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Nexus Between Digital Finance and Renewable Energy Usage: An Empirical Analysis From Twelve Selected Indian States

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This study conducts an empirical investigation into the relationship between digital finance and renewable energy usage across 12 Indian states, with a focus on both urban and rural areas. By collecting state-wise data from 2008 to 2022 and employing various panel techniques, the research finds that digital finance positively influences the adoption of renewable energy in India, including in rural and urban regions. The study recommends addressing the digital divide to enhance the utilization of renewable energy.

I. Introduction

The study examines the nexus between digital finance and renewable energy usage in India. The importance of the study is threefold. Firstly, the integration of digital finance and renewable energy is crucial for policymakers, particularly in emerging economies like India (Yu et al., 2022). Secondly, as the country transitions towards net zero carbon emissions by 2070, leveraging digital financial tools can significantly enhance the adoption and efficiency of renewable energy sources (Das & Ghosh, 2023). Finally, India, being one of the fastest-growing economies, faces a dual challenge: meeting its energy demands while minimizing environmental impacts. Digital finance, including mobile banking, online payments, green digital finance and blockchain technologies, can play a pivotal role in financing and managing renewable energy projects, furthering sustainable development goals. For instance, Xiao et al. (2024) find that green digital finance is conducive to sustainable development goals through the impact of energy transitions in China.

Theoretically, our study is based on two major theories: Technological Innovation System (TIS) and Sustainable Financial Theory (SFT). TIS theory examines how digital financial technologies (e.g., blockchain, smart contracts) can drive innovation in the renewable energy sector, particularly in areas like decentralized energy trading and peer-to-peer energy markets (Hekkert et al., 2007). Further, SFT focuses on how digital finance can support sustainable development by mobilizing capital for renewable energy projects (Bocken et al., 2014).

There is a plethora of studies that investigate the nexus between digital finance, such as blockchain, mobile/internet banking, digital payment systems, peer-to-peer lending, and crowdfunding platforms, and its impact on investment and innovation in the field of renewable energy (Chen, 2023; Ma, 2023; Mao et al., 2023; Razzaq et al., 2023; Zhao & Zhao, 2023). Further, additional studies focus on digital finance, such as mobile banking and digital payment systems, and its potential to support microfinance institutions by assisting poorer households with access to affordable renewable energy solutions. For example, one company called Solar Electric Light Company (SELCO) India uses digital finance solutions to offer affordable solar home systems through pay-as-you-go (PAYG) models. Through this model, rural households can make small payments by using their mobile app or digital payment method, making solar energy easily accessible despite its high upfront costs (Adwek et al., 2020; Cao, 2023).

However, the research gap in the existing literature is twofold. Firstly, region-wise studies on digital finance and renewable energy usage are rare in the existing literature. Secondly, the study will shed light on the role of digital finance in overcoming financial and infrastructural barriers to renewable energy adoption in different regions. Additionally, it will explore how digital platforms can facilitate decentralized energy systems and empower local communities.

The current study contributes to the existing literature in the following ways. First, the study focuses on region-wise studies on digital finance and renewable energy usage. Thus, it helps policymakers of chosen states to develop

Table 1. Number of States and Description of Variables

States Name	Variables Name	Indicators	Data Sources
Haryana	Response Variable		
Himachal Pradesh	Renewable Energy (RE)	Total renewable energy generation (Million kWh)	CMIE States of India
Punjab	Explanatory Variable		
Rajasthan	Digital Finance (DF)	Interaction of mobile phone and credit-deposit ratio	CMIE States of India
Assam	Control Variables		
Odisha	Capital Inflow	Total Capital Received	CMIE States of India
West Bengal	Human Capital	Literacy Rate	CMIE States of India
Karnataka	Economic Development	Per Capita GDP	CMIE States of India
Kerala			
Tamil Nadu			
Gujarat			
Maharashtra			

This table presents the details of the states and variables under consideration. The analysis incorporates data from twelve states. Additionally, five key variables are considered: renewable energy, digital finance, capital inflow, human capital, and economic development. The data is sourced from the CMIE States of India database.

policies for incentives to boost renewable energy use. Finally, this study contributes to the existing body of knowledge by addressing the unexplored intersection of digital finance and renewable energy in India. It offers valuable insights for policymakers, investors, and academics interested in fostering sustainable development through innovative financial mechanisms.

The next section presents discussion on data and methodology. Major findings are discussed in the third section. Finally, the study provides concluding remarks in the fourth section.

