Targeted Electricity Subsidies and Rural Development: Evidence from India's RGGVY Program

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Abstract

This study examines the socioeconomic impacts of India's Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), a rural electrification program that aimed to provide free grid connections to below poverty line (BPL) households. Leveraging the staggered rollout of the scheme and using panel data from the India Human Development Survey (2004-05 and 2011-12), this study examines outcomes related to electricity access, income, employment, and education. Findings suggest that each additional year of exposure to electrification leads to significant gains in income, a shift toward non-agricultural employment, and improvements in educational attainment—effects that are observed among BPL households, but not for non-BPL households. These results highlight the importance of targeted policy design for inclusive rural development.

Keywords: Rural electrification, Electricity access, Energy policy, RGGVY, India, Difference-in-differences, Socioeconomic impact

1. Introduction

Electricity access is included in the seventh Sustainable Development Goal that focus on universal access to affordable and reliable electricity supply(World Bank (2023)). However, despite substantial investment and efforts, roughly 700 million people still lack access to electricity. Of these, 550 million reside in rural areas. There are significant regional differences, as most of these rural households live in South Asia and sub-Saharan Africa(World Bank (2023)). Significant funding has gone into rural electrification programs from the World Bank and Asian Development Bank

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because of the wide acceptance of the fact that rural electrification has positive impacts(Raitzer et al. (2019)). Impact of rural electrification varies significantly across studies and depends on the geographical region(Bos et al. (2018);Jimenez (2017)). Electricity access increases household income(Khurana and Sangita (2022)), overall village-level employment, and the number of micro-enterprises in India(Chaurey et al. (2012)). Khandker et al. (2014) found that a "larger share of benefits accrues to wealthier rural households, with poorer having more limited use of electricity," showing differential impact for income levels. Therefore, understanding the effectiveness of targeted electricity subsidies is critical for designing inclusive development policies, especially in low and middle-income countries where energy access remains a significant barrier to poverty alleviation.

India's rural electrification efforts through Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) represent one of the largest policy experiments aimed at reducing energy poverty and fostering socioeconomic development. Despite the scale and ambition of RGGVY, there is limited evidence on its causal impact on household-level outcomes, especially for Below Poverty Line (BPL[1]) households who were explicitly targeted by the scheme. Existing studies on rural electrification in India (e.g.,Khandker et al. (2012);Sedai et al. (2021)) often focus on aggregate impacts or specific marginalized groups (e.g., Scheduled Castes/Scheduled Tribes), but they do not rigorously examine the heterogeneous effects of the provision of targeted subsidies to the poorest households. This study fills this gap by leveraging the spatial and temporal variation in RGGVY's rollout to estimate its causal impact on the BPL households' socioeconomic outcomes.

In 2005, almost 350 million people in rural India lived without access to electricity(World Bank (2023)). We can see the striking differences between rural and urban electrification in India(Figure 1). The Government of India launched the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in 2005 to address this. The scheme aimed to electrify all un-electrified villages/habitations and to provide access to electricity to all rural households in un-electrified and electrified villages across 27 Indian states. India gained almost universal electrification in 2020(Agrawal et al. (2020)). This makes studying rural electrification in the Indian context very valuable to get insights into ongoing problems and policy making for electrification in the context of the development of the sub-Saharan Africa region and others with similar levels of electricity access (Figure A.6).

[1] a benchmark used by the government of India to indicate economic disadvantage and to identify individuals and households in need; in terms of income(Rs) per person per month

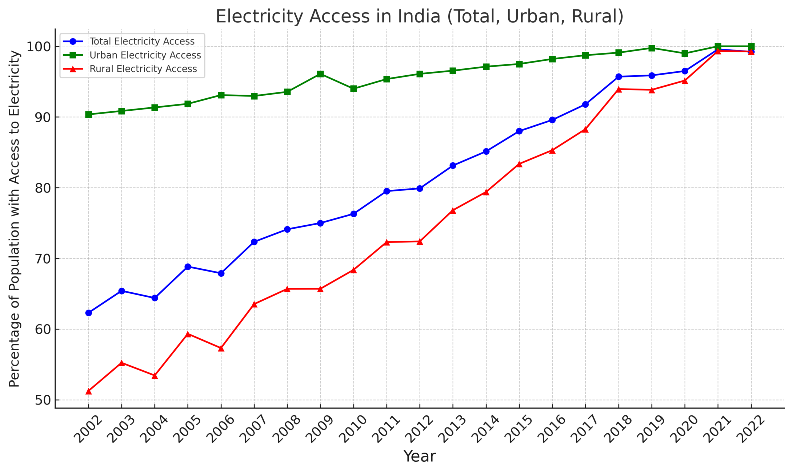


Figure 1: Rural vs Urban Electricity Access in India (2000-2022).
(Source: World Bank data.)

2. Literature Review

The effects of electricity access on household outcomes vary by geographical regions and the socioeconomic categories to which the household belongs. Studies done in Bangladesh and Vietnam found that grid electrification has significant positive impacts on households' income and expenditure(Khandker et al. (2009),Khandker et al. (2013),Khandker et al. (2014)). In Bangladesh, an increase in household income can be as much as 30%, and in Vietnam, up to 28%. In South Africa, evidence suggests that household electrification also increases employment by releasing women from home production activities and enabling micro-enterprises (Dinkelman (2011)). Improved electricity access also improves children's educational outcomes because of increased study time (Aguirre-Bielschowsky (2014)). In Vietnam, Khandker et al. (2013) found that household electrification increases school attendance of boys by 6.3% and for girls, it increases by 9.0%. A number of studies show greater effects on educational outcomes for girls(van de Walle et al. (2017), Banerjee et al. (2014)), suggesting the significance of electricity access in reinforcing gender equality.

The extent to which these benefits accrue for different sections of society in a region remains an area of ongoing debate. In Bangladesh and India, households in higher income percentiles experienced income increases nearly twice as large as those in lower percentiles, with households in the 15th percentile often seeing no significant benefits at all (Khandker et al. (2012);Samad and Zhang (2017)). According to Khandker et al. (2013), Electrification generally favors wealthier households, who are better positioned to leverage electricity for income-generating activities and consumption increases. Similar disparities were observed in Cambodia, where wealthier households saw a 36% increase in consumption, compared to a 22% increase for poorer households (Saing (2018)). In Ghana and Tanzania, electrification programs produced more equitable results, with lower and middle-income households benefiting the most in terms of income and business activity, while wealthier households saw limited gains (Adu et al. (2018);Chaplin et al. (2017)).

In the context of India, a number of studies have looked at the impact of rural electrification on different marginalized groups(Hindu SC/ST and Muslims). Electrification enables marginalized households to increase their consumption and assets and helps them move out of poverty, but these effects were found to be smaller than those for dominant groups(Hindu forward castes and OBC)(Sedai et al. (2021)). Also, improvement in terms of daily supply hours and monthly outage days are found to be less for SC/ST households in comparison to others(Pelz et al. (2021)). But caste and religion are not the only decisive parameters for disadvantaged groups; income levels plays a major role, too(Khandker et al. (2014)).

This study contributes to the literature in three key ways. First, it provides the first comprehensive evaluation of the RGGVY scheme's impact on household-level outcomes, exploiting both spatial and temporal variation in program rollout. Unlike prior studies(Burlig and Preonas (2016)) which examine electrification broadly at the village or district level, this study focuses on the specific policy provision of free connections for BPL[2] households which addresses the gap in the literature to understand the impact of having the provision of targeted subsidies in the electrification schemes. Second, prior studies that often employ binary treatment indicators (e.g., electrified vs. non-electrified; Khandker et al. (2012);Dinkelman (2011)), this study uses years of exposure as the main treatment variable. This continuous variable captures the marginal impact on the household outcomes of RGGVY implementation. Third, estimating differential effects to the BPL households sheds light on the inclusivity of electrification programs, providing evidence on whether benefits accrue disproportionately to the poor. These contributions are particularly relevant for policymakers in India and other developing regions, such as sub-Saharan Africa, where electrification still remains a critical development challenge.

