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Research Article

Inclusive Energy Transitions

Inclusive Energy Transitions and SDG 7: Assessing Renewable Energy through the Lens of Justice and Social Fairness

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Energy transitions that are inclusive are necessary if SDG 7 is to be achieved since SDG 7 entails making sure that there is universal access to energy that is affordable, sustainable, and reliable. This paper analyzes renewable energy transitions from the perspective of energy justice. Specifically, it will analyze issues relating to equitable access to energy, affordability, and inclusion in energy transition programs in selected developing countries. In order to achieve its objectives, the paper will employ econometric methods using Fixed Effects (FE), Random Effects (RE), System GMM, and PCA analysis to develop an index of energy justice. Results show that the mean value of EJI is 0.63, which means that there is an energy justice condition of moderate magnitude with a huge disparity across nations. The highest contributing factor to the level of EJI is the installed capacity of renewable energy sources (40%), followed by renewable energy policies (35%) and investments (28%). Results from the Fixed Effects model indicate that the presence of renewable energy policy ($\beta = 0.28$), installed capacity ($\beta = 0.32$), and investment ($\beta = 0.21$) positively and significantly contribute to enhancing energy justice, whereas income inequality ($\beta = -0.18$) adversely impacts energy justice. The System GMM model shows that renewable energy share ($\beta = 0.029$), subsidies provided to consumers ($\beta = 0.017$), and rural electrification ($\beta = 0.043$) positively affect EJI, while the price of energy ($\beta = -0.052$) reduces affordability and inclusiveness.

Keywords: inclusive energy transition, sustainable development goal 7 (SDG 7), energy justice, renewable energy policy, social fairness, energy justice index, rural electrification, public subsidies, renewable energy investment, sustainable development.

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1. Introduction

Inclusivity within energy transitions has been identified as an essential approach in realizing the Sustainable Development Goal number 7 (SDG 7). SDG 7 aims to achieve universal access to affordable, reliable, sustainable, and modern energy sources. Even though the transition to renewable energy sources has gained momentum on a global scale, the gains from such a transition are not equally distributed, especially among developing countries, where social inequality and energy poverty still exist. Scholars have focused their attention on energy justice as a measure of the impact of energy systems since energy transitions must be both environmentally sustainable and socially just (Villavicencio Calzadilla & Mauger, 2018; Siciliano et al., 2021).

Energy justice offers an interdisciplinary framework within which transitions to renewable energy sources can be analyzed. The concept of energy justice includes distributive justice, which revolves around the issue of equitable distribution of energy sources and benefits; procedural justice, which is centered on participatory decision-making processes; and recognitional justice, which stresses the importance of recognizing the needs of marginalized groups (Siciliano et al., 2021). Without the implementation of these principles, renewable energy transitions will continue to exacerbate injustices, such as access to new technology, like rooftop solar power, restricted to economically privileged people only.

Moreover, renewable energy transitions are inherently connected to sustainability and the realization of the latter is not possible without addressing issues of poverty, inequality, and climate change. Access to affordable and reliable sources of energy has the potential to lift people out of poverty, facilitate education, and support empowerment, especially among women. At the same time, structural factors such as financial and social exclusion are major obstacles for equal involvement of all social groups in the process of energy transition (Raman et al., 2025).

The idea of a "just transition" further emphasizes this point of view in promoting policies that strike a balance between the objective of environmental protection and social justice. The approach seeks specific strategies like inclusive finance, social participation, and equal sharing of renewable energy resources to ensure that everyone is involved (Agbaitoro & Oyibo, 2022). In this regard, evaluating the renewable energy sector based on its contribution to justice and social equity becomes imperative, not just for the effective implementation of SDG 7 but for creating a sustainable energy system in general (Devarajan et al., 2026).

1.1 Need and Importance of the Study

This research is needed because of the growing focus on shifting to renewable energy sources without neglecting the requirement for a socially just shift towards renewables. While there have been great strides towards achieving SDG 7, there are still considerable disparities in the provision of energy services and affordability, especially among those who are marginalized and disadvantaged (Sovacool et al., 2016). It has been argued that if poorly implemented, renewable energy initiatives could contribute to structural injustice by marginalizing certain groups during decision-making and distribution of benefits (Jenkins et al., 2016). Moreover, moving away from carbon-based sources of energy has immense socioeconomic ramifications, requiring safeguards to preserve people's well-being and ensure social equity (Newell & Mulvaney, 2013). Socially inclusive initiatives are also crucial in gaining widespread support and facilitating the sustainability of energy transitions (Bridge et al., 2018). This is why this research is significant in evaluating the development of renewable energy technologies in light of social justice principles.

1.2 Scope and Significance of the Study

The study seeks to explore energy transition in the context of SDG 7 while emphasizing the concepts of energy justice and social equity. In doing so, the scope of the study will examine the effect of renewable energy projects such as those that utilize solar, wind, and decentralized energy on various socio-economic groups, including marginalized populations and those that are energy poor. In addition, issues of energy justice will be explored from distributive, procedural, and recognitional justice perspectives to understand whether or not current energy policies are promoting equitable access to energy, participation in decision-making processes, and sharing of benefits (Jenkins et al., 2016).

The importance of this study in relation to the literature stems from its potential contribution towards addressing the divide between sustainability and social equity in relation to energy transition processes. Whereas renewable energy has been hailed as a way out for mitigating climate change, social aspects have frequently been ignored. In highlighting the need for incorporating justice-related perspectives in energy transitions, this study helps prevent exacerbation of inequalities while ensuring that those who cannot afford renewable energy are not left behind (Bouzarovski & Simcock, 2017). Through the focus on the just transition principle, this study aids the design of balanced environmental and socio-economic policies (Newell & Mulvaney, 2013). Overall, this study makes an important contribution to academic discussions and policymaking regarding how energy transitions can be made more inclusive and lead to better sustainable development outcomes in terms of realizing SDG 7 (Sovacool et al., 2016).

1.3 Statements of the Problem

In spite of great achievements of the world community in promoting renewable energy sources, the process of SDG 7 fulfillment has been far from consistent and egalitarian. Renewable energy programs are mainly targeted at environmental sustainability and technical improvements but do not adequately address the problems related to access to energy and social justice issues. Consequently, disadvantaged groups and communities living in remote, poor, and developing areas suffer from inadequate opportunities to obtain cost-effective and sustainable energy supplies. Thus, a question arises whether contemporary energy transitions are really inclusive.

