2. Methodology

2.1 The Theoretical Model

The model developed in this study closely follows that of Kemmler (2007) on the choice of using electricity by rural households but at a longitudinal level. In this model households choose whether to use electricity based on the utility of the alternatives of using or not using electricity and the use of electricity depends upon the geographic conditions, household characteristics and the supply of electricity. The restricted utility is represented as:

$$U = f(G, H, S)$$

where H is a vector of household characteristics such as income, social network, education, household size, sex and age of household head. S is a vector describing the attributes of electricity supply and G is the vector of geographic demand variables. The attributes of electricity supply is described by using the price of electricity paid by households[6], the percentages of forced outages as a measure of supply quality and community electrification. Following the definition of electricity as in the introduction, we assume if less than 10% of the households use electricity, the village is not electrified, and it is unlikely that the household has access to electricity. Villages having more than 10% of the households using electricity considered as electrified.

We consider the geographic demand variable S with district dummies, this is because power outages are transformer and load based and hence, they can be localized at the district level. Kemmler (2007) used state dummies to capture the electricity tariff. Our analysis is at the local level given that electricity supply and tariffs are increasingly localized with privatization and private sector participation in the electricity market. Also power outages are mostly local owing to transformer or grid failure (Joseph, 2010). Following the enactment of Electricity Act '2003, a comprehensive change was undertaken through a market-oriented reform process. Restructuring and reformation have entailed formation of businesses such as GENCO (Generation Company), TRANSCO (Transmission Company), and DISCOM (distribution company) to improve the efficiency of the sector (Lahiri et al., 2010).

[6] In order to facilitate electricity access for the poor, the State Electricity Boards offer a minimum units of electricity at a subsidized tariff. This subsidized tariff is considered as the price of electricity in our model. Later we use the same price in the cost benefit analysis.

At any point of time t, a household i chooses to use electricity if the utility derived from using it U_{1t} is larger than the utility by not using it U_{0t}. Following the random utility models, the net utility derived by household i is expressed by the latent variable y_{it}^{*} such that

$y_{it}^{*} = U_{i1t} - U_{i0t} > 0 \rightarrow$ choose to use electricity and if

$y_{it}^{*} = U_{i1t} - U_{i0t} < 0 \rightarrow$ choose to not use electricity

$$y_{it}^{*} = X_{it}^{\beta} + u_{it}$$

where $u_{it} = \epsilon_{i1t} - \epsilon_{i0t}$. X is a vector of all the explanatory variables of G, H and S. β is a vector of the coefficients and u_{it} is the stochastic capturing the uncertainty at any point in time. We hypothesize that these utility functions vary across income groups and regions as discussed in the introduction.

We estimate the casual effect of electricity on household monthly consumption expenditure, real income, assets and status of poverty. We consider that these outcomes are conditional on electricity access and hours, the baseline panel fixed effects estimate is as follows:

$$Y_{ijt} = \alpha_{ij} + \beta X_{ijt} + \delta R_{ijt} + \gamma E_{ijt} + \epsilon_{ijt} \qquad (1)$$

where, Y_{ijt} denotes the outcome variable of interest, in our case the monthly consumption expenditure, real income and assets of the household i in village j at time t. X_{ijt} is a vector of household observable demographic and socioeconomic characteristics such as size, social networks, loans, membership in credit associations of the household and head's age, sex and education. R_{ijt} is the hours of electricity in the $i-th$ household in the $j-th$ community in time t (0 to 24 hours in a day). Similarly, E_{ijt} is access to electricity of the $i-th$ household in the $j-th$ community in time t (1 for households with electricity access and 0 for those without). Panel fixed effects controls for unobserved household characteristics through the constant α_{ij}. ϵ_{ijt} is the randomly distributed error term and β, γ, and δ are unknown parameters to be estimated. The aim is to estimate the effect of access and hours of electricity, measured by the coefficients δ and γ with two separate fixed effects regression for access and quality (hours).

Assuming that there are economic incentives to use electricity, if villages were randomly selected for grid extension and household electrification occurred randomly, then an estimation of a panel fixed effects model in equation (1) would provide unbiased estimates of the impact of electrification. However, in India households are not randomly connected to electricity or villages are not randomly selected for electrification (Khandker et al., 2014). The decision is based on observed and unobserved characteristics, such as area topography, population density, populist policies, productive potential or a household's ability to perceive returns to investment. This leads to endogeneity of village- and household-level electricity connection. In the case of household electrification, endogeneity can manifest in various ways. It may be due to time varying omitted variable bias motivated by unobserved factors at the household level, or household perception about potential benefits of electricity leads to a positive self-selection bias, there could be reverse causality with higher income leading to more hours of electricity. Endogeneity may also arise from simultaneity if household's adoption of electricity and the outcome such as income are jointly determined (Khandker et al., 2014). Thus equation (1) would yield biased impact estimates. In order to address this problem of endogeneity, we instrument the household's electricity-connection decision. The first stage estimate of instrumental variables (IVs) is obtained by estimating the following demand equation for electricity access and hours of electricity

$$E_{ijt} = \alpha_{ij} + \beta X_{ijt} + \theta I_{ijt} + \epsilon_{ijt} \qquad (2)$$

$$R_{ijt} = \alpha_{ij} + \beta X_{ijt} + \theta I_{ijt} + \epsilon_{ijt} \qquad (3)$$

where I_{ijt} is the vector of instruments that only affect the demand for access (2) and the quality of electricity (3) by household i in village j in time t, but does not affect the outcomes of interest such as household monthly consumption expenditure, household income and assets. These outcomes are affected only indirectly through household's access to electricity.

