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Bridging the Rural-Urban Gaps in Electricity Access: The Effectiveness of the SAUBHAGYA Scheme in India

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Abstract

Access to reliable energy is an important prerequisite for the development of a nation. The energy ladder and stacking hypotheses recognize the crucial role of households' access to cleaner and more convenient energy sources for inclusive and sustainable development. Accordingly, the Government of India and other state governments have taken several steps towards universal electrification in the country. However, a part of the rural households in different parts of the country still lack access to reliable electricity, revealing a rural-urban gap in this regard. Given these backdrops, the present study explores the factors influencing households' electricity access in major Indian states. The study uses data on 224,712 sample households compiled from the 5th round of the National Family Health Survey (NFHS) and estimates binary logit model. The results indicate that socio-economic conditions such as place of residence, wealth status, and caste category of the household along with age, gender, and literacy level of the family head have significant influence on electricity access. The findings emphasize the importance of necessary interventions in order to overcome the rural-urban gaps in electricity access. In this connection, the decrease in rural-urban gaps in electricity access as revealed in the NFHS data of the last two rounds indicates the effectiveness of the SAUBHAGYA scheme. The findings also provide useful insights for different stakeholders and policymakers in designing other supporting strategies to bridge the rural-urban gaps in electricity access and facilitating inclusive development.

Keywords: Electricity Access, National Family Health Survey, Rural-Urban Gaps, SAUBHAGYA, India

1. Introduction

Increasing demand for energy to drive diverse activities poses a significant challenge to its overall supply globally, as the conventional sources are not only restricted and limited, but also cause significant environmental degradation. Further, rising energy requirements along with their limited availability necessitates exploration of the alternative options (Eras et al., 2019). Additionally, the Sustainable Development Goal 7 (SDG 7) of the United Nations aims at achieving universal access to affordable, dependable, sustainable, and modern energy sources (Lin & Kaewkhunok, 2021). In this connection, adoption of renewable energy sources aligns with targets set in the SDGs and helps in increasing energy access on sustained basis. Moreover, access to reliable energy is prerequisite for boosting productivity and fostering socio-economic development (Zhang et al., 2019; Mehmood et al., 2022). In this Context, the role of electricity access in sustaining long-term economic growth is well-documented (Tang & Tan, 2013; Nepal & Paija, 2019), highlighting improvement in electricity access as a key priority for the global policy agenda (Murshed & Ozturk, 2023).

However, evidences indicate disparities between rural and urban areas regarding both quality and availability of electricity, particularly in developing countries (Yadoo et al., 2011). Urban areas with concentrated economic activity tend to enjoy a consistent electricity supply along with well-developed infrastructure and greater investment from both the private and public sectors (Tripathi, 2017). Further, higher population density in urban areas reduces the per capita cost of infrastructure development, making it more economically viable for governments and service providers to invest in energy grids and regular upgradation of the infrastructure (Cattaneo et al., 2022). In contrast, the rural counterpart manifests numerous barriers and challenges to electricity access. Geographic isolation, lower population densities, and inadequate infrastructure significantly raise the cost of extending national grids to these regions, making universal electricity access difficult (Yadoo et al., 2011; IEA, 2017; Hossain, 2018). Further, many remote villages in India experience regular power outages lasting for long (Sharma et al., 2019). Therefore, rural communities are forced to rely on locally available energy sources like firewood, cow dung, crop waste, and kerosene (Masukujjaman et al., 2021).

In this context, the study aims to address these concerns by examining the status of electricity access, identifying the underlying factors, and exploring the impact of **SAUBHAGYA** to bridge the rural-urban gaps in Indian states. The paper has been structured into five interconnected sections. The first section gives the background, problem statement, and key the research objectives, highlighting the importance of electricity access and the rural-urban electricity gaps in the Indian context. The second section presents the critical insights from the literature on factors influencing households' electricity access. The source of data used and the tools and techniques applied are discussed in the third section. This section also includes the geographical location of the study area, selection of the sample states, and the variables considered. The findings are presented and discussed in the fourth section. The last paper summarizes the key findings, limitations, and recommendations of the study.

