Path to Green Prosperity : Evaluating the Interconnected Factors of Industry, Finance, and Energy in Developing Economies

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Abstract

Purpose : The transition to renewable energy is essential for sustainable economic growth and environmental stability, and understanding the role of financial development (FD) in facilitating this shift is critical. This study investigated the impact of FD on renewable energy consumption across 101 economies, with a focus on the role of financial institutions.

Design/Methodology/Approach : The study used a dynamic panel model to investigate the association between renewable energy consumption and FD in 101 economies. The model included these three variables to evaluate the influence of essential factors (market access, market efficiency, and financial institutions) on renewable energy increase.

Findings : The findings revealed a positive correlation between renewable energy consumption in developed nations and FD, while the association was not statistically significant in developing economies. Financial institutions, especially banks, played a crucial role in enhancing renewable energy consumption, with factors such as accessibility, efficiency, and vertical cohesiveness of financial markets significantly influencing renewable energy adoption. The results also highlighted the practical implications of FD on renewable energy uptake, indicating that an approximate 0.01244 increase in renewable energy uptake corresponded to a per unit increase in the financial development index.

Practical Implications : Governments could target establishing renewable energy funds and provide tax incentives to financial institutions to leverage financial institutions for renewable energy harnessing.

Originality/Value : The research contributed to the existing literature by providing a comprehensive analysis of the relationship between FD and renewable energy adoption, emphasizing the crucial role of financial institutions in promoting sustainable energy practices.

Keywords : **dynamic model, renewable energy, financial development, industrialization, greenhouse**

JEL Classification Codes : O16, Q43, Q56

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Population growth significantly impacts human evolution and societal needs. Energy, crucial for societal function and economic growth, has historically relied on fossil fuels like natural gas, oil, and coal. This dependence has caused environmental issues such as ozone depletion, the greenhouse effect, and expanded carbon footprints (Ullah et al., 2022; Xie et al., 2022). Potential fossil fuel shortages could lead to energy deficits, economic instability, increased costs, reduced productivity, and greater reliance on imports. Conversely, energy surpluses can stabilize prices, foster economic growth, and support energy-intensive industries, promoting energy exports and reducing domestic costs, thus enhancing economic stability (Gaur & Bansal, 2010; Goyal & Kumar, 2018; Gupta & Dalal, 2022; Kaushik et al., 2013; Nayak & Barodawala, 2021; Sahoo et al., 2024; Singh & Kaur, 2020). Without a doubt, financial development (FD) is essential to promoting renewable energy. This development is what supplies the necessary resources and tools to soak up renewable energy. Green bonds, with more than $300 billion issued by the end of 2020, are another area of notable growth. These bonds are most commonly used to finance mega transition projects, such as Germany's Energiewende or the scaling of solar capacity in China. Coupled with the promising trend of increasing ESG investments, this trend is set to continue, keeping us informed and knowledgeable about the financial aspects of the renewable energy sector.

Their research is built around conserving energy to save the world. Renewable energy development, however, is geographically flexible. Although it requires massive investment in infrastructure and skilled labor, it eliminates greenhouse gases. Seamless integration of policies governing the energy sectors with finance is critical in establishing sustainable energy frameworks (Xu et al., 2024). Using a sample of 101 observations, this study explores the global response concerning the effect of FD on renewable energy adoption, thereby offering regional and national policy implications. It highlights the economic disparities between industrialized and developing countries, with the hope of dispelling misunderstandings and providing extensive policy suggestions for attaining the realm of green prosperity generated by sustainable practices. Our results, which are supported and illustrated by different pieces of literature, are of significant importance. The previous sources of information have helped inform our investigation and how we interpret our findings.

Literature Review

Environmental Kuznets Curve (EKC): A Theoretical Viewpoint

Grossman and Krueger's (1995) environmental Kuznets curve (EKC) proposed a parabolic relationship between environmental quality and economic growth. As economies develop, environmental degradation increases due to higher resource use, but eventually, it declines with technological advancements and improved practices (Kumar, 2022; Syed et al., 2021). This theory underpins the dynamic interaction between economic growth and environmental sustainability, focusing on how development influences environmental outcomes (Obamuyi, 2012; Saini & Muniyoor, 2022).

Financial Development and Energy Consumption

Financial development impacts energy consumption in several ways. Sadorsky (2011) identified three mechanisms: lower interest rates encourage investment in energy-consuming appliances, accessible financial channels support business expansion and increased production energy needs, and investor sentiment drives higher economic activity and energy use (Kumar & Biswal, 2019). Conversely, Chiu and Lee (2020) argued that businesses might reduce energy consumption to enhance efficiency and cut costs, potentially decreasing energy use.

