

THE DIFFERENTIAL ECONOMIC BENEFITS OF RURAL ELECTRIFICATION IN INDIA: QUANTILE REGRESSION ESTIMATION

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Abstract: Rural electrification not only provides affordable modern energy to rural households at a cheaper price but also improves the quality of life and economic development of the rural sector. The welfare gains of electricity are not the same across households. This paper tries to understand who benefits the most from rural electrification - the poor or the rich rural households. The differential effects of rural electrification on household income and expenditures on health and children's education are estimated using the 2011-2012 IHDS-II survey data applying the quantile regression method. The estimated results show that household electrification increases both household income and expenditure. The higher-income rural households benefit more than the lower-income households from rural electrification. The upper-income rural households gain more in terms of the education of children relative to poor-income households from rural electrification. Rural electrification benefits are higher for median health expenditure households than either for lower or upper quantile households. The larger benefits from rural electrification accrue to the better-off rural households through higher consumption and use of electricity for many productive uses and electrification benefits accrue from multiple channels.

Introduction

Energy is essential for basic human needs and economic activity. Among the sources of energy, electricity remains the chief form. Apart from the conventional energy sources like hydro and thermal electricity, solar as well as wind energy sources are increasingly used

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all over the world. Providing electricity to all households is one of the avowed objectives of any government around the world as it brings a host of economic and social benefits to the public. However, as of 2017, over 1 billion people worldwide i.e.14 per cent of the global population lack household electric power, mostly in rural and remote areas. India is home to a third of the world's population without access to electricity. Electrification typically begins in cities and towns and gradually extends to rural areas which run into roadblocks rural areas. In many countries, communities to be connected to the power grid are identified on a "least cost" basis, which favours larger communities nearer to the existing grid, roads and towns. This World Bank-promoted approach is often necessary to secure the financial viability of the rural electrification programme.

Providing electricity to rural and remote area households is a challenging task. The high cost of providing electricity in rural areas with a thin population, low consumption, and remote places with difficult terrain makes greater electricity losses and expensive customer support and equipment maintenance making it costly to implement rural electrification. Expanding the national grid is expensive and the lack of capital to grow infrastructure is prohibitive. Though rural electrification is significant, it does not solve the energy access to people because electricity constitutes only a minimal component of the energy mix of the poor in rural areas. Though for long many studies ascertain a positive causal impact of large-scale rural electrification on economic development, in recent years few studies show a substantially smaller impact of rural electrification by disentangling the impact of electricity access from general economic growth (Burlig and Preonas, 2021).

India has achieved providing electrification to all of its 597,464 census villages by 2018. In India, a village is deemed to be electrified, if 10 per cent of all the households of the village have access to electricity and if electricity is provided to all public spaces such as schools, panchayat offices, health centres, community centres and health centres in the village. However, only 91 per cent of households in India are electrified and only about 60 per cent of rural households are connected. Moreover, rural electrification is not uniform and last-mile connectivity is not still achieved. The National Sample Survey and Census figures show that in India nearly 90 per cent of rural households and about 30 per cent of urban households use traditional energies for cooking. While urban households enjoy growth in electricity consumption and capacity, rural households face frequent power disruption and long durations of electricity outages. Frequent power cuts have become a norm for rural households in India. Rural communities suffer from market failures as the national power grids fall short of their demand for electricity.

Rural electrification not only provides affordable modern energy at a cheaper price but also improves rural people's quality of life and is a catalyst to spur growth on a range of socioeconomic fronts. Apart from providing lighting and power to household appliances,

access to electricity would make households better off and increase productivity in rural activities. Rural electrification provides power to agricultural irrigation pump sets and rural industries. Rural electrification also confers health, education and environmental benefits to rural households. The health benefits from rural electrification accrue through several channels like improved access and provision of health facilities/hospitals, cleaner indoor and outdoor air as households reduce the use of polluting fuels for cooking, improved healthcare awareness through increased access to television and better nutrition from improved knowledge and storage facilities in many household appliances like refrigerator. Electrification also enables women to free time from fuel collection and cooking to spend time in other ways like reading watching TV, childcare, home business, greater participation in community activities and socialising.