[2] a benchmark used by the government of India to indicate economic disadvantage and to identify individuals and households in need; in terms of income(Rs) per person per month

2.1. Rural Electrification in India: RGGVY Scheme

At the time of independence, out of 560,000 villages, India had only 1,500 electrified villages(Banerjee et al. (2014)) as the main focus was on towns and industrial areas. After Independence, India considered electricity access crucial for overall socio-economic development and modernization. But the focus remained primarily on supporting industries and urban electrification, and rural electrification remained ignored till the late 1960s(Fetter and Usmani (2024)). This approach was largely influenced by the belief that industrialization and urbanization were the primary engines of economic growth, with rural development expected to follow as a secondary consequence (Ministry of Power, Government of India (2004-05)). The next decades observed several reforms in the field of rural electrification, and it was considered a 'basic need' in the fifth-year plan (1974-79). But even after decades of efforts and rural electrification programs, almost 125,000 villages remained unelectrified in 2004. Villages which were electrified faced problems of inconsistent power supply, and the problem of electricity access continued as village electrification did not result in household-level electrification as 57% rural households still lacked grid connections(Burlig and Preonas (2016)).

Against this backdrop, the Government of India launched the 'Power for All' program under the ambit of the National Electricity Policy in 2005. All the previously existing rural electrification schemes were merged, and Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was launched. This scheme aimed to electrify 100,000 previously unelectrified villages and 300,000 "partially-electrified" villages across 27 states. It sought to provide electricity access to all rural households, in general, and provide 23.4 million free electricity connections to households of below the poverty line. The scheme focused on developing infrastructures (transmission lines, distribution lines, and transformers etc) and addressing issues such as lack of power, low load density, rising cost of delivery, and poor quality of power supply. It was mainly funded(90:10) by the central government, but in order to receive funding, States had to submit detailed Project Reports(DPRs[3]) based on village-level surveys conducted by local implementing agencies(State Electricity Boards).

The implementation of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) involved a multi-tiered institutional approval process. As documented by the Ministry of Power (2013), all Detailed Project Reports (DPRs) submitted by State Governments were first scrutinized and appraised by the Rural Electrification Cor-

[3]DPRs outlined in detail the village-level implementation plan, set of villages eligible, related infrastructure needs, number of households expected to be connected, and expected project costs in a particular district.

poration (REC[4]). These DPRs were then presented to the Monitoring Committee (MC), which served as the sanctioning authority for RGGVY. Based on REC's appraisal and recommendations, the Monitoring Committee granted project approvals. Districts were divided mainly into multiple phases corresponding to India's Tenth (2002-2007) and Eleventh (2007-2012) Five-Year Plans based on the rule of "*first come, first served*". After meeting this criterion, in the 10th plan, 235 projects were found eligible, and funds were distributed during 2005-2008, and in the 11th plan,341 projects were authorized for the scheme and received funds during the years 2008-2011. Number of sanctioned projects in a particular year is given in detail in the Table 1.

Prior to the formal launch of RGGVY, a total of 127 rural electrification projects were approved in the first Monitoring Committee meeting held on 21 July 2005. This included 111 projects under the Accelerated Electrification of One Lakh Villages and One Crore Households (AEOLV-OCH) scheme.[5] Although AEOLV-OCH differed in scope from RGGVY, these projects were granted *ex post facto* approval, indicating a policy shift towards consolidating rural electrification efforts under a unified scheme. Table A.6 presents the number of projects sanctioned and their total approved costs in key Monitoring Committee meetings.

RGGVY received over Rupees 253 billion in funds, and around 17.5 million households were connected to the grid(Sreekumar and Dixit (2011)). It also considered the development of micro enterprises, small to medium industries, "to facilitate overall rural development, employment generation, and poverty alleviation"(Ministry of Power, 2005). As per the government reports(Lok Sabha Secretariat (2013)), 76.74% of the below-poverty-line households were electrified. In the case of the above poverty line category, only 1.5 million households received grid connection, which constitutes only 3% of the total targeted households(54.6 million)(Sreekumar and Dixit (2011)). It is clear that the provision of free electricity connections for BPL households played a major role. Burlig and Preonas (2016) did the first large-scale evaluation of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) and found limited improvements in socioeconomic indicators at the village level, with effects varying by village size. However, given that the scheme explicitly targeted Below Poverty Line (BPL)

[4]REC was set up in 1969 and finances and promotes power projects across India

[5]The Accelerated Electrification of One Lakh Villages and One Crore Households (AEOLV-OCH) scheme, launched in 2004 by the Ministry of Power, marked a pivotal step in India's rural electrification efforts prior to the rollout of RGGVY. The scheme aimed to fast-track electricity access for unserved villages and households by leveraging both conventional grid and non-grid technologies—such as solar PV, biomass gasifiers, mini-hydel, and hybrid systems.

Table 1: Year-wise Summary of RGGVY Implementation Progress

Variable Label	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total**
Project cost Sanctioned (in Rs. Lakhs)	39995	573287	336773	28880	1592488	54280	18841	2644543
Awarded cost/Revised cost (in Rs. Lakhs)	48800	784758	439876	34202	2015116	54178	18436	3395365
Total Amount Released (in Rs. Lakhs)	48711	733412	393138	29347	1700477	37495	11233	2953813
Total Amount Released (in %)	99.82	93.46	89.37	85.81	84.39	69.21	60.93	87.00
Electrification of Un-/De-Electrified villages, revised coverage	4169	45923	12545	1457	45076	1096	31	110297
Electrification of Un-/De-Electrified villages, achievement in number	4169	45898	12251	1456	44255	598	31	108658
Electrification of Un-/De-Electrified villages, achievement in %	100.00	99.95	97.66	99.93	98.18	54.56	100.00	98.51
Intensive Electrification of Electrified villages, revised coverage	0	62495	35610	2435	215740	2957	1590	320827
Intensive Electrification of Electrified villages, achievement in number	0	61439	35250	2078	205145	1338	1321	306571
Intensive Electrification of Electrified villages, achievement in %	0.00	98.31	98.99	85.34	95.09	45.25	83.08	95.56
No. of Connections to BPL Households, revised coverage	167402	5000261	2172610	213062	14178588	248495	117485	22097903
No. of Connections to BPL Households, achievement in number	167402	4950677	2833591	202259	13004210	115111	90988	21364238
No. of Connections to BPL Households, achievement in %	100.00	99.01	130.42	94.93	91.72	46.32	77.45	96.68
Number of sanctioned projects	7	**175**	56	3	**323**	9	9	**582****
Number of awarded projects*	0	100	105	39	183	124	25	**576**
Plan wise number of projects	241				341			

Note: * 5 awarded in year 2011. **This table is generated from the open data access provided by Burlig and Preonas (2016) at the Harvard Dataverse. There were multiple projects sanctioned in a single district, so this is not equal to the number of districts.

households, this study hypothesizes that its impact on socioeconomic outcomes may be more substantial for these households and tests this hypothesis using household-level data. By focusing on the impacts of RGGVY on major socioeconomic indicators like income, employment, and education, this study contributes to the existing literature on the role of rural electrification in India's broader development goals and provide insights into the design of future electrification initiatives aimed at poverty reduction and rural empowerment.