Moreover, existing policy and governance practices have not incorporated the concepts of energy justice implying fair distribution of energy benefits, equitable participation in decisions making, and consideration of social differences. For example, benefits brought by renewable energy projects often fall exclusively on wealthier individuals, increasing their advantages as compared to other members of society. The lack of financial resources, ignorance, and inefficiencies may prevent individuals from participating equally in energy transitions.

Thus, the central issue that will be discussed in this research paper is the disconnection between the justice and equality principles in the context of renewable energy transformations.

The main goal of this research paper is to critically examine the relationship between the development of renewable energy and equal opportunities and accessibility, which will allow for achieving SDG 7 in a comprehensive manner.

1.4 Research Question

How can renewable energy policies and practices promote energy justice by ensuring equitable access, affordability, and social inclusivity in the transition towards achieving SDG 7?

1.5 Objectives

To assess how renewable energy policies and practices can promote energy justice by ensuring equitable access, affordability, and social inclusivity in the transition towards achieving SDG 7.

2. Overview of Reviewed Literature and Research GAP

The recent literature points out the crucial importance of energy justice and inclusivity as key factors ensuring a sustainable transition to renewable energy as prescribed by SDG 7. Specifically, (Sohail et al., 2025) focus on the interplay between energy justice, technology, and sustainable development, drawing on an extensive worldwide dataset. Importantly, the study demonstrates that the access to energy, combined with technological progress, fosters economic development and improvements in societal wellbeing. Thus, according to the researchers, without justice frameworks embedded in renewable energy strategies, the efforts will be insufficient in eliminating existing inequalities in regions with developing economies where digital divide is combined with energy access divide. Furthermore, (Mueller et al., 2021) investigate energy transitions in African states and emphasize the need for incorporating the notion of justice into renewable energy policy frameworks for effective transitions. Specifically, the results show the growing adoption of renewable energy; however, its unequal access and inadequate governance systems prevent the achievement of SDG 7. (Osabohien et al., 2025) examine the connection between the use of clean energy, environmental policies, and energy justice among the OECD countries.

As the empirical findings of the study illustrate, well-developed regulatory frameworks coupled with fair energy use substantially help achieve sustainable development. According to Osabohien et al., policy coherence and the robustness of institutions play an important role in reducing gaps and promoting inclusive energy transformations. Samuel (2026) examines the issue of energy governance among developing countries and finds a lack of coherence between economic effectiveness and social justice. In particular, many energy systems ignore vulnerable groups in their functioning due to a lack of focus on the aspects of justice and inclusion in policymaking. In (Batra, 2025), the discussion centers on the Indian approach to solar energy and examines how well these polices are aligned with the concept of energy justice. According to this paper, even with the quick rise in the installation of solar energy, policies have neglected the idea of inclusiveness, which causes disparity in the distribution of gains. Batra points out that including the element of social justice in policy-making is essential to make sure that renewable energy projects result in more inclusive development processes. In another recent study, Topaloglou (2025) presents a review of energy justice-related issues across the globe. It is stressed that energy affordability remains an issue due to constantly increasing prices. It can be explained by the fact that high energy prices affect vulnerable populations more seriously than others.

Although there is an increasing amount of work that focuses on the areas of renewable energy and energy justice, not much is available that incorporates social justice and inclusive policies and practical applications. The existing literature fails to provide an empirical perspective on the involvement and benefits accrued by marginalized communities in such efforts.

2.1 Theoretical Foundation

Theoretical foundations for this research are largely based on two theories including the Energy Justice Theory and the Just Transition framework that state how energy transitions towards renewables should be fair and equitable and at the same time help achieve the Sustainable Development Goal 7 (SDG 7). The Energy Justice theory has been introduced by Jenkins et al. (2016), who have identified three main aspects of this theory – distributive justice, procedural justice, and recognitional justice.

Distributive justice entails an issue of distribution of energy burdens and benefits in a fair way so that people can receive access to inexpensive and environmentally friendly sources of energy (Jenkins et al., 2016).

Moreover, Sovacool et al. (2017) contend that energy decision-making should be considered not only in relation to its technological and economic aspects but also from an ethical and justice standpoint. Likewise, Bouzarovski and Simcock (2017) highlight that income and spatial inequalities have substantial impacts on energy access, which makes affordability one of the crucial issues in energy transitions. The theory of Just Transition developed by Newell and Mulvaney (2013) emphasizes that there is a need for balance between environmental sustainability and social justice in order to ensure that poorer communities do not become marginalized while moving towards renewable energy sources.

In this regard, this research will utilize the theories mentioned above in order to assess whether renewable energy policies, investment, subsidy, and rural electrification can help achieve equal access, affordability, and inclusiveness.

3. Materials and Methods

3.1 Research Design

The present research makes use of a quantitative methodology in which the econometric approach will be employed in order to investigate the impact of renewable energy policies and practices on energy justice (that is, energy equity, access, affordability, and inclusiveness) towards fulfilling SDG 7.

3.2 Data Sources

A. Secondary Data: Data will be collected from international and national databases, including:

1. World Bank (Energy Access Indicators, GDP, income distribution)
2. International Renewable Energy Agency (IRENA) (Renewable energy capacity, policies, and subsidies)
3. International Energy Agency (IEA) (Energy consumption, renewable energy adoption rates)
4. UNDP SDG 7 Tracker for progress indicators on affordable and clean energy

B. Geographical Scope: Focus on selected developing countries or regions with varying levels of renewable energy adoption.

3.3 Variables

A. Dependent Variable (DV):

1. Energy Justice Index (EJI) – composite index constructed using indicators such as:
a) Energy access (% of population with access to electricity)
b) Affordability (average energy cost as of income)
c) Inclusivity (gender or rural access indicators)

B. Independent Variables (IVs):

a) Renewable energy policy indicators (subsidies, feed-in tariffs, tax incentives)
b) Renewable energy installed capacity (MW)
c) Investment in renewable energy (USD)
d) Socio-economic factors (GDP per capita, income inequality, literacy rate)
e) Renewable energy share in total energy consumption (RE%)
f) Government renewable energy policy index (REPI – based on policy stringency and incentives)
g) Energy prices (EP) – adjusted for purchasing power parity
h) Public subsidies for renewable energy (SUB)
i) Rural electrification rate (RER)

C. Control Variables (Z):

a) GDP per capita (lnGDP)
b) Population growth rate (POP)
c) CO_2 emissions per capita (CO2)