Empirical Evidence on Economic Growth and Energy Consumption

The link between economic growth and energy consumption varies. Lefatsa et al. (2021) suggested that economic expansion generally increases energy use, while Ahmed et al. (2022), Gómez and Rodríguez (2019), and Ouyang and Li (2018) found that growth might reduce energy use. Kumar et al. (2019) demonstrated that financial openness, stock markets, and financial intermediation significantly affected energy consumption, with their panel smooth regression (PSTR) analysis of 22 countries revealing notable financial impacts.

Financial Development and Adoption of Renewable Energy

In the adoption of renewable energy, FD plays a crucial role. Lahiani et al. (2021), Nguyen et al. (2022), and Topcu and Payne (2017) showed that robust financial institutions facilitate renewable projects through low-interest loans. Kutan et al. (2018) found a positive link between stock market growth and renewable energy consumption, aiding CO2 emission reduction. The FD adds growth to renewable energy by 42.42%, as mentioned by Ji and Zhang (2019), supported by Alsagr and van Hemmen (2021) and Eren et al. (2019) for India and upper-middle-income countries.

Divergent Findings and Regional Variations

Despite a generally positive link, some studies report conflicting results. Assi et al. (2021) and Yi et al. (2023) found limited or no impact in specific regions, while Lei et al. (2022) and Saadaoui (2022) noted temporary negative effects in China and the Middle East, respectively. Conversely, Le et al. (2020) and Raza et al. (2020) also found positive relationships between renewable energy usage and capital development, and banking factors increase renewable energy in rich countries (Saygın & İskenderoğlu, 2022). Such studies raised the number of poorly understood effects economic advancement has on renewable resources adoption; thus, there is space for better research.

Methodology

We employ a dynamic panel model in our study, allowing us to assess the temporal influence of FD on renewable energy utilization. It allows for delayed effects and evolving relationships between variables. Our analysis is twofold, deriving financial growth patterns that affect banking and stock market factors. Compared with previous studies that only examined the linear effects of FD on renewable energy, our new strategy investigates threshold effects. It informs the varying roles of FD in renewable energy development across different populations, wealth, and technology levels.

Method of Data

From pretests on the panel data as a whole, including panel cointegration tests, correlation coefficient examining, and panel unit root, to look for evidence that the data are useable for the dynamic panel model. As the second step, we used more than a decade (2010–2022) of reliable and comparable data from three international financial institutions, central banks, and global databases. Renewables were expressed as kg of oil equivalent per capita. We also consider industrial structure, economic growth, trade liberalization, and overseas investment to control for other variables.

↳ **The Model Specification :** The panel data model was utilized to regress financial deepening on renewable energy consumption in 101 countries. We selected this model to consider both time-series and cross-country heterogeneity in the data and to provide a richer analysis.

↳ **Natural Logarithm Transformation :** The natural logarithm transformation was used for variables like Total Samples (TO) to reduce asymmetry and thereby identify a suitable regression model. So, based on the analysis, the regression equation is as follows (Alsagr & van Hemmen, 2021; Le et al., 2020; Saygın & İskenderoğlu, 2022) :

$$RECRi = \beta 0 + \beta 1 FDi + \beta 2 TOi + \beta 3 ISi + \beta 4 EGi + \beta 5 L.RECi + \epsilon i RECRi = \beta 0 + \beta 1 FDi + \beta 2 TOi + \beta 3 ISi + \beta 4 EGi + \beta 5 L.RECi + \epsilon i \quad \ldots\ldots (1)$$

Where, *RECRi* represents renewable energy consumption per capita in country *i* ; *FDi*, *TOi*, *ISi*, *EGi*, and *L* are the FD, TO, institutional strength, growth of the economic, and lagged consumption of renewable energy variables, respectively.

↳ **Estimation Technique :** We applied the fixed effects estimation method to estimate the coefficients of the regression equation. This technique was chosen to account for unobserved country-specific effects that may influence renewable energy consumption.

↳ **Model Validation :** We conducted various diagnostic tests, including the Breusch–Pagan test for heteroscedasticity, to validate the regression model. The results of these tests indicate that the model is robust and reliable.

↳ **Robustness Checks :** We conducted sensitivity analyses and tested alternative model specifications to ensure the robustness of our results. These additional analyses confirmed the stability of our findings.