II. Data and Methodology

The data presented here are sourced from the Centre for Monitoring Indian Economy (CMIE) states of India. During the collection of state-wise data from CMIE, it was noted that information on mobile phones was available for only 12 Indian states. Consequently, this study employs data from these 12 states, covering the period from 2008 to 2022, for empirical analysis.

Next, we outline the methodology employed in the study. Three panel econometric models are utilised. Model 1 encompasses the complete sample, which includes both rural and urban renewable energy usage alongside digital finance. Model 2 is focused on the interplay between renewable energy usage and digital finance within urban areas, whereas Model 3 examines these variables within rural areas. The specifications of the models are as follows:

Model 1

$$RE_{it} = \alpha + \beta_1 DF_{it} + \delta_i Z_{it} + \varepsilon_{it} \quad (1)$$

Model 2

$$RE_{it} = \alpha + \beta_1 DF_{UR_{it}} + \delta_i Z_{it} + \varepsilon_{it} \quad (2)$$

Model 3

$$RE_{it} = \alpha + \beta_1 DF_{RU_{it}} + \delta_i Z_{it} + \varepsilon_{it} \quad (3)$$

In above equations, RE_{it} refers to renewable energy and is used as the dependent variable across the three models.

On the independent variable side, three different variables are introduced. In Equation (1), DF_{it} represents digital finance and is used as an independent variable denoting total states-wise digital finance. In Equation (2), $DF_{UR_{it}}$ signifies digital finance urban, and in Equation (3), $DF_{RU_{it}}$ symbolizes digital finance rural. i represents i^{th} states and t is used to represent the period. The variable Z_{it} refers to the vector of three control variables, namely human capital proxied by literacy rate, total capital inflow proxied by total capital receipt (TCR), and economic development proxied by per capita state gross domestic product (PCSGDP), for each state at period t . All control variables are well supported by the existing literature.

III. Major Findings

All the panel regression results are presented in Tables 2, 3, and 4. Table 2 displays the regression results for the full sample. Table 3 presents the regression results for urban areas, while Table 4 provides the regression results for rural areas. The main findings indicate that digital finance has a positive and significant impact on the use of renewable energy across all three sampled areas (full sample, urban areas, and rural areas) in Indian states. Moreover, it can be inferred that the growth in digital payment technologies has contributed to the increased adoption of renewable energy across the 12 selected states and urban-rural regions of India.

Table 2 demonstrates that, for the full sample, the positive impact of digital finance on renewable energy remains consistent across all four model specifications. However, in Tables 3 and 4, which pertain to urban and rural areas respectively, the initial two models (FE and RE) indicated a negative effect. After addressing autocorrelation and heteroscedasticity issues, a positive effect of digital finance on renewable energy usage was observed. Consequently, according to the superior model results, it is evident that dig-

Table 2. Impact of digital finance on renewable energy use- full sample

Variables	FE Model 1	RE Model 2	PCSEs Model 3	FGLS Model 4
Constant	-34064.72 * (0.002)	-24303.84 * (0.009)	-2340.473 (0.455)	-2340.473 (0.617)
DF_T	67.28048** (0.042)	80.40735* (0.004)	107.0865* (0.000)	107.0865* (0.000)
TCR	0.0085245 * (0.00)	80.40735* (0.000)	0.0092427* (0.000)	0.0092427* (0.000)
LIT	382.5843* (0.005)	239.1546** (0.038)	-83.24456*** (0.064)	-83.24456 (0.159)
PCSGDP	0.0043657 (0.582)	0.0102186 (0.168)	0.0272853 * (0.000)	0.0272853* (0.000)
Observation	180	180	180	180
R-square	0.3707	0.4707	0.5647	
F-statistics	41.10			
Prob. (F-statistics)	0.000			
Wald chi2		170.89	347.61	233.49
Prob > chi2		0.000	0.000	0.000
No. of states	12	12	12	12

This table presents the results of four panel econometric models. The findings indicate that *DF* positively influences *RE* usage across the models. Additionally, *TCR* and *PCSGDP* have a positive impact. Conversely, *LIT* negatively affects *RE* usage, as only primary education is considered for literacy. Probability values are provided in parentheses. Finally, *, **, *** denote statistical significance at 1%, 5%, and 10% levels, respectively.