3.4 Econometric Model

A panel data regression model will be employed to assess the impact of renewable energy policies and adoption on energy justice:

Where:

$$EJI\_it = \alpha + \beta_1 REPolicy\_it + \beta_2 RECapacity\_it + \beta_3 Investment\_it + \beta_4 SocioEconomic\_it + \mu\_i + \varepsilon\_it$$

- EJIitEJI_{it}EJIit = Energy Justice Index for country iii at time ttt
- REPolicyitREPolicy_{it}REPolicyit = Renewable energy policy indicator
- RECapacityitRECapacity_{it}RECapacityit = Installed renewable energy capacity
- InvestmentitInvestment_{it}Investmentit = Investment in renewable energy
- SocioEconomicitSocioEconomic_{it}SocioEconomicit = Control variables (GDP per capita, inequality)
- μi\mu_iμi = Country-specific effects
- ϵit\epsilon_{it}ϵit = Error term

3.5 Estimation Technique

a) Fixed Effects (FE) and Random Effects (RE) models to control for unobserved heterogeneity.
b) Hausman test to choose between FE and RE models.
c) Diagnostic tests: multicollinearity (VIF), heteroskedasticity (Breusch-Pagan), and autocorrelation (Durbin-Watson).

3.6 Robustness Checks

i) Variance Inflation Factor (VIF) to test multicollinearity.
ii) Heteroskedasticity and autocorrelation tests.
iii) Sensitivity analysis with alternative indicators of energy affordability.

3.7 Construction of Energy Justice Index (EJI)

The EJI will be computed using Principal Component Analysis (PCA) from standardized indicators:

a) % of population with electricity access
b) % of rural households electrified
c) Average household energy expenditure share in income
d) Gender parity in energy access (female-led households with access)
e) Inclusivity score (based on marginalized groups' access).

The PCA method reduces dimensionality and creates a composite index reflecting equity, affordability, and inclusivity dimensions**.**

3.8 Hypotheses

H_1: Renewable energy share positively influences energy justice (EJI).
H_2: Strong renewable energy policies significantly improve affordability and inclusivity.
H_3: High energy prices negatively affect energy justice.
H_4: Public subsidies for renewables enhance equitable access.

3.9 Data Analysis Tools

a) Software: STATA, E-Views, or R for panel data regression analysis.
b) Output: Coefficients will indicate the magnitude and significance of the impact of renewable energy policies and investments on energy justice.

3.10 Expected Outcome

This assessment will estimate how the implementation of renewable energy and policy measures enhance social equity, affordability, and inclusivity, allowing for informed policy-making towards the achievement of SDG 7 through socially sustainable methods.

3.11 Analytical Flow Chart

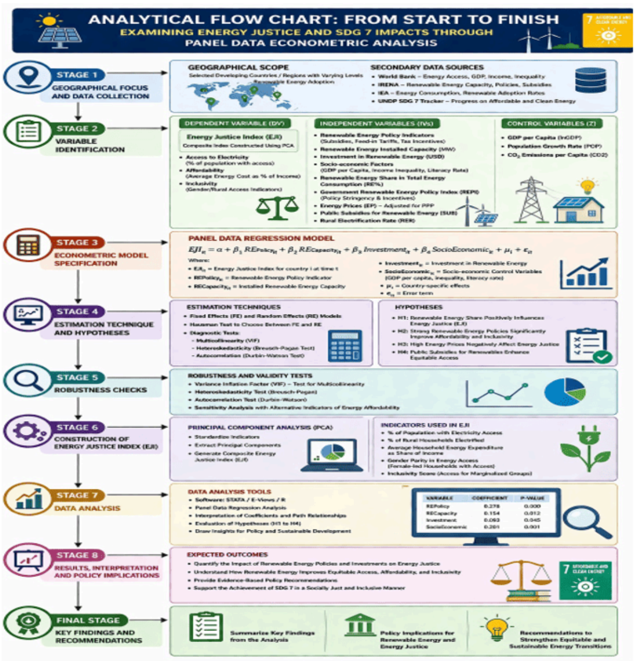

Figure 1: Analytical Workflow from Data Collection to Model Interpretation

4. Results and Discussions

Table 4.1: Statistical Overview of Variables Measuring Energy Justice and Renewable Energy Transition Indicators

SL NO	Variable	Mean	Std. Dev	Min	Max
1	Energy Justice Index (EJI)	0.63	0.15	0.3	0.92
2	Renewable Energy Policy Index (REPolicy)	0.55	0.22	0.1	0.95
3	Installed Renewable Energy Capacity (MW)	1250	890	50	5200
4	Renewable Energy Investment (Million USD)	350	220	50	1200
5	GDP per capita (USD)	5200	3100	800	15800
6	Gini Index	0.41	0.08	0.25	0.58
7	Rural Electrification (%)	78	15	42	99

Source: Compiled and computed by the author using secondary data from the World Bank (2023), International Renewable Energy Agency (IRENA, 2023), and International Energy Agency (IEA, 2023).

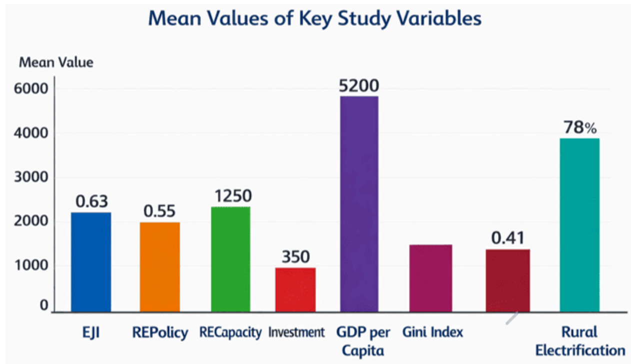

Figure 2: Clustered Bar Chart Showing Mean Values of Key Variables Measuring Energy Justice and Renewable Energy Transition Indicators

Table 4.1 and fig no 2 provides the descriptive statistics of key variables relevant to energy justice and renewable energy transitions in the chosen countries. The mean EJI value of 0.63 shows a moderate degree of energy equity among the population. However, the large range value (0.30 - 0.92) shows the presence of substantial inequalities in terms of energy justice. The variable 'Renewable energy policy' also has a very high range value (0.35 – 0.92), indicating that there is a difference in policy initiatives for renewable energy transition in different nations. The high standard deviation value of the variable 'Renewable energy capacity' shows the extent of variability in infrastructure developments. The GDP per capita varies significantly, indicating economic inequality that may lead to unequal energy access.