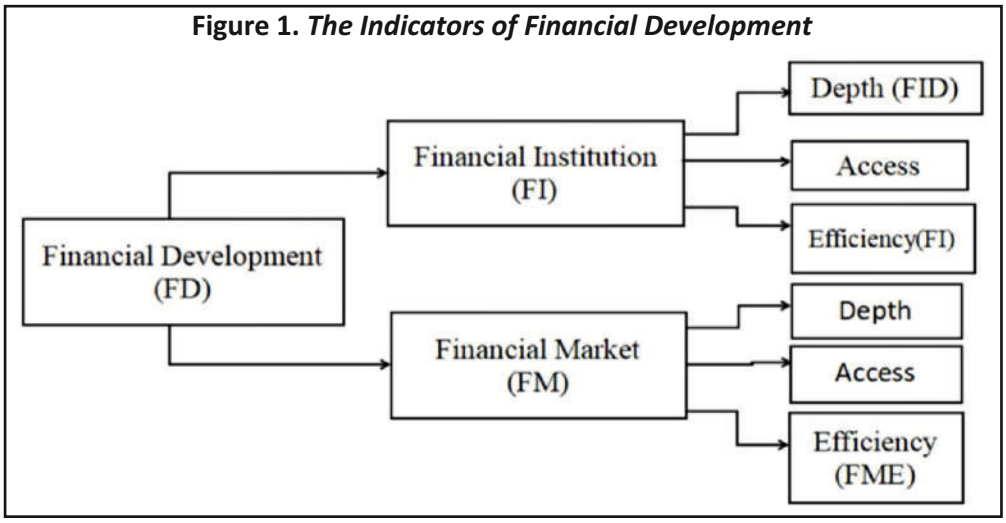
Sources of Data

↳ **Indicators of Financial Development :** We utilize various indicators covering both banking and stock market variables. These indicators are sourced from reputable international financial institutions, central banks, and global economic databases. This approach ensures the reliability and comparability of FD metrics across various countries.

The nine variable indexes are illustrated in Figure 1 and determined through an extensive literature review as well as theoretical and empirical results of renewable energy consumption and FD (Svirydzenka, 2016). Values of these indexes were selected to represent key features of both fields, therefore providing better analysis. This selection process has targeted broadly utilized and excessively acclaimed signifiers that maintain significant perceptions of interaction between the consumption of renewable energy and economic development (Ma & Fu, 2020; Ruza & Caro-Carretero, 2022). The index availability of data in most economies was considered to guarantee analytical feasibility (Choi & Lugovskyy, 2019).

↳ **Renewable Energy Consumption in the Sector :** Data for renewable energy consumption were obtained from reputable sources such as international energy agencies, environmental organizations, and government reports. Comparisons across countries are cross-sections, necessitating similar units of measurement and accounting methods. The per capita amounts of renewable energy usage are measured in kilograms of oil equivalent (Padhan et al., 2020; Shahbaz et al., 2020; Xie et al., 2021). Such methodology is consistent with other empirical research on renewable energy consumption (Saygın & İskenderoğlu, 2022; Svirydzenka, 2016). The observed control

Figure 1. ***The Indicators of Financial Development***



variables in this test were economic growth, trade openness, foreign direct investment (FDI), and industrial structure to take into account other determinants. These indicators include (but are not limited to) the FM index, FIE index, financial institution depth (FID) index, financial market accessibility (FMA) index, FD index, and financial market efficiency (FME) index (Svirydzenka, 2016) to evaluate the performance and accessibility of financial markets (FMs). The others were obtained from the World Development Indicators (WDI) database. We applied log transformation to the dependent variable REC, which may be difficult to interpret while also being known to produce violations of normal distribution and heteroskedasticity.

Analysis and Results

This segment empirically assesses the adoption of renewable energy and its impact on FD. The following section, Preliminary Assessments of the Model, confirms the adequacy of the data through preliminary evaluations of the selected model, with detailed analysis across three tiers of FD presented in the section Primary Effects of Financial Development to Examination of Financial Development at the Third Level.

Preliminary Assessments of the Model

The model estimation data were assessed for adequacy before empirical analysis. Panel cointegration, unit root, and correlation coefficient tests were performed. Panel unit root analysis revealed non-stationary data, and correlation coefficient analysis identified multicollinearity. The panel cointegration test assessed variable cointegration. Tables 1 to 3 summarize these initial tests, which form the basis for subsequent regression analysis.