For the instruments to be valid, two conditions are required; (i) θ is not a vector of zeros and (ii) $Cov(I_{ijt}, \epsilon_{ijt}) = 0$. The first condition implies that at least one instrument must significantly affect household's decision to gain access to electricity or increase the demand for the hours of electricity. The second condition requires that the instruments only affect a household's electrification decision and does not directly affect the outcomes variables described above.

We use the same instrument as Khandker et al. (2014), a vector of instruments that include the mean village level access and hours. The variable indicates the mean village level electricity access and hours for a household in a community *(j)* at time *(t)*. The two instruments interact with household observed characteristics as household head's age, gender, size, social network, loans and education. Proportion of households with access and hours of electricity serve as instruments because of peer pressure, conspicuous consumption or demonstration effects. Households tend to follow their neighbors or other associates in the village. If neighbors gain access or have access to more hours of electricity, then a household without electricity can signal lower socioeconomic standing, which households would be expected to avoid if they can afford it (Khandker et al., 2014). We expect that the higher the percentage of connections and hours of electricity in a village, the higher is the likelihood of a household living in that village to adopt and acquire better electrification, provided the household can afford the connection fee and associated costs.

The exogeneity condition for the instrument is also expected to hold because mean village level access and hours should not directly affect household consumption expenditure, household income and assets, which depend on initial wealth, occupation, size and education among other characteristics of the household. Household’s income and expenditure do not depend on the mean village level electrification because household’s expenditure decision depends mainly on the size, and age composition rather than whether other households in the village have access electricity or hours with electricity supply (Khandker et al., 2014). Khandker et al. (2014) also conducts a correlation between income, expenditure and instruments and find the correlation to be low to indicate any direct relationship between the instrument and the outcome.

2.2 Estimation Strategy

Our model follows the panel 2SLS fixed effects model by (Semykina & Wooldridge, 2010). We do not reject the hypothesis of no selection bias and allow for arbitrary correlation between the unobserved effect and the explanatory variables. We use fixed effects Instrumental variables regression (FE-IV), which is robust to correlations between unobserved effects and explanatory and instrumental variables. The model does not require specification of the reduced form equations for endogenous variables and makes no assumptions of errors distribution. At the heart of our model is the within transformation of the variable. The form of the model is as in (4)

$$y_{it} = Y_{it}\gamma + X_{1it}\beta + \alpha_{ij} + v_{it}$$

$$y_{it} = Z_{it}\delta + \alpha_{ij} + v_{it}, \quad t = 1, 2 \quad i = 1,2, \dots\dots, N \quad (4)$$

where y_{it} is the dependent variable. For our study we use monthly per capita consumption expenditure, real income and assets of the household to proxy household welfare.

Y_{it} is either a dummy (access to electricity), or a continuous variable (hours of electricity), and these variables are allowed to be correlated with the v_{it}. X_{1it} is a 1 x $k_1$vector of observations of the exogenous variables included as control variables. $Z_{it} = [Y_{it} X_{it}]$; γ is the coefficient of interest, β is a 1 x k_1 vector of coefficients for the controls, α_{ij} is the unobserved effect, v_{it} are the idiosyncratic errors. δ is a $K \times 1$ vector of coefficients, where $K = 1 + k_1$. We use demographic and socio-economic characteristics as controls: education, sex, age, social network, loans and membership in savings and credit associations as socio-economic controls. Panel fixed captures the time invariant characteristics such as district and caste fixed among others. In order to allow for correlation between the regressors and the idiosyncratic errors, we assume the existence of instruments, z_{it}, which are strictly exogenous conditional on α_i, which captures the time invariant characteristics. This permits for unspecified correlation between $z_{it}$and α_i, but requires z_{it} to be uncorrelated with {u_{ir} : r = 1, ..., T} (Semykina & Wooldridge, 2010).

We allow some elements of X_{1it} to be correlated with the idiosyncratic errors, as occurs in simultaneous equation models with measurement errors and time varying omitted variables. Our instruments are the mean village level, as also used by (Rao, 2013) and (Khandker et al., 2014). In addition to the instrumenting by electricity access, we use the mean level of electricity hours at the village level as an additional instrument. Our sample has approximately 30-35 households per village. Hence we assume that there is enough variation at the geographic level to consider the IV we use. Moreover, following Rao (2013) and Khandker et al. (2014), we assume the existence of geographic instruments z_{it}, which are strictly exogenous conditional on α_i. The underlying logic of the IV is that the mean level of electricity at the village level has peer pressure effects on the household's decision to acquire electricity but it does not affect the household's consumption, income, assets and standard of living. This permits for unspecified correlation between z_{it} and α_i. Since FE estimator involves time-demeaning, we assume that all variables in X_{1it} and z_{it} are time-varying.