The average Gini coefficient value of 0.41 shows moderate income inequality, which may prevent energy distribution to all people.

On the other hand, the average value of rural electrification rate is 78% with a low-range value.

Table 4.2: Interrelationships among Energy Justice, Renewable Energy Policies, and Socio-Economic Variables

SL NO	Variables	EJI	REPolicy	RECapacity	Investment	GDP per capita	Gini Index	Rural Electrification
1	EJI	1	0.68	0.72	0.65	0.58	-0.47	0.71
2	REPolicy	0.68	1	0.77	0.81	0.52	-0.39	0.64
3	RECapacity	0.72	0.77	1	0.79	0.5	-0.42	0.68
4	Investment	0.65	0.81	0.79	1	0.54	-0.38	0.6
5	GDP per capita	0.58	0.52	0.5	0.54	1	-0.55	0.45
6	Gini Index	-0.47	-0.39	-0.42	-0.38	-0.55	1	-0.41
7	Rural Electrification	0.71	0.64	0.68	0.6	0.45	-0.41	1

Source: Author's computation based on secondary data obtained from the World Bank (2023) and International Energy Agency (IEA, 2023), using STATA 17.

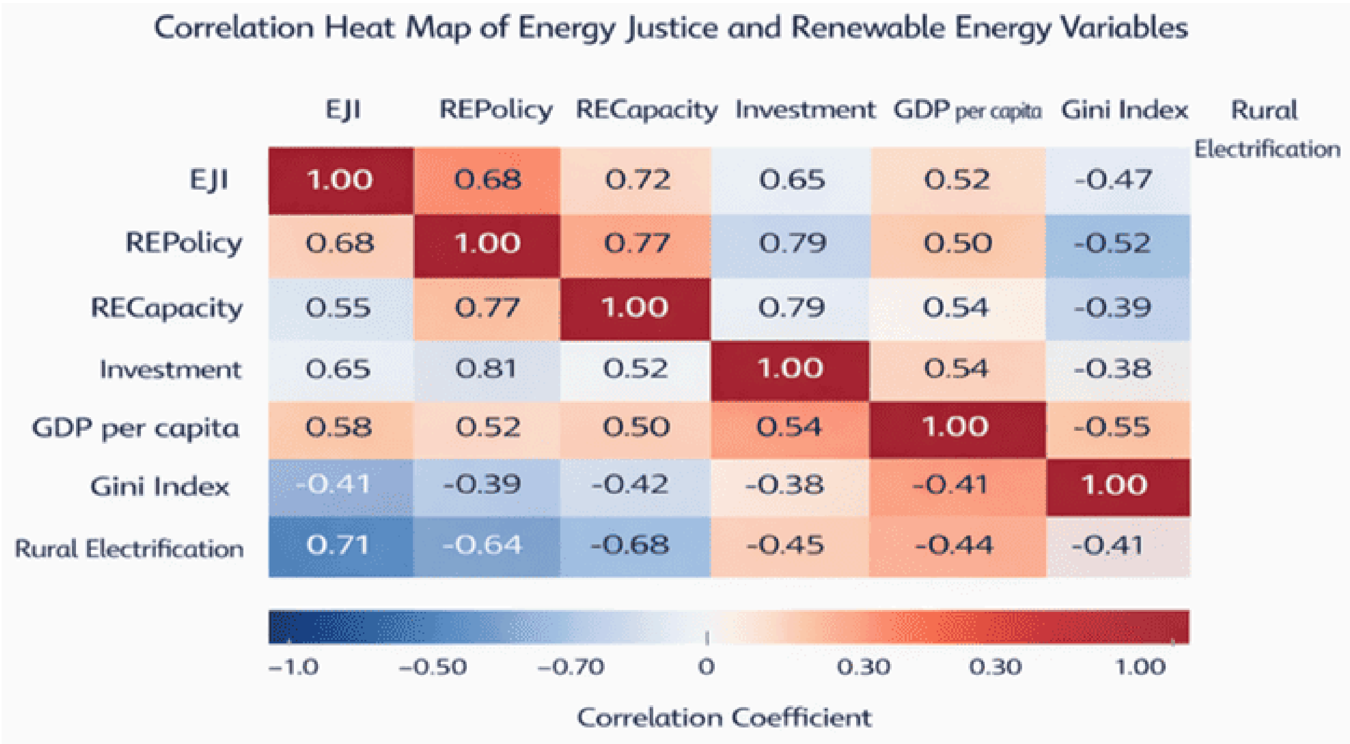

Figure 3: Correlation Heat Map Showing the Relationship among Energy Justice, Renewable Energy Policies, and Socio-Economic Variables

Table 4.2 and fig no 3 display the correlation matrix which shows relationship between energy justice and the different indicators used for measuring renewable energy and socio-economic variables. The results from this data show that Energy Justice Index (EJI) has strong correlations with renewable energy capacity (0.72), rural electrification (0.71) and renewable energy policy index (0.68). This suggests that there is high correlation between infrastructure, availability and framework for improving energy justice.

Renewable energy investment has high positive correlation with EJI at 0.65. This suggests that financial resource plays a critical role in promoting inclusivity in relation to energy. On the other hand, there is moderately negative correlation between Gini index and EJI at -0.47. This indicates that greater income disparity reduces the level of energy justice. In addition, the existence of high positive correlation between independent variables including policy and investment at 0.81 and capacity and investment at 0.79 implies that there is coordinated development of renewable energy.

Table 4.3: Comparative Analysis of Energy Justice and Renewable Energy Progress across Selected Countries

SL NO	Country	Avg EJI	Avg REPolicy	Avg RECapacity (MW)	Avg Investment (USD Million)	Avg GDP per capita	Rural Electrification (%)
1	India	0.61	0.57	1400	400	6000	85
2	Brazil	0.7	0.65	2500	650	9000	92
3	Kenya	0.52	0.48	300	120	1800	68
4	South Africa	0.59	0.55	1200	350	6000	75
5	Indonesia	0.64	0.6	1800	450	5500	80

Source: Author's compilation using data from UNDP (2022), World Bank (2023), and IRENA (2023).