Table 1. ***Variables' Correlation Matrix***

Variables	*TO*	*FDI*	*EG*	*FD*	*REC*	*IS*
TO	1					
FDI	0.1542	1				
EG	0.0356	0.2967	1			
FDI	–0.0201	0.0598	–0.0098	1		
REC	–0.2954	–0.0143	0.0256	0.1123	1	
IS	0.0293	0.0982	0.1542	0.0356	0.0293	1

Table 2. ***Results of Test of Unit Root***

Items	Fisher	Breitung	HT	IPS	LLC
REC	–8.2680***	–2.4166***	0.6668**	–2.1608**	–2.6442***
	(0.0040)	(0.0068)	(0.0226)	(0.0140)	
IS	–14.0684***	–4.2446***	0.8644***	–2.0446***	–12.4244***
	(0.0000)	(0.0000)	(0.0000)	(0.0011)	(0.0000)
FD	–14.8484***	–2.6618***	0.8082***	–4.6668***	8.2842***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
FDI	–16.2612***	–4.2624***	0.2461***	–12.4126***	–2.8216***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
EG	–18.8042***	–2.8086***	0.2688***	–16.0428***	–18.0460***
	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0000
TO	–12.4660***	–2.4208***	0.8668***	–2.1286***	–6.4101***
	(0.0000)	(0.0002)	(0.0000)	(0.0008)	(0.0000)

Notes. Levin–Lin–Chu (LLC), Harris–Tzavalis (HT), and Im–Pesaran–Shin (IPS) tests were used to improve information quality and consistency. Test results contain *p*-values in brackets. ** and *** correspond to 5% and 1% significance levels, respectively.

Table 3. ***Results of the Cointegration Test***

Approach	Statistics
Westerlund	4.8743*** (0.0000)
Pedroni	5.7312*** (0.0000)
Kao	6.4123*** (0.0000)

Panel unit root testing followed methods by Breitung (2001) and Harris and Tzavalis (1999), while panel cointegration research was guided by Kao (1999), Pedroni (2004), and Westerlund (2005).

Early studies demonstrated that all regression analyses are suitable for empirical research. The correlation matrices' coefficients were always below 0.85, showing no multicollinearity. Unit root testing showed stationary sequences without unit roots for all variables. The variables also showed sustained cointegration in cointegration experiments.

Although early assessments are crucial for data acceptability for model estimates, we focused primarily on them for the initial regression of the complete sample (Table 4). The realization that these assessments essentially evaluate data appropriateness and take time to give helpful research information prompted this choice. On request, more detailed regression results can be provided.

Table 4. ***First Level of Financial Development – Regression Findings***

Items	Developing Economies	Developed Economies	Total Samples
Samples	74	27	101
Hansen Test	68.62 (0.288)	26.48 (0.141)	80.24 (0.201)
AR (1)	–4.20*** (0.000)	–4.21*** (0.000)	–4.18*** (0.000)
AR (2)	–0.12 (0.808)	–0.86 (0.220)	–0.48 (0.444)
FDI	0.01244 (0.16)	–0.04466* (–1.66)	0.01464 (0.42)
TO	0.02688* (1.84)	0.14182** (2.01)	0.02881*** (2.88)
IS	–0.06648 (1.28)	0.42402 (0.88)	–0.06688 (1.41)

EG	0.02022*** (2.42)	–0.00618 (0.18)	0.01624*** (2.22)
FD	0.01486 (0.60)	0.21420*** (2.16)	0.04144*** (4.02)
L.*REC*	0.88146*** (48.66)	0.88121*** (28.04)	0.88468*** (61.48)

Note. Significance levels are denoted by * as 10%, ** as 5%, and *** as 1%.

We introduce L.*REC* as the initial lag component of *REC* alongside the autocorrelation estimators AR(1) and AR(2). Parameter variables include *t*-statistics in brackets, with *p*-values for AR(1), AR(2), and Hansen tests also shown in brackets. Significance levels are denoted by * as 10%, ** as 5%, and *** as 1%, significance levels. Similar notations may be used in subsequent tables.

Primary Effects of Financial Development

Our research work examines how FD impacts renewable energy consumption by distinguishing between developing and developed nations using the FD index. Table 5 presents GMM estimate misspecification test results, which indicate that the three regressions passed the tests. AR(1) exhibits significant first-order autocorrelation, whereas AR(2) does not. Hansen's test results are insignificant, validating the instrumental variable theories. The regression analysis indicates that a 5% increase in renewable energy consumption correlates with a 1% improvement in FD, implying that the expansion of the banking sector fosters greater demand for renewable energy. The mean FD for all nations increased from 0.24 in 1991 to 0.38 in 2014, supporting that FD promotes renewable energy adoption, as evidenced by Alsagr and van Hemmen (2021) and Eren et al. (2019).