3. Data

This study primarily relies on data from the India Human Development Survey (IHDS), a nationally representative dataset which was conducted in two rounds: 2004–2005 (Round I) and 2011–2012 (Round II), and covered 384 districts. Around 40,018 households were surveyed in both rounds of IHDS, which makes this suitable for panel estimation. The timing of the first round coincides with the launch of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in 2005, while the second round offers a sufficient post-intervention period (approximately five years) to evaluate the medium-term impacts of the scheme. Also the survey was conducted before the announcement of RGGVY, which rules out any possible bias in answers related to electricity indicators.

To measure the number of years of exposure to the RGGVY scheme, this study uses administrative implementation data on RGGVY projects, made publicly available by Burlig and Preonas (2016) at the Harvard Dataverse. This dataset includes detailed information on the different aspects of the scheme like the sanction date of a project for a particular district, information about the BPL household covered, and progress of the project across districts during different phases of the program (Table 1). For some districts, there were multiple sanctioned projects between 2005 and 2011. Study considers the earliest year of sanction for that particular district. This district-level administrative data was merged with the IHDS household survey by constructing a unique district identifier based on 2001 Census district codes. As a result, for each household, the data gives the number of years their district had been potentially exposed to the RGGVY program by the time of the second survey round of IHDS(2011-12). We define the duration of exposure as the difference between the year of the second survey round and the project's sanction year. This variable serves as the measure of treatment intensity. This integrated dataset provides a robust empirical framework to assess the impact of RGGVY on household welfare, particularly among rural and socioeconomically disadvantaged households, and supports a continuous difference-in-differences identification strategy. Study restricts the sample to rural households to align with the program's intended focus on rural electrification. Outcome variables are divided into the following four main categories, summary statistics for these variables are presented in the table 2. .

- **Income outcomes**: These include total household income, crop income, non-agricultural income, and income from business activities. All income variables are adjusted for inflation and transformed using the inverse hyperbolic sine (IHS) to reduce the influence of outliers and accommodate zero or negative values.

- **Employment outcomes**: Binary indicators of whether any household member reported for any work, along with specific indicators of non-agricultural work, self-employment in business, and salaried employment; in each case, numbers of hours worked would be more than or equal to 240 hours of work/year.

- **Educational attainment**: These include the highest level of education achieved by any adult household member and binary indicators for any household member with primary (grade 5), secondary (grade 10), higher secondary (grade 12), and graduate-level completion.

- **Electricity-related outcomes**: These include indicators for household electricity access, ownership of electric appliances (such as televisions and fans), and reported hours of daily electricity supply.

4. Empirical Strategy

This study employs a difference-in-differences (DiD) framework to estimate the causal impact of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) on key household-level outcomes, including income, employment, education, and electricity access. The identification strategy exploits spatial and temporal variation in the rollout of RGGVY across Indian districts between 2005 and 2011, in combination with panel data from the India Human Development Survey (IHDS) conducted in 2004-05 and 2011-12. "DOE" (*duration of exposure*) is defined as treatment intensity, which measures the number of years a district had been exposed to RGGVY at the time of the second round of the survey. This variable captures program intensity and allows us to distinguish districts with earlier sanctioning from those where projects were sanctioned later. As households are located within districts, this variation is reflected at the household level.

There was a provision in the RGGVY scheme to provide free electricity connections to below poverty line households, which conceptualizes our main exogenous

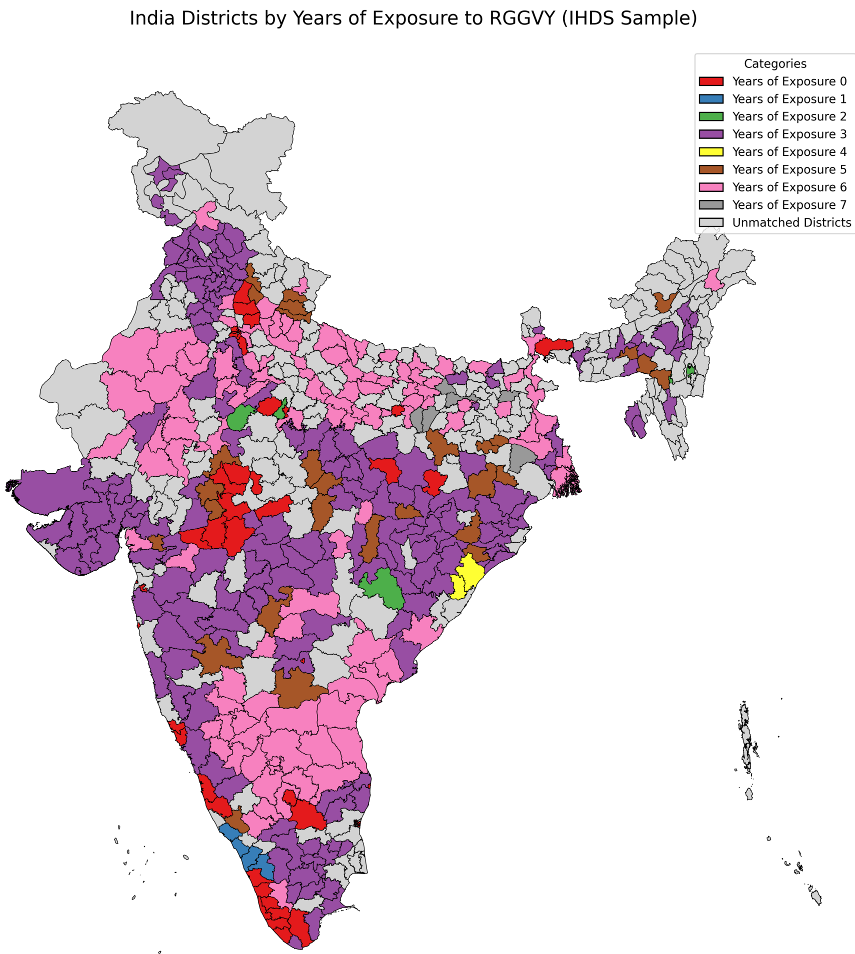


Figure 2: RGGVY Districts: IHDS Full Sample

Table 2: Summary Statistics of Outcome Variables

Variable	Mean	SD	Min	Max	Obs
Income	11.582	2.950	-15	17	56410
Consumption Expenditure	12.208	0.814	7	17	56374
Crop Income	4.784	6.402	-15	17	56410
Non-Ag Income	4.002	5.320	0	15	56410
Business Income	1.853	4.241	-13	16	56410
Any work	0.943	0.233	0	1	56410
Any non-ag work	0.325	0.468	0	1	56410
Any business work	0.143	0.351	0	1	56410
Any salary work	0.201	0.401	0	1	56410
Highest adult literate	0.764	0.425	0	1	56410
Education: Primary or Higher (5+)	0.685	0.464	0	1	56410
Education: Secondary or Higher (10+)	0.342	0.475	0	1	56410
Education: High Secondary or Higher (12+)	0.202	0.402	0	1	56410
Education: Graduate	0.094	0.292	0	1	56410
Electricity Connection	0.759	0.428	0	1	56049
Electricity Supply Hours	14.132	6.749	0	24	42458
Uses kerosene for lighting	0.547	0.498	0	1	56410
Owns Television	0.478	0.500	0	1	56363
Owns Electric Fan	0.588	0.492	0	1	56367

- Note: Outcome variables include inflation-adjusted income (total, crop, non-agricultural, and business) transformed using the inverse hyperbolic sine; binary employment indicators capturing work type and intensity; educational attainment level of any member of the household; and household electricity access, appliance ownership, and Electricity hours.

treatment since it was not the household's decision to self-select into the treatment group. This provision is expected to have a significant impact on socioeconomic indicators of below poverty line households in comparison to other households, as non-BPL households have to pay for having the electricity connections. To estimate the heterogeneous treatment effects by economic status, DOE is interacted with a binary variable indicating whether a household was below the poverty line (BPL). The main estimating equation takes the following form:

$$Y_{idt} = \alpha_i + \lambda_t + \delta_d t + \theta_1 \text{BPL}_{it} + \theta_2 \text{DOE}_{dt} + \theta_3 (\text{BPL}_i \times \text{DOE}_{dt}) + \varepsilon_{idt} \quad (1)$$

where Y_{idt} denotes the outcome for household i in district d in survey year t.