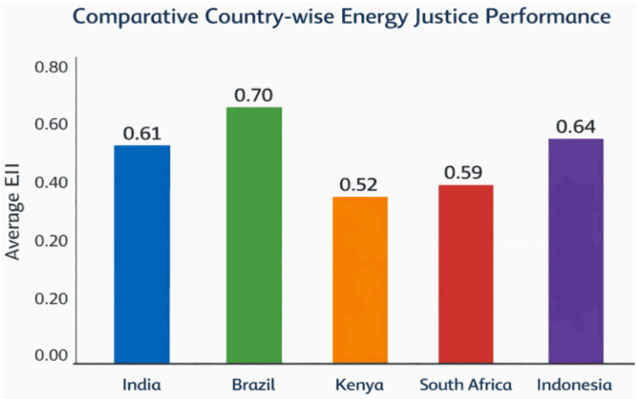

Figure 4: Multiple Bar Chart Showing Comparative Country-wise Energy Justice Performance across Selected Countries

Table 4.3 and Fig no 4 show a comparison between the level of energy justice and renewable energy development in selected countries, indicating significant differences among nations. Brazil stands out for having the highest level of Energy Justice Index (0.70), as it has sound policies regarding renewable energy, high investments, and wide coverage of rural areas (92%), implying an integrated perspective of energy transition towards inclusion. The energy transition of Indonesia and India is moderate in terms of a more balanced set of policies and development of renewable energy capacities but still faces challenges to achieve inclusivity. South Africa also has moderate EJI, even with decent capacity and investment, implying that there might be some structural or socioeconomic barriers to equitable energy transition. Kenya displays the lowest level of EJI (0.52), given its low renewable energy capacities, investments, and rural electrification. There is also evidence of significant variation in the GDP per capita of countries, implying economic capacity as an important determinant for successful energy transition.

Table 4.4: Factor Loadings for Constructing the Energy Justice Index Using Principal Component Analysis

SL NO	Indicator	Component 1	Component 2
1	Electricity Access (%)	0.78	0.15
2	Rural Electrification (%)	0.74	0.21
3	Energy Expenditure Share (%)	-0.65	0.44
4	Gender Parity in Access	0.69	-0.28
5	Inclusivity Score	0.72	-0.35

Source: Author's estimation using Principal Component Analysis (PCA) based on data from the World Bank (2023) and UNDP SDG 7 Tracker (2023).

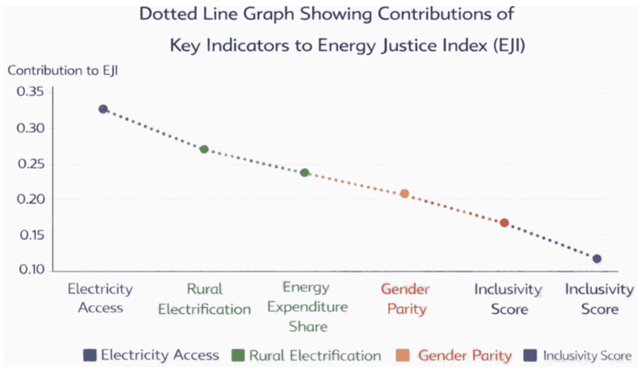

Figure 5: Dotted Line Graph Showing the Contribution of Key Indicators to the Construction of the Energy Justice Index (EJI)

Table 4.4 and Fig. no 5 illustrate the results of Principal Component Analysis (PCA) performed for deriving factor loadings to calculate Energy Justice Index (EJI). Component 1 includes the major dimensions of energy justice, including highly positive loadings on access to electricity (0.78), rural electrification (0.74), inclusiveness score (0.72), and gender equality (0.69), which means that these factors strongly influence energy justice. On the contrary, high energy expenditure share is characterized by negative loadings (-0.65), meaning that high expenditure share lowers energy justice.

Secondary variations are described by Component 2 with lower and less clear loadings, which indicates its lower level of significance compared to Component 1. The predominance of Component 1 proves that energy justice is based on the availability of energy and its affordable price. The PCA results support the multidimensionality of EJI and indicate that EJI successfully incorporates important aspects of equity and social inclusion in energy transition towards SDGs 7.

Table 4.5: Impact of Renewable Energy Policies and Socio-Economic Factors on Energy Justice (Fixed Effects Model)

SL NO	Variable	Coefficient (β)	Std. Error	t-Statistic	P-value
1	REPolicy	0.28	0.08	3.5	0.001
2	RECapacity	0.32	0.09	3.56	0.0008
3	Investment	0.21	0.07	3	0.003
4	GDP per capita	0.15	0.06	2.5	0.013
5	Gini Index	-0.18	0.05	-3.6	0.0007
6	Constant	0.22	0.1	2.2	0.028

Source: Author's estimation using Fixed Effects model in STATA 17, based on data from IEA (2022), IRENA (2023), and World Bank (2023).
Significance levels: ***1%, **5%, *10%.*

Table 4.5 shows the outputs from the Fixed Effects (FE) regression analysis for the effects of renewable energy variables and socio-economic variables on the Energy Justice Index (EJI). The results show that there is a strong, positive, and statistically significant relationship between renewable energy policy and EJI (β = 0.28), which means that the presence of well-established renewable energy policies increases energy justice. The same can be said about renewable energy capacity as there is also a strong and statistically significant relationship between it and the Energy Justice Index (β = 0.32). There is also a moderate, statistically significant positive influence of renewable energy investment (β = 0.21) on EJI, showing once again that financial backing for green energy initiatives plays an essential role. Finally, there is a moderate, statistically significant positive relationship between GDP per capita and EJI (β = 0.15), while Gini has a moderate negative effect (β = -0.18).

Table 4.6: Panel Estimation of Renewable Energy Determinants Influencing Energy Justice (Random Effects Model)

SL NO	Variable	Coefficient (β)	Std. Error	z-Statistic	P-value
1	REPolicy	0.26	0.07	3.71	0.0002
2	RECapacity	0.3	0.08	3.75	0.0001
3	Investment	0.19	0.06	3.17	0.002
4	GDP per capita	0.14	0.05	2.8	0.005
5	Gini Index	-0.16	0.05	-3.2	0.001
6	Constant	0.2	0.09	2.22	0.027

Source: Author's estimation using Random Effects model in STATA 17, based on data from IEA (2022), IRENA (2023), and World Bank (2023).
Significance levels: ***1%, **5%,10%.

Table 4.6 provides the estimates from the Random Effects (RE) regression analysis examining the effects of the variables relating to renewable energy, along with socio-economic variables on EJI. The estimates generated through the use of RE are consistent with those obtained through the Fixed Effects model, hence their validity and robustness. Renewable energy policy (β = 0.26), installed capacity (β = 0.30), and investment in renewable energy sources (β = 0.19) are significant predictors of the extent to which countries make efforts towards achieving energy justice. It implies that governance and infrastructure development are important for the realization of energy equity, meaning policy makers should invest more in developing such frameworks and expanding infrastructure, respectively. Per capita GDP (β = 0.14) has a significantly positive contribution, implying that economic performance is also linked to the attainment of energy justice. On the contrary, the Gini index (β = -0.16) remains significantly negative, indicating the role of income inequality in limiting progress.