2. Review of Literature

2.1 Determinants of Electricity Access in Rural Areas

Rural electricity access is often limited due to geographical remoteness, inadequate infrastructure, and socio-economic challenges. Key barriers include distribution losses, low-income levels, high dependency burdens, and dispersed populations, which collectively hinder grid expansion (Poloamina & Umoh, 2023). Female-headed households have greater motivation to adopt cleaner energies, as women typically face higher exposure to indoor air pollution and play important roles in household energy decisions (Rahut et al., 2016; Awan et al., 2024). In addition, higher levels of education and wealth significantly improve access to reliable electricity (Yadav et al., 2021; Jin et al., 2023). Further, political support and targeted infrastructure investment are crucial for reducing rural energy poverty (Ogunro & Afolabi, 2022). However, financial constraints and weak regulatory systems continue to delay electrification (Babalola et al., 2022). The influence of land ownership and household head age on clean energy adoption remains mixed across studies; some studies show positive correlations and others show negative or inconclusive results (Pandey & Chaubal, 2011; Rahut et al., 2016; Rahut et al., 2017; Awan et al., 2024) in this regard. Additionally, geographical constraints such as hilly terrains, dense forests, and deserts increase the financial and technical challenges of grid expansion, leading rural households to rely on traditional energy sources (IEA, 2017; Bensch et al., 2017). In this context, decentralized renewable energy solutions like off-grid solar systems offer cost-effective and scalable alternatives to traditional electrification (Sovacool, 2019).

2.2 Determinants of Electricity Access in Urban Areas

Conversely, urban and peri-urban areas have better electricity access due to closeness to existing infrastructure. Concentration of economic activities in urban centres often attracts more significant investments in energy infrastructure, contributing to improved household access (Dinkelman, 2011; Angelou et al., 2019). However, significant disparities are seen within urban regions, particularly among marginalised groups such as the urban poor and residents of informal settlements, who often experience unreliable supply or face affordability issues (Kojima & Trimble, 2016; Lewis et al., 2017). Moreover, geographical and informal settlements in urban areas can lead to exclusion from formal electrification programmes. In addition, socio-economic inequalities intersect with spatial marginalization, further exacerbating gaps in electricity access. While urban households are likely to have greater access to various national policies and interventions, addressing these intra-urban disparities remains critical to ensuring inclusive and equitable energy access for all.

While several studies have explored the determinants of electricity access in both rural and urban settings, notable research gaps remain. There is limited evidence on how government interventions have influenced the decrease in the rural-urban electricity access gaps across Indian states. Moreover, few studies integrate socio-economic factors with program-specific evaluations, especially at the household level. In addition, regional disparities remain underexplored, and there is a lack of holistic analyses to assess the long-term effectiveness of electrification schemes.

3. Methods

3.1 Overview of the Study Area

Figure 1 illustrates the geographical location of the selected states in this study. The study focuses on ten selected Indian states having the highest rural-urban gaps in electricity access, as identified in the latest round of the National Family Health Survey (NFHS-5).

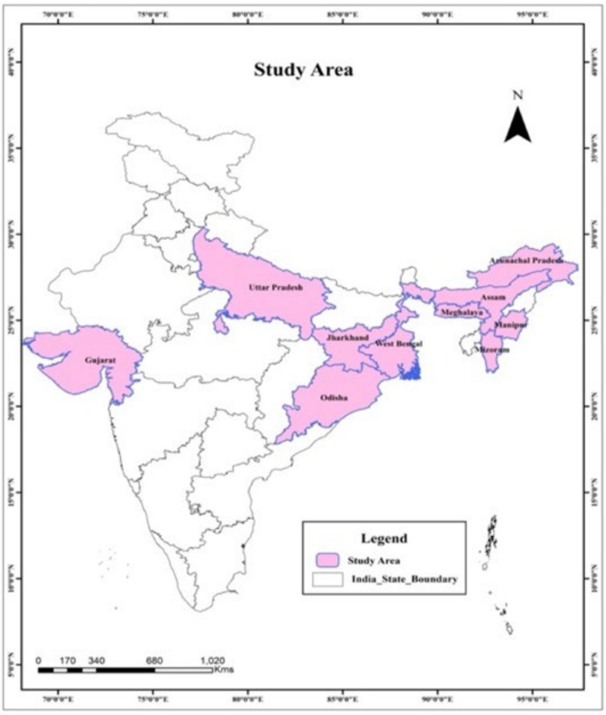

Figure 1: Location map of the study area
Source: Created by author using ArcMap 10.8

The states included in this study are Uttar Pradesh, Jharkhand, Assam, Meghalaya, Arunachal Pradesh, West Bengal, Gujarat, Mizoram, Manipur, and Odisha. This selection is based on the ranks in rural-urban electricity access gaps. For example, Uttar Pradesh shows the highest gap (9.17 percent), whereas Odisha stands at the tenth position with a gap of 2.88 percent (Table 1). Besides, these states also represent diverse geographical and demographic settings, ranging from the populous heartland of Northern India to the remote and hilly terrains of the Northeast, each with unique socio-economic and infrastructural challenges. The significant gaps in electricity access highlight the inequalities in energy distribution despite high electrification intensity at the aggregate level. Thus, the selected states would provide a comprehensive understanding of the factors contributing to the disparities in electricity access and the role of the SAUBHAGYA scheme in bridging the rural-urban gaps in this regard.