Our findings reveal on renewable energy that FD influences differently of affluent versus less-developed nations. In industrialized countries, the FD coefficient indicates a significant positive effect, while in emerging economies, although positive, the FD coefficients were not statistically significant, suggesting a minimal impact on renewable energy use. This complexity reflects the interplay between economic growth and sustainable energy, supported by Assi et al. (2021), Lei et al. (2022), Le et al. (2020), and Mallick et al. (2024). Established economies had a mean FD of 0.60 (up from 0.43 in 1991 to 0.64 in 2014) compared to emerging economies, which increased from 0.17 to 0.28. Analysis of 75 developing nations showed that FD increased renewable energy use in developing countries by 10%, though the impact in emerging markets was not statistically significant

Table 5. ***Findings from the Initial Tier of Financial Development (in Developing Economies)***

Items	Other Developing Economies	Emerging Market
Samples	21	52
Hansen Test	44.82 (0.282)	11.06 (0.242)
AR (1)	–2.68*** (0.000)	–2.61*** (0.008)
AR (2)	0.84 (0.402)	–0.61 (0.444)
FDI	–0.02864 (–0.44)	–0.02112 (–1.26)
TO	0.02842 (1.16)	0.02662* (1.62)
IS	–0.06246 (0.84)	–0.16882* (1.68)
EG	0.02002*** (2.21)	0.04482** (2.04)
FD	–0.10224 (1.08)	0.40808* (1.66)
L.*REC*	0.86084 ***(28.64)	0.86128*** (12.62)

Note. * as 10%, ** as 5%, and *** as 1%, significance levels.

(Pedroni, 2004; Sun et al., 2022). When evaluating the progress of the economy and renewable energy, national differences are essential.

Examination of the Second Tier of Financial Development

Our next step was to examine how various works affect renewable energy use in FD. This review focuses on FM and FI, second-level indexes. The entire dataset and varied subgroups were examined for these impacts. Tables 6 and 7 provide comprehensive regression findings.

The empirical findings reveal that financial institutions (FIs) significantly influence global renewable energy adoption, while FMs have minimal impact. The analysis shows a strong positive correlation for FIs, highlighting their crucial role in renewable energy financing. Conversely, the FM coefficient was statistically insignificant, indicating that FMs do not affect renewable energy consumption. FIs and FMs positively correlate with renewable energy reduction in industrialized nations. However, FIs influence renewable energy in developing countries,

Table 6. ***Outcomes from the Regression Analysis for the Second Tier of Financial Development (FI)***

Items	Developing Economies	Developed Economies	Total Samples
Samples	74	27	101
Hansen Test	68.08 (0.264)	24.08 (0.460)	80.62 (0.122)
AR (1)	–4.24*** (0.000)	–4.18*** (0.000)	–4.08*** (0.000)
AR (2)	–0.26 (0.618)	–0.86 (0.222)	–0.68 (0.424)
FDI	–0.01204 (–0.14)	–0.06441** (–2.04)	–0.01140 (–0.28)
TO	0.01414 (0.60)	0.11812 (1.64)	0.01224 (0.44)
IS	–0.01862 (–1.44)	0.24862 (0.28)	–0.02846* (–1.68)
EG	0.02866*** (2.26)	–0.00410 (–0.14)	0.02066*** (2.68)
FI	0.16811** (2.21)	0.28484*** (2.62)	0.12804*** (2.62)
L.*REC*	0.84284*** (22.64)	0.86881*** (28.08)	0.86128*** (26.41)

Note. * as 10%, ** as 5%, and *** as 1%, significance levels.

Table 7. ***Regression Analysis Focusing on the Secondary Tier of Financial Development (FM)***

Items	Developing Economies	Developed Economies	Total Samples
Samples	74	27	101
Hansen Test	66.80 (0.412)	26.21 (0.148)	81.20 (0.220)
AR (1)	–4.26*** (0.000)	–4.21*** (0.000)	–4.22*** (0.000)
AR (2)	–0.24 (0.626)	–0.86 (0.222)	–0.66 (0.442)
FDI	0.00162 (0.02)	–0.06411** (–1.86)	–0.01668 (–0.64)
TO	0.02068*** (2.61)	0.16201** (2.26)	0.04012*** (4.00)
IS	–0.06428 (–1.10)	0.40648 (0.80)	–0.01628 (–0.62)
EG	0.02266*** (2.60)	–0.01206 (–0.40)	0.01864*** (2.04)
FM	0.01242 (0.64)	0.14444*** (2.01)	0.02880 (1.18)
L.*REC*	0.88222*** (46.12)	0.86428*** (26.82)	0.86608*** (80.44)

Note. * as 10%, ** as 5%, and *** as 1%, significance levels.

while FMs do not. Historically, banks have been pivotal in financing renewable energy due to their extensive economic ties and the high costs associated with renewable projects. Industrialized nations benefit from well-developed stock markets that reduce financing costs and promote energy transitions, while emerging markets often lack efficient stock exchanges, limiting investment in green start-ups. FIs contribute significantly to renewable energy benefits through economic development.