3. Data

We use the panel data of IHDS from 2005-2012 thereby making the analysis longitudinal rather than cross-section to capture the within and between variations. Using a panel allows to capture the household time invariant characteristics and compare it to OLS for IHDS 2012 with district and caste fixed effects to provide a robust picture. IHDS 2005 and 2012 are merged to obtain an unbalanced panel with 83% of observations matched, similar matches have been found in previous studies using IHDS panel. (i) We use the binary of electrification to study the extensive margin and (ii) hours of electricity (0-24) for the intensive margin. The effects of interest for household welfare are: Monthly per capita consumption expenditure, real income, assets, and poverty status of households. For assets, we undertake an unweighted asset category and principal component analysis of household and productive assets. A cost-benefit analysis is then carried out with the coefficient of explanatory variables for real income at the intensive margins.

Table 1 shows the summary statistics at the national level between 2005 and 2012. IHDS 1, 2005 has 42,045 households and IHDS 2, 2012 has 42,144 households. Not all households are tracked in both survey waves, hence the unbalanced with 83% households matched. The survey is rich in terms of multi-dimensional aspects of human development and provides adequate covariates as controls thereby explaining a larger variation in the outcome of interest in terms of household welfare. We extract data on household income, head's age, sex, education, household size, caste, social networks and participation in credit cooperatives and loans from banks which could affect household consumption, income, assets and status of poverty. The data is tracked at the village level allowing for control of unobserved variation at caste and district level.

There is a 9% increase in access between 2005 and 2012. However, in terms of hours of electricity at national level, there is a 0.4 hours decrease in the availability. Mean hours of electricity for the poor during the best of economic times has also decreased. This is also the case for the same group of households when we track them in the two surveys. Although there has been considerable attempt to increase electricity supply, the impetus seems to have been on provision of access and not the continuity (quality) of electricity. In rural areas mean hours of electricity has stagnated between 13-14 hours a day in the reference period. On the other hand, cost of electricity to households per month almost doubled in the reference period from Rs. 148 to Rs. 280, partly due to tariff rebalancing and privatization of electricity supply geared towards cost recovery.

Table 1: Summary Statistics, India Human Development Survey 2005-2012

	2005			2012			
	Obs.	**Mean**	**sd**	**Obs.**	**Mean**	**sd**	**p-value**
Per capita Exp./Month (Rs)	39302	973.56	1039.86	42122	2422.07	31593.61	***
Income per capita/Annual (Rs.)	39302	12089.82	20909.77	42145	29403.00	53998.72	***
Assets (0-29)	39302	12.51	6.22	42122	15.44	6.64	**
Poor (0/1)	39302	0.19	0.39	42122	0.16	0.37	*
Household Head Edu. Years	39302	7.65	5.09	42134	8.30	5.10	*
Household Head Age	39302	47.10	13.47	42139	49.71	13.57	
Household Head Sex (1-male, 2-female)	39302	1.10	0.30	42139	1.14	0.35	
Electricity Access (0/1)	39302	0.79	0.42	41981	0.87	0.33	**
Electricity Hours/Day	24751	15.74	7.13	36588	15.23	6.87	
Electricity Cost/Monthly (Rs.)	39302	148.25	239.34	36458	280.19	428.13	***
Free Electricity	39302	0.10	0.30	42145	0.09	0.28	
State Electricity Bill/Company	39302	0.65	0.47	42145	0.64	0.48	
Social network HH (0/1)	38714	0.36	0.48	42049	0.27	0.25	***
Urban (0/1)	39302	0.38	0.48	42145	0.36	0.48	
Illegal Electricity (0/1)				42145	0.05	0.22	

	2005			2012		
	Obs.	Mean	sd	Obs.	Mean	sd
Electricity Access (0/1)	22814	0.79	0.18	29269	0.88	0.32
Hours of Electricity/Day	22814	15.67	7.17	25713	15.27	6.89
Social Network	22502	0.39	0.49	29308	0.07	0.25
Urban	22814	0.39	0.49	29375	0.34	0.47

Source: Author elaboration using India Human Development Survey 2005-2012
Rs. is Indian National Rupee

4. Results

4.1. Results at the Extensive Margins

The results for the impact of access on monthly per capita consumption expenditure are presented in Table 2[7]. The results of the first stage regression are significant at 1%. Coefficient of access to electricity is significant with the fixed effects regression specification (1) and the instrumental variable fixed effect regression (2) at the national level. The coefficient is higher with the instrumental variables (IV) regression, showing that moving from no access to having access increases the monthly consumption expenditure by 60%. The IV regression shows a negative

[7] First stage regression for access and hours of electricity is in appendix table A2

selection bias in our model. Households with higher monthly per capita consumption would likely have access to electricity from various sources. Better off households have access to generators, inverters or might have a VIP connection line which is common. Access has a significant effect in rural areas and the results are robust as shown in specifications (3) and (4) in Table 1. In urban areas, the panel fixed effect regression is significant and has an effect of 6%, whereas the IV regression has a very strong effect on monthly consumption expenditure in urban areas, but the effect is not significant.

