Let There Be Light: Addressing Heterogeneity in Welfare Gains from Rural Electrification in India

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Abstract

Who benefits more from rural electrification in India? In this paper, the author uses panel data from 2005 to 2012 to examine how welfare from electrification varies with respect to the social-group, income, and legality of connection of rural households in India. Using instrumental variables in a first-difference model and in quantile regression, we find heterogeneity in several dimensions of welfare. Electrification benefitted marginalised groups more through reductions in fuel usage, increased agricultural income, hours of study-time and work-hours for women, and higher likelihood of escaping poverty. On the other hand, dominant groups saw greater marginal benefits in most income and expenditure categories, male study-time and work-hours, as well as in the likelihood of having amenities in the household. Quantile regression estimates of welfare revealed a U-shaped pattern: the poorest and richest tended to benefit more than middle-income groups. Legal connections generally experienced greater marginal benefits than illegal connections, though the latter saw greater reductions in non-renewable fuel usage. Gains from electricity access were more heterogeneous than gains from quality of supply, suggesting that improvements on the intensive margin of electrification may be more effective in mitigating historical inequities.

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1 Introduction

Does electrification bring significant welfare gains to rural households? There are ample theoretical reasons to believe that the answer ought to be yes. Intuitively, one can expect better educational outcomes resulting from improved lighting that enables children to study later into the night. Access to electronic appliances reduces time spent on chores, enabling homemakers to invest in other activities (e.g., sewing) that can be income-generating. Businesses can remain open longer, and devices such as radios and television can increase exposure to information, thereby improving access to opportunities.

Despite many such plausible reasons, the evidence for welfare gains from rural electrification remain mixed. Some studies find large gains in income and consumption (Khandker et al 2009, Khandker et al. 2012); others report moderate gains (Chakravorty et al. 2014), while still others, notably Bensch et al. (2011), using administrative data from Rwanda, find no gains at all.

This is because there are several factors that obscure the effect of rural electrification on household welfare. First, there is possibility of endogeneity resulting from the joint determination of electricity acquisition and increases in income and consumption, thereby making it difficult to establish the direction of causality (Aklin et al. 2020). Recent papers have also shown that the quality of electricity matters more than mere electricity acquisition (Chakravorty et al. 2014). However, in India, both grid extension and intensification are non-random, and depend on observed and unobserved factors such as topography, electoral politics, and self-perceived gains from electrification, leading to self-selection bias and systematic heterogeneity at district-and-household levels (Aklin et al. 2020). Finally, in India, an estimated 27% of all electricity generated is lost to power theft, meaning that many households are electrified via illegal connections (Central Electricity Authority 2020). Returns to electricity are likely to vary depending on whether it is stolen or not, but no study has attempted to address this gap as of yet.

The main objective of this paper is thus to understand how household welfare from rural electrification varies across multiple dimensions. In essence, the author aims to answer the following question: Who benefits more from rural electrification, how, and by how much? Here, the main focus is on three sources of heterogeneity: social-group (caste), income, and legality of electricity connection. To address issues of endogeneity, the author has used the instrumental variables technique in a first-difference panel model. To examine the distribution of benefits by income-groups, quantile regression is used. The analysis is based on a balanced sample of households from two waves of the Indian Human Development Survey (2005 and 2012). The richness of this dataset allows the author to assess the impact of electrification on a wide range of socioeconomic variables.

The remainder of the paper is structured as follows: Section 2 situates our research in the existing literature. Section 3 describes the data, while Section 4 elucidates our estimation strategy. In Section 5, 6, and 7, we discuss our results by social-group (caste), income, and legality of connection respectively. Section 8 concludes, and Section 9 presents the tables from our analysis.

2 Literature Review

In early 21st century, scholars had attempted to analyse the relationship between electrification and development in India, but due to a lack of sufficiently granular data, were unable move beyond simple correlation and make causal links (Barnes et al. 2003; Cust et al. 2007). However, following the launch of India's national rural electrification program, Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in 2005, several studies used quasi-experimental techniques to establish causation. These analyses mostly focused on village-level dynamics, ignoring changes within households (Usmani & Fetter 2020; Burlig & Preonas 2016; Kooijman-van Dijk 2012).

While later studies have turned toward household gains, they have either focused on only one dimension of welfare i.e., income, consumption, etc. (Rao 2013), or been limited to state-wide effects (Millinger et al. 2012; Thomas et al. 2020), or evaluated only the extensive margin of electrification efforts (Khandker et al. 2014), overlooking the effect of the reliability of power supply on welfare. Some of these concerns have recently been addressed in the literature. For instance, a growing body of work has studied electrification at the intensive margin i.e., how additional hours of electricity affects returns (Samad & Zhang 2016; Sedai et al. 2020). Walle (2015) distinguishes between internal (household) and external (village-level) effects while analysing long-run returns to electrification, although their data is old (1981-98).

Differences in electrification benefits across gender (Samad & Zhang 2019) and income-groups have also been studied (Khandker et al. 2014), though the latter relies on cross-sectional data, so is unable to capture changes in returns to electricity over time. Finally, in discussing the distributional impact of electricity access, this paper contributes to a rich dialogue on the impact of energy welfare schemes on caste and income inequality in India (Saxena and Bhattacharya 2018; Pelz and Urpelainen 2020). In the following sections, the author limits their discussion to only those heterogeneities that we believe have not yet been well-documented in the literature.

3 Data

The author uses household-level data from the 2005 and 2012 waves of the Indian Human Development Survey (IHDS), a nationally-representative panel survey that collects information on a wide-range of socio-economic factors, including data on electricity.[1] The 2005 dataset covers 41,554 households from 383 districts in 33 states and union territories, covering 97.5% of the Indian population. For the 2012 round, 83% of the original households were interviewed, along with 2,134 new households, resulting in a total of 42,152 households (Desai and Vanneman 2012). For this paper, the author restricts the dataset to rural areas. The author only considers households interviewed in both rounds. Therefore, the final sample consists of 18,388 households.[2]

[1] For analysis, we create the variable "Quality of Electricity" by subtracting "Average Hours of Power Outage" (given by IHDS) from 24 for each household. This represents the average daily hours of electricity received by household.

[2] In cases where households split between 2005 and 2012, the 2012 households are matched with their parent household in 2005 using a matching ID provided by IHDS.

All monetary variables are deflated to 2005 prices using the IHDS deflator.

3.1 Descriptive Statistics

Table 1 reveals that overall, electrification rate increased from 69 per cent in 2005 to 82% in 2012, an average growth-rate of approximately 2 per cent a year. However, this masks considerable inter-state heterogeneity. While areas such as Delhi were almost fully electrified by 2005 (97%), less than 40% of households in Bihar had electricity in 2012. All regions, however, witnessed rapid electrification during this period, largely due to the launch of RGGVY in 2005. While RGGVY expanded electricity access to over 17.5 million rural households by 2011, its results on the intensive margin were criticised heavily (Sreekumar and Dixit 2011). Connected households experienced large power outages, and nightlight data showed that many villages remained dark for several years after being connected (Min and Gaba 2016). This is reflected in the sample which shows that average quality of supply deteriorated between 2005 and 2012.

Table 1: Sample Electrification Rate and Quality of Supply

	2005	2012
Percentage households electrified	68.99	82.33
Average quality of electricity (hrs/day)	14.47	13.66
Observations	18388	22329

Source: Author's calculations based on IHDS 2005 & 2012.

Table 2 denotes the summary statistics of outcome variables. Here, the author finds that kerosene consumption and time spent on bio-fuel were less in households with electricity, although the means are only significantly different for 2012. Both absolute and growth-rates of income and expenditure are greater in households with electricity. Electrified households are much less likely to be poor, and have systematically better access to basic amenities: flush toilet, piped water, motor-vehicle, and cell-phone. On average, children study more and adults work longer hours in connected households. Notably, however, female labour force participation rate and likelihood of borrowing does not depend on the connection status of the household. These comparisons are consistent across both survey years.