Examination of Financial Development at the Third Level

We thoroughly examined how FD influences renewable energy consumption, scrutinizing six specific third-level indices. Table 8 outlines the outcomes for FIE, FIA, and FID, whereas Table 9 delineates the outcomes for FME, FMD, and FMA. These findings are statistically significant, with *p*-values less than 0.05.

Table 8. ***FIE, FIA, and FID Regression Studies for the Third Tier of Financial Development***

Items	FIE	FIA	FID
Samples	74	27	101
Hansen Test	86.04 (0.202)	82.04 (0.246)	82.64 (0.221)
AR (1)	–4.12*** (0.000)	–4.21*** (0.000)	–4.21*** (0.000)
AR (2)	–0.66 (0.444)	–0.80 (0.426)	–0.68 (0.428)
FDI	0.00860 (0.26)	0.00264 (0.11)	0.00444 (0.16)
TO	0.02866*** (2.64)	0.02286*** (2.61)	0.02612*** (4.01)
IS	–0.04446 (–1.46)	–0.06686 (–1.42)	–0.06860 (–1.44)
EG	0.02021* (1.84)	0.01828*** (2.28)	0.01868*** (2.40)
FIE/FIA/FID	0.16211* (1.81)	0.04846*** (4.60)	0.02668** (2.28)
L.*REC*	0.86614*** (28.28)	0.88281*** (61.06)	0.88426*** (66.64)

Note. * as 10%, ** as 5%, and *** as 1%, significance levels.

Table 9. ***FME, FMA, and FMD Regression Studies for the Third Tier of Financial Development***

Items	FME	FMA	FMD
Samples	74	27	101
Hansen Test	64.28 (0.242)	66.88 (0.161)	81.14 (0.114)
AR (1)	–4.66*** (0.000)	–4.46*** (0.000)	–4.00*** (0.000)
AR (2)	–0.68 (0.428)	–0.62 (0.462)	–0.62 (0.461)
FDI	–0.08624 (–1.41)	–0.01640 (–0.41)	–0.00486 (–0.12)
TO	0.01442 (0.40)	0.02866 (0.61)	0.02686 (0.84)
IS	–0.08208** (–2.28)	–0.08610*** (–2.66)	–0.04288** (–2.08)
EG	0.02222** (2.02)	0.04144*** (2.62)	0.02666** (1.86)
FME/FMA/FMD	0.22822*** (4.28)	0.08482 (1.42)	0.08028 (1.21)
L.*REC*	0.84664*** (24.44)	0.84662*** (18.41)	0.84180*** (18.08)

Note. * as 10%, ** as 5%, and *** as 1%, significance levels.

The study used actual data to examine how institutions' depth, availability, and efficiency influence renewable energy and FMs. Svirydzenka (2016) defined depth as the size of the market and the ease of trading, both of which influence the accessibility of financial services and the efficient utilization of resources. Table 8 shows that increases in financial institution efficiency (FIE), financial institutional availability (FIA), and FID correlate with the consumption of renewable energy by a rise of 0.6%. Table 9 reveals that FME had a significant positive impact, with a 0.8% increase in renewable energy usage per unit rise in FME. These findings highlight the critical role of FIs in advancing renewable energy. Notably, improvements in efficiency have a significant impact, whereas FMs exhibit a relatively minor effect.

Durability and Resilience Tests

Financial Development Indices

Svirydzenka's index technique examined how renewable energy use is affected due to FD (Sun et al., 2022). Domestic credit to the private sector as Gross Domestic Production percentage (FDR1) and the total value of traded shares as Gross Domestic Production percentage (FDR2) were used to validate the empirical results. FDR1 was sampled across 101 economies, consistent with previous regressions. Due to data limitations, FDR2 encompassed only 60 economies. Consequently, regression analyses were conducted on the entire sample and subgroups for FDR1, while FDR2 was analyzed only on the whole sample. The results for FDR1 and FDR2 are presented in Tables 10 and 11, respectively.