Table 2: Extensive Margin- Panel Regression - Impact of access on Monthly Per Capita Consumption Expenditure

VARIABLES	(1) Fixed Effects-All	(2) Fixed Effects-IVAll	(3) Fixed Effects Rural	(4) Fixed Effects-IV Rural	(5) Fixed Effects Urban	(6) Fixed Effects-IV Urban
Electricity	0.08***	0.60***	0.08***	0.56**	0.06**	0.78***
	(0.01)	(0.19)	(0.01)	(0.22)	(0.02)	(0.07)
Log Real Income	0.10***	0.10***	0.08***	0.08***	0.15***	0.14***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
Household Head Education	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household Head Sex	-0.04***	-0.03**	-0.03	-0.02	-0.06***	-0.06***
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Household Head Age	0.00	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household Size	-0.13***	-0.13***	-0.12***	-0.13***	-0.13***	-0.13***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Social Network	0.14***	0.10***	0.15***	0.12***	0.11***	0.08***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
Loan Banks	0.08***	0.08***	0.06***	0.06***	0.12***	0.12***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Membership ROSCA	0.05***	0.05***	0.06***	0.06***	0.03*	0.03
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Year	0.88***	0.82***	0.90***	0.82***	0.84***	0.80***
	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.03)
Constant	5.96***	5.65***	6.06***	5.79***	5.65***	4.92***
	(0.05)	(0.13)	(0.06)	(0.14)	(0.10)	(0.50)
Observations	55,695	55,469	35,786	35,786	18,341	18,341
R-squared	0.690		0.691		0.690	
Number of id	29,338	29,112	18,428	18,428	9,342	9,342

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We use two instruments as treatments, the local average of electricity (dummy) at the district level, and the local average of electricity hours (in a day) at the district level. The coefficient on instrumental variable regression at the all India level shows that: as household moves from no access to having access, there is a 60% increase in the monthly per capita consumption in rupees. Comparison of the panel and the instrumental variable regression supports the negative self-selection argument discussed above, household with higher consumption tend to have higher access to electricity. The coefficient of rural and urban areas show that as household gain electricity, their monthly consumption increases by 0.56% and 0.78% respectively. This coefficient reflects the importance of access to electricity.

Since we have an unbalanced panel, the matching of households is approximately 83% in Table 1. Our model captures 69% of the variation in monthly consumption expenditure. Real income is, as expected, significant in all specifications and has a stronger effect in urban areas. Household head's education significantly determines consumption, but the magnitude is 1% across all specifications. Household head's age is insignificant, while having female-headed households seems to have a negative effect on monthly consumption overall and in urban areas, but the results are not significant in rural areas.

Social network in terms of having membership in rotating savings and credit associations, or acquaintances with a government official outside community has a strong positive effect on consumption expenditure which highlights the server effect of social interactions. However, as noted in the summary statistics, social network has been decreasing among households across the two surveys. Loan from banks also has a strong positive effect on consumption expenditure. The time period from 2005-2012 has had a strong positive effect on household consumption expenditure which signifies the rapid economic growth registered during this period, GDP growth rate 9% approx. per annum (Planning Commission, 2013) and its possible trickle downs at the household level.

Table 3 shows the result of panel fixed effects and instrumental variable regressions for poor rural and poor urban households. The effect of access on monthly per capita consumption expenditure for the poor in both rural and urban areas are positive. In specifications (2) and (4) the coefficients 0.37 and 0.48 of the IV regressions show that the impact on consumption expenditure in rural and urban areas for the poor is strong and significant at 1%. Comparison of the results of fixed effects and fixed effects IV regression shows that there is a negative selection bias in the model, that is, household with higher monthly per capita expenditure can by themselves meet the need for electricity through other means, e.g. inverters and generators.

Table 3: Extensive Margin- Effect of electricity on monthly per capita consumption for the poor in rural and urban India, 2005-2012

VARIABLES	(1) Fixed Effects Poor Urban	(2) Fixed Effects-IV- Poor Urban	(3) Fixed Effects- Poor Rural	(4) Fixed Effects-IV Poor Rural
Electricity	0.06	0.37***	0.05**	0.48***
	(0.04)	(0.05)	(0.02)	(0.39)
Log Real Income	0.08	0.07	0.05***	0.04***
	(0.05)	(0.05)	(0.01)	(0.01)
Household Head Education	0.01**	0.01	0.00	-0.00
	(0.01)	(0.01)	(0.00)	(0.00)
Household Head Sex	0.05	0.04	-0.06*	-0.06
	(0.06)	(0.07)	(0.03)	(0.04)
Household Head Age	-0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Household Size	-0.04***	-0.03***	-0.04***	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)
Social Network	0.07*	0.07	0.07**	0.04
	(0.04)	(0.05)	(0.03)	(0.05)
Loan Banks	0.02	0.00	0.03	0.01
	(0.05)	(0.05)	(0.04)	(0.04)
Membership ROSCA	-0.00	-0.01	0.05	0.03
	(0.06)	(0.06)	(0.03)	(0.04)
Year	0.69***	0.65***	0.91***	0.80***
	(0.04)	(0.04)	(0.01)	(0.10)
Constant	5.17***	5.03***	5.31***	5.17***
	(0.57)	(0.58)	(0.13)	(0.21)
Observations	2,720	2,720	6,712	6,712
R-squared	0.748		0.856	
Number of id	2,248	2,248	5,470	5,470

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 shows the effect of access on the non-poor in urban and rural area. The effect of access for both rural and urban non-poor is positive, and the coefficients are significant at 1%. Our results corroborate and provide evidence of the likelihood of such an event. It is very unlikely that a non-poor household would not have electricity in urban areas. However, if it is the case, the impact of access is such that monthly per capita consumption expenditure (mpce) would increase by 81%, but such an event is unlikely, and so is insignificant. On the other hand, the effect of access for the non-poor in a rural is a 53% increase in monthly consumption expenditure.