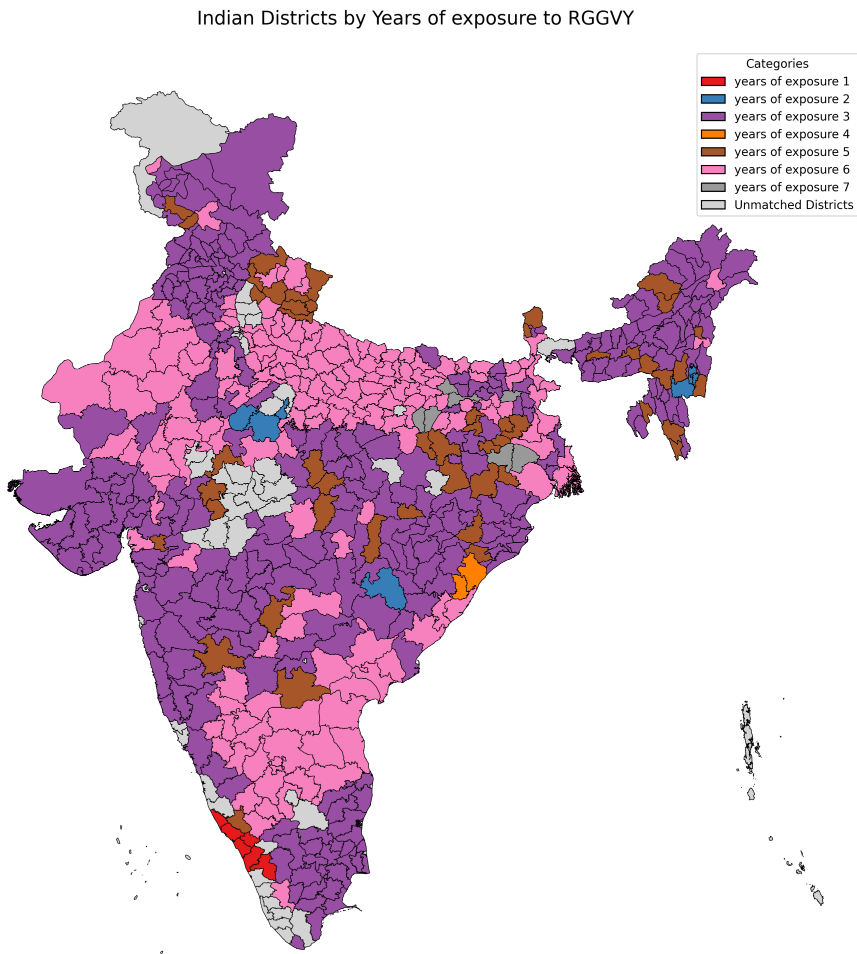


Figure 3: RGGVY Districts: Full sample

The model includes household fixed effects (α_i) to absorb time-invariant heterogeneity across households, year fixed effects (λ_t) to capture national-level macroeconomic shocks, and district-specific linear time trends ($\delta_d t$) to allow for heterogeneous growth paths across districts. trends. Our DD identifying assumption is that, after these trends are controlled for, different phase districts would have continued on parallel counterfactual trajectories absent RGGVY. This analysis fails to reject parallel trends before RGGVY[6] implementation. The interaction term ($\text{BPL}_i \times \text{DOE}_{dt}$) captures differential impacts of program exposure on BPL households. Standard errors are clustered at the district level to account for serial correlation.

There is no guarantee that districts were randomly selected, resulting in a possible selection bias. However, model specification takes care of both level and trends in outcome variables at the district level by including district-specific linear trends. It also take care of year on year macroeconomic changes in outcomes which may have affected all the districts. Therefore, any effect that is captured by the coefficient of the treatment variable, estimates the causal effect of the RGGVY scheme. The only other paper that examine the direct impact of RGGVY(Burlig and Preonas (2016)) uses RDD(Regression Discontinuity Design) as their main specification which exploites the exogenous cutoff at village level hence they are unable to observe the heterogeneous impact of the treatment at the household level, especially for those most likely to benefit from the program (i.e., BPL households). Studies that evaluates the impact on these outcomes at the household level (e.g., Khandker et al. (2012),Sedai et al. (2021))usually take electricity access as their main explanatory variable and address the issue of endogenity by incorporating Instrumental Variable specification where exclusion and relevance conditions need to be satisfied. While these studies provide useful insights, they often suffer from endogeneity or fail to account for the policy-driven nature of electrification. This framework explicitly models treatment intensity (via duration of exposure) and exploits the household-level targeting design of RGGVY (which provided free connections to BPL households), which allows to estimate impacts that are more directly relevant for policy targeting.

5. Pre-trend in Electricity Outcomes

To assess the validity of the parallel trends assumption[7] for the difference-in-differences framework, we conduct pre-trend analysis examining trends in key elec-

[6]See table 3, our district-level pret-rend estimates are all statistically indistinguishable from zero

[7]In the absence of treatment, both control and treatment groups should follow the same trend, otherwise estimates would not be causal.

tricity outcome variables before and after the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) announcement in 2005. Using data from the National Sample Survey (NSS) for the years 1999-2000, 2004-2005, and 2009-2010, we run our model at district level to check for pre-trends between groups of districts sanctioned in different phases of RGGVY. Model specification to check the pre-tend at the district level is given as(Burlig and Preonas (2016)):

$$Y_{idt} = \alpha_i + \lambda_t + \delta_{dt} + \theta_1 \text{DOE}_{dt} + \varepsilon_{idt} \tag{2}$$

where Y_{idt} denotes the outcome for household i in district d in survey year t. The model includes household fixed effects (α_i) to absorb time-invariant heterogeneity across households, year fixed effects (λ_t) to capture national-level macroeconomic shocks.To address possible non-random placement of districts into RGGVY's first wave, we allow for three families of linear trends, collected in (δ_{dt}): (i) within each state, separate trends for districts grouped by quartiles of 2005 household expenditure (to absorb within-state prioritization of poorer areas); (ii) nationwide, separate trends for districts grouped by deciles of 2005 household expenditure (to absorb selection on absolute poverty across states); and (iii) state-specific trends. Our DiD identification then assumes that, conditional on these trends, districts sanctioned in different phases would have followed parallel counterfactual paths in the absence of RGGVY(Burlig and Preonas (2016)).