FDR1 typically signifies comprehensive financial progress. As shown in Table 10, the positive and significant FDR1 coefficients in regressions for developed and total economies indicate that a unit increase in FDR1 may raise renewable energy use by 1.2%. However, its impact on underdeveloped economies remains to be seen. These findings are consistent with FD regressions. Conversely, Table 11 highlights the insignificance of the FDR2 coefficient, suggesting that a unit increase in FDR2 does not affect renewable energy consumption by 0.5%. FDR2, closely tied to the stock market, reveals negligible economic market influence on regressions, supporting previous evidence that FMs do not impact global renewable energy use. The data limitation, with only 60 economies, affects generalizability, yet the analysis remains insightful within the given context.

Table 10. ***FDR1 Regression Outcome***

Items	Developing Economies	Developed Economies	Total Samples
Samples	74	27	101
Hansen Test	68.68 (0.282)	22.10 (0.186)	81.41 (0.260)
AR (1)	–4.20*** (0.000)	–2.88*** (0.000)	–4.18*** (0.000)
AR (2)	–0.12 (0.806)	–0.86 (0.226)	–0.60 (0.448)
FDI	0.01412 (0.18)	–0.11220** (–2.06)	0.01462 (0.42)
TO	0.02642* (1.64)	0.08204 (0.84)	0.02680** (2.42)
IS	–0.08426 (–1.44)	0.81418 (0.66)	–0.06008 (–1.40)
EG	0.02106*** (2.46)	–0.02224 (–0.60)	0.01684*** (2.28)
FDR1	–0.00216 (–0.24)	0.22214** (2.04)	0.02282*** (2.10)
L.*REC*	0.88688*** (42.46)	0.64648*** (14.66)	0.88486*** (68.84)

Note. * as 10%, ** as 5%, and *** as 1%, significance levels.

Table 11. ***FDR2 Regression Outcome***

Items	Total Samples
Samples	55
Hansen Test	48.82 (0.282)
AR (1)	–4.48*** (0.000)
AR (2)	–0.26 (0.614)
FDI	–0.04108 (–0.88)
TO	0.01486 (0.22)
IS	–0.04622 (–0.14)
EG	–0.01861 (–0.68)
FDR2	0.04662 (1.21)
L.*REC*	0.66184*** (16.26)

Note. *** corresponding to 1% significance levels.

Determinants Impacting the Utilization of Renewable Energy

Empirical studies estimate renewable energy usage per capita. We often use fundamental measures like CO2 emissions per GDP to compare cross-national variables. However, empirical research on renewable energy use utilizing this technique needs to be more extensive. Our scientific study scrutinizes the interrelation between the consumption of renewable energy and FD. RECR, a new indicator, compares GDP to the consumption of renewable energy. With GDP, this number makes comparisons between nations on renewable energy consumption more realistic. We examined the overall influence of FD in our early studies. The sole variation from Table 5's regressions was the dependent variable. Table 12 exhibits informal exam outcomes.

The FD coefficients are statistically significant at 10% and 5% for developed economies and the entire sample, respectively ($p < 0.10$ and $p < 0.05$), while emerging economies show no significant coefficient. Table 4 reveals similarities between GDP and renewable energy use per capita, suggesting both measure economic sizes. Variations in national GDP and renewable energy use over time may lead to undefined RECR, explaining its limited empirical use. The findings show lower means for financial development indices (FDIs), trade openness (TO), and industrialization (IS) in developing economies compared to developed ones. Developed economies

Table 12. ***RECR Regression Outcome***

Items	Developing Economies	Developed Economies	Total Samples
Samples	74	27	101
Hansen Test	44.22 (0.118)	24.88 (0.246)	86.18 (0.282)
AR (1)	–4.10*** (0.000)	–4.11*** (0.000)	–4.06*** (0.000)
AR (2)	–0.12 (0.804)	–0.84 (0.246)	–0.40 (0.618)
FDI	0.01444 (0.12)	–0.08166* (–1.82)	–0.02224 (–0.28)
TO	–0.02082 (–0.04)	0.14021* (1.60)	–0.01260 (–0.21)
IS	–0.02812 (–1.26)	0.40864 (0.68)	–0.02261 (–1.61)
EG	–0.08622*** (–4.21)	–0.08048** (–2.46)	–0.01281*** (–4.88)
FD	–0.24188 (–0.86)	0.21218** (2.16)	0.22060* (1.61)
L.*RECR*	0.84262*** (16.24)	0.82661*** (16.88)	0.82821*** (28.20)

Note. * as 10%, ** as 5%, and *** as 1%, significance levels.