Table 4: Extensive Margin - Effect of electricity on monthly per capita consumption for Non-poor in rural and urban India, 2005-2012

VARIABLES	(1) Fixed Effects-Non-Poor Urban	(2) Fixed Effects-IV-Non-Poor Urban	(3) Fixed Effects-Non-Poor Rural	(4) Fixed Effects-IV-Non-Poor Rural
Electricity	0.05	0.81	0.06***	0.53***
	(0.04)	(0.80)	(0.01)	(0.20)
Log Real Income	0.13***	0.12***	0.07***	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)
Household Head Education	0.01***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)
Household Head Sex	-0.04	-0.05	-0.00	0.00
	(0.03)	(0.03)	(0.02)	(0.02)
Household Head Age	0.00	0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Household Size	-0.12***	-0.13***	-0.11***	-0.11***
	(0.00)	(0.01)	(0.00)	(0.00)
Social Network	0.08***	0.07***	0.13***	0.11***
	(0.01)	(0.02)	(0.01)	(0.02)
Loan Banks	0.11***	0.12***	0.06***	
	(0.02)	(0.02)	(0.01)	
Membership ROSCA	0.03	0.04*	0.06***	0.06***
	(0.02)	(0.02)	(0.01)	(0.01)
Year	0.81***	0.79***	0.90***	0.85***
	(0.01)	(0.02)	(0.01)	(0.03)
Constant	5.98***	5.10***	6.29***	5.99***
	(0.11)	(0.68)	(0.07)	(0.14)
Observations	15,621	15,621	29,074	29,074
R-squared	0.685		0.710	
Number of id	8,830	8,830	17,046	17,046

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2. Intensive Margins

Table 5 shows that the effect of one additional hour of electricity on the monthly per capita consumption expenditure for all areas, rural areas and the poor. The coefficients are significant for all households, rural households and households that are poor. The model exhibits a negative self-selection bias underlining the theory that households whose consumption expenditures are high show a preference for more electricity hours as they can always afford it. The IV results are significant for all specifications. In all areas, there is a 4% increase in mpce associated with an additional hour of electricity service, ceteris paribus. The effects are equally strong for both poor and non-poor in rural areas and the poor in both rural and urban areas. One more hour of electricity implies a 3% increase in the mpce for the poor and a 3 % increase in mpce for a household in a rural area.

These results corroborate with the summary statistics in Table A1. For both years, on an average, poor have 14 hours of electricity and hence an additional hour means a 3% increase in mpce. Similarly, in rural areas the average is 13 hours and so one more hour means a 3% increase in mpce. All control variables exhibit expected sign and significance.

Table 5: Intensive Margin- Panel Regression- Impact of having one more hour of electricity on Monthly Per Capita Consumption Expenditure

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	FE	FE-IV	FE Rural	FE-IV Rural	FE Poor	FE-IV Poor
Electricity Hours	0.00	0.04**	0.00	0.03*	0.00***	0.03**
	(0.00)	(0.02)	(0.00)	(0.02)	(0.00)	(0.01)
Log real income	0.11***	0.11***	0.09***	0.09***	0.06**	0.06**
	(0.00)	(0.01)	(0.01)	(0.01)	(0.03)	(0.03)
Household Head Edu.	0.01***	0.01***	0.01***	0.01***	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household Head Sex	-0.04***	-0.05***	-0.03	-0.05**	0.04	0.05
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.04)
Household Head Age	0.00	0.00	-0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household size	-0.13***	-0.13***	-0.13***	-0.13***	-0.03***	-0.03***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Social network	0.15***	0.15***	0.17***	0.17***	0.11***	0.12***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.04)
Loan banks	0.08***	0.07***	0.06***	0.06***	0.02	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.04)
Membership ROSCA	0.05***	0.03*	0.06***	0.04*	0.04	0.06
	(0.01)	(0.02)	(0.01)	(0.02)	(0.04)	(0.04)
Year	0.89***	0.91***	0.92***	0.92***	0.85***	0.83***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)
Constant	5.98***	5.45***	6.12***	5.76***	5.17***	4.88***
	(0.06)	(0.25)	(0.07)	(0.21)	(0.28)	(0.33)
Observations	47,358	47,358	28,822	28,822	6,948	6,948
R-squared	0.685		0.685		0.818	
Number of id	26,655	26,655	16,478	16,478	6,058	6,058

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3. Robustness Check with Cross Section Data

Table 6 shows a cross section model for the year 2012. We aim to examine the effect of an additional hour of electricity on real income. Since in India, real income is dependent on time invariant characteristics such as caste and geography, we control for these time invariant characteristics. The effect of an additional hour of electricity on income is significant and positive for all specifications and the results are robust for varying number of observations and across all specifications. The effect is strongest in urban areas, which as expected, trade and commerce thrives on electricity in urban areas, and an extra hour of electricity means a lot. The negative selection bias is evident at the cross-sectional level but weaker than the panel regressions.