Table 3: Pretrends (2000–2005): Electricity Outcomes

	elec_quantity	elec_q_yn	mth_pc_exp	elec_light	tv	fan	ac	fridge
Duration of Exposure	-0.275	-0.003	3.915	-0.003	-0.006	-0.001	-0.002	-0.002
	(0.461)	(0.006)	(7.493)	(0.006)	(0.004)	(0.006)	(0.002)	(0.002)
	[-1.180; 0.631]	[-0.015; 0.008]	[-10.806; 18.637]	[-0.015; 0.007]	[-0.015; 0.002]	[-0.013; 0.010]	[-0.005; 0.002]	[-0.005; 0.001]
Pooled mean of Y	26.258	0.516	959.321	0.532	0.214	0.297	0.0270	0.0369
Mean of Y in 2000	23.656	0.472	998.051	0.496	0.182	0.246	0.0189	0.0272
Mean of Y in 2005	28.860	0.561	920.590	0.568	0.245	0.348	0.0354	0.0466
Observations	1024	1024	1024	1024	1024	1024	1024	1024
Clusters (clustvar)	503	503	503	503	503	503	503	503
R^2	0.905	0.960	0.914	0.961	0.934	0.952	0.902	0.948
RMSE	9.931	0.092	129.935	0.092	0.065	0.085	0.0291	0.0258

Notes: Coefficients show the effect of *Duration of Exposure to RGGVY*. Parentheses contain cluster-robust SEs; brackets contain 95% CIs. None of the estimates are statistically significant at the 10% level. **Outcome names:** *elec_quantity* = electricity quantity (kWh); *elec_q_yn* = share of households consuming any electricity; *mth_pc_exp* = monthly per-capita expenditure (Rs); *elec_light* = share of households with electric lighting; *tv* = share of households owning a television ,etc;

The analysis also collapses household-level data to district-level means by treatment status and NSS round, focusing on electricity-related outcomes (e.g., share of households with electric fans, TVs, lighting, and electricity consumption) and plots data points across the three periods, with a dotted vertical line at 2005 to indicate the RGGVY announcement, allowing visual inspection of pre-treatment trends and post-treatment divergences. Figures 4 and 5 present the plots for household electrical appliance usage and electricity-related outcomes, respectively. By these, we compare districts sanctioned in 2005 that got treatment earlier (treated, years to exposure = 6) with those sanctioned in 2008 (control, years to exposure = 3). For electric fans and TVs, the treated and control groups exhibit similar trends in 2000, supporting the parallel trends assumption, with divergence after 2005 indicating a positive treatment effect for treated districts. Air conditioning and refrigerator(higher-priced goods) ownership shows limited changes, as low-income households may still not be able to afford these. Figure 5 illustrates trends in electricity consumption, electric lighting, and per capita expenditure. The share of households consuming any electricity and using electric lighting increases more rapidly in treated districts post-2005, consistent with RGGVY's focus on free connections for BPL households. These plots provide suggestive evidence that RGGVY drove improvements in electricity access and appliance ownership, particularly for low-income households, but highlight the need for further robustness checks to confirm causal impacts.

6. Results and Discussion

Table 4 reports main empirical estimates of the heterogeneous impacts of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) on socioeconomic outcomes for below poverty line (BPL) households.

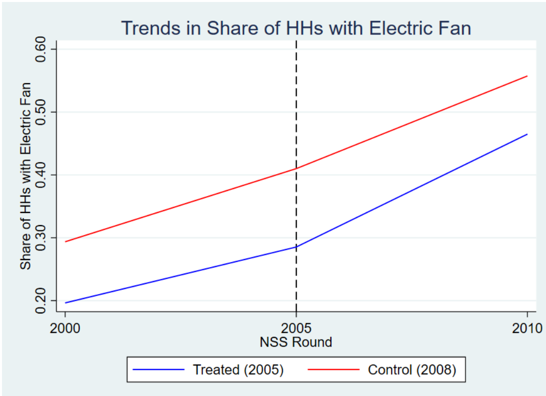
For binary outcomes(e.g., Electricity access, TV ownership, Literate adult, any work, etc), Y_{idt} takes the value 0 or 1 and the model is termed as a linear probability model (LPM). Coefficients of linear probability models directly indicate changes in outcome probability. The coefficient of the interaction term between BPL status and years of exposure (`BPL × Exposure`) is positive and statistically significant ($\hat{\theta}_3 = 0.018$), indicating a 1.8 percentage point increase per year of exposure in the probability of electricity connection. Given a baseline electricity access rate of 65.5% for BPL households in 2004, this translates to a 2.6% relative improvement annually. This means that districts that were exposed to treatment earlier have a faster rate of electrification to BPL households compared to other households. Appliance ownership also increases significantly. The probability of television ownership rises by 1.5 percentage points and fan ownership by 2.0 percentage points per year of exposure. However, no significant effects are observed on hours of electricity supply and kerosene use. Persistent kerosene reliance may result due to unreliable electricity supply or affordability constraints, as noted in Dinkelman (2011), who highlights similar challenges in rural electrification contexts. These findings indicate that while RGGVY successfully increased access and use of electrical appliances, reliability of electricity supply remains a critical barrier.

Employment outcomes highlight mechanisms through which electrification influences livelihoods. The probability of any household member reporting any work(more

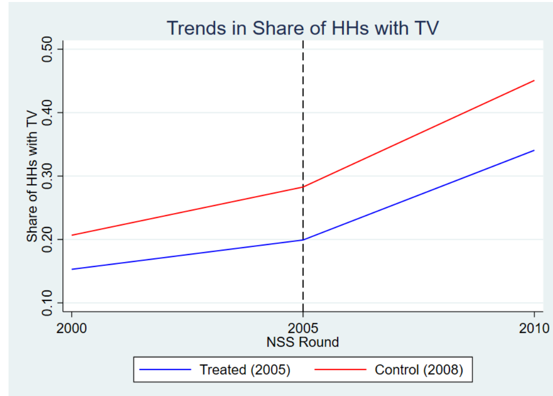
Table 4: Impact on Socioeconomic Outcomes: With district-specific trends

Category	**Outcome**	**Exposure**	**BPL**	**BPL × Exposure**	**Baseline mean**	**R-squared**	**Obs.**
	Electricity	0.219** (0.093)	-0.030*** (0.008)	0.018*** (0.002)	0.646	0.76	50,683
	Elec Hours	0.528** (0.223)	-0.052 (0.137)	0.029 (0.033)	14.359	0.85	33,841
Electricity/Appliance	Kerosene Use	0.139* (0.079)	0.013 (0.010)	-0.001 (0.002)	0.611	0.70	51,270
	TV Ownership	-0.002 (0.068)	-0.044*** (0.010)	0.015*** (0.003)	0.285	0.72	51,198
	Fan Ownership	-0.005 (0.035)	-0.053*** (0.010)	0.020*** (0.003)	0.390	0.76	51,203
	Total Income	0.146*** (0.020)	-0.137** (0.070)	0.044** (0.018)	10.954	0.54	51,270
	Consumption	-0.119*** (0.010)	-0.038*** (0.014)	0.017*** (0.003)	11.632	0.80	51,210
Income (IHS)	Crop Income	0.201 (0.250)	0.074 (0.133)	0.063 (0.041)	4.328	0.65	51,270
	Non-Ag Income	-0.909** (0.382)	-0.147 (0.108)	0.144*** (0.033)	3.397	0.67	51,270
	Business Income	-0.110 (0.249)	-0.034 (0.076)	0.007 (0.022)	1.611	0.66	51,270
	Any Work	-0.038*** (0.012)	-0.006 (0.004)	0.003*** (0.001)	0.976	0.56	51,270
Employment (Binary)	Non-Ag Work	-0.056*** (0.021)	-0.002 (0.010)	0.006** (0.003)	0.309	0.65	51,270
	Business Work	-0.035 (0.027)	-0.012** (0.006)	0.004* (0.002)	0.132	0.65	51,270
	Salary Work	0.005 (0.009)	-0.021*** (0.008)	0.006*** (0.002)	0.151	0.65	51,270
	Literate Adult	0.014** (0.006)	-0.026*** (0.007)	0.008*** (0.002)	0.673	0.72	51,270
	Primary+	0.013 (0.010)	-0.039*** (0.007)	0.012*** (0.002)	0.557	0.74	51,270
Education (Binary)	Secondary+	-0.012 (0.010)	-0.021*** (0.008)	0.004** (0.002)	0.220	0.77	51,270
	Higher Sec+	0.000 (0.007)	-0.012* (0.007)	0.001 (0.002)	0.109	0.74	51,270
	Graduate	0.017*** (0.001)	-0.002 (0.005)	0.000 (0.001)	0.043	0.73	51,270

