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Cambridge Working Papers in Economics: 2045

ELECTRIFICATION AND SOCIO-ECONOMIC EMPOWERMENT OF WOMEN IN INDIA

Ashish Kumar Sedai
Rabindra Nepal
Tooraj Jamasb

15 May 2020

This study examines the effect of quality of electrification on empowerment of women in terms of