Electrification also influences education both by improving school and teaching quality and increasing the study time of pupils at the home, which ultimately results in higher earnings. Educational attainment and higher future earnings. Khandker *et al.* (2014) report that household access to electricity increases school enrollment by about 6 per cent for boys and 7.4 per cent for girls, and employment hours by more than 17 per cent for women and by 1.5 per cent for men. Thus, rural electrification increases the labour supply of men and women, schooling of boys and girls, household income and expenditure and helps in reducing poverty. An examination of 50 impact evaluation studies on the effects of access to electricity finds substantial welfare gains, especially for women and small firms. On average, electrification is associated with an improvement of around 7 per cent in school enrollment, 25 per cent in employment and 30 per cent in income (Jimenez, 2017).

An independent evaluation of many rural electrification schemes around the world shows that the benefits of rural electrification span a wide range and rates of returns on rural electrification are sufficient to warrant the investment (World Bank, 2008). In India, access to electricity increases household per capita income by nearly 38.6 per cent and the increase in electricity consumption raises income by 0.6 per cent (Khandker *et al.* 2014). The summarised benefits of rural electrification are the income benefits through new work opportunities, especially in nonfarm activities, leisure and domestic benefits from lighting and TV/radio, time savings from household chores which can be used for leisure and productive activities, education benefits through higher earnings for children living in electrified households that have higher educational attainment, increased productivity of home business through higher revenues of existing businesses and the creation of new home business, increased agricultural productivity through higher revenues, improved health outcomes and reduced mortality through improved indoor air quality from changes in lighting source, reduced fertility at lower costs, achieved through information channels

that use electricity instead of reproductive health programs, public goods benefits, such as increased security and lower environmental contamination.

The effect of rural electrification on rural household welfare that operates through various ways on income is presented schematically in Figure 1. The figure reveals that rural electrification increases access to grid connections and off-grid options available to the rural households such as changes in the pattern of energy use, coping costs, indoor pollution, information sources like radio, television and mobile phones, health, education, labour supply, time allocation to market and non-market activities, and complementarities through the interaction effect. These changes promote the livelihood of rural households by promoting productivity, income and consumption, and reducing poverty in rural areas. According to Khandker et al (2014), an one-hour increase in the village level availability of increases the rate of household adoption by 2.7 per cent and electricity consumption by 14.4 per cent. This shows the enormous potential for consumption gains from a modest improvement in rural electricity service.

Though rural electrification provides opportunities for welfare gains to all rural households, an understanding of electrification benefits on the basis of the average impact of access and consumption of electricity is incomplete. The average effect does not reveal anything about how rural electrification affects the various segments of the rural population, especially those who gain the most from electricity provision is not clear. All rural households

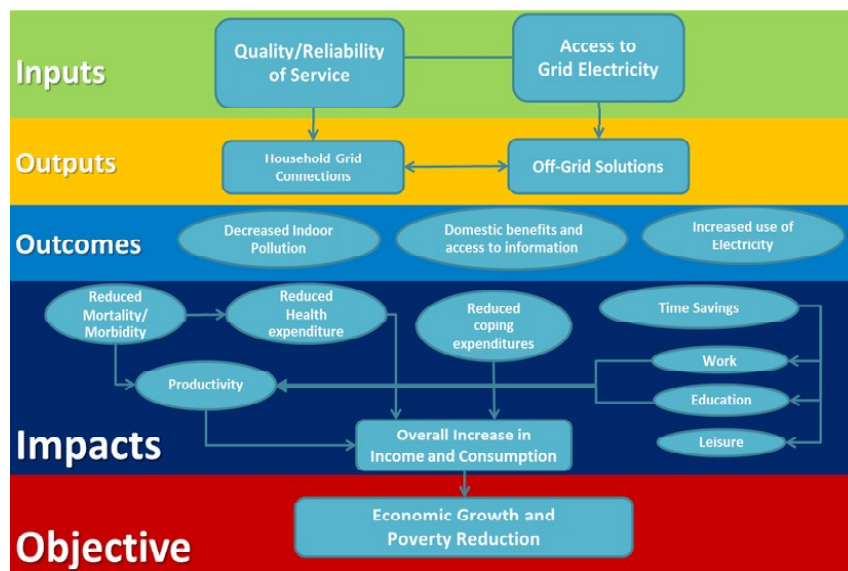


Figure 1: Impact Pathways of Rural Electrification on Household Welfare

Source: Torero (2015).

do not derive the same gains from the use of electricity. The rural electrification benefits accrue differently for different households. As the poor have only limited use of electricity, the larger share of benefits from rural electrification may accrue to wealthier rural households. The productive use of electricity is highly dependent on a household's physical and human capital endowments. The rich and well-informed households may put into use the electricity in diversified use than the poor and unformed households and hence may reap greater benefits from electricity consumption.