Table 2: Summary Statistics of Outcomes by Access to Electricity

Variables	2005		2012	
	Electricity	Non-Electricity	Electricity	Non-Electricity
Kerosene Consumption (litres/month)	3.65 (0.22)	3.31 (0.93)	3.05 (0.53)*	2.68 (0.32)
Time Spent on Bio-Fuel Collection (min/wk.)	109.6 (11.16)	109.0 (9.49)	135.7 (12.43)*	103.4 (11.06)
Per Capita Agri Income /1000 (Rs/yr.)	3.43 (4.7)*	7.22 (5.2)	4.67 (3.6)*	9.46 (5.4)
Per Capita Non-Agricultural Wage /1000 (Rs/yr.)	2.95 (2.82)	7.45 (10.2)	3.81 (15.1)	10.06 (12.3)
Annual Household Income /1000 (Rs/yr.	46.9 (36.0)*	100.2 (60.6)	50.2 (52.9)*	111.9 (100)
Below Poverty Line [a]	0.39 (0.18)*	0.16 (0.09)	0.34 (0.24)*	0.16 (0.10)
Annual Household Income /1000 (Rs/yr.	46.9 (36.0)*	100.2 (60.6)	50.2 (52.9)*	111.9 (100)
Annual hh. Consumption Expenditure /1000 (Rs/yr.)	59.5 (72.6)*	106.1 (110.2)	62.7 (80.1)*	109.4 (120.2)
Food Expenses (Rs/yr.)	18.7 (25.2)*	23.0 (30.1)	20.8 (18.5)*	27.5 (30.0)
Non-food Expenses (Rs/yr.) [b]	13.4 (15.1)*	33.9 (35.4)	16.7 (20.3)*	35.0 (38.6)
Medical Expenses /1000 (Rs/yr.) [c]	0.38 (0.14)*	0.54 (0.27)	0.43 (0.35)*	0.48 (0.56)
Loan from Bank (0/1) [d]	0.50 (0.24)	0.46 (0.41)	0.58 (0.51)	0.58 (0.43)
Number of Loans in the Past 5 Years	1.66 (2.12)	1.41 (1.52)	1.70 (2.04)	1.88 (1.90)
Flush Toilet in the Household (0/1)	0.03 (0.01)*	0.17 (0.09)	0.05 (0.01)*	0.31 (0.20)
Pipe Water in the House (0/1)	0.03 (0.01)*	0.22 (0.14)	0.03 (0.01)*	0.25 (0.14)
Household Owns Any Motor Vehicle (0/1)	0.02 (0.01)*	0.18 (0.12)	0.05 (0.01)*	0.27 (0.15)
Household Owns At Least 1 Cell-Phone (0/1)	0.00 (0.00)*	0.05 (0.02)	0.50 (0.38)*	0.80 (0.66)
Time spent in studies by boys (hours/month)	17.8 (20.3)*	25.6 (32.9)	21.9 (27.4)*	30.3 (34.5)
Time spent in studies by girls (hours/month)	15.2 (12.1)*	23.1 (20.2)	19.9 (15.0)*	28.8 (30.7)
Employment for Men (hours/week)	40.3 (26.0)*	48.5 (32.5)	34.8 (30.2)*	42.7 (29.0)
Employment for Women (hours/week)	13.7 (8.2)*	17.9 (12.1)	11.9 (6.3)*	16.2 (14.4)
Labour Force Participation by Women [e]	0.514 (0.31)	0.473 (0.40)	0.565 (0.30)	0.526 (0.32)

Source: Author's calculations based on IHDS 2005 & 2012.

Notes: Standard deviation in parenthesis. Hh = Household. *: The means of outcome variable of households with and without electricity are statistically different at 5%.

[a]: Defined as the likelihood of a household to be poor, where "poor" is defined using state-wise poverty lines.

[b]: Non-food expenses exclude medical and business-related expenses.

[c]: Refers only to out-patient medical costs. [d]: Defined as whether household borrowed from a bank in the preceding 5 years. [e]: Female labour force participation is calculated as the ratio of working women to total working-age women.

4 Methodology

4.1 First Difference Estimator

We first operationalise a base model for estimating the impact of electrification:

$$Y_{ijt} = \alpha + \beta X_{ijt} + \gamma C_{jt} + \lambda D_{ijt} + \eta(D_{ijt} * E_{ijt}) + \theta_i + \theta_{it} + \epsilon_{ijt} \tag{1}$$

Where i indexes a household, j denotes district, and t time period. Y_{ijt} denotes the outcome variable of interest. The outcome variables of the study are listed in Table 2. X_{ijt} is a vector of all household-level control variables.[3] C_{jt} is a vector of district-level controls.[4] D_{ijt} is a dummy variable denoting electrification status of household i in district j at time t (1

[3]Age, gender, and education of household head, size of household, access to tap water and toilets, ownership of land and non-land assets, maximum schooling of adults aged 18 and above, and home ownership status.

[4]Log of average annual income of households, population density, presence of paved roads, banks, markets, presence of social programs (government employment, adult education, etc.), whether crop-yield is below normal, and prices of alternate fuels).

for electrified, 0 for not). E_{ijt} denotes the average daily hours of electricity received by a household. This represents quality of power supply. θ_{i} and θ_{jt} are household and district-time fixed-effects, while ϵ_{ijt} is the idiosyncratic error term.

While fixed-effects control for heterogeneity from observed household and district characteristics, an OLS estimation of Equation (1) will likely be biased due to endogeneity and simultaneity between D_{ijt}, E_{ijt} and Y_{ijt}. This is due to the non-random nature of grid expansion highlighted in Burlig & Preonas (2016) such that unobserved household-and-district characteristics are correlated with both electricity acquisition and outcome variables.

In this case, assuming household-level unobserved characteristics are time-invariant, the author addresses the problem of endogeneity by differencing Equation (1) to eliminate unobserved time-invariant factors. Since there are only two time-periods (2005 = 0, 2012 = 1), this gives us:

$$Y_{ij1} - Y_{ij0} = (\alpha_1 - \alpha_1) + \beta(X_{ij1} - X_{ij0}) + \gamma(C_{j1} - C_{j0}) + \lambda(D_{ij1} - D_{ij0}) + \eta(D_{ij1} * E_{ij1} - D_{ij0} * E_{ij0}) + (\theta_i - \theta_i) + (\theta_{j1} - \theta_{j0}) + (\varepsilon_{ij1} - \varepsilon_{ij0}) \tag{2a}$$

Or,

$$\Delta Y_{ijt} = \beta\Delta X_{ij} + \gamma\Delta C_j + \lambda\Delta D_{ij} + \eta\Delta(D_{ij} * E_{ij}) + \theta_j + \Delta\varepsilon_i \tag{2b}$$

Where θ_{j} is district fixed-effects. Since time-invariant household fixed-effects are differenced out, Equation (2b) should ideally give unbiased estimates of the welfare from electrification. However, there remain some concerns regarding dynamic effects of electrification. If unobserved time-varying fixed-effects are introduced into Equation (1) and then differenced, we get:

$$\Delta Y_{ijt} = \beta\Delta X_{ij} + \gamma\Delta C_j + \lambda\Delta D_{ij} + \eta\Delta(D_{ij} * E_{ij}) + \Delta\eta_i + \theta_j + \Delta\varepsilon_i \tag{3}$$

Where η_{it} represents the time-varying household effects. As the author finds, time-varying effects are not eliminated by first-differencing, so it is possible that a fixed-effects estimation as in Equation (2b) would be biased.