Table 1: State-wise rural-urban electricity access in India, 2019-21

State	NFHS (5th Round)			Gap (%)	Rank
	Total (%)	Urban (%)	Rural (%)		
Uttar Pradesh	89.77	97.11	87.94	9.17	1
Jharkhand	92.87	98.79	91.50	7.29	2
Assam	92.95	98.75	92.06	6.68	3
Meghalaya	90.96	96.12	90.28	5.84	4
Arunachal Pradesh	94.83	99.41	93.66	5.75	5
West Bengal	96.54	99.17	95.42	3.76	6
Gujarat	96.82	99.23	95.71	3.52	7
Mizoram	97.46	99.45	96.00	3.45	8
Manipur	96.24	98.75	95.39	3.37	9
Odisha	96.12	98.60	95.72	2.88	10
Maharashtra	96.93	98.81	96.02	2.79	11
Rajasthan	97.66	99.53	97.14	2.39	12
Chhattisgarh	97.60	99.29	97.21	2.08	13
Tripura	97.42	99.06	97.03	2.03	14
Madhya Pradesh	98.00	99.26	97.67	1.59	15
Nagaland	98.52	99.55	98.19	1.35	16
Kerala	99.32	99.86	98.94	0.92	17
Tamil Nadu	98.89	99.27	98.60	0.67	18
Karnataka	98.83	99.26	98.65	0.61	19
Telangana	99.24	99.65	99.09	0.56	20
Bihar	95.96	96.38	95.92	0.47	21
Andhra Pradesh	99.17	99.47	99.06	0.41	22
Uttaranchal	99.38	99.70	99.30	0.41	23
Haryana	99.50	99.76	99.38	0.37	24
Sikkim	99.20	99.50	99.14	0.36	25
Punjab	99.59	99.64	99.56	0.08	26
Goa	100.00	100.00	100.00	0.00	27
Himachal Pradesh	99.34	98.80	99.39	-0.59	28

Source: Calculated using 5th round of the National Family Health Survey.

3.2 Database

The present study utilizes secondary data from the NFHS, a nationally representative dataset widely employed for analyzing health, demographic, and developmental indicators in India. Since its launch in 1992, the NFHS has conducted five rounds of surveys. All the rounds of the survey were conducted by the 'International Institute for Population Sciences' (IIPS), with the technical assistance from the 'United States Agency for International Development' (USAID) under the 'Ministry of Health and Family Welfare' (MoHFW), Government of India. The present paper focuses on ten selected states with high rural-urban gaps in electricity access using unit-level data from the 5th round of the NFHS. The dataset includes 1,77,672 rural households and 47,040 urban households, ensuring a large and balanced sample that enhances the robustness of the findings.

3.4 Variables Consider

The dependent variable of the study is binary, coded as 1 if the household has electricity access and 0 otherwise. The independent variables include both socio-demographic and spatial factors. These comprise the place of residence (urban = 1, rural = 0) (Onyeji et al., 2012; Awan et al., 2024), gender of the household head coded as female = 1, male = 0 (Rahut et al., 2016; Awan et al., 2024), and age of the household head used in natural logarithmic scale (Rahut et al., 2017; Awan et al., 2024). Additional predictors include education of the household head that takes value 1 for the literate head and 0 otherwise (Yadav et al., 2021; Jin et al., 2023), caste category taking value 1 for the marginalized groups and 0 otherwise (Pandey & Chaubal, 2011), and wealth index coded as 1 for poor, 2 for middle, and 3 for rich households (Timilsina, R. R., et al., 2024). The regression model also includes administrative location of the selected states through dummy variables to account for regional heterogeneity (Kemmler et al., 2007). These variables are selected based on the theoretical relevance and empirical findings from previous studies and are expected to have varying impacts on household electricity access.