Table 13. ***Effects of Financial Development Indicators on Renewable Energy Adoption in Diverse Economies***

Financial Development Index	Developing Economies	Developed Economies
FIE	0.035	0.021
FMA	0.028	0.019
FMD	0.042	0.029

exhibit higher energy generation (EG) and financial depth (FD), indicating more advanced sectors. The adoption of renewable energy in emerging economies is positively impacted by financial development, particularly through FDI, FD, and economic growth (EG), as shown in Tables 4 through 12. In contrast, developed economies show mixed results in TO, FME, and financial market depth (FMD), underscoring the need for tailored policies.

Table 13 presents the developing and developed economies and the impact of FDI (FIE, FMA, FMD) on the consumption of renewable energy. Higher FIE implies higher financial inclusion, which is linked with higher demand for renewable energy. Financial inclusion policies may have a positive effect on renewable energy ownership. Likewise, stronger FMA, as measured by the further potential in approaching the FM, increases renewable energy consumption, underlining that the role of access to the FM was vital to growing the share of RE. In addition, a high FMD, which is examined for deeper FMs, is likewise associated with greater renewable energy consumption, further indicating that a developed FM level can create an environment through which renewable energy investments are carried. In conclusion, the findings highlight the need for a more supportive and inclusive financial policy where market access and depth can be enhanced to facilitate renewable energy technologies worldwide.

Conclusion

Using the dynamic panel model, we analyze the effect of consumption on RE on financial development across developing and developed economies. The results reveal a positive global relationship, especially in developed economies, in which advanced financial systems are critical in accelerating renewable energy adoption. However, the effect in developing economies may be more significant, particularly as the latter are more susceptible to sharp rises and falls within emerging market capital flows and will need custom-made financial strategies appropriate to regional realities. Differentiated impact analysis is one of the most important novelties of the study to show how financial development affects renewable energy consumption differently in different economic circumstances. Using a dynamic panel model accounts for temporal dynamics and variations, an extension not explored in previous studies. Moreover, analyzing several financial indices gives us more detailed information on their effect on renewables penetration.

Implications

Theoretical Implications

The studies contribute a novel theoretical insight by exploring the role of financial development in renewable energy consumption conditional on different economic circumstances. This global positive correlation, even more so in developed economies, reinforces theories that FMs and institutions are key to sustainable development by providing the means for green investments. FDI, FMA, and FMD positively influence renewable energy consumption in the case of FDI, but the relationship is heterogeneous across the sample of 22 developed and 22

developing economies. The resilient financial systems of developed economies square with theories highlighting the comparative advantage of more profound, advanced FMs in promoting sustainable growth. In light of this, the relatively minor effects on developing economies point to answering theories pertinent to the areas themselves.

Practical Implications

Policymakers and FIs should enhance financial infrastructure to support renewable energy transitions. Promoting financial inclusivity and market accessibility could bolster renewable energy initiatives.

Societal Implications

Financial development aids sustainable development goals (SDGs) by boosting renewable energy investments, creating jobs, reducing carbon emissions, and enhancing energy security, thereby supporting environmental sustainability and economic growth.

Recommendations

To enhance renewable energy adoption, establish funds for low-interest loans or grants, offer tax incentives, issue green bonds, and promote public–private partnerships (PPPs) for supportive investment and collaboration.

Limitations of the Study and Scope for Further Research

The study's focus on 101 economies may limit generalizability. Future research should use broader datasets and consider additional variables like technological advancements and socioeconomic factors.

Authors' Contribution

Arya Kumar conceived the research idea and spearheaded the development of qualitative and quantitative study designs. Mousumi Dash played a pivotal role in extracting and curating high-quality research papers, meticulously filtering them based on relevant keywords and synthesizing key concepts and codes essential to the study's framework. The analytical methods were rigorously verified and overseen by Arya Kumar, Sweta Leena Hota, and Asokan Vasudevan, ensuring the robustness of the study's analytical approach, while Debashisa Mohanty and Anuj Kumar provided critical support in data organization and preliminary analysis. The empirical research, including the numerical computations and application for statistical analysis, was conducted under the guidance of Arya Kumar and Anuj Kumar. Arya Kumar meticulously drafted the manuscript. Each author's contribution was integral to the study, reflecting a collaborative effort to advance knowledge in the field.

Conflict of Interest

The authors affirm that they have no connections or relationships with organizations or entities with a financial or non-financial stake in the subjects or materials discussed in this manuscript.

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