decentralized system (i.e., fragmentation) limits and slows the design of an effective renewable energy regulatory regime and implementation framework, leading to a distortion in the energy market dynamics. As a result, firms that specialize in RE face difficulty while entering and operating in the energy market.

This is especially true for the LMIC and LIC, where there were higher gaps in the transmission channels that reduce income inequality through higher REC. Even for the UMIC, we find that the relative elasticity of the variables was lower than the HIC; thus, the impact of RE being an energy price stabilizing force to decrease inequality may be constrained by the existence of such inefficiency. Therefore, considerable importance should be given to synchronized institutional reforms, especially in developing countries, by implementing legitimate regulatory programs in renewable energy technology exploration, market

monitoring mechanisms, pricing systems, robust labor laws, investment mechanisms, and finally, dissemination programs.

Since FDI has a positive impact on REC patterns, especially in the HIC and the UMIC, promoting multinational firms that use different RE technologies and promoting REC within the industries of these regions are strongly recommended. A suggestion to overcome the oscillation pattern of RE investment shock is formulating an RE investment policy that would help to facilitate different types of investment for RE development. Primarily, policies should focus on facilitating investments into the RE projects that have higher advantages, such as small to medium scale solar grid projects, solar home systems, and community-wise small-scale biogas plants, waste-to-energy plants in urban or semi-urban areas, etc.

Refs. [63–65] argue that the low level of investment in RE is due to the phenomenon of investment irreversibility, which is linked to concerns about returns due to risk and uncertainty. This discourages private investors, including FDIs, from investing in renewable energy and encourages them to seek out safer investments. Therefore, safer investment options should be created by augmenting innovative finance such as Energy Transition Mechanism (ETM), Corporate Power Purchase Agreements (CPPAs), and Green Bonds, coupled with integrated green finance and digital financing mechanisms that can result in higher RE investments. For the LMIC and the LIC, better demand-side investments from households in RE can be created through higher access to microcredits and small loans through the conventional approach as well as by introducing Financial Technologies (FinTechs).

Apart from local RE development agendas following [66], this paper emphasizes the need for measures such as open trade regimes (bilateral or multilateral) and specific financial incentives for RE technologies and RE infrastructure development. In addition, this paper proposes that a regional integrated RE legislation should be drafted to strengthen technical cooperation among countries, the use of standard rules to maximize inter-country RE investment, information exchange within firms, and cooperation with countries from neighboring regions. It would also be beneficial to raise societal awareness since, in the LMIC and the LIC, both consumers and political interests tend to overlook RE as a major energy source.

An extension of this paper could be to analyze the theorized relationship between FDI, RE, and Gini coefficient at the disaggregated level with a similar modeling framework. Since we have used a large, aggregated dataset, there is potential for missing information that can be addressed by performing sector-specific or country specific-studies. For instance, instead of taking FDI in general, we could look at the FDI in only the RE sector to understand the implications of FDI more specifically in RE and wellbeing. This would provide information on more critical aspects for policymakers to redesign national-level policies. In addition, another avenue of extension could be to analyze the variables from the regional perspectives like the MENA region, EU, Sub-Saharan Africa, OECD countries, and also from the perspectives of economic cooperation like the ASEAN, SAARC, and BRICS. The differences in the results between the regions or corporations could be further analyzed. Overall, this novel thinking can be explored in many dimensions to find more localized results.

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