Table 6: OLS and 2SLS-IV- Impact of having more electricity on Log Real Income

VARIABLES	(1) OLS-All	(2) IV-All	(3) IV-Poor	(4) IV-Non-Poor	(5) IV-Rural	(6) IV-Urban	(7) IV-Rural Poor
Electricity Hours	0.01***	0.01***	0.02***	0.01***	0.01***	0.14***	0.02***
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.05)	(0.01)
Household Head Educ.	0.05***	0.05***	0.02***	0.05***	0.05***	0.06***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Household Head Sex	-0.10***	-0.10***	-0.08**	-0.09***	-0.10***	-0.18	-0.07*
	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.11)	(0.04)
Household Head Age	0.00***	0.00***	-0.00*	0.00***	0.00***	0.01**	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household Size	0.10***	0.10***	0.14***	0.11***	0.10***	0.06***	0.14***
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.02)	(0.01)
Social Network	0.22***	0.22***	0.03	0.22***	0.22***	0.19	0.03
	(0.03)	(0.03)	(0.05)	(0.03)	(0.03)	(0.14)	(0.05)
Forward Caste	-0.05**	-0.05**	0.02	-0.06***	-0.06***	-0.15	0.02
	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.13)	(0.04)
Other Backward Caste	-0.01	-0.01	0.00	-0.03	-0.00	-0.04	0.01
	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.14)	(0.04)
Scheduled Caste/Tribe	0.11***	0.11***	0.05	0.09***	0.12***	0.00	0.05
	(0.02)	(0.02)	(0.05)	(0.03)	(0.02)	(0.15)	(0.05)
Bus Stop in Area	-0.00	-0.00	-0.00	-0.00	-0.00	0.48**	0.00
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.21)	(0.02)
Investment Banks	0.22***	0.22***	0.08***	0.21***	0.22***	0.10	0.08***
	(0.01)	(0.01)	(0.03)	(0.02)	(0.01)	(0.08)	(0.03)
Constant	9.84***	9.82***	8.20***	9.81***	9.81***	8.82***	8.17***
	(0.13)	(0.13)	(0.47)	(0.13)	(0.13)	(0.54)	(0.47)
District FE	353	353	353	353	353	353	353
Observations	21,560	21,560	3,644	17,912	20,815	745	3,549
R-squared	0.331	0.331	0.396	0.326	0.329	0.133	0.400

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

For all areas, an increase in one hour of electricity increases real income by 1% in both the OLS and the IV fixed effects. For the poor in both rural and urban areas there is a 2% increase in real income with an additional hour of electricity. The effect is somewhat weaker for the non-poor at 1%. Interestingly the strongest effect of this specification among the caste is for the schedule tribe/caste, which are concentrated in the Eastern and North-Eastern areas with highest hours of load shedding with maximum gap without subsidy (pfcindia report, 2016). However, in recent years the impetus on energy sales has led to an astounding 16% increase in revenue in 2016 (pfcindia report, 2016).

Table 7 shows the effect of access and hours of electricity on unweighted assets. Moving from no access to having access increases assets by 9 more assets. Note that household assets range from 0-29, see Table A3 for the effects of electrification through a Principal Component Analysis of household assets. On the other hand, an additional hour of electricity has differential effects on asset creation depending on the margins of electricity deficiency. Households with less than 8 hours of electricity tend to gain more assets with electrification as compared to households with less than 12 and 16 hours of electricity.

For households with less than 8 hours of electricity an additional hour means nearly half more of an asset. When we do not restrict the electricity hours, an additional hour of electricity implies a 0.08 unit increase in the number of assets for the households. Although, it is not sound to compare unweighted assets to wealth of households, it gives a fair analysis of the impact of electricity on household wealth. All control variables exhibit expected sign and significance. Also, the negative selection is picked up by the asset's regression showing that households with higher assets have better electricity access and more hours of electricity.

Table 8 shows that electrification has had a positive and significant effect on household poverty reduction. We could categorize households with less than 8 hours as being acutely electricity deficient. In specification 1 we find that access increases the probability of moving out of poverty by 22%. From specification 2 onwards we focus on the impact of hours of electricity on poverty in rural areas with different hours of electricity access. An increase in hours of electricity increases the probability of moving out of poverty by 2%. This coefficient is identical for rural areas also. For households with less than 8 hours of electricity a day, an additional hour of electricity implies a 10% probability of moving out of poverty. As expected, the coefficient is smaller: 5% with 12 or less hours of electricity and 3% probability for 16 or less hours of electricity.