3.5 Tools and Techniques

This study estimated a binary logit model to examine the factors influencing electricity access. It is appropriate for analyzing the limited dependent variables with binary outcomes (Paul et al., 2023). The classical linear regression models are not preferred in such contexts due to their inability to handle dichotomous dependent variables effectively. The binary logit model is, therefore, applied to estimate the probability of household electricity access based on selected socio-demographic and economic predictors. This approach enables a more accurate and interpretable estimation of the factors influencing the probability of electricity access across different household groups and regional contexts.

$$ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 Place\ of\ Residence_i + \beta_2 Gender\ of\ the\ Head_i + \beta_3 Log\ Age\ of\ the\ Head_i + \beta_4 Education\ of\ the\ Head_i + \beta_5 Caste\ category_i + \beta_6 Wealth\ Index_i + \beta_7 Location\ Dummy_i + \varepsilon_i \quad (1)$$

Here, $ln\left(\frac{P_i}{1-P_i}\right)$ represents the natural logarithm of the odd ratio with P_i being the probability that a household has electricity access. Further, α is the intercept term, representing the log odds of having electricity access when all independent variables are zero (hypothetical scenario), β_j (j = 1,..,7) denotes the coefficients associated with the j^{th} independent variable, and ε_i stands for the random disturbance term.

4. Results and Discussions

This section of the paper presents and discusses the regression results on the factors impacting the probability of households' access to electricity across the selected Indian states. In addition to checking the robustness of the estimated models, the necessary statistical tests have also been carried out. The summary statistics are presented in Table 2. Very low values of the variance inflation factors (VIFs) indicate that the estimated model does not have any severe multicollinearity problem (Swain & Mishra, 2020; Paul et al., 2023), ensuring reliability of regression results.

Table 2: Summary statistics of selected variables

Variables	Observations	Mean	Standard Deviation	Min.	Max.
Electricity access	2,24,712	0.934	0.248	0	1
Place of residence	2,24,712	0.209	0.407	0	1
Gender of household head	2,24,712	0.172	0.377	0	1
Log age of household Head	2,24,712	3.842	0.302	2.565	4.554
Education of household head	2,24,712	0.703	0.457	0	1
Caste category	2,24,712	0.472	0.499	0	1
Wealth index	2,24,712	1.674	0.842	1	3

Source: Calculated using secondary data from the National Family Health Survey.

4.1 Determinants of Electricity Access

The results of the estimated logistic regression models (Table 3) provide in-depth insights about the determinants of the probability of households' electricity access across the Indian states. Place of residence remains a dominant predictor, with rural households significantly less likely to have electricity access than their urban counterpart. The Wald-Chi^2 statistics indicate that all the estimated models are statistically significant, though with low explanatory power as indicated by the value of the Pseudo R^2.

Table 3: Estimated logit model for the overall sample

Electricity Access		Overall	Rural	Urban
Variables	**Sub category**	**Odd ratio**	**Odd ratio**	**Odd ratio**
Place of residence	Rural	Base	--	--
	Urban	0.174*** (0.00)	--	--
Gender of household head	Male	Base	Base	Base
	Female	-0.006 (0.787)	0.005 (0.831)	-0.197 (0.76)
Age of household head	Log of age	0.281*** (0.00)	0.306*** (0.00)	-0.105 (0.422)
Education of household head	Illiterate	Base	Base	Base
	Literate	0.545*** (0.00)	0.565*** (0.00)	0.094 (0.284)
Caste category	Others	Base	Base	Base
	SCs and STs	-0.262*** (0.00)	-0.268*** (0.00)	-0.125 (0.146)
Wealth Index	Poor	Base	Base	Base
	Middle	3.050*** (0.00)	3.128*** (0.00)	2.814*** (0.00)
	Rich	4.379*** (0.00)	4.264*** (0.00)	4.839*** (0.00)
Location (State)	Uttar Pradesh	Base	Base	Base
	Arunachal	0.958*** (0.00)	0.919*** (0.00)	1.980*** (0.00)
	Manipur	1.256*** (0.00)	1.209*** (0.00)	1.974*** (0.00)
	Mizoram	0.922*** (0.00)	0.898*** (0.00)	1.369*** (0.00)
	Meghalaya	0.591*** (0.00)	0.588*** (0.00)	0.735*** (0.00)
	Assam	0.965*** (0.00)	0.939*** (0.00)	1.642*** (0.00)
	West Bengal	1.305*** (0.00)	1.257*** (0.00)	2.015*** (0.00)
	Jharkhand	0.870*** (0.00)	0.829*** (0.00)	1.753*** (0.00)
	Odisha	1.367*** (0.00)	1.357*** (0.00)	1.601*** (0.00)
	Gujrat	0.953*** (0.00)	0.969*** (0.00)	0.810*** (0.00)
Constant		0.188 (0.13)	0.097 (0.449)	1.781*** (0.001)
Wald chi^2(16)		7880.92	6491.45	1226.81
Prob > chi^2		0.0000	0.0000	0.0000
Pseudo R^2		0.1759	0.1392	0.3230
Log pseudolikelihood		-44932.197	-42266.781	-2599.390
Number of observations		224,712	177,672	47,040