To ascertain the differential effects of household electrification, this study examines how electrification benefits are distributed across different segments of rural households. To assess heterogeneity in welfare gains of electricity, this study analyses the effect of electricity on a range of household outcomes at different points of the distribution of the outcomes. The outcomes considered are household expenditures on consumption, education and health, probably the outcomes potentially affected immediately after electrification. The main objective of this study is to understand who benefits the most, the poor or the rich rural households, from rural electrification. The focus is on whether the electrification benefits accrued to richer households vary from those accrued to poorer ones in terms of income and expenditure impacts. To estimate the differential effects of electricity on the household welfare outcomes at different points of their conditional distribution, this study follows the quantile regression method. The quantile regression estimation permits looking beyond the average effect and describes the responses at every point of the conditional distribution of the outcomes. The data used in this study is derived from the 2011-2012 India Human Development Survey (IHDS-II).

Review of Literature

Khandker *et al.* (2013) estimate the welfare outcomes of rural electrification viz. income, expenditure and children's education in Vietnam using panel data of 1120 households in 41 communes for the period 2002-2005 applying the difference-in-difference fixed effects panel regression method. The estimated results show that grid electrification has positive effects on household income, expenditure and education. The commune-level electricity connection generates externality benefitting the poor more than the rich farm more than the non-farm, and schooling time of girls than that of boys. The household-level power connection generates the opposite externality, the rich benefit more than the poor, non-farm more than the farm, and boys over girls in schooling time. The study calculates, on certain cost structures, that the cost of serving electricity to a new rural household is US\$4.20 per month and the income gain due to electricity connectivity is US\$22.1 per month. In terms of cost-benefits, the rural electrification benefit accrual exceeds the costs more than by 4 times in Vietnam.

Huang (2015) analyse the determinants of household electricity consumption at different quantiles and try to identify the characteristics of high electricity consuming households in Taiwan over the period 1981-2011 applying the quantile regression method. The study finds that the effects of demographic, socioeconomic and household dwelling electricity consumption differ and change across quantiles of households' electricity consumption over time in Taiwan. The household income and household size are significant in all quantiles for each year. The results show that more electricity is consumed by households with higher income, large household sizes and more elderly members. Households with large housing areas, homes with more appliances, owner-occupied, multi-floor and business-use contribute to higher household electricity consumption. On a per capita basis, the study finds that low-income and small size households consume more electricity.

Arraiz and Calero (2015) study the impact of access to electricity on welfare in Peru using the 2007 Peruvian population and housing census applying the propensity score matching at the community as well as at the household levels. The estimated result shows a positive impact of solar-powered home systems (SHSs) on traditional spending on energy. Households with SHSs spend less on the traditional source of energy, candles and batteries for flashlights, and the saved amount is commensurate to the fee for SHS use. In households with SHSs, members are awake for more time, women spend more time in household activities and less time outside the home on farming activities, and men spend more time on home business activities. The SHSs have translated into more years of schooling among elementary school students and higher rates of enrollment in secondary school. However, there is no evidence of SHS's impact on income or poverty.

Aguirre (2017) analyses the indirect impact of rural electrification on schooling in 987 electrified (654) and non-electrified (333) households across 96 rural population centres in Peru in 2013 applying the instrumental variable regression method. The study examines the relationship between the proportion of rural households connected to the electricity grid and the time children spend studying at home. The study finds that the greater the likelihood of a household being connected to the electricity grid, the more time the children spend studying at home. The study estimates that by providing households with access to electricity, on average, children study an extra 94-137 minutes at home per day, a 39.8-58.4 per cent gain. The study calculates that these extra hours that children spend studying at the home amount to US\$51.68 per child benefit due to the electricity connection to a rural household.

Samad and Zhang (2017) analyse empirically the hypothesis that the magnitude and the nature of benefits associated with electrification are highly context-dependent. The paper uses panel data of 7,018 rural households from Bangladesh for 2005 and 2010 and

applies the instrumental variable and propensity score weighted fixed effects models. Bangladesh for 2005 and 2010. The determinants of the heterogeneity in the nature and magnitude of electrification benefits are examined by the quality of electricity supply and the number of years of being connected to the grid. The estimated results show that some benefits of electrification accrue only over the long run and power outages have a negative impact on development outcomes. The overall gain from expanding access to and improving the reliability of electricity supply in Bangladesh is estimated to be US\$2.3 billion a year.