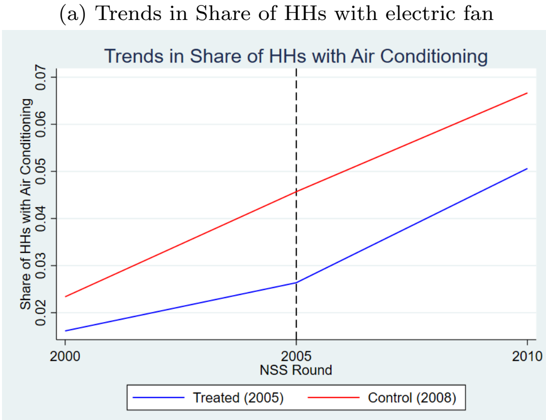
- Note: All regressions include household fixed effects, district-specific time trends, and year fixed effects. Standard errors clustered at the district level. Outcome variables are defined as follows: electricity/appliance and education indicators are binary; income outcomes are inverse hyperbolic sine transformed; employment indicators are also binary and represent the probability of that type of work hours *geq* 240 hours/year. Baseline mean column represents the outcomes mean for below poverty line households in the year 2004. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.



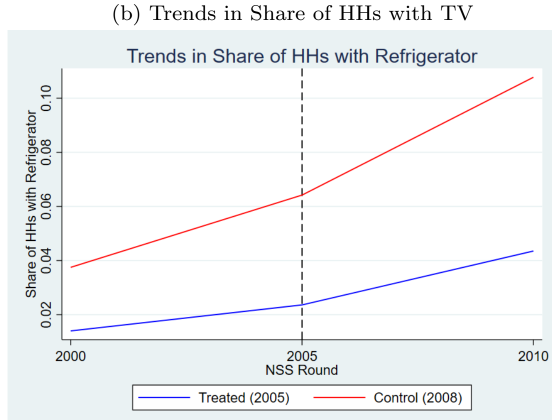
(a) Trends in Share of HHs with electric fan



(b) Trends in Share of HHs with TV



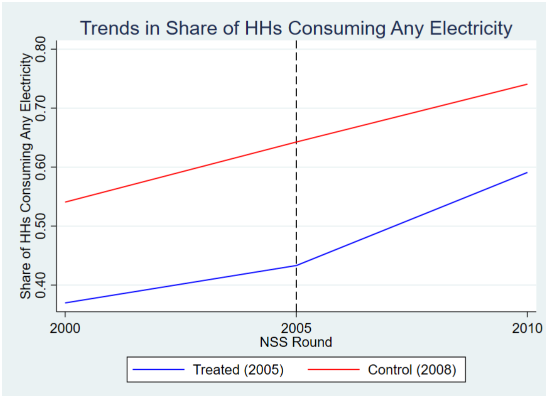
(c) Trends in Share of HHs with air conditioning



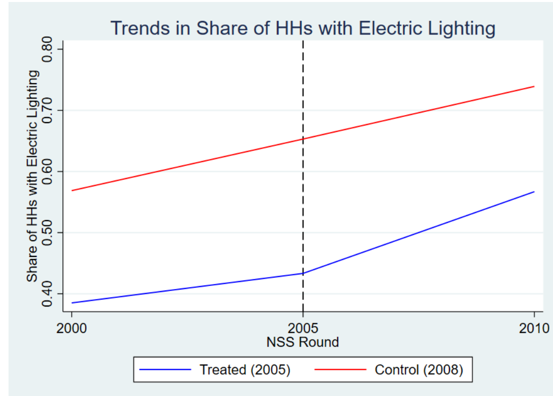
(d) Trends in Share of HHs with refrigerator

Figure 4: Trends in Household Electrical Appliance Usage

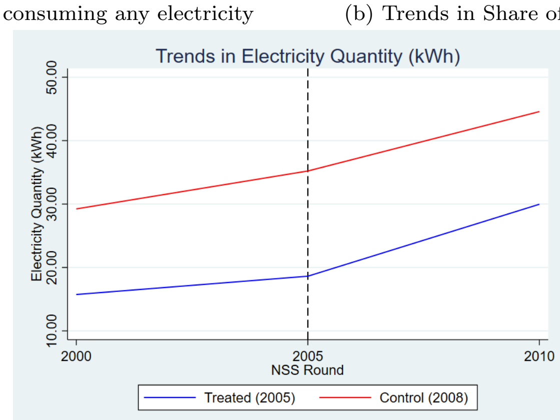
than or equal to 240 hours/year) increases by 0.3 percentage points ($p < 0.05$) for the BPL households. A more disaggregated analysis shows that these results drive by increased opportunities in the non-agricultural work which increases by 0.6 percentage points ($p < 0.10$) per year of exposure. Increase in use of electrical appliances may result into set up of small and medium enterprises which increases opportunities of self-employment by businesses. Results show 0.4 percentage points ($p < 0.10$) increase in the probability that any household member is engaged in business activity. Probability that any member of the household has salaried employment increases by 0.6 percentage points ($p < 0.05$) per year of exposure for BPL households. Despite modest magnitudes, these findings suggest the increased availability of work opportunities for the BPL households in the non-farm sector due to electrification. Hence scheme reduces barriers to labor force participation and supports engagement



(a) Trends in Share of HHs consuming any electricity



(b) Trends in Share of HHs with electric lighting



(c) Trends in Electricity Quantity (kWh)

Figure 5: Trends in Household Electricity and Expenditure

in stable or formal work, indicating a potential structural shift due to electrification. These results are in line with (Dinkelman (2011)), who found similar impacts in South Africa.

Improved lighting allows students to study after dark, a critical factor in rural areas with limited daylight study time (Khandker et al. (2013)). Additionally, it can improve household economic conditions, reducing financial barriers to education. The program leads to a 0.8 percentage point increase in the probability of having a literate adult in a BPL household ($p < 0.01$).Primary education completion rates also rise significantly, with a 1.2 percentage point increase ($p < 0.01$).At the secondary level, RGGVY is associated with a modest probability increase of 0.4 percentage point. This smaller effect may reflect the higher opportunity costs of continuing education at this stage, particularly in rural settings where economic pressures often lead to early workforce entry. Notably, no significant effects are observed for higher secondary or graduate-level outcomes. This lack of impact at higher levels is consistent with prior research indicating that electrification's benefits in the short term are most pronounced in contexts with a low level of educational attainment (Lipscomb et al. (2013)), where barriers to basic education are more significant.