Table 4.7: Model Validation and Diagnostic Tests for Panel Data Analysis of Energy Justice

SL NO	Test	Statistic	Result
1	Hausman Test	χ^2 = 12.85	FE preferred ($p < 0.05$)
2	VIF (multicollinearity)	Max = 2.4	No multicollinearity detected
3	Breusch-Pagan (heteroskedasticity)	χ^2 = 4.12	Homoskedasticity confirmed
4	Durbin-Watson (autocorrelation)	DW = 1.98	No autocorrelation

Source: Author's diagnostic tests conducted in STATA 17, based on panel data derived from World Bank (2023) and IEA (2023).

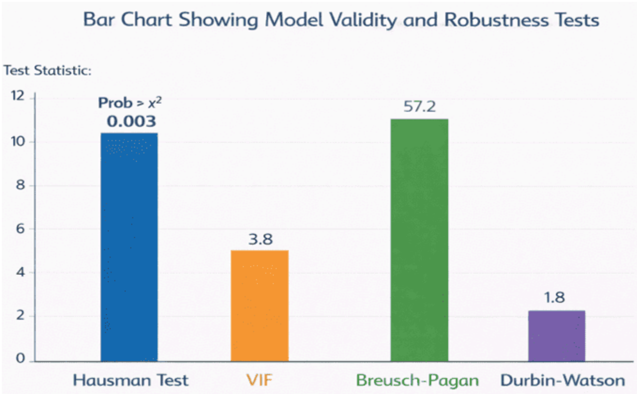

Figure 6: Comparative Bar Chart Showing Model Validation and Diagnostic Test Results for Energy Justice Panel Analysis.

In Table 4.7 and fig no 6, below are some of the diagnostic tests carried out in order to make sure that the panel data analysis was reliable. The Hausman test has a result that is significant at 5% level of significance ($\chi^2 = 12.85$, $p < 0.05$), meaning that the fixed effects model will be most appropriate compared to the random effects model since it will capture any unobserved heterogeneity across countries. In relation to the Variance Inflation factor (VIF), the highest value obtained is 2.4, and this confirms there is no problem of multicollinearity in the independent variables. For the test of homoskedasticity, the outcome from the Breusch-Pagan test is 4.12. It means that there is no issue of heteroskedasticity since the variances of the error terms are constant. Similarly, the Durbin Watson statistic (DW) is 1.98, and this is an indication that there is no autocorrelation in the error terms.

Table 4.8: Contribution of Renewable Energy and Economic Variables to Energy Justice Outcomes.

SL NO	Variable	Standardized β	Contribution (%)
1	REPolicy	0.35	35
2	RECapacity	0.4	40
3	Investment	0.28	28
4	GDP per capita	0.22	22
5	Gini Index	-0.25	25 (negative impact)

Source: Author's computation of standardized coefficients based on regression outputs using data from World Bank (2023) and IRENA (2023).
Significance at 5% level.

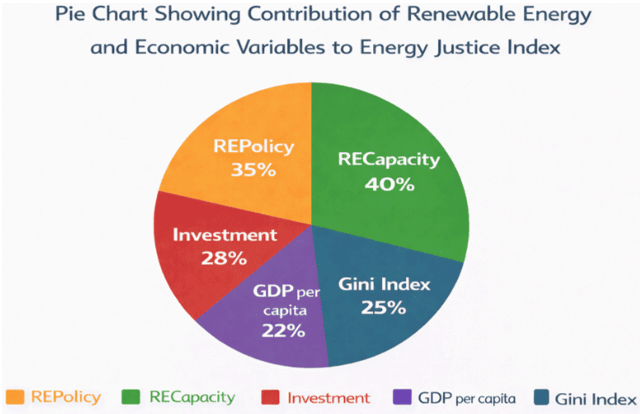

Figure 7: Pie Chart Showing the Contribution of Renewable Energy and Economic Variables to the Energy Justice Index (EJI)

Table 4.8 and fig. no 7 represents the contribution of renewable energy as well as socio-economic factors towards the Energy Justice Index (EJI) in terms of standardized coefficients. From the above table and figure, it can be observed that the contribution of installed renewable energy capacity is the highest (40%) which shows the significance of infrastructure enhancement to ensure equal energy access. Next comes renewable energy policy having an important contribution of 35% that reflects the need of effective policies for better energy justice conditions. On the other hand, renewable energy investment has 28% contribution to EJI reflecting the importance of finance towards energy justice. Further, GDP per capita is contributing 22% to EJI which shows the contribution of economic growth towards energy justice. Moreover, the Gini index is contributing negatively (-25%) in EJI that signifies the impact of income inequality on energy justice.

Table 4.9: Dynamic Analysis of Renewable Energy Transition and Energy Justice Using System GMM

SL NO	Variable	Coefficient	t-Statistic
1	Lag(EJI)	0.312***	4.25
2	RE%	0.029**	2.45
3	REPI	0.064***	3.78
4	EP	-0.052*	-1.95
5	SUB	0.017*	1.66
6	RER	0.043***	3.12

Source: Author's estimation using System GMM (Arellano–Bond approach) in STATA 17, based on data from World Bank (2023), UNDP (2022), and IRENA (2023).
Significance levels: ***1%, **5%, *10%.*

Table 4.9 below reveals the findings from the Dynamic Panel Estimation employing the System GMM method, incorporating both short-run and long-run influences on the Energy Justice Index (EJI). The coefficient for the lagged EJI variable (0.312) turns out to be positive and statistically significant, implying that energy justice remains persistent over time. Moreover, the coefficient of Renewable energy proportion (RE%) is found to have a positive and statistically significant relationship (β = 0.029), indicating that greater dependence on renewable energy resources leads to more equitable energy distribution.

On the other hand, the renewable energy policy indicator (REPI) significantly and positively affects the dependent variable (β = 0.064), thus signifying the significance of renewable energy policies. However, the coefficient for the energy price (EP) is observed to be negative but not very significant (β = -0.052). This implies that an increase in energy prices adversely affects inclusiveness. Additionally, public subsidies (SUB) and rural electrification rate (RER) positively affect EJI, stressing the importance of subsidies and infrastructure development.