Kumar and Rauniyar (2018) investigate the income and educational impacts of a rural electrification programme in Bhutan using primary survey data and applying the propensity score matching method. The study finds about 62 per cent of the sample households are electrified and they are generally better off than non-electrified households. The propensity-based weight regression results show that electricity provision improves the economic and educational outcomes of rural households. While access to electricity increases non-farm income by 61 per cent, it has no significant effect on farm income. The results further show that in electrified households children gained 0.72 additional years of schooling, an increase of 24 per cent, and 9 minutes of evening study time at home per day in rural Bhutan.

In India, Khandkar *et al.* (2012) analyse the impact of electrification on the average and distributional benefits to households in rural India and attempt to determine who benefits most from rural electrification using household survey data. The instrumental variable fixed effects method is used to determine who benefits most from rural electrification and the quantile regression method is used to estimate the distributional effects of electrification. The study finds that rural electrification increases the labour supply of men and women, schooling of boys and girls and household income and expenditure. Rural electrification helps to reduce poverty, time allocated to fuelwood collection by household members and increase the time allocated to studying by boys and girls. On who benefits most from rural electrification, the study finds that the larger share of benefits accrues to wealthier rural households, with poorer ones having more limited use of electricity. The analysis also shows that the restricted supply of electricity due to frequent power outages negatively affects both household electricity connection and its consumption thereby reducing the expected benefits of rural electrification.

Chakravorty *et al.* (2014) estimate the effect of connecting a household to the grid on household income in rural India during 1994-2005 using two rounds of a representative panel of more than 10,000 households and applying the instrumental variables method. Specifically, the study focuses on improved access to electricity defining the quality of electricity as hours of daily supply and outages. The study uses the district-level density of transmission cables as the instrument for the electrification status of the household. The

estimated result shows that the grid connection increases the non-agricultural incomes of rural households by about 9 per cent. Importantly, the grid connection in conjunction with the fewer outages and more hours per day, measuring the higher quality of electricity, increases non-agricultural income by about 28.6 per cent in the same period.

Samad and Zhang (2016) estimate the welfare impact of rural electrification in India using household panel survey data for 2005 and 2012 applying the propensity score weighted fixed effects model. The study finds that electrification is associated with a broad range of social and economic benefits for rural households. However, the reliability of electricity service is important for the accrual of benefits. While gaining access to electricity alone is associated with only a 9.6 per cent increase in income, electricity access in combination with a reliable power supply is associated with a 17 per cent increase in income. Increasing both the access rate and reducing power outages in rural India increases the net gain by US\$11 billion a year. The study also finds that lower-income households benefit more from access to electricity than higher-income households.

Burlig and Preonas (2021) estimate the causal effects of rural electrification on development in India using satellite images of nighttime brightness in villages applying the regression discontinuity and difference-in-difference methods. The study finds that rural electrification increased electricity access and consumption in villages. However, the study finds that village electrification has generated a limited economic impact in the villages viz. male and female agricultural and non-agricultural employment, asset ownership, housing stock, household wealth, household poverty, household income, and school enrollment. Even the modest changes in economic outcomes do not stand statistical scrutiny as the effects greater than 0.26 standard deviations are rejected across all economic indicators. The benefits also do not outweigh the costs of electrification of small villages and in large villages, electrification provides sizable per capita benefits at lower average costs.

Data and Methodology

This study on the differential effects of electrification on household welfare uses the secondary cross-section data from the second round (2011-2012) Indian Human Development Survey (IHDS-II). The IHDS-II is a nationally representative survey of 42,152 households, 27,579 from 1,503 villages and 14,573 from 971 urban neighbourhoods across India, totalling 41,106 households. The data set contains a wealth of information on various aspects of the household including access to electricity, consumption and tariffs, and other household energy sources. This study is based on 22,453 samples of the IHDS-II. The household well-being indicators considered in this study are household per capita income, health expenditure and expenditure on children's education. The independent variables used in this study are electricity tariff paid, kerosene purchase, expenditure on

fuel, and household demographic variables like age and gender of the household head, highest adult education, household size, and a number of elderly members in the household.

Quantile Regression Method

The ordinary least squares estimation predicts the mean or average of the dependent variable for a given set of independent variables. Since the mean does not describe the whole distribution, it does not fully describe the relationship between outcome and its determinants. Hence, the conditional mean model can not be extended to non-central locations of the response variable and does not capture the differential impact of the covariates at other locations across the different levels of the outcome variable. A more comprehensive picture of the predictors on the response variable can be obtained by using quantile regression. The quantile regression extends the linear regression approach allowing the effect of covariates on the entire distribution of the outcome variable, not merely its conditional mean. The quantile regression estimates the change in outcome at a specified quantile of the outcome distribution corresponding to a unit change in the covariate. While an OLS regression estimate calculates the change in the mean of the outcome variable as some function of a set of covariates, a quantile regression fits other parts (quantiles) of the distribution of the outcome variable which enables to observe the changes in impacts from one quantile to another over the entire distribution of the outcome.