For continuous outcomes like (Income, Consumption Expenditure etc), Outcome variables Y_{idt} are inflation-adjusted and has been transformed using the inverse hyperbolic sine (IHS), $\text{IHS}(y) = \ln(y + \sqrt{y^2+1})$, which helps to take care of zeros and negatives values. Here, θ_3 approximates a percentage change. For total income ($\theta_3 = 0.044$, $p < 0.10$), each year of RGGVY exposure increases IHS-transformed total household income by 0.044 units, which translates into roughly a 4.4% increase per year of exposure. The most substantial gains are observed in non-agricultural income ($\hat{\theta}_3 = 0.144$), highlighting the role of electrification in facilitating income diversification into non-farm activities. This finding aligns with prior literature suggesting that electricity access enables the setting up of small-scale enterprises, value-added services, and increased non-farm employment opportunities (Khandker et al. (2012); van de Walle et al. (2017)). For example, reliable electricity can power tools, machinery, and lighting, thereby supporting micro-enterprises such as tailoring, food processing, or retail shops. These activities often provide higher returns than traditional agricultural work. Monthly consumption expenditure also exhibits a significant increase ($\theta_3 = 0.017$), reflecting improved living standards and greater purchasing power among electrified households. However, the analysis finds no significant effects on crop income or business income.

7. Sensitivity Analysis

We restrict the sample to districts sanctioned in 2005 (the first wave). This subsample consists of a uniform treatment cohort, which minimizes potential biases arising from heterogeneity and systematic differences in districts treated in different waves of the scheme. Since the intervention provided free electricity connections to below-poverty-line (BPL) households, BPL households form the treatment group, with non-BPL households as the control group. We then estimate a two-period difference-in-differences with household fixed effects and year fixed effects (and, where noted, district-specific linear trends), clustering standard errors at the district level. This design helps isolate the incremental effect of the BPL connection provision, separate from general district electrification. The regression specification follows below.

$$Y_{idt} = \beta_0 + \beta_1(\text{BPL}_{id} \times \text{Post}_t) + \beta_2(\text{BPL}_{id}) + \gamma_i + \delta_d t + \lambda_t + \epsilon_{idt}, \quad (3)$$

where:

- Y_{idt} represents the outcome variable for household i in district d at time t.
- BPL_{id} is a binary indicator equal to 1 if the household is classified as BPL, and 0 otherwise.
- Post_t is a binary indicator equal to 1 for the post-treatment period (2011), and 0 for the pretreatment period(2005).
- $\text{BPL}_{id} \times \text{Post}_t$ is the interaction term, capturing the treatment effect.
- γ_i denotes household fixed effects, controlling for time-invariant household characteristics.
- $\delta_d t$ represents district-specific linear time trends, accounting for district-level heterogeneity in outcome trends.
- λ_t denotes year fixed effects, capturing common time shocks.
- ϵ_{idt} is the error term, with standard errors clustered at the district level to account for within-district correlation.

The coefficient of interest, β_1, estimates the impact of free electricity connections on BPL households relative to non-BPL households.

The results, summarized in Table 5, indicate varied impacts across outcome categories. In the electricity and appliance panel, the intervention significantly increased the probability of electricity access (0.069, $p < 0.01$) and fan ownership (0.086, $p < 0.01$), with a modest increase in TV ownership (0.039, $p < 0.10$) compared to non-BPL households. However, no significant effect was observed on electricity hours or kerosene use. In the income panel, significant effects were found for consumption (0.077, $p < 0.01$) and non-agricultural income (0.742, $p < 0.01$), suggesting improved economic welfare. Employment outcomes showed no significant changes. In education outcomes, significant improvements were observed in the probability of having any literate adult in the household (0.049, $p < 0.05$) and primary education attainment (0.078, $p < 0.01$), but for higher educational levels, we don't find any impact.

These observations suggest that the results mostly remained consistent, reinforcing the robustness of the estimated treatment effects.There are some outcomes for which we observe significant results earlier, but they have not been observed here such as employment outcomes. This may occur due to our restricted sample size.

Table 5: Robustness checks: Combined Outcomes (districts sanctioned in year 2005)

	BPL	BPL × Post	Baseline Mean	R-squared	Observations
Electricity and Appliance Ownership Outcomes					
Electricity	−0.017(0.016)	0.069***(0.018)	0.630	0.76	17,754
Elec Hours	0.029(0.306)	0.195(0.307)	12.401	0.80	9,963
Kerosene use	0.038**(0.018)	−0.007(0.017)	0.700	0.64	17,998
TV	−0.029(0.019)	0.039*(0.023)	0.277	0.70	17,978
Fan	−0.032**(0.016)	0.086***(0.023)	0.366	0.75	17,981
Income Outcomes					
Total Income	−0.018(0.149)	0.153(0.167)	10.933	0.53	17,998
Consumption Expenditure	−0.029(0.025)	0.077***(0.027)	11.730	0.76	17,986
Crop Income	0.158(0.266)	0.429(0.362)	4.021	0.62	17,998
Non-Ag Income	−0.227(0.182)	0.742***(0.261)	3.257	0.66	17,998
Business Income	−0.037(0.120)	−0.060(0.173)	1.549	0.67	17,998
Employment Outcomes					
Any Work	−0.002(0.008)	0.011(0.010)	0.974	0.57	17,998
Non-Ag Work	−0.008(0.016)	0.034(0.023)	0.298	0.64	17,998
Business Work	−0.015(0.010)	0.013(0.014)	0.134	0.66	17,998
Work Salary	−0.029**(0.014)	0.028(0.017)	0.140	0.64	17,998
Education Outcomes					
Literate Adult	−0.037**(0.014)	0.049**(0.019)	0.618	0.72	17,998
Primary+	−0.048***(0.014)	0.078***(0.018)	0.507	0.74	17,998
Secondary+	−0.029**(0.014)	0.020(0.014)	0.209	0.77	17,998
High Sec+	−0.013(0.012)	0.002(0.016)	0.102	0.74	17,998
Graduate	0.006(0.008)	−0.007(0.011)	0.042	0.73	17,998

Standard errors in parentheses

Baseline Mean contains the outcomes mean for below poverty line households in the year 2004.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- Note: All regressions include household fixed effects, district-specific time trends, and year fixed effects. Standard errors clustered at the district level. Outcome variables are defined as follows: electricity/appliance and education indicators are binary; income outcomes are inverse hyperbolic sine transformed; employment indicators are also binary and represent the probability of that type of work hours ≥ 240 hours/year. Baseline column contains the outcomes mean for below poverty line households in the year 2004. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Other potential limitations include the possibility of spillover effects from BPL to non-BPL households within electrified districts, which could attenuate the estimated ATT, and the reliance on self-reported BPL status, which may introduce measurement error(Bertrand et al. (2004)).

We have also performed other robustness checks by having different combinations of phase-wise districts and observe similar results, which validates our findings. These results tables are given in the appendix.

8. Conclusion

India's Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) represents one of the most ambitious rural electrification initiatives globally, targeting universal electricity access with a specific focus on Below Poverty Line (BPL) households. This study examines the socioeconomic impacts of the provision to provide free electricity connections to below poverty line households by exploiting the program's staggered rollout across Indian districts from 2005 to 2011 and utilizing the panel data from the India Human Development Survey (IHDS, 2004–05 and 2011–12). Study uses a continuous difference-in-differences (DID) framework with treatment intensity defined as years of exposure, and estimates causal effects on key outcomes (electricity access, appliance ownership, employment, income and educational attainment), with a particular emphasis on heterogeneous impacts for BPL households. Findings of the study suggests that Rajiv Gandhi Grameen Vidyutikaran Yojana(RGGVY) significantly improved electricity access, appliance ownership, non-agricultural income, consumption, and basic education among BPL households. Effects are observed among the targeted group, reflecting the program's design of providing free connections to BPL households. While effect sizes are moderate, they accumulate over time.