Source: Calculated 5th round of the National Family Health Survey.

Note: ***, **, and * significance at 1 percent, 5 percent and 10 percent respectively.

As regards the individual coefficients, it is found that, despite several initiatives to bridge the gaps, residing in rural areas still presents a structural disadvantage. The existing studies also showed that limited infrastructure, geographical remoteness, and higher costs of grid extension in non-urban areas may limit access to electricity (Dinkelman, 2011; Bensch et al., 2017; Angelou et al., 2019). Further, households with aged head have greater probability of electricity access in rural areas, whereas it does not have any significant impact for the urban counterparts. This is so possibly because energy preferences vary with age cohort (Rahut et al., 2020; Awan et al., 2024). However, the gender of the household head does not have any significant influence on the probability of electricity access. This is contradictory to the findings in the existing studies that cleaner energy adoption reduces women's health risks and enhances their decision-making roles (Rahut et al., 2016; Awan et al., 2024). Notably, gender inequality in energy sector showed decreasing trend overtime (Timilsina, R. R., et al., 2024).

The results also show that education of household heads raises the probability of overall electricity access and also that in rural areas. This is so as education results in greater health awareness and economic benefits of modern energy use (Yadav et al., 2021; Jin et al., 2023; Awan et al., 2024). Further, households belonging to Scheduled Caste and Scheduled Tribe categories have significantly lower odds of electricity access. This confirms the notion that structural and locational disadvantages of these groups limit their access to infrastructure facilities (Paul et al., 2023; Saxena & Bhattacharya, 2018). Wealth index also emerges as a significant factor influencing households' electricity access. It is found that the middle and upper-income households are more likely to have electricity access than the poor. The study by Rahut et al. (2014) also found that economic status influences households' to access various infrastructure facilities.

The results also indicate location-based differences in electricity access by the households with the states like West Bengal, Odisha, and Manipur having significantly higher odds compared to Uttar Pradesh and the states of Meghalaya, Jharkhand, and Gujarat lagging behind. Such inter-state variations in households' electricity access may arise from geographic remoteness, policy imperfections, or several institutional challenges, along with differences in socio-economic conditions. The findings, thus, confirm that electricity access in India is shaped by spatial and socio-economic factors, suggesting the need for intersectional, state-specific, and inclusive energy policies in order to address the underlying inequalities.

4.2 Effect of SAUBHAGYA Scheme on Electricity Access

Figure 2 represents a comparative scenario of the state-wise variations in rural-urban gaps in electricity access between the 4th and 5th rounds of the NFHS. It indicates a significant decline in the electricity access gaps, especially in the states like Uttar Pradesh, Jharkhand, Assam, and Arunachal Pradesh. Further, the states such as West Bengal, Gujarat, and Odisha have made steady improvements in bridging the rural-urban gaps in electricity access. Importantly, the North-eastern states like Mizoram, Manipur, and Meghalaya show significant progress in this regard, despite their topographical challenges. One may contribute this progress to the implementation of the 'Pradhan Mantri Sahaj Bijli Har Ghar Yojana-SAUBHAGYA' in the late 2017. This flagship programme was successful in electrifying over 28 million households by March 2022, leading to the last-mile connectivity, providing free or subsidised connections, and deploying solar photovoltaic systems in remote areas. Between September 2017 and March 2022, a total of 9,180,571 households in Uttar Pradesh, 1,730,708 in Jharkhand, 2,326,656 in Assam, 47,089 in Arunachal Pradesh, and 2,452,444 in Odisha were electrified under the SAUBHAGYA scheme, with partial support from the 'Deen Dayal Upadhyaya Gram Jyoti Yojana' (DDUGJY) (Ministry of Power, 2024). Additionally, the states like Gujarat and Rajasthan have also achieved last-mile electricity access through this initiative (Jain, 2025).