The quantile regression estimates the conditional quantile functions. The quantile regression is a generalisation of median regression to other quantiles of the distribution function and is robust to outliers and heavy distributions. Given a linear regression function:

$$y_i = \beta x_i + \varepsilon_i \quad (1)$$

The conditional quantile at q^{th} quantile of y can be specified as:

$$Q_{y_i}(q | x_i) = \beta_q x_i^q \quad (2)$$

In analogy with classical linear regression methods which are based on minimising sums of squared residuals and meant to estimate models for conditional mean functions, the quantile regression method is based on minimising asymmetrically weighted absolute residuals giving differential weights to positive and negative residuals and intend to estimate conditional median function and a full range of other conditional quantile functions. While the ordinary least squares minimise the sum of the squares of the errors, $\sum \varepsilon_i^2$, the quantile regression minimises $\sum q |\varepsilon_i| + \sum (1-q) |\varepsilon_i|$ a sum that gives the asymmetric penalties $q |\varepsilon_i|$ for underprediction and $(1-q) |\varepsilon_i|$ for overprediction.

Following Koenker and Bassett (1978), the quantile regression model can be specified as:

$$y_i = \beta_q x_i + \varepsilon_{qi} \quad q \in (0,1) \quad (3)$$

where q denotes the quantiles. The q^{th} unconditional quantile is obtained by optimising:

$$\text{Min } \Sigma \rho_q (y_i - \varepsilon_q) \tag{4}$$

where the function $\rho_q (\cdot)$ is the absolute value function. Given a random sample of observations, the estimates of conditional quantile functions are obtained as a linear programming solution to:

$$\text{Min } \Sigma \rho_q [y_i - \varepsilon(x, \beta)] \tag{5}$$

Consider a real-valued random variable y characterised by the distribution function:

$$f(y) = P(y \leq y_0) \tag{6}$$

The q^{th} quantile of y is defined as:

$$Q_q = \inf\{y: f(y) \leq q\} \tag{7}$$

Given a set of regressors, X_p , the quantile regression can be specified as:

$$f_q = (q - \beta_q x_i | x_i) = P(y_i < q | x_i) \tag{8}$$

where the distribution of the error term ε_{qi} is unspecified and the only constraint being the quantile restriction:

$$Q_q (\varepsilon_{qi} | x_i) = 0 \tag{9}$$

The estimate of the conditional mean function is specified as:

$$\hat{\beta} = \arg \min_{\beta} \Sigma_{i=1}^N (y_i - \beta x_i)^2 \tag{10}$$

The linear conditional quantile function is specified as:

$$Q_y(q | x_i = x_0) = \beta_0 x_i \tag{11}$$

which can be estimated by solving the equivalent of expression:

$$\hat{\beta}_0 = \arg \min_{\beta} \Sigma_{i=1}^N \gamma_q (y_i - \beta x_i) \tag{12}$$

where $\rho_q(\varepsilon)$ is the so-called check function defined as:

$$\rho_q(u) = \begin{cases} q\varepsilon & \text{if } \varepsilon \geq 0 \\ (q-1)\varepsilon & \text{if } \varepsilon < 0 \end{cases} \tag{13}$$

Assuming that y is linearly dependent on a vector of exogenous variables x , the conditional quantile function can be specified as:

$$Q_y(q | x_i) = \min [\Sigma q | y_i - \varepsilon_q | + \Sigma(1-q) | y_i - \varepsilon_q |] \quad (0 < q < 1) \tag{14}$$

The expanded version of the quantile regression is specified as:

$$\min_{\beta} [\Sigma_{i: y_i \geq \beta x_i} q | y_i - \beta x_i | + \Sigma_{i: y_i < \beta x_i} (1-q) | y_i - \beta x_i |] = \min \Sigma \rho_q (y_i - \varepsilon_{qi}) \tag{15}$$

For a unit change in a regressor, the marginal effect is the coefficient for the qth quantile:

$$\frac{\partial Q_y(q | x_i)}{\partial x_i} = \beta_q \tag{16}$$

Thus, a quantile regression parameter q estimates the change at the specified quantile of the response variable y produced by a unit change in the independent variable x i.e. the marginal effect.