These results give insights into the role of targeted interventions in achieving inclusive rural development. However, complementary measures—such as improving service reliability, ensuring affordability, and promoting productive electricity use—are critical to maximizing developmental impacts. Globally, this study offers lessons for electrification programs in low-income countries, such as Ethiopia's National Electrification Program, which targets universal access by 2025. The difference-in-differences approach leverages robust temporal and spatial variation, but limitations persist. District specific linear trends have been included in the model equation, which addresses the issue that districts of different phases were on different linear growth paths, but there may be nonlinear trends that we have not taken care of, and additional robustness checks are needed. This study evaluates the short- to medium-term socioeconomic impacts of the RGGVY, which may not capture the impacts on variables that require long-term exposure to have significant change. Future research could utilize recent datasets to examine the long-term effects of rural electrification and may complement these with a primary survey, which could offer deeper insights into the impact of targeted electrification policies.

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Appendix A. Appendix

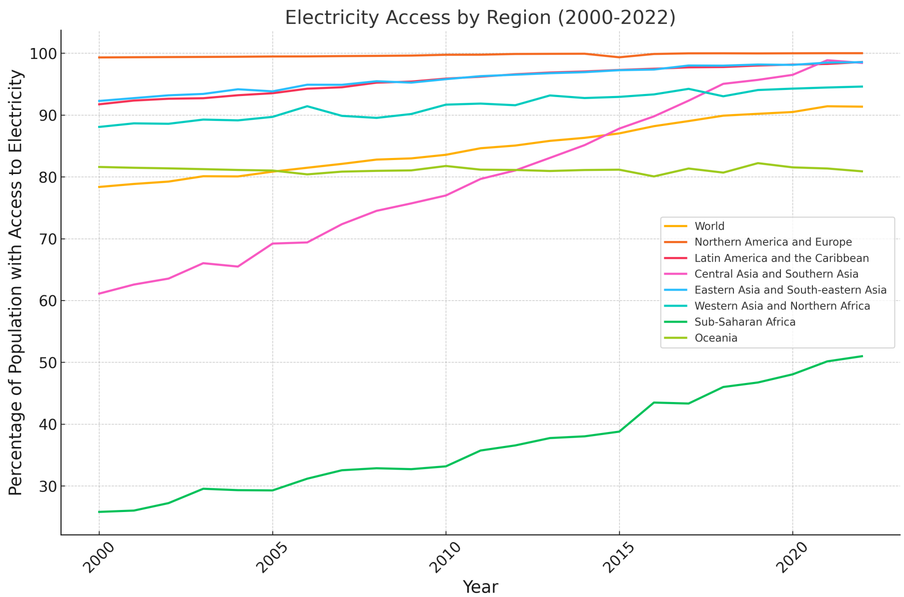

Figure A.6: Electricity Access in different regions (2000-2022).
(Source: Authors' plot using World Bank data.)

Table A.6: Projects Sanctioned in Monitoring Committee Meetings under Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)

Sl. No.	**Meeting**	**Date**	**Projects Sanctioned**	**Project Cost (Cr)**
1	1st Meeting	21.07.2005	127	4904.34
2	7th Meeting	09.05.2006	24	576.06
3	8th Meeting	20.07.2006	26	2023.46
4	15th Meeting	22.01.2008	215	7975.52
5	16th Meeting	04.02.2008	26	2168.09
6	19th Meeting	13.03.2008	51	2049.22
7	20th Meeting	19.03.2008	13	812.57
8	21st Meeting	28.03.2008	11	1022.46

- Source—Comptroller and Auditor General of India (CAG, 2013) Performance Audit Report on RGGVY.

Table A.7: Household Characteristics for BPL and APL Households in 2004

	BPL 2004							APL 2004						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Household Has Electricity Connection	0.841	0.634	0.657	0.659	0.655	0.630	0.430	0.918	0.773	0.806	0.651	0.685	0.529	0.600
Daily Hours of Electricity Supply	22.155	10.689	15.674	23.483	14.437	12.401	4.300	22.333	8.825	15.226	22.976	13.798	11.772	4.053
Kerosene Light	0.609	0.634	0.538	0.136	0.639	0.700	0.946	0.374	0.798	0.420	0.095	0.619	0.723	0.936
Owns Television	0.420	0.254	0.301	0.364	0.239	0.277	0.075	0.694	0.286	0.543	0.365	0.410	0.352	0.224
Owns Electric Fan	0.812	0.268	0.419	0.614	0.318	0.366	0.183	0.918	0.424	0.647	0.540	0.487	0.432	0.344
IHS trans. values of INCOME[a]	11.661	11.384	10.938	11.021	11.049	10.933	10.751	12.179	11.270	11.407	10.336	11.318	11.107	11.021
IHS trans. values of COTOTAL	11.765	11.466	11.582	11.628	11.508	11.730	11.737	12.224	11.697	11.984	11.537	11.843	11.932	12.057
IHS trans. values of INCCROP	0.581	7.422	4.297	3.536	5.612	4.021	5.529	2.137	7.672	5.294	3.248	5.813	5.618	6.601
IHS trans. values of INCNONAG	5.564	3.562	3.331	3.953	4.134	3.257	2.698	2.961	1.869	2.534	2.246	3.427	3.175	2.322
IHS trans. values of INCBUSINESS	0.991	2.958	1.652	2.218	1.458	1.549	2.593	2.730	1.663	1.837	2.161	2.048	2.183	3.112
Any Work	0.957	0.986	0.976	0.932	0.984	0.974	0.968	0.850	0.993	0.955	0.810	0.977	0.948	0.984
Any Non-Agricultural Work	0.478	0.324	0.301	0.386	0.376	0.298	0.237	0.252	0.152	0.225	0.206	0.320	0.292	0.208
Any Business	0.087	0.183	0.128	0.182	0.127	0.134	0.247	0.218	0.084	0.148	0.175	0.171	0.187	0.272
Any Salary	0.130	0.099	0.159	0.227	0.152	0.140	0.151	0.286	0.098	0.249	0.111	0.208	0.175	0.160
HQ10-16 N wk (≥240hrs): Any Job	1.681	3.239	2.495	2.091	2.615	2.442	2.710	1.429	3.007	2.463	1.222	2.561	2.216	2.400
HQ13 7.3 N wk (≥240hrs): Nonag Wage	0.725	0.423	0.444	0.545	0.641	0.448	0.301	0.327	0.219	0.332	0.222	0.516	0.412	0.288
HQ14-16 nf12,13 N wk (≥240hrs): Business	0.101	0.282	0.203	0.364	0.188	0.193	0.419	0.259	0.125	0.216	0.206	0.258	0.279	0.488
Highest Adult Literate in Household (HHEDUC ≥ 1)	0.971	0.690	0.706	0.659	0.706	0.618	0.505	1.000	0.717	0.808	0.762	0.791	0.717	0.704
Highest Education: Primary or Higher (5+)	0.957	0.606	0.586	0.455	0.585	0.507	0.430	0.966	0.650	0.741	0.635	0.706	0.635	0.680
Highest Education: Secondary or Higher (10+)	0.319	0.239	0.235	0.045	0.190	0.209	0.161	0.578	0.219	0.393	0.270	0.330	0.319	0.384
Highest Education: High Secondary or Higher (12+)	0.116	0.225	0.114	0.000	0.113	0.102	0.054	0.374	0.158	0.217	0.143	0.225	0.192	0.272
Highest Education: Bachelors	0.029	0.169	0.043	0.000	0.043	0.042	0.032	0.224	0.081	0.102	0.127	0.107	0.094	0.104

[a] IHS refers to Inverse Hyperbolic Sine transformation.