4.2 Instrumental Variables

As discussed above, fixed-effects differencing depends on the assumption of time-invariance of unobserved factors. This may not hold true in this case. To address this, the author uses an instrumental variable (IV) approach to induce exogenous variation in electricity access and quality. The chosen instrument is "average household electricity-hours of districts in a state, except the district of the i-th household". Using a district-level instrument allows the author to eliminate any potential for reverse causality at the household-level. This is because the mean hours of household electricity of other districts in the state are expected to influence i-th household's access and reliability of power supply, both through proximity to grid as well as through presence of government programs (instrument relevance). However, it is not expected to directly affect outcome variables (exclusion restriction). Outcomes such as household income, consumption, and education depend primarily on occupation, initial wealth, assets, household size, school quality of the district, and possibly household electricity access (Sedai et al. 2020).

The first-stage of the IV approach are estimated using the following equations:

$$\Delta D_{ij} = \beta \Delta X_{ij} + \gamma \Delta C_j + \lambda \Delta Z_{ij} + \theta_j + \Delta \varepsilon_i \tag{4}$$

$$\Delta E_{ij} = \beta \Delta X_{ij} + \gamma \Delta C_j + \lambda \Delta Z_{ij} + \theta_j + \Delta \varepsilon_i \tag{5}$$

Where Z_{ijt} represents the average daily hours of household electricity of all districts in the state except district j of household i at time t. Equation (4) is estimated using a Probit model, while Equation (5) is estimated as a regression model. The predicted values of ΔD_{ij} and ΔE_{ij} from the first stage i.e., ΔD_{ij} and ΔE_{ij}, are then used to estimate Equation (2b):

$$\Delta Y_{ijt} = \beta \Delta X_{ij} + \gamma \Delta C_j + \lambda \Delta \underline{D}_{ij} + \eta \Delta \left(\underline{D}_{ij} * \underline{E}_{ij} \right) + \theta_j + \Delta \varepsilon_i \tag{6}$$

Table 3 shows results from the first-stage IV regression. The Kleibergen-Paap's rk Wald F-statistic measuring weak instruments is also reported, and the author finds that the F-statistic is considerably higher than its critical value of 11 (Staiger and Stock, 1997), meaning that weak instrument is not a problem in the analysis. In both cases, model (1) is run without district fixed-effects, while the model (2) includes it. The effect on both dependent variables reduces once district fixed-effects are introduced. Column (2) of connection status implies that for a one-hour increase in average electricity hours in other districts of the state, the probability of a household being electrified increases by 4.2% on average. On the other panel, Column (2) of quality of supply indicates that for a one-hour increase in average electricity-hours in other districts of the state, the quality of electricity of an electrified household increases on average by 0.699 hours.

Table 3: First-Stage Regression Estimates

	Connection Status		Quality of Supply	
	(1)	(2)	(1)	(2)
(Avg. Electricity Hours Other Districts in State)	0.061^{b}	0.042^{a}	0.858^{a}	0.699^{a}
	(0.017)	(0.019)	(0.219)	(0.187)
Observations	55513	55513	41683	41683
K-P F-stat (weak ident)	42.2	36.6	4.2	5.6

Source: Author's calculations based on IHDS 2005 & 2012.
Notes: Heteroscedasticity robust standard errors in parenthesis. Significance: ^{a}: $p < 0.01$, ^{b}: $p < 0.05$. K-P F-stat is greater than 11 for all specifications, meaning that the instrument is strong. Column (1) excludes district fixed-effects, while Column (2) includes it.

5 By Caste

Academics have documented persistent patterns of caste-based inequality in policy implementation (Dreze and Sen 2013; Bros & Couttenier 2010). While research has shown clear inequities in energy access, less is understood about how social biases differentially affect welfare from energy programs (Aklin et al. 2020). Thus, in this section, the author addresses how ensuing benefits from electrification vary with respect to the caste of the household.[5] For comparison, the author has also included Muslims in the analysis.

5.1 Descriptive Statistics

In Table 4, the author find that Forward Castes (FCs)—the historically privileged castes —recorded the highest percentage of electrified households in both rounds of IHDS (84 % and 94.6% respectively). This was followed by Other Backward Classes (OBCs), Scheduled Castes (SCs), and Muslims. While Scheduled Tribes (STs) recorded the lowest electrification rate in 2005 (54.1%), they also witnessed the fastest increase in electricity access between 2005 and 2012 (by 22.9%). In general, disadvantaged groups witnessed quicker growth in electricity access.[6]

Table 4: Sample Characteristics by Social-Group

Social Group	Year	Percentage Households Electrified	Avg. Quality of Electricity (hrs/day)	Obs.
Scheduled Caste	2005	66.5	14.12	6457
	2012	80.6	12.33	6250
Scheduled Tribe	2005	54.1	13.58	2973
	2012	77.0	13.78	3031
Other Backward Classes	2005	72.8	13.71	10204
	2012	83.0	11.36	9704
Forward Castes	2005	84.0	17.41	5127
	2012	94.6	15.29	5129
Muslims	2005	60.1	13.39	2671
	2012	81.0	11.31	2529

Source: Author's calculations based on IHDS 2005 & 2012.

The story on the intensive margin, however, is far less impressive. All social groups (except STs) registered a decrease in the average quality of electricity between 2005 and 2012. Although FCs witnessed the sharpest decline (by 2.23 hours), they also received the highest average daily hours of electricity in both years (17.4 and 15.2 hours respectively). Marginalised groups (SCs, STs, OBCs, and Muslims) received electricity for about half a day on average. Such large power outages are reflective of the lack of policy focus toward infrastructure development to support the growing electricity demand.

5.2 Split-Sample Estimation and Results

Since the author is concerned with comparing marginal effects, the sample can be split and Equations (2b) and (6) can be separately estimated by social-group. Tables 5 and 6 show estimates of how electricity access and quality affect outcomes by social-groups respectively.

[5]For simplicity, we define "household caste" as the caste of the head of the household. In doing so, we lose some information since differences in the castes of household members may indirectly affect welfare gains by influencing accessibility to resources. However, only about 5 percent of the families in the IHDS dataset are products of inter-caste marriages, so the simplification does not seriously compromise our estimates.

[6]SCs, STs, OBCs, and Muslims are collectively referred to as marginalized/backward groups.

All models include district fixed-effects. As the author finds, there is considerable heterogeneity in marginal welfare among social-groups. While in most cases the results show larger benefits for Forward Castes, there are some notable exceptions.

[Table 5 here][7]

For instance, marginalised groups experienced a greater reduction in fuel usage due to electrification. IV-estimates show that while electricity access decreased monthly kerosene consumption by 0.34 litres for FCs, for marginalised groups, the reduction ranged between 0.42 and 0.56 litres (STs and SCs respectively). The negative effect of electricity access and quality (as shown in Table 6) on bio-fuel collection time was also larger in backward groups. These results are statistically significant at 5-percent level.

Aside from agricultural income, all income and expenditure variables showed larger increases in Forward Castes. Electricity access to village pumps accelerates groundwater extraction which enables irrigation of high-yielding crops (Smith and Urpelainen 2016). This increases agricultural income, and since lower-castes are disproportionately employed in farming (Mosse 2018), this channel of benefits expectedly affects them more. With respect to other monetary variables, FCs, on average, have higher income and better access to village markets (Thorat and Lee 2005). As a result, FCs can more easily buy productivity-enhancing appliances that proportionately increase both income and expenditure.

[Table 6 here]

Both access and quality effects for amenities (flush toilet, cell-phone and motor-vehicle) were positive and largest for FCs. Availability of such amenities are strongly linked with geographical factors (Kemmler 2007). Village-level studies reveal that marginalised groups tend to reside in outlying areas, and despite the availability of power supply, such remotes areas lack the infrastructure to provide these amenities (Sadath and Acharya 2017). However, non-FC groups experienced a greater reduction in the likelihood of being poor.