Empirical Analysis

Table 1 presents the descriptive statistics of the variables in the empirical analysis of the effect of electricity on rural household welfare. The mean electricity tariff paid in a month is ₹ 204. The rural households also spend ₹ 60.39 on kerosene and the average household expenditure on fuel like LPG, cow dung and firewood excluding kerosene is ₹ 313 in a month. The mean age of the household head is 49.78 years. The average household size is 5.18 persons and the mean of elderly persons in the household is 0.40. On average, rural households spend monthly ₹ 5670 on children’s education and ₹ 6842 on the health of household members. The average highest adult education is secondary education. The mean log per capita income is ₹ 9.65 per year. The standard deviations of the variables show a significant spread of the values.

Table 1: Descriptive Statistics of Variables

<i>Variable</i>	<i>Definition</i>	<i>Mean</i>	<i>Std. den.</i>
lnHPCI	Natural logarithm of average household income per person (₹ per annum)	9.65	3.94
EDExp	Household expenditure on children’s education (₹ per annum)	5670.14	4792.21
HLExp	Household expenditure on health and medicine including outpatient services and medical inpatient services (₹ per annum)	6842.14	5538.16
ETExp	Electricity tariff paid (₹ per month)	203.97	314.10
KEExp	Household expenditure on kerosene (₹ per month)	60.39	66.79
FUExp	Household expenditure on fuel like LPG, firewood, cow dung, excluding kerosene (₹ per month)	313.00	268.26
HHAge	Age of the household head (yrs)	49.78	13.22
HHSIZE	Total number of persons in the household	5.18	2.34
HHedu	Education of the highest educated household member (yrs)	6.26	4.92
HHGen	If the household head is male=1, 0 otherwise	0.92	0.25
Elder	If the household has elderly persons aged 60 years and above=1, 0 otherwise	0.40	0.49
N	No. of observations	22,453	

To analyse the differential effects of rural electrification benefits on household welfare and to ascertain who benefits most from rural electrification, the quantile regression estimation is used. The effect of electricity consumption on household income, and education and health expenditures are estimated at the 25th, 50th and 75th quantiles. The study also reports OLS estimates. The estimated results are presented in Tables 2-4. Table 2 presents the household electrification effects on household income per capita. The estimated coefficients of monthly electricity tariff on household income are positive and statistically significant in all regressions. An increase in electricity payment on average increases household income per capita by 4 per cent per year. At the 25th quantile, the household per capita income increases by 5 per cent, by 6 per cent at the median quantile and by about 8 per cent at the 75th quantile of income distribution for an increase in electricity consumption in the household. The access and consumption of electricity by the household increases household income by a percentage point at every quarter of the income distribution. The higher-income households put into a more productive use of electricity consumed raises their income level. Thus, higher-income households tend to benefit more relative to lower-income households in rural India from rural electrification.

The income-enhancing effect of household energy use is also supported by the significant positive coefficient estimates of kerosene and other fuel consumption. The household income per capita increases by 2 per cent with an increase in the other forms of energy use. The households at the lower end of income distribution depend more on kerosene than households in the upper end as a source of energy. While an increase in the age of the household head and the higher education of a household member are associated positively with household income per capita, large household size and the presence of elderly members in the household decrease household income per capita. Household income per capita increases by 2 per cent with the increasing education level of the household member and decreases by 1 per cent per annum with an increase in household size and elders respectively. The estimates do not reveal any substantial difference across the income distribution by age, education and elderly. However, household heads make a difference in household income. While the income per capita in male-headed households decreases by 5 per cent in the lower quantiles of household income, at the upper-income quantiles the household income increases by 2 per cent in male-headed households relative to female-headed households in rural India.

The importance rural households attach to the education of their children can be gauged from the substantial effect of electricity use on educational expenditure. Children from these households go to school during day time and also spend time working on the farm, non-farm and household activities. The time available to them to study and do homework is only during the nighttime burning the electric light. As Table 3 shows, the

Table 2: Quantile Regression Estimates of Electrification Effects on Household Income Per Capita