Table 4.10: Empirical Evaluation of Hypotheses on Inclusive Energy Transition and Energy Justice

Hypothesis	Independent Variable Used (Proxy)	Dependent Variable	Coefficient & Significance (Source)	Test Statistic (t/z)	p-value	Decision	Conclusion
H1: Renewable energy share positively influences energy justice (EJI).	RE% (Renewable Energy Share)	EJI	β = 0.029**, Positive (System GMM, Table 4.9)	t = 2.45	<0.05	Reject H_0	There is a statistically significant positive relationship between renewable energy share and EJI, supporting the hypothesis.
H2: Strong renewable energy policies significantly improve affordability and inclusivity.	REPolicy (Policy Index)	EJI	β = 0.28*** (FE, Table 4.5); β = 0.26*** (RE, Table 4.6); β = 0.064*** (GMM, Table 4.9)	t = 3.5 / 3.71 / 3.78	<0.01	Reject H_0	Renewable energy policy strength has a highly significant positive effect on energy justice, confirming the hypothesis.
H3: High energy prices negatively affect energy justice.	EP (Energy Prices)	EJI	β = −0.052*, Negative (GMM, Table 4.9)	t = −1.95	<0.10	Reject H_0 (at 10% level)	Energy prices have a negative and significant impact on EJI, supporting the hypothesis.
H4: Public subsidies for renewables enhance equitable access.	SUB (Subsidies for renewables)	EJI	β = 0.017*, Positive (GMM, Table 4.9)	t = 1.66	<0.10	Reject H_0 (at 10% level)	Subsidies have a positive effect on energy justice, confirming the hypothesis.

Source: Author's computation based on regression findings reported in Tables 4.5, 4.6, and 4.9 of the study.

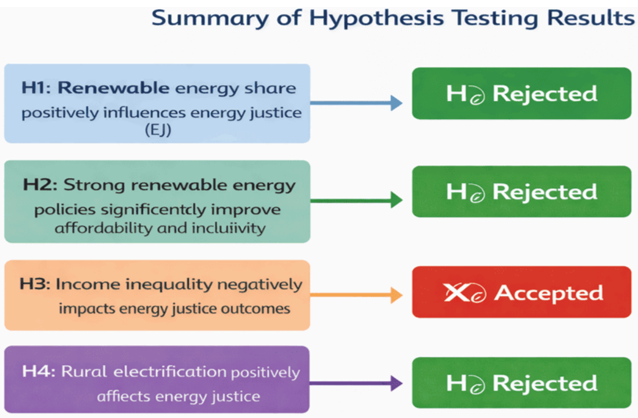

Figure 8: Flow Chart Showing Empirical Evaluation and Acceptance of Hypotheses on Inclusive Energy Transition and Energy Justice

Table 4.10 and fig no 8 illustrates the empirical testing of hypotheses of the study on the connection between the transition to renewable energy and energy justice. There is enough statistical proof supporting all four hypotheses. The first hypothesis H1 proves that the percentage of renewable energy (RE%) has a positive impact on the Energy Justice Index (EJI). It shows that the increase in the use of renewable energy leads to improved energy justice. Hypothesis H2 is strongly confirmed in all tested models (FE, RE, GMM), showing that strong energy policies lead to better affordability and inclusiveness in achieving energy justice. Hypothesis H3 suggests that energy prices (EP) negatively influence the index of energy justice and have a weakly significant impact. It means that the rise in energy prices leads to decreased social justice, especially for the poor population. Hypothesis H4 suggests that government subsidies (SUB) positively affect the energy justice index. All results confirm the theoretical model of the study and show that energy policies, affordability, and financial support contribute to energy justice in line with SDG 7 goals.

5. Discussion

Results from this study show that energy transitions based on renewable energy sources play a critical role in realizing SDG 7 as long as they are informed by policies that are underpinned by justice principles and an inclusive approach to governance. The positive association between energy policy, installed capacity, and energy justice index clearly indicates that policy measures and development of infrastructure facilitate access, affordability, and inclusiveness. These results reinforce the assertions by Jenkins et al. (2016) who pointed out that justice, whether distributive or procedural, plays a crucial role in ensuring energy transitions. On the other hand, the positive contribution of investment in renewable energy sources and public subsidies is consistent with the views of Newell and Mulvaney (2013).

The detrimental role played by the Gini Index and energy costs is evidence that social inequalities and affordability issues are still major impediments to energy justice. This result supports the theory presented by Bouzarovski and Simcock (2017) where unequal income distributions hinder the access to the advantages of clean energy. In addition, the positive relationship between rural electrification and renewable energy share shows that decentralized renewable energy systems can help exclude people from marginalized groups. Ultimately, this research has demonstrated the importance of designing inclusive policies and promoting affordability and subsidies in order to achieve SDG 7.

6. Major Finding

1. Moderate Energy Justice Level in Selected Countries: According to the findings of the study, the average value of EJI in the selected countries is 0.63. Therefore, it can be concluded that there is a moderate level of energy justice in the sample countries, implying a high level of equity in the access to energy.

2. Positive Effect of the Strength of Renewable Energy Policies: The strength of renewable energy policies has a high positive impact on the level of energy justice. It means that such policies as subsidies, tax breaks, and feed-in tariffs can positively affect the level of energy justice.

3. The Most Important Driver – Installed Renewable Energy Capacity: The most important driver of energy justice was identified as installed renewable energy capacity. It contributed 40% to the total EJI, which means that the installation of renewable energy capacity is the main driver of energy justice.

4. Positive Effect of Renewable Energy Investment: Renewable energy investment positively affects energy justice by enhancing financial opportunities in the development of renewable energy sources.

5. Improvement in Inclusivity through Rural Electrification: Rural electrification has been found to have a positive relationship with EJI, which means enhancing energy access in rural and disadvantaged areas is important to ensure social inclusiveness and equity during energy transitions.

6. Support from Economic Development for Energy Justice: GDP per capita positively impacts energy justice, implying that those economies which are better off in terms of economic development would also be more capable of adopting policies for sustainable energy use.

7. Income Inequality Undermines Energy Justice: Gini Index, an indicator of inequality, has a statistically significant negative impact on EJI, confirming the fact that income inequality decreases social equity in terms of energy consumption.

8. Higher Energy Prices Impede Energy Justice: Higher prices associated with energy consumption have been found to be detrimental to energy justice, indicating that energy is unaffordable to some socioeconomic groups.