6 By Income

Next, the author examines how benefits from electricity vary with respect to income and expenditure levels of households. Richer households have significantly better endowments and can thus derive greater benefits from electrification. However, research thus far has remained ambiguous, with studies either producing conflicting results (Samad & Zhang 2016; Khandker et al. 2014), or focussing on specific segments of the income distribution (Bhattacharyya and Das 2017). We contribute to this debate by estimating welfare across various categories of income and expenditure.

6.1 Quantile Regression

Quantile regression is used to estimate the effect of the independent variable on different quantiles of the dependent variable's distribution. For this exercise, the author uses a semi-

[7] Larger tables have been presented together in Section 9 ("Tables") of this paper.

parametric approach to examine quantile treatment effects (QTE) of household electrification on income and expenditure of households. The author follows the method developed in Koenker and Bassett (1978). Following the notation in previous equations, we define our base model as follows:

$$Q_\tau\left(Y_{it} \mid HD_{it}, D_{it}, E_{it}\right) = \alpha_\tau + \beta_\tau HD_{it} + \lambda_\tau D_{it} + \eta_\tau E_{it} + \theta_i + \varepsilon_\tau, \tau\epsilon[0,1] \quad (7)$$

Where $Q_\tau\left(Y_{it} \mid HD_{it}, D_{it}, E_{it}\right)$ denotes the quantile τ of outcome Y_i in time t, conditional on HD_{it}, D_{it} and E_{it}. All outcome variables are mentioned in Table 7. It is a vector of household and district-level controls. The QTE of electrification in a given survey-year is:

$$\lambda_\tau = \Delta_\tau = Q_\tau\left(Y_1\right) - Q_\tau\left(Y_0\right) \quad (8)$$

Where $Q_\tau\left(Y_1\right)$ and $Q_\tau\left(Y_0\right)$ are respective quantiles τ of Y_1 and Y_0, and Y_1 and Y_0 are outcomes with and without electricity. The QTE between the two-periods (2005 and 2012) is:

$$Q_\tau \Delta Y_{it} = \Delta\alpha_\tau + \beta_\tau \Delta HD_i + \lambda_\tau \Delta D_i + \eta_\tau \Delta E_i + \theta_j + \varepsilon_\tau \quad (9)$$

Where θ_j represents district fixed-effects. The author uses AZ the IV implementation of Equation (9) using the "ivqr" package in R. In Table 7, we report aggregate effects of electrification (conditional on electricity quality) by income and expenditure quantiles, and Figure 1 presents them visually.

6.2 Results and Discussion

Figure 1 reveals a U-shaped pattern in the effect of electrification across income groups. For all categories, marginal benefits for the highest and lowest quantiles were high, while middle quantiles (30th and 50th) tended to benefit the least in percentage terms. Households in the 10th quantile of agricultural income, for instance, witnessed a 15.9% increase in their agricultural income due to electrification, while households in 50th and 90th quantiles showed 10.1% and 24.4% increases respectively. Contrary to previous studies, the results show that benefits from electrification favour both the richest and the poorest.

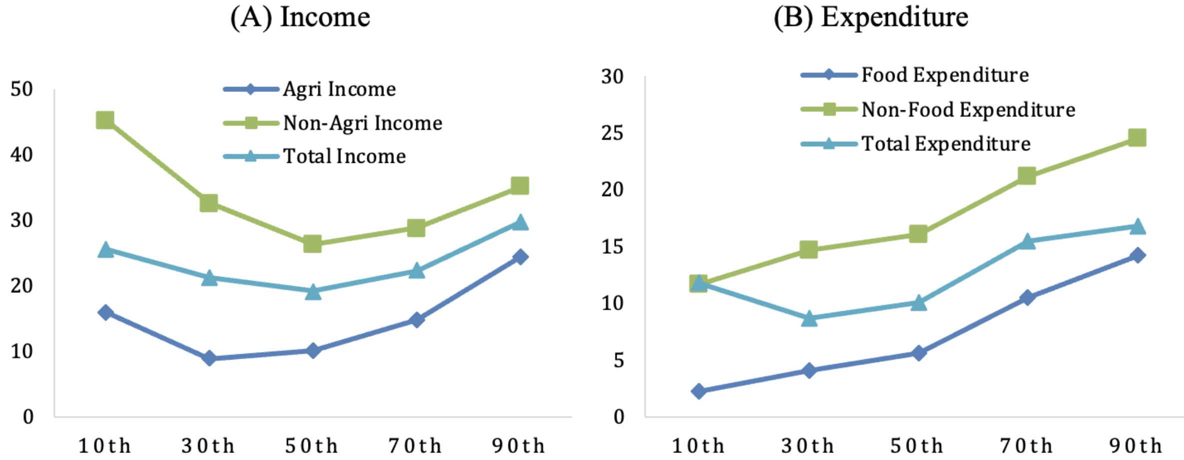
Table 7: Quantile Regression Estimates of Electrification on Income and Expenditure

Quantile (Percentile)	Agri Income	Non-Agri Income	Total Income	Food Expenditure	Non-Food Expenditure	Total Expenditure
10th	0.159 [c]	0.452 [a]	0.255	0.023 [b]	0.117 [c]	0.118 [b]
	(0.001)	(0.014)	(0.102)	(0.002)	(0.001)	(0.019)
30th	0.089 [c]	0.326 [a]	0.212 [b]	0.041 [b]	0.147	0.087 [a]
	(0.002)	(0.017)	(0.089)	(0.005)	(0.004)	(0.009)
50th	0.101 [c]	0.263 [b]	0.192	0.056 [c]	0.161	0.101 [c]
	(0.003)	(0.021)	(0.077)	(0.004)	(0.005)	(0.037)
70th	0.148 [b]	0.288 [b]	0.223 [c]	0.105 [a]	0.212 [a]	0.155 [c]
	(0.012)	(0.032)	(0.067)	(0.002)	(0.032)	(0.072)
90th	0.244 [b]	0.351 [b]	0.297 [c]	0.142 [c]	0.245 [b]	0.168 [c]
	(0.014)	(0.048)	(0.085)	(0.007)	(0.058)	(0.080)

Source: Author's calculations based on IHDS 2005 & 2012.

Notes: Marginal effects are reported. Significance: [a]: $p < 0.01$, [b]: $p < 0.05$, [c]: $p < 0.10$. Standard errors in parentheses are clustered at the district-level. All variables are expressed in log form.

Figure 1: Quantile Regression Estimates of Welfare from Electricity Access



Source: Author's calculations based on IHDS 2005 & 2012
Notes: The figures are created using the coefficients from Table 7. All variables were expressed in log form and have been converted to percentage here.

As Panel (B) of Figure 1 shows, benefits of electrification accrue more to higher expenditure quantiles (though the line for total expenditure is also somewhat U-shaped). Households in the highest quantile (90th) of food expenditure accumulate benefits that are over six times as much as those in the 10th quantile (2.3% compared to 14.2%). Generally, electrification impacts are higher across income than expenditure quantiles. This is not surprising since it is expected that when electrification increases income, households (especially poorer ones) are likely to be more conservative in raising their spending. This is supported by studies in India which show that incomes rise proportionately faster than expenditure following positive productivity shocks (Jayachandran 2006).

The U-shaped pattern seems puzzling at first, but there are several good reasons for it. As discussed earlier, there are many channels through which electrification benefits a household: greater working hours through lighting, productivity enhancing appliances that free time from domestic labour, improved access to opportunities via cell-phones and television, etc. Of course, the rich can exploit these channels to a greater extent which explains why their marginal benefits are high. On the other hand, electrification effects can also be poor-favouring (Samad and Zhang 2016). For poor households in rural India, electricity as well as basic agricultural machinery is fully subsidised (owing to The Electricity Act, 2003), therefore even marginal improvements in productivity via use of electrified equipment can significantly increase their relative income as they do not need to pay electricity bills (Dinkelman 2011).