Table 7: Fixed Effects and IV- Impact of Electricity on Unweighted Assets

VARIABLES	(1) FE-All	(2) FE-IV All	(3) FE All	(4) FE-IV All	(5) FE-All Electricity<8 hours	(6) FE-All-IV Electricity<8 hours
Electricity	1.97***	9.34***				
	(0.06)	(1.71)				
Log Real Income	0.65***	0.55***	0.66***	0.65***	0.41***	0.38***
	(0.02)	(0.04)	(0.02)	(0.03)	(0.09)	(0.09)
Household Head Educ.	0.14***	0.12***	0.13***	0.13***	0.11***	0.10***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.03)
Household Head Sex	-0.24***	-0.18*	-0.22***	-0.22***	-0.02	-0.02
	(0.07)	(0.09)	(0.08)	(0.08)	(0.31)	(0.32)
Household Head Age	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Household Size	0.09***	0.07***	0.10***	0.10***	0.11**	0.13**
	(0.01)	(0.02)	(0.01)	(0.01)	(0.05)	(0.05)
Social Network	0.16***	-0.32***	0.45***	0.41***	0.49**	0.26
	(0.04)	(0.12)	(0.04)	(0.05)	(0.19)	(0.25)
Loan Banks	0.34***	0.39***	0.30***	0.30***	0.30	0.37*
	(0.05)	(0.06)	(0.05)	(0.05)	(0.21)	(0.22)
Membership ROSCA	0.61***	0.64***	0.49***	0.48***	0.39	0.23
	(0.06)	(0.07)	(0.06)	(0.06)	(0.31)	(0.34)
Year	3.31***	2.43***	3.87***	3.81***	3.55***	2.61***
	(0.03)	(0.21)	(0.03)	(0.04)	(0.15)	(0.67)
Electricity hours			0.04***	0.08***	0.17***	0.49**
			(0.00)	(0.02)	(0.03)	(0.22)
Constant	2.51***	-1.90*	3.64***	3.30***	3.08***	2.91***
	(0.28)	(1.08)	(0.30)	(0.34)	(1.03)	(1.06)
Observations	55,696	55,470	52,199	52,199	13,075	13,075
R-squared	0.580		0.605		0.588	
Number of id	29,339	29,113	28,653	28,653	11,510	11,510

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results from the extensive and the intensive margins of electrification highlight the relative usefulness of electricity for different income levels and different regions. The findings show that access and each additional hour of electricity has different usefulness for people who are poor, middle class, and the rich in rural and urban areas. An additional hour, in general, means more (stronger effect on real income) for the poor than the non-poor, more usefulness for an urban poor as compared to the rural poor. An additional hour means more for an urban household as compared to a rural household. This highlights the relative importance of electrification in urban areas with more opportunities attached to electrification as compared to rural areas where the role of electrification is limited to cooking and lighting.

Table 8: Logit Fixed Effects: Impact of Electricity on Status of Poverty

VARIABLES	(1) All	(2) All	(3) Rural	(4) Rural Electricity Hours < 8	(5) Rural Electricity Hours < 12	(6) Rural Electricity Hours < 16
Electricity	0.22***					
	(0.06)					
Log Real Income	0.42***	0.44***	0.35***	0.20*	0.25***	0.29***
	(0.03)	(0.04)	(0.04)	(0.11)	(0.08)	(0.06)
Household Head Education	0.04***	0.04***	0.03***	0.05*	0.05**	0.04***
	(0.01)	(0.01)	(0.01)	(0.03)	(0.02)	(0.02)
Household Head Sex	-0.37***	-0.33***	-0.30**	0.39	-0.22	-0.17
	(0.10)	(0.11)	(0.14)	(0.39)	(0.26)	(0.21)
Household Head Age	0.00	0.00	0.01	0.02*	0.02**	0.01
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Household Size	-0.52***	-0.51***	-0.51***	-0.43***	-0.52***	-0.46***
	(0.02)	(0.02)	(0.03)	(0.07)	(0.05)	(0.04)
Social Network	0.60***	0.59***	0.68***	0.66**	0.70***	0.62***
	(0.07)	(0.07)	(0.09)	(0.29)	(0.18)	(0.14)
Year	0.30***	0.34***	0.00	-0.40*	-0.02	0.07
	(0.04)	(0.04)	(0.05)	(0.22)	(0.12)	(0.09)
Membership ROSCA	0.22***	0.25***	0.11	-0.16	-0.09	-0.02
	(0.08)	(0.09)	(0.11)	(0.40)	(0.26)	(0.19)
Loan Banks	0.15*	0.14*	0.05	0.37	0.05	0.03
	(0.08)	(0.08)	(0.10)	(0.32)	(0.19)	(0.15)
Electricity Hours		0.01***	0.02***	0.10***	0.05***	0.03***
		(0.00)	(0.00)	(0.04)	(0.02)	(0.01)
Observations	11,648	9,476	6,074	674	1,658	2,678
Number of id	5,824	4,738	3,037	337	829	1,339

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Condition for categorizing a household as poverty changed between 2005-2012, as per the level of inflation (Consumer Price Index) and the report of the Tendulkar Committee report (Krishna, 2009). Our model adjusts for the revised poverty standard line by using poor category across year.

On the other hand, access to electricity is more important (stronger effect on monthly per capita consumption expenditure) for households in urban areas than in rural areas, while it means more to a poor rural household than a poor urban household which highlights the lack of penetration of private suppliers. In areas with acute electricity deficiency, an additional hour has stronger effects on poverty reduction which signifies the role of electrification and the lack thereof in reducing absolute poverty.

Social networks and real income are the two other determining factors in transitioning out of poverty. The cost benefit analysis in Table 9 shows a large cost benefit difference using the coefficients of the IV regressions as the magnitude of benefit and the monthly price paid as electricity bill as the cost.[8] The table shows the cost and benefit in income of adding one hour of electricity at the margin of electricity deficiency. High income households have the highest benefit from an additional hour of electricity - five times worth the cost of an additional hour. The net benefit to the poor per hour of electricity is Rs. 0.55, while for the middle class it is Rs. 1.724 and for the rich it is Rs 4.341. The gap between the benefits and costs declines with income levels.