Dependent variable: lnHPCI

<i>Variable</i>	<i>OLS estimates</i>	<i>Quantile regression estimates</i>		
		<i>25th</i>	<i>50th</i>	<i>75th</i>
ETExp	0.042*(6.94)	0.055*(6.82)	0.066*(6.86)	0.078*(6.11)
KEExp	0.022*(2.63)	0.057*(4.11)	0.024**(2.26)	0.022***(1.73)
FUExp	0.023*(2.15)	0.026***(2.10)	0.029**(2.25)	0.028*(2.75)
HHAge	0.008*(5.37)	0.006*(4.27)	0.008*(3.79)	0.010*(6.43)
HHGen	-0.001(0.07)	-0.051***(1.73)	0.009***(0.36)	0.021***(0.82)
HHsize	-0.098*(3.33)	-0.094**(2.55)	-0.104*(3.96)	-0.110*(3.40)
HHedu	0.211*(4.15)	0.168*(5.90)	0.201*(3.23)	0.226*(3.98)
Elder	-0.081*(5.78)	-0.089*(4.89)	-0.056*(3.62)	-0.070*(4.33)
R ² /Pseudo R ²	0.121	0.163	0.196	0.132

Note: Absolute t-values in parentheses. *, **, *** significant at 1, 5, 10 per cent levels.

effect of electricity price on household education expenditure is significantly positive at all levels of educational expenditure. On average, an increase in electricity use increases household expenditure on the education of children by 5 per cent. At the 25th quantile of educational expenditure, the marginal effect of electricity tariff is lower by one per cent, but at the 75th quantile, an increase in electricity price increases almost 10 per cent in the educational expenditure of the rural household. The differential effect of electricity tariff at the extreme ends of the household educational expenditure may be due to two reasons viz. electricity consumption and tariff structure. The poor households consume less electricity while the rich households use more electricity. The differential electricity tariff implies households consuming more electricity progressively pay more per unit of electricity consumed. Moreover, for poor households electricity is either free up to certain units consumed or highly subsidised. expenditure at the lower end of the expenditure distribution may be due to subsidised electricity available to poor-income households. Thus, rich and wealthy households benefit more in terms of the education of children relative to poor income households from rural electrification in India.

In consonance with electricity use, the dependence on kerosene decreases and hence the effect of kerosene on educational expenditure is negative but statically insignificant in all regressions. However, the use of other forms of energy increases household educational expenditure significantly positively. While an increase in the expenditure on fuel increases

educational expenditure by about 1 per cent at the 25th quantile, the effect is a sizable 5 per cent at the 75th quantile. The effect of the highest education of a household member on household education expenditure is mixed. While the average effect of adult education on education expenditure is about a positive 2 per cent, it is a negative 1 per cent at the 25th quantile and a positive 8 per cent at the median quantile and 3 per cent at the 75th quantile of education expenditure. The presence of elders in the household has a negative effect on household educational expenditure, but more members in the household increase the expenditure on children's education in rural households of India. The male headship has a strong positive effect on the household expenditure on the education of children. The effect increases from an insignificant 2 per cent at the lower end to a significant 8 per cent at the upper end of the education expenditure of the household.

Table 3: Quantile Regression Estimates of Electrification Effects on Household Education Expenditure

Dependent variable: EDExp

Variable	OLS estimates	Quantile regression estimates		
		25 th	50 th	75 th
ETExp	0.535*(7.28)	0.107**(2.26)	0.252*(8.95)	0.949*(6.90)
KEExp	-0.444(0.31)	-0.072(0.46)	-0.097*(0.16)	-0.724*(0.61)
FUExp	0.371*(2.29)	0.140*(3.46)	0.342*(3.82)	0.544*(4.27)
HHAge	0.454(1.10)	-1.352(1.44)	0.248(0.07)	0.929(1.31)
HHGen	0.470*(3.43)	0.217(1.18)	0.548*(3.40)	0.768*(5.75)
HHsize	0.521*(7.03)	0.774*(4.94)	0.426*(3.00)	0.932*(4.31)
HHedu	0.261*(2.60)	-0.113(0.68)	0.808*(4.93)	0.281*(3.18)
Elder	-1.058*(4.59)	-2.969(1.18)	-3.657*(3.69)	-4.256*(4.51)
R ² /Pseudo R ²	0.13	0.18	0.14	0.19

Note: Absolute t-values in parentheses. *,**,*** significant at 1, 5, 10 per cent levels.