However, Table 7 suggests that it is electrification's impact on non-agricultural income that is most poor-favouring: The 10th quantile witnessed a 45.2% increase, compared to only 26.3% for the 50th quantile. Since the poor mainly use electricity for lighting, this suggests that the main channel of benefits come from increased working hours. Rathi and Vermaak (2018) showed that household electrification delayed dinner-time by one hour on average (by raising productive hours) while increasing women's income by 20%. In richer households, benefits seem to come from the use of varied appliances that increase productivity. Many commercial appliances are only profitable when power supply is reliable, and since upper quantiles have a higher willingness to pay, they receive more stable connections which help maximise returns to electrification (Bensch et al. 2011). This is supported by the author's findings that electrification's impact on non-food expenditure is highly rich-favouring (24.5% for 90th quantile, compared to only 11.7% for 10th quantile).

In this narrative, middle quantiles seem to be stuck: their incomes are too high to be significantly improved by increased working hours alone, but not high enough to be able to afford the appliances and stable connection that can optimise gains from electrification. This hypothesis is partly supported by Fried and Lagakos (2017) who show that rural electrification in Kenya most significantly raised the marginal products of labour of the lowest-paying occupations (traditional farming) as well that of business owners. Overall, these findings highlight the need for policymakers to address the cost element of reliable connections so that investments into appliances can be profitable for all income groups.

7 Legality of Connection

7.1 Defining an Illegal Connection

Finally, we compare the electrification benefits by legality of the household connection. We identify a household as "illegally" obtaining electricity if they report access to electricity but do not receive or pay bills despite not being covered under government schemes.[8] Households that report paying to neighbours for electricity are also defined as illegal connections. As shown in Table 8, illegal connections accounted for roughly 17% of the electrified households in 2005 and 11% in 2012. Generally, they faced much poorer quality of electricity. In 2012, a legal connection had electricity for 14.5 hours a day on average, compared to 8.64 hours for an illegal connection. As we would expect given their poorer quality of electricity,

Table 8: Sample Characteristic by Legality of Connection

	2005		2012	
	Legal	Illegal	Legal	Illegal
Average Quality of Electricity (hrs/day)	15.86	10.33	14.51	8.64
Observations	10529	2157	16361	2022

Source: Author's calculations based on IHDS 2005 & 2012.

Table 9 shows that illegal connections consumed significantly higher kerosene and spent more time on bio-fuel collection. They were almost thrice as likely to be below the poverty line, and per capita agricultural and non-agricultural income incomes of legal connections were higher for both years. Households with illegal connections had an average annual

[8]The IHDS questionnaire asks separate questions for payment of bills and coverage by energy subsidy programs. We create a dummy variable "Legality of Connection" by combining answers to the aforementioned questions.

consumption expenditure of 51,800 INR, compared to 69,700 INR for legal connections in 2012. With respect to specific categories of expenditure, while annual non-food expenditure was significantly higher in legally connected households (30,300 INR compared to 24,700 INR in 2012), food and medical expenses of the two samples were not statistically different.

Legally connected households are almost twice more likely to borrow from a bank, though interestingly, there is no difference between the total number of loans taken in 5 years between the two samples. With respect to amenities, legally connected households are more likely to have both flush toilets, piped water, and motor vehicle, though the latter is only significant in 2012. Children in illegally connected households study lesser hours. In 2005, a boy in a typical legally connected household studies for 26.9 hours a month compared to 22 hours a month in illegally connected households. Employment hours for both men and women showed a similar trend, though noticeable, female labour force participation showed the opposite pattern: In 2005, 68.6% of working-age females participated in the labour force, compared to only 45.5 per cent in legally connected households.

Table 9: Summary Statistics of Outcomes by Legality of Connection

Variables	2005		2012	
	Legal	Illegal	Legal	Illegal
Kerosene Consumption (litres/month)	2.99 *	3.98	2.2 *	3.45
Time Spent on Bio-Fuel Collection (min/wk.)	98.33 *	140.2	90.8 *	134.6
Per Capita Agri Income /1000 (Rs/yr.)	8.05 *	4.45	10.7 *	6.26
Per Capita Non-Agricultural Wage /1000 (Rs/yr.)	8.26 *	6.80	11.33 *	9.87
Annual Household Income /1000 (Rs/yr.)	103.9 *	90.4	114.9 *	93.5
Below Poverty Line	0.12 *	0.36	0.13 *	0.32
Annual hh. Consumption Expenditure /1000 (Rs/yr.)	113.5 *	87.5	117 *	89.98
Food Expenses (Rs/yr.)	23.7	22.9	28.2	27.6
Non-food Expenses (Rs/yr.)	37.2 *	20.2	40.3 *	24.7
Medical Expenses /1000 (Rs/yr.)	0.56	0.49	0.50	0.46
Loan from Bank (0/1)	0.55 *	0.27	0.63 *	0.29
Number of Loans in the Past 5 Years	1.43	1.30	1.94	1.77
Flush Toilet in the Household (0/1)	0.21 *	0.09	0.32	0.27
Pipe Water in the House (0/1)	0.22	0.22	0.25	0.24
Household Owns Any Motor Vehicle (0/1)	0.20	0.16	0.28	0.25
Household Owns At Least 1 Cell-Phone (0/1)	0.05	0.03	0.85 *	0.58
Time spent in studies by boys (hours/month)	26.9 *	22.0	33.7 *	23.1
Time spent in studies by girls (hours/month)	23.8 *	22.9	29 *	26.9
Employment for Men (hours/week)	49.3 *	46.1	43.8 *	40.3
Employment for Women (hours/week)	19.2 *	15.5	18 *	13.6
Labour Force Participation by Women	0.455 *	0.686	0.501 *	0.740

Source: Author's calculations based on IHDS 2005 & 2012.
Notes: Standard deviation in parentheses. *: The means of outcome variable of households with and without electricity are statistically different at 5%.

7.2 Results

Table 10 presents the estimates of Equations (2b) and (6) by legality of connection. Here we focus on the effect of an additional hour of electricity supply. In general, instrumental variable estimates reveal larger effects than the simple first-difference model, implying a more significant causal relationship once unobserved heterogeneity is accounted for.

Several counterintuitive patterns emerge here. The author finds that marginal improvements in quality of electricity reduced fuel consumption by a greater extent in households with illegal connections. An additional hour of electricity reduced kerosene consumption by 0.186 litres a month for legally connected households, compared to 0.213 litres for illegal connections. This may reflect a degree of self-selection. Households that obtain illegal connections are often poorer, and farther away from markets where bio-fuel is available (Sadath and Acharya 2017). Whereas legally connected households usually have access to alternative sources such as LPG, illegally connected households are more dependent on kerosene and bio-fuel for all activities, therefore additional electricity proportionately reduces use of non-renewables by a greater margin for these households as they are more dependent on it to begin with.