Table 3. Impact of Digital Finance on Renewable Energy: For Urban India

Variables	FE Model 1	RE Model 2	PCSEs Model 3	FGLS Model 4
Constant	-23673.95** (0.027)	-13885.15 (0.131)	6968.329** (0.026)	6968.329 (0.145)
DF_UR	-12.47681 (0.283)	-9.296575 (0.409)	31.33209* (0.000)	31.33209* (0.004)
TCR	0.0076359* (0.000)	0.0084722* (0.000)	0.0134813* (0.000)	0.0134813* (0.000)
LIT	327.3311** (0.019)	192.6706 (0.106)	-143.4837* (0.002)	-143.4837** (0.024)
PCSGDP	0.0013405 (0.869)	0.006935 (0.372)	0.0306364* (0.000)	0.0306364* (0.000)
Observation	180	180	180	180
R-square	0.224	0.321	0.484	
F-statistics	39.61			
Prob. (F-statistics)	0.000			
Wald chi2		157.60	222.51	169.18
Prob > chi2		0.000	0.000	0.000
No. of states	12	12	12	12

This table presents the econometric results of *DF* and *RE* in urban India. The analysis shows that *DF* has a positive impact on *RE*. Similarly, *TCR* and *PCSGDP* also have positive impacts across four models. However, *LIT* has a negative impact on *RE*. Probability values are provided in parenthesis. Additionally, *, **, *** denote 1%, 5%, and 10% levels of significance, respectively.

ital finance has become a significant element of the Indian economy, especially in promoting renewable energy projects. The positive influence of digital finance on renewable energy in these three sample areas can be attributed to the pioneering roles played by both the central and various state governments over the years.

The results of the three control variables, in addition to the main variable (digital finance), produce consistent out-

comes across the three regression models. The first control variable (total capital receipt) is found to have a positive and significant impact on renewable energy across the three regression models. Total capital receipts, through various forms including loans, disinvestment proceeds, grants, and asset sales, contribute to promoting renewable energy. The second control variable (literacy) yields unexpected results across the three models (see Tables 2, 3, and

Table 4. Impact of Digital Finance on Renewable Energy: For Rural India

Variables	FE Model 1	RE Model 2	PCSEs Model 3	FGLS Model 4
Constant	-21930.05** (0.040)	-12398.81 (0.174)	7826.823* (0.009)	7826.823*** (0.096)
<i>DF_RU</i>	-13.58169 (0.108)	-11.05154 (0.175)	25.89989* (0.000)	7826.823* (0.001)
<i>TCR</i>	0.0072726* (0.000)	0.0081332* (0.000)	0.0144836* (0.000)	0.0144836* (0.000)
<i>LIT</i>	314.6635 ** (0.023)	182.284 (0.122)	-163.31* (0.000)	-163.31** (0.010)
<i>PCSGDP</i>	-0.0005123 (0.950)	0.0053386 (0.499)	0.0312762* (0.000)	0.0312762* (0.000)
Observation	180	180	180	180
R-square	0.2217	0.3152	0.4905	
F-statistics	40.32			
Prob. (F-statistics)	0.000			
Wald chi2		159.42	228.95	173.29
Prob > chi2		0.000	0.000	0.000
No. of states	12	12	12	12

Table 4 presents the empirical findings of *DF* and *RE* in rural India. The study observes that *DF* positively affects *RE*. Likewise, *TCR* and *PCSGDP* also show positive impacts with minor variations. Conversely, *LIT* negatively affects *RE* with minor variations. Probability values are listed in parentheses. Finally, *, **, *** denote significance levels of 1%, 5%, and 10%, respectively.

4). Across the four model specifications in these three regression models, literacy consistently shows negative results. This could be due to the unavailability of secondary or tertiary level education data, leading to basic literacy being used as a proxy for human capital. Lastly, the third control variable (*PCSGDP*) shows a positive effect across the three regression models. This indicates that as incomes rise, individuals' acceptance of renewable energy sources increases. The findings on *PCSGDP* align with expectations, as the relationship between rising income and the usage of renewable energy is straightforward. As individual income increases, the capacity to afford renewable energy also increases.

IV. Conclusion

This study aims to empirically examine the impact of digital finance on renewable energy usage in 12 selected Indian states. In addition to the overall state-level analysis, the study also investigates this objective within urban and

rural contexts. The empirical findings indicate that digital finance contributes to the increase in renewable energy usage across the sample states and in both urban and rural areas. The study shows that in all three regression models (full sample, urban, and rural areas), digital finance is associated with renewable energy usage. Moreover, the results for the control variables demonstrate that total capital receipt and per capita state *GDP* positively influence renewable energy usage, while the basic literacy rate negatively affects it among the selected Indian states.

Based on these empirical results, the study suggests that to promote renewable energy and achieve net-zero carbon emissions in the future, Indian states should address the existing digital divide. By tackling these challenges, India can use digital finance to meet its renewable energy targets and build a sustainable and inclusive energy future.

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