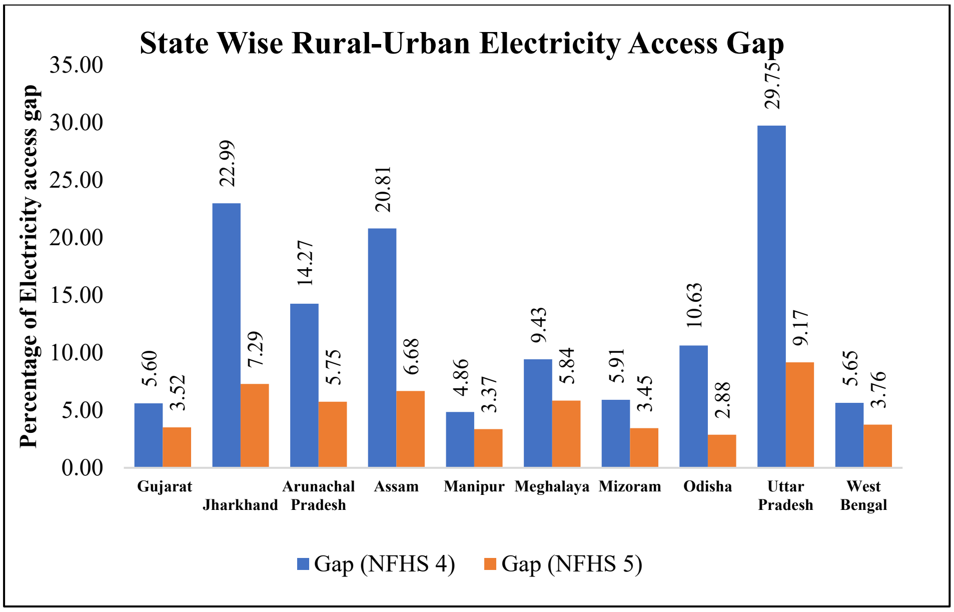

Figure 2: State-wise rural-urban electricity access gap in India
Source: 4th and 5th rounds of the National Family Health Survey.

The above discussion indicates that the electricity access gaps have decreased after implementation of the SAUBHGYA. Since this scheme has led to the expansion of the grid penetration and off-grid solutions significantly, the previously unconnected households, particularly in the rural and remote areas, could gain access to reliable electricity after the implementation of this initiative. However, assessing the specific contributions of the scheme and any robust conclusions in this regard require further in-depth scrutiny, which opens up an important scope for future research.

5. Conclusion

This paper examines the progress in electricity access in India and the underlying factors, with a particular focus on the rural-urban gaps and the impact of the initiative SAUBHAGYA. The findings underscore that households' electricity access is influenced by a combination of spatial, socio-economic, and demographic factors. Rural households from the socially disadvantaged groups having less wealth and younger head with no formal education, consistently experience lower electricity access. However, the initiatives like SAUBHAGYA seem to have played a critical role in bridging the rural-rural gaps in this regard. The study finds a significant decline in the rural-urban electricity access gaps across the Indian states after implementation of the SAUBHAGYA, reflecting its effectiveness in providing the last-mile connectivity and reaching the disadvantaged populations.

The empirical results thus emphasize the important role of education, wealth, and geographic location in shaping access to basic amenities. Further, the inter-state differences in the gaps in electricity access indicate the importance of regional challenges posed by the geographical and socio-economic constraints along with policy and institutional limitations at the state-level. Accordingly, the study suggests continued investment in rural electrification infrastructure development, initiatives for targeted socio-economic upliftment, and greater deployment of renewable energy solutions in remote locations. These steps are critical not only to ensure universal and equitable electricity access, but also to drive broader developmental outcomes in health, education, and livelihoods.

While the present paper is based on a comprehensive review of the existing literature and recently available data, and thus provides an evidence-based foundation for policies and further exploration of the underlying dynamics, it has the following limitations: First, the study uses the state-specific dummy variables to examine the inter-state differences in electricity access. Hence, the findings can be more robust with inclusion of necessary state-specific control variables like socio-economic conditions, infrastructure facilities, government support in different states, etc. Additionally, estimation of marginal effects can provide better insights on the comparative impact of the independent variables on electricity access, enabling more precise policy and institutional measures. Hence, future research in this area can be directed towards exploring these aspects.

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