Table 10: Effect of Electricity Hours on Outcomes by Legality of Connection

Variables	Legal		Illegal	
	FD	FD-IV	FD	FD-IV
Kerosene Consumption (litres/month)	-0.084 ^{a}(0.004)	-0.186 ^{a} (0.004)	-0.085 ^{a} (0.021)	-0.213 ^{a} (0.042)
Time Spent on Bio-Fuel Collection (min/wk.)	-9.23 ^{b} (1.063)	-10.41 ^{a} (1.423)	-14.24 ^{b} (3.6)	-12.85 ^{c} (2.74)
Log Per Capita Agri Income (Rs/yr.)	0.028 ^{b} (0.012)	0.031 ^{a} (0.013)	0.012 ^{b} (0.016)	0.015 ^{b} (0.005)
Log Per Capita Non-Agricultural Wage (Rs/yr.)	0.042 ^{a} (0.005)	0.053 ^{c} (0.005)	0.037 ^{a} (0.007)	0.038 ^{c} (0.002)
Log Annual Household Income (Rs/yr.)	0.011 ^{b} (0.008)	0.026 ^{b} (0.002)	0.010 ^{b} (0.010)	0.009 ^{b} (0.010)
Below Poverty Line	0.014 ^{c} (0.012)	0.019 ^{c} (0.007)	0.032 ^{c} (0.008)	0.025 ^{c} (0.007)
Log Annual hh. Consumption Expenditure (Rs/yr.)	0.007 ^{b} (0.066)	0.008 ^{b} (0.065)	0.004 ^{c} (0.074)	0.006 ^{c} (0.035)
Log Food Expenditure (Rs/yr.)	0.012 ^{a} (0.004)	0.011 ^{a} (0.005)	0.008 ^{b} (0.006)	0.008 ^{c} (0.005)
Log Non-food Expenses (Rs/yr.)	0.018 ^{a} (0.063)	0.024 ^{b} (0.032)	0.015 ^{b} (0.118)	0.017 ^{c} (0.043)
Log Medical Expenses (Rs/yr.)	0.002 ^{c} (0.011)	-0.005 ^{c} (0.014)	-0.008 (0.035)	-0.01 ^{b} (0.034)
Loan from Bank (0/1)	0.000 (0.012)	0.002 (0.012)	0.000 (0.013)	0.001 (0.021)
Number of Loans in the Past 5 Years	0.142 ^{a} (0.025)	0.097 (0.025)	0.086 (0.028)	0.128 (0.029)
Flush Toilet in the Household (0/1)	0.004 (0.05)	0.005 ^{c} (0.043)	0.002 ^{c} (0.029)	0.003 ^{c} (0.030)
Pipe Water in the House (0/1)	0.000 (0.001)	0.002 (0.001)	0.008 (0.001)	0.008 (0.001)
Household Owns Any Motor Vehicle (0/1)	0.001 (0.019)	0.001 (0.002)	0.002 (0.005)	0.002 (0.005)
Household Owns At Least 1 Cell-Phone (0/1)	0.012 ^{c} (0.028)	0.010 ^{b} (0.025)	0.003 ^{c} (0.005)	0.005 ^{c} (0.007)
Time spent in studies by boys (hours/month)	0.279 ^{c} (0.028)	0.282 ^{c} (0.025)	0.221 ^{c} (0.005)	0.343 ^{c} (0.007)
Time spent in studies by girls (hours/month)	0.42 ^{a} (0.059)	0.441 ^{a} (0.039)	0.287 ^{a} (0.043)	0.33 ^{a} (0.097)
Log Employment for Men (hours/week)	0.010 ^{b} (0.002)	0.009 ^{b} (0.004)	0.014 ^{c} (0.003)	0.014 ^{c} (0.007)
Log Employment for Women (hours/week)	0.019 ^{c} (0.009)	0.026 ^{c} (0.005)	0.023 ^{b} (0.009)	0.033 ^{b} (0.003)
Labour Force Participation by Women	0.007 (0.004)	0.009 (0.014)	0.003 (0.012)	0.006 (0.008)
District Fixed-Effects	Yes	Yes	Yes	Yes
Observations	26891	26891	4179	4179

Source: Author's calculations based on IHDS 2005 & 2012.
Notes: Significance: ^{a}: $p < 0.01$, ^{b}: $p < 0.05$, ^{c}: $p < 0.10$. All outcome variables are differenced. Standard errors in parentheses are clustered at the district-level. Information regarding control and instrumental variables will be found in Section (4a) and (4b) respectively.

Almost all income and expenditure variables show greater proportionate increase in legally connected households. For instance, an additional hour of electricity raises agricultural income by 3% for legally connected households, while by only 1.5 percent for illegally connected households. However, medical expenses showed an opposite trend. While an additional hour of electricity reduces medical expenditure by only 0.5% for legally connected households, illegally connected households witness a 1% reduction, i.e., double the effect. Illegally connected households also had a greater likelihood of escaping poverty (marginal effect of 2.5%, compared to 1.9%). This may once again reflect some self-selection: Households are sufficiently motivated to obtain an illegal again (despite the greater risk) only when they know they will benefit significantly from it (Aklin et al. 2020). Similar to the caste results, while electricity quality did not impact likelihood of borrowing from a bank, it increases total number of loans by a greater margin in illegally connected households, though the effects were small. An additional hour increased number of loans by 0.128 for illegal connections, compared to 0.09 for its counterpart.

Results for amenities were inconclusive. The instrumental variable estimates of the likelihood of having piped water, flush water, and motor-vehicle were statistically insignificant, even at 10%. The effect of electricity hours is generally greater for legally connected households with respect to both educational and labour-market variables, and benefits greater more to women than men. An additional hour of electricity, for instance, increased women's hours worked by 3.3%, compared to 1.4% for men in illegally connected households. This is consistent with the aforementioned idea that electricity benefits women more as they bear the brunt of household work (Kohlin et al 2011). Finally, female labour force participation was also not significantly affected by electricity quality.

8 Conclusion and Policy Recommendations

Provision of electricity is considered a central aspect of rural development. In this paper, the author examined how benefits from rural electrification varied with respect to the social-group and income of the household. To do so, the author used instrumental variables techniques on household data from 2005 to 2012. Similar to Chakravorty (2014), the author found that instrumental variable estimates generally revealed larger benefits than the simple first-difference model, meaning that the causal impact of electrification is greater after controlling for unobserved heterogeneity.

The author documents heterogeneity in several dimensions of welfare, and find that generally, electrification is associated with significant benefits across all income and social-group categories. Marginalised groups benefited more through reductions in fuel usage, increased agricultural income and hours of study-time and work for women, and in the likelihood of escaping poverty. On the other hand, dominant groups saw larger marginal benefits in most income and expenditure categories, male study-time and work-hours, as well as the likelihood of having amenities in the household. Quantile regression estimates of welfare with respect to income and expenditure revealed a U-shaped pattern. The poorest and richest tended to benefit more than middle-income groups. Finally, illegal connections not only experienced longer outages, but also lesser marginal benefits in most dimensions of welfare.

Welfare from electricity access tended to vary more than from quality of supply, meaning that improving the reliability of connections can be effective in mitigating the unequal effects of electrification. Frequent power outages and voltage fluctuations in non-dominant households prevent investment into appliances that maximise returns to electrification. However, from a policy-perspective, while efforts should be made to make electricity cheap, subsidies should not fully cover its cost. As Burgess et al. (2020) shows, treating electricity as a right results in inefficient power use and lower bill payments, which then prevents expansion of reliable connections.

To improve last-mile connectivity, state governments can also deploy renewable energy-based solutions. In fact, the price of LED lights and lithium-ion batteries (main components of solar home-systems) have reduced by over 70% in the last ten years, much faster than the price of electricity (IRENA 2019). This paper highlights the need to evaluate electrification projects across multiple dimensions, not just along the extensive margin. Indeed, national governments would benefit from adopting multi-faceted evaluation indices such as the Global Tracking Framework (GTF) launched by the World Bank and the United Nations under the Sustainable Energy for All (SE4ALL) program. Finally, since this study focusses on household benefits, the author is unable to understand how rural electrification affects structural transformation and migration patterns. In the longer-term, these may be the channels through which the full effect of electrification is realised.