Table 9: Cost benefit Analysis from two sources of electricity

Income Level	**SEB/Company**		**Illegal**	
Monthly	Cost	Benefit	Cost	Benefit
All Categories	0.84	2.368	0.103	1.376
Poor	0.652	1.199	0.059	0.859
Middle Class	0.88	2.604	0.157	2.104
Comfortable	1.381	5.722	0.423	3.63

Source: Authors Elaboration using IHDS 2005-2012

Note: Units is Rs. Price of electricity per hour is derived using 2012 prices and the marginal benefits are the coefficients of the fixed effect IV regressions

For the poor, the benefits are almost twice as much as they pay if the supply is from the state electricity board. Interestingly, the benefits are ten times the cost if the electricity is from a stolen connection which justifies the argument of rampant theft of electricity posed by Joseph (2010). For the middle class, it is three times what they pay. Strong ascending correlation between price and benefit, suggests that each hour of electricity demand is valued more than the price charged for each additional hour at the going rate. Hence, a progressive pricing and calculated price discriminations for the poor and the well-off could help achieve the goal of complete electrification.

[8] We use the actual prize paid by individuals at the household level to estimate the cost of electricity for an additional hour. Although the prices are subsidized, we can understand the gap in the benefits and costs at the subsidized rate.

As India lags behind in renewable energy, these results are positive signs for distributors to understand the benefit of an additional hour of service to the consumer. This analysis reflects on the ongoing issue in evaluating the impact of electricity common China, Brazil and in other major developing economies (Pereira et al., 2011).

5. Conclusion

This study investigates the relationship the relationship between electrification and household welfare in India during 2005-2012 using panel/cross-section fixed effects regression and logistic regression. We analyse the causal impact of electrification on monthly per capita consumption expenditure, real income, household and other assets and the status of poverty. Our results show that having access to electricity is crucial for household welfare both in urban and rural areas, especially for the poor.

At the extensive margin there is an increase of more than 50% in the monthly consumption expenditure of households with access to electricity in rural areas. Poor in urban areas have 37% increase in consumption expenditure with access to electricity. Non-poor in rural areas have an 53% increase in consumption expenditure with electricity access. At the intensive margin, an increase in the hour of electricity means a 4% increase in the monthly consumption expenditure of the overall population. One additional hour of electricity increases the monthly consumption expenditure of rural households by 3% and for the poor households by 3%. In terms of income, an additional hour of electricity increases urban household's real income by 14%, real income of rural poor by 2% and real income of poor in both areas by 2%.

Access and hours of electrification has also far-reaching impact on building household assets and transitioning out of poverty. Having access to electricity increases household assets by 9 units on a scale of 0-29. An additional hour of electricity for those with less than 8 hours of electricity in a day increases assets by 0.48 (nearly half an asset). Access to electricity increases household assets by 2.72 units and an additional hour of electricity increases household assets by 0.17 units. Access to electricity also seems to have a significant impact on poverty reduction especially in rural areas and among those who are deprived of good quality of electricity. Having access to electricity improves the probability of transitioning out of poverty by 22%. An additional hour of electricity for households with less than 8 hours of service improves the probability of transitioning out of poverty by 10%, 5% for households with access less than 12 hours, and 3% for households with access less than 16 hours.

We find that electrification is vital for meeting the growing demand for electricity and we reassert the need to move beyond counting the connections (Aklin et al., 2016) to household welfare in India. The socio-economic effects of electrification can be estimated if different dimensions of access are measured. The results assert that there is a strong and almost linear association between hours of supply and household welfare in the five realms of welfare studied. Our results suggest that this indicator should be prioritized in studies of access. This finding has implications for efforts such as the Global Tracking Framework (GTF), which has made important contributions by re-conceptualizing electricity access as multi-dimensional. The results testify to the importance of multi-dimensional approaches that measure access on a multi-tiered scale, instead of simply classifying households as connected or non-connected. This approach can be used to analyse measures of electricity access in surveys, avoiding the need to collapse the data at the mean village or district level. For social scientists, our study provides a steppingstone in developing comparable measures of access, and energy access more generally, and apply in other countries.

Aklin et al. (2016) state that if policy interventions increase the daily duration of supply at a low cost, the benefits to the population are potentially large. Our analysis show that there is a significant difference between the benefit and costs of electricity for households. Hence, there is a potential to tap the effective demand from the consumers point of view. Overall, the situation for policy makers is intriguing. Households need electricity as it has multifaceted spillovers at the micro and the macro socio-economy of the state and the nation. Electricity has to be provided but not as a freebie, users need to understand the price to pay in terms of the resources forgone.

The results highlight the importance of considering quality in energy poverty research. Household electricity connections are a natural focus in early efforts in rural electrification, but the rapid extension of national grids, and the spread of off-grid alternatives, necessitates focus on service quality. We find a robust association between access and number of hours of service available and household welfare. Electrification improve lives and hence a sustained effort to understand and contribute to increase service quality should be a priority, especially in severely affected areas. Settling down with access is a policy sleep once from which they have to awaken.

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