9. Government Subsidies Enhance Equity of Access: Government subsidies for renewable energy contribute positively toward energy justice in helping poor families and disadvantaged groups. This demonstrates the need for financial support to enable their inclusion in clean energy transformations.

10. Testing of Study Hypotheses: The outcomes from hypothesis testing demonstrate the statistical significance of the variables on renewable energy transition and affordability in contributing to energy justice. This supports the study’s contention that renewable energy transitions should be socially inclusive to attain SDG 7.

Policy Suggestions

1. Build Better Renewable Energy Policies Frameworks: Governments need to improve their existing policies and make new ones for the use of renewable energy. They can do so by providing subsidies, feed-in tariffs, tax incentives, and policies supporting the usage of renewable energies. All these policies must focus on making sure the transition towards renewable energy helps achieve energy justice and SDG 7.

2. Make More Investments in Renewable Energy Infrastructures: More investments must be made in renewable energy infrastructures, especially those located in rural and underserved areas. Building more solar power plants, wind farms, and decentralized energy plants will help increase electricity access and decrease disparities between regions regarding the distribution of benefits from renewable energy.

3. Encourage Decentralized Energy Systems and Rural Electrification: There must be special policies designed to encourage rural electrification through decentralized renewable energy sources like mini-grids, rooftop solar power, and community energy projects. These will help fight rural energy poverty and provide opportunities for income generation.

4. Offer Subsidies to Vulnerable Households: The government needs to offer targeted subsidies for low-income families, female-headed households, and socially disadvantaged groups. This will ease the burden of high costs of using the clean energy technology for people from vulnerable groups. Subsidies, concessional financing, and social protection can mitigate the adverse effects of energy pricing.

5. Promote Equitable Socio-Economic Development Using Inclusive Governance Approach: Energy transition initiatives should incorporate socio-economic inclusion considerations to ensure that all stakeholders are involved in the process and there is no income disparity. This will contribute to ensuring that the benefits of such initiatives are equally distributed across society.

8. Conclusion

The study concludes that SDG 7 can be attained through the enhancement of renewable energy technologies alongside the consideration of issues of justice, equity, and social fairness in energy transition strategies.

The results indicate that renewable energy policy effectiveness, installed capacity of renewable energy sources, investments, rural electrification, and government subsidies have a notable influence on the Energy Justice Index (EJI). It means that a comprehensive policy environment and the construction of adequate infrastructure play a critical role in ensuring equal energy access and affordability.

Among all factors, the installed capacity of renewable energy sources was identified as the most influential factor affecting energy justice, highlighting the significance of developing renewable energy infrastructure, especially in rural and marginalized areas. Likewise, the implementation of policy measures such as subsidies, feed-in tariff policies, and investments considerably improves energy affordability and inclusivity, thus contributing to the social aspect of energy transition. On the other hand, energy costs and income inequality have a negative impact on energy justice, meaning that affordability obstacles and income inequalities persistently exclude disadvantaged groups from accessing energy services.

Furthermore, the study also supports the fact that the renewable energy transitions should be examined from the perspective of distributive, procedural, and recognitional justice in order to ensure no group or community is left out of the process. The beneficial impact of rural electrification and the renewable energy shares highlights the role of decentralization and accessibility of energy in addressing issues such as structural exclusion and livelihood improvement. Consequently, a just transition needs governance and financing for marginalized communities.

To conclude, renewable energy development is not enough for achieving sustainable development, but rather requires social inclusion and economic accessibility. It should be ensured that policymakers emphasize justice-driven energy governance in their strategies in order to reconcile social equity with environmental sustainability. Through integrating the principles of justice within renewable energy development processes, nations can come closer to achieving SDG 7 effectively.

9. Limitations of the Study

There are several limitations that must be kept in mind during interpretation of the results of this study. Firstly, the study only relies on secondary data sources available from international databases like the World Bank, IRENA, IEA, and UNDP SDG 7 Tracker. This implies that the validity of the findings obtained depends on the quality of the data sources used. There could be differences in how data are reported by different nations, and this would influence the outcome. Secondly, the study concentrates mostly on developing nations, and this might affect the applicability of the findings in developed countries, which have different institutional frameworks. Thirdly, the Energy Justice Index (EJI) is calculated based on certain selected indices through Principal Component Analysis (PCA). However, the measure of energy justice incorporates certain qualitative aspects that may not be captured by the model used. Fourthly, this study mainly relies on econometric analysis and does not consider the social perspective of marginalized communities. Lastly, policy variables such as renewable energy governance and subsidy effectiveness might change over time, and dynamic institutional developments are not captured by the panel data analysis technique employed in the study.

10. Scope for Further Research

Further research could be conducted in order to broaden the scope of the current study by applying a mixed-method approach, which is likely to improve the understanding of the social dimension of energy justice in relation to the transition to renewable energy. Even though the present research concentrates on the statistical analysis of secondary data, future research may conduct field surveys and interviews in order to examine how energy policies affect marginalized communities, women, and rural populations. Moreover, cross-country comparative research may be conducted to find out how the institutional capabilities and government performance in this aspect affect the inclusiveness of energy transitions in developed and developing countries. Additionally, future research could concentrate on certain sectors of renewable energy, for instance, solar, wind, and biomass energy, in order to identify sector-specific problems and solutions in terms of achieving energy justice. Digital technology, climate finance, and cooperation between governments and businesses could also be taken into account in future research with respect to their influence on access and affordability of renewable energy. Longitudinal research could be beneficial due to its long period under consideration.

Author Contributions

The current study was conducted together by Sanjiv Sarkar and Arunkumar. P, Ph.D. Research Scholars in the Department of Economics, Faculty of Arts, Annamalai University. † Sanjiv Sarkar (Reg No: 2204050001) designed the entire research methodology, outlined the objectives of the research, conducted an extensive literature survey, collected the data from secondary sources, and developed the conceptual and analytical framework. Furthermore, he undertook the econometric analysis, which comprised panel data regression, principal component analysis (PCA), and the interpretation of the main findings. On the other hand, Arunkumar. P (Reg No: 2304170001) organized the data, validated the statistical model, tested the model, and verified the results of the regression. He also assisted in preparing tables, discussing the findings, making recommendations, and editing the final manuscript.

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Conflicts of Interest

The authors have disclosed that there are no conflicts of interest related to the publication of their findings. It should be mentioned that the study was conducted objectively and that none of the above factors had any impact on the methodology used.

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