Table 4 presents the health benefits of rural electrification in India. The estimated coefficients of electricity price paid are consistently positive and statistically significant in all regressions. An increase in electricity tariff increases household health expenditure on average by 3 per cent. The household health expenditure increases by 3 per cent at the 25th quantile and by 6 per cent at the median quantile and 3 per cent at the 75th quantile. The effect of kerosene expenditure on health expenditure is not statistically significant at the upper health expenditure level. But, its effect is significantly positive at lower and middle quantiles. The

other fuel consumption expenditure increases the average household health expenditure by 2 per cent. Both lower and upper quantile households spend 1.5 per cent on health for an increase in fuel consumption, the median quantile households incur almost double the expenditure, 3 per cent. Overall, the effect of rural electrification benefits accrual is higher for median health expenditure households than either for lower or upper quantile households.

An increase in the age of the household head increases health expenditure by 6 per cent in all households. Households with old age people incur more on health, increasing health expenditure by 3 per cent per elderly member. At the 25th quantile, the health expenditure of the household increase by 3 per cent in households with the elderly and the elderly effect is 2 per cent at the 75th quantile of the health expenditure distribution, while the median health expenditure households incur an additional 4 per cent with the presence of elderly in the household. Similarly, household size and education in the household are significantly positively associated with household health expenditure. While household size effect on health expenditure increases from 2 per cent to 4 per cent, the education effect decreases from 6 per cent to 3.6 per cent from the lower to higher levels of the household health expenditure distribution.

Table 4: Quantile Regression Estimates of Electrification Effects on Household Health Expenditure

Dependent variable: HLExp

Variable	OLS estimates	Quantile regression estimates		
		25 th	50 th	75 th
ETExp	0.041***(1.70)	0.037*(3.43)	0.063*(3.81)	0.029*(3.27)
KEExp	-0.197(0.06)	0.167**(2.34)	0.435***(1.80)	0.065(0.04)
FUExp	0.220*(2.39)	0.141*(3.11)	0.286*(4.51)	0.147*(3.76)
HHAge	0.626*(2.83)	0.915*(3.07)	0.541*(3.76)	0.477*(3.26)
HHGen	-0.587(-0.06)	0.472(0.37)	0.811(0.13)	0.910**(2.32)
HHsize	0.303*(2.82)	0.202*(3.45)	0.722*(3.93)	0.396*(3.66)
HHedu	0.964*(4.70)	0.578**(2.01)	0.501*(3.62)	0.368*(4.21)
Elder	0.313(1.11)	0.274*(3.37)	0.389*(4.88)	0.217*(5.22)
R ² /Pseudo R ²	0.14	0.18	0.16	0.14

Note: Absolute t-values in parentheses. *,**,*** significant at 1, 5, 10 per cent levels.

Conclusion

India has been massively electrifying rural areas. This rural electrification effort even in remote and inaccessible areas confers a multitude of benefits to its population. Apart

from lighting both households and public places, connection to the grid induces rural economic activities enhancing household income, improving the health of household members and education of children. The main objectives of this study are to examine the rural electrification effects on household welfare and if so who benefits from grid connectivity in rural India. The study focuses on the household welfare indicators of household income per capita, expenditure on health of household members and expenditure on education of children in the household. As household needs and consumption differ widely across rural households, so also do the benefits of rural electrification. Hence this study estimates the differential effects of electricity on household welfare outcomes at different points of the outcome distribution by applying the quantile regression method using the 2011-2012 India Human Development Survey (IHDS-II) data. The quantile regression estimation permits looking beyond the average effect and describes the responses at every point of the conditional distribution of the outcomes.

The empirical estimates of this study show that household welfare increases following rural electrification. The household income and expenditures on health and education are positively and significantly associated with an increase in the electricity tariff payment. The quantile regression estimates reveal heterogeneity in rural electrification benefits across rural households. While the average household income per capita increases by 4 per cent for an increase in the monthly electricity tariff, electricity consumption increases income per capita by a percentage point at every quarter of the income distribution. At the 25th quantile, the household per capita income increases by 5 per cent, by 6 per cent at the median quantile and by about 8 per cent at the 75th quantile of income distribution for an increase in electricity consumption in the household. Overall, higher-income rural households of India tend to benefit more than the lower-income households from rural electrification.

Similarly, the upper-income rural households gain more in terms of the education of children relative to poor-income households from rural electrification. As regards health, the effect of rural electrification benefits is higher for median health expenditure households than either for lower or upper quantile households. Further, the inter-quantile variation in the impact of electricity is greater for expenditures than for income. The greater benefits to better-off rural households from rural electrification accrue through higher consumption and use of electricity. For poor households, electricity consumption mainly is only for lighting but for rich households, electricity is for many productive uses and electrification benefits accrue from multiple channels. Provision of regular without power-cuts and outages will help the rural household to raise their living standards and improve the education and health of their family.

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