A. Tables

Table 5: Impact of Access to Electricity on Outcomes by Social Group

Variables	Forward Castes		Scheduled Castes		Scheduled Tribes		OBCs		Muslims	
	FD	FD-IV	FD	FD-IV	FD	FD-IV	FD	FD-IV	FD	FD-IV
Kerosene Consumption (litres/month)	-0.145[a] (0.002)	-0.344[a] (0.005)	-0.397[c] (0.032)	-0.562[a] (0.035)	-0.232[a] (0.022)	-0.422[a] (0.025)	-0.552[b] (0.002)	-0.449[a] (0.006)	-0.333[b] (0.022)	-0.541[a] (0.025)
Time Spent on Bio-Fuel Collection (min/wk.)	-38.2[c] (1.244)	-40.6[b] (1.155)	-52.346[a] (1.341)	-61.526[b] (1.421)	-32.0 (0.957)	-41.5[c] (1.015)	-45.3[c] (1.121)	-54.2[b] (1.241)	-58.3[c] (1.253)	-51.8[b] (1.279)
Log Per Capita Agri Income (Rs/yr.)	0.088[a] (0.025)	0.100[c] (0.024)	0.189[a] (0.041)	0.191[c] (0.083)	0.201[a] (0.029)	0.212 (0.059)	0.101[a] (0.045)	0.144[a] (0.074)	0.257[a] (0.025)	0.163[c] (0.026)
Log Per Capita Non-Agricultural Wage (Rs/yr.)	0.372 (0.027)	0.431[a] (0.028)	0.233 (0.012)	0.258[b] (0.012)	0.20[c] (0.01)	0.223[a] (0.01)	0.384[a] (0.014)	0.289[a] (0.012)	0.301[a] (0.019)	0.298[a] (0.02)
Log Annual Household Income (Rs/yr.)	0.2805[a] (0.052)	0.311[a] (0.068)	0.167 (0.058)	0.191[b] (0.059)	0.144[a] (0.058)	0.1615 (0.059)	0.3205[b] (0.036)	0.226[b] (0.036)	0.251[a] (0.037)	0.255 (0.048)
Below Poverty Line	-0.062 (0.001)	-0.058[a] (0.001)	-0.078[b] (0.006)	-0.099[a] (0.006)	-0.087 (0.006)	-0.102[a] (0.006)	-0.114[b] (0.003)	-0.124[a] (0.003)	-0.152[b] (0.004)	-0.135[c] (0.003)
Log Annual hh. Consumption Expenditure (Rs/yr.)	0.162[a] (0.025)	0.181[b] (0.027)	0.142 (0.028)	0.169[a] (0.031)	0.121 (0.028)	0.101[a] (0.031)	0.125[b] (0.017)	0.107 (0.019)	0.12 (0.017)	0.124[a] (0.019)
Log Food Expenses (Rs/yr.)	0.026[b] (0.002)	0.042 (0.002)	0.052 (0.002)	0.088 (0.002)	0.078 (0.002)	0.089 (0.002)	0.01[c] (0.001)	0.021 (0.001)	0.091 (0.001)	0.151 (0.001)
Log Non-food Expenses (Rs/yr.)	0.31 (0.144)	0.329[a] (0.158)	0.233 (0.147)	0.254[a] (0.148)	0.577[b] (0.147)	0.399[a] (0.148)	0.292[a] (0.091)	0.401 (0.092)	0.111 (0.102)	0.246[a] (0.112)
Log Medical Expenses (Rs/yr.)	0.012 (0.003)	-0.027 (0.004)	0.013[b] (0.003)	0.014 (0.004)	-0.014 (0.003)	-0.012 (0.004)	-0.019 (0.001)	-0.028 (0.002)	-0.015 (0.002)	0.018[c] (0.002)
Loan from Bank (0/1)	0.000 (0.000)	0.01 (0.002)	0.000 (0.000)	0.02 (0.002)	0.02 (0.000)	0.02 (0.002)	0.01 (0.000)	0.01 (0.001)	0.03 (0.000)	0.01 (0.001)
Number of Loans in the Past 5 Years	0.519[b] (0.031)	0.622[a] (0.038)	0.671[a] (0.023)	0.388[a] (0.018)	0.54[a] (0.031)	0.651[b] (0.038)	0.344 (0.019)	0.495[a] (0.023)	0.841[a] (0.016)	0.461[a] (0.012)
Flush Toilet in the Household (0/1)	0.043[b] (0.002)	0.068[b] (0.002)	0.011[b] (0.002)	0.052[b] (0.002)	0.038 (0.002)	0.084[b] (0.002)	0.066 (0.001)	0.074[b] (0.001)	0.089[b] (0.001)	0.078 (0.001)
Pipe Water in the House (0/1)	0.023 (0.004)	0.044 (0.005)	0.023 (0.002)	0.012 (0.003)	0.041 (0.003)	0.067 (0.004)	0.089 (0.003)	0.063 (0.002)	0.101 (0.000)	0.072 (0.000)
Household Owns Any Motor Vehicle (0/1)	0.012[a] (0.001)	0.023[b] (0.001)	0.034[b] (0.002)	0.021[a] (0.001)	0.03 (0.002)	0.021[a] (0.001)	0.03[b] (0.001)	0.031 (0.000)	0.016[a] (0.000)	0.012[a] (0.000)
Household Owns At Least 1 Cell-Phone (0/1)	0.082[a] (0.041)	0.054[a] (0.045)	0.035[c] (0.044)	0.026[b] (0.031)	0.024[a] (0.044)	0.045[a] (0.031)	0.033[b] (0.027)	0.031[a] (0.019)	0.081[a] (0.029)	0.019[a] (0.032)
Time spent in studies by boys (hours/month)	4.047[b] (0.023)	4.815[b] (0.029)	3.03[a] (0.023)	2.81[c] (0.271)	6.95[a] (0.123)	3.88[c] (0.179)	7.22[b] (0.076)	4.20[a] (0.111)	6.17[a] (0.016)	2.04[a] (0.020)
Time spent in studies by girls (hours/month)	3.01 (0.127)	2.99[a] (0.116)	4.21 (0.123)	3.87[a] (0.096)	5.28[a] (0.123)	4.02 (0.096)	3.77 (0.077)	5.55 (0.060)	2.38[a] (0.09)	1.65[a] (0.083)
Log Employment for Men (hours/week)	0.108[a] (0.002)	0.069[a] (0.001)	0.078[c] (0.002)	0.111[c] (0.001)	0.146[c] (0.002)	0.096[a] (0.001)	0.167[a] (0.001)	0.177[c] (0.000)	0.202[c] (0.001)	0.066 (0.000)
Log Employment for Women (hours/week)	0.134[a] (0.021)	0.233[c] (0.031)	0.355[a] (0.021)	0.382[a] (0.031)	0.562[a] (0.021)	0.455[a] (0.031)	0.231[a] (0.013)	0.308[b] (0.019)	0.084 (0.015)	0.093[a] (0.022)

Labour Force Participation by Women	0.027 (0.001)	0.015 (0.002)	0.052 (0.001)	0.067 (0.002)	0.08 (0.001)	0.092 (0.002)	0.023 (0.002)	0.068 (0.001)	0.023 (0.003)	0.011 [c] (0.001)
District Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10133	10133	12032	12032	5481	5481	18674	18674	4998	4998

Source: Author's calculation based on IHDS 2005 & 2012.

Notes: Significance: [a]: $p < 0.01$, [b]: $p < 0.05$, [c]: $p < 0.10$. All outcome variables are differenced. Standard errors in parentheses are clustered at the district-level. FD = First Difference estimates. FD-IV: First Difference estimate with Instrumental Variables. OBC = Other Backward Classes. Information regarding control and instrumental variables will be found in Section (4a) and (4b) respectively.

Table 6: Impact of Quality of Electricity on Outcomes by Social Group

Variables	Forward Castes		Scheduled Castes		Scheduled Tribes		OBCs		Muslims	
	FD	FD-IV	FD	FD-IV	FD	FD-IV	FD	FD-IV	FD	FD-IV
Kerosene Consumption (litres/month)	-0.052[a] (0.104)	-0.093[a] (0.094)	-0.128[a] (0.352)	-0.208[a] (0.582)	-0.241[b] (0.107)	-0.154[a] (0.025)	-0.842[b] (0.124)	-0.128[a] (0.094)	-0.152[a] (0.284)	-0.177[a] (0.118)
Time Spent on Bio-Fuel Collection (min/wk.)	-9.34 (0.325)	-10.25[a] (0.925)	-1.58[a] (0.645)	-11.28[a] (0.657)	-7.41[b] (0.759)	-14.66[a] (0.719)	-18.95[a] (0.726)	-10.39[a] (0.76)	-15.5[a] (0.761)	-8.35[c] (0.779)
Log of Per Capita Agri Income (Rs/yr.)	0.072[b] (0.004)	0.045[b] (0.005)	0.026[b] (0.002)	0.037[c] (0.019)	0.038[a] (0.003)	0.024[a] (0.074)	0.003[b] (0.030)	0.011[a] (0.008)	-0.22[c] (0.017)	0.041[a] (0.005)
Log of Per Capita Non-Agricultural Wage (Rs/yr.)	0.037[b] (0.344)	0.068[a] (0.295)	0.004 (0.085)	0.043[a] (0.059)	0.003[b] (0.058)	0.003[c] (0.059)	0.452[a] (0.037)	0.034[b] (0.046)	0.026[b] (0.021)	0.008[c] (0.052)
Log of Annual Household Income (Rs/yr.)	0.017[a] (0.689)	0.03[a] (0.481)	0.063[b] (0.582)	0.028[b] (0.584)	0.025[a] (0.549)	0.029[a] (0.571)	0.001[b] (0.568)	0.02[a] (0.562)	0.052[a] (0.567)	0.025[a] (0.566)
Below Poverty Line	-0.012[a] (0.004)	-0.013[b] (0.004)	-0.011[b] (0.075)	-0.02[a] (0.031)	-0.017[a] (0.028)	-0.023[a] (0.031)	-0.049[a] (0.111)	-0.024[a] (0.055)	-0.006[c] (0.045)	-0.018[c] (0.5)
Log of Annual hh. Consumption Expenditure (Rs/yr.)	0.009[a] (0.045)	0.016[a] (0.094)	0.019[c] (0.015)	0.004[c] (0.002)	0.007[c] (0.002)	0.013[c] (0.002)	0.259[a] (0.06)	0.015[c] (0.055)	0.158[a] (0.078)	0.008[a] (0.058)
Log of Food Expenses (Rs/yr.)	0.011 (0.753)	0.008 (0.851)	0.001 (0.582)	0.008 (0.24)	0.001 (0.663)	0.005 (0.475)	0.000[c] (0.241)	0.007 (0.441)	0.002 (0.754)	0.002 (0.597)
Log of Non-food Expenses (Rs/yr.)	0.014[a] (0.044)	0.019[a] (0.075)	0.04[c] (0.073)	0.014[a] (0.058)	0.004[a] (0.084)	0.007[a] (0.048)	0.005[b] (0.019)	0.005[c] (0.054)	0.2[b] (0.084)	0.015[c] (0.077)
Log of Medical Expenses (Rs/yr.)	-0.235 (0.083)	-0.005 (0.099)	0.002 (0.084)	0.007 (0.077)	0.017[c] (0.079)	0.006[c] (0.043)	0.004 (0.021)	0.012 (0.038)	-0.089 (0.079)	-0.017 (0.027)
Loan from Bank (0/1)	0.025[a] (0.002)	0.004[a] (0.001)	0.001[b] (0.039)	0.001[a] (0.143)	0.021[b] (0.006)	0.002[a] (0.014)	-0.013[a] (0.019)	0.000[a] (0.022)	0.001[c] (0.018)	0.001[a] (0.02)
Number of Loans in the Past 5 Years	0.006 (0.001)	0.067[a] (0.017)	0.268[a] (0.102)	0.119[a] (0.026)	0.039[a] (0.005)	0.088[b] (0.004)	0.332[b] (0.009)	0.072[a] (0.006)	0.004[b] (0.028)	0.129[a] (0.039)
Flush Toilet in the Household (0/1)	0.015 (0.002)	0.009 (0.021)	0.035 (0.089)	0.012 (0.03)	0.002 (0.004)	0.004 (0.005)	-0.004 (0.037)	0.047 (0.015)	0.029 (0.053)	0.053 (0.054)
Pipe Water in the House (0/1)	0.005[a] (0.003)	0.004[a] (0.032)	0.000[b] (0.077)	0.003[b] (0.043)	0.018[b] (0.002)	0.003[b] (0.032)	0.000[b] (0.072)	0.000[b] (0.035)	0.001[b] (0.088)	0.001[c] (0.057)
Household Owns Any Motor Vehicle (0/1)	0.001 (0.012)	0.002[a] (0.048)	0.000[b] (0.067)	0.001[b] (0.053)	0.000[c] (0.007)	0.001[b] (0.058)	0.023[b] (0.08)	0.001[c] (0.048)	0.002[b] (0.061)	0.002[b] (0.072)
Household Owns At Least 1 Cell-Phone (0/1)	0.005[c] (0.014)	0.037[a] (0.004)	0.000[a] (0.085)	0.02[b] (0.205)	0.352[a] (0.053)	0.016[a] (0.013)	0.038[a] (0.059)	0.049[a] (0.11)	0.031[b] (0.098)	0.057[b] (0.074)
Time spent in studies by boys (hours/month)	0.264 (0.042)	0.573 (0.005)	0.073 (0.038)	0.239 (0.041)	0.193 (0.245)	0.382 (0.074)	0.173 (0.044)	0.284 (0.432)	0.405 (0.016)	0.475 (0.02)
Time spent in studies by girls (hours/month)	0.167[c] (0.158)	0.229[a] (0.325)	0.451[a] (0.428)	0.384[b] (0.827)	1.336[c] (0.083)	0.405[a] (0.629)	1.06[b] (0.084)	0.571[b] (0.888)	0.217[b] (0.09)	0.219[b] (0.083)
Log Employment for Men (hours/week)	0.006[b] (0.059)	0.012[b] (0.055)	0.002[c] (0.018)	0.002[c] (0.088)	0.253[a] (0.032)	0.094[b] (0.072)	0.04[b] (0.05)	0.012[b] (0.002)	0.049[b] (0.001)	0.014[b] (0.000)
Log Employment for Women (hours/week)	0.004[a] (0.093)	0.021[a] (0.72)	0.03[b] (0.042)	0.038[a] (0.004)	0.138[b] (0.006)	0.031[c] (0.005)	0.026[c] (0.031)	0.035[c] (0.028)	0.003[b] (0.015)	0.001[a] (0.022)
Labour Force Participation by Women	0.001 (0.017)	0.002 (0.002)	0.001 (0.001)	0.001 (0.014)	0.000[c] (0.04)	0.001[a] (0.044)	0.002 (0.074)	0.004 (0.049)	-0.001[c] (0.000)	-0.006[a] (0.001)
District Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Observations	8917	8917	8783	8783	3617	3617	14565	14565	3498	3498

Source: Author's calculation based on IHDS 2005 & 2012.

Notes: Significance: a: $p < 0.01$, b: $p < 0.05$, c: $p < 0.10$. All outcome variables are differenced. Standard errors in parentheses are clustered at the district-level. Independent variable "Quality of Electricity" is defined as "Average number of hours of electricity a household receives daily" and is a continuous variable ranging from 0 to 24.
FD = First Difference estimates. FD-IV: First Difference estimate with Instrumental Variables. OBC: Other Backward Classes. Information regarding control and instrumental variables will be found in Section (4a) and (4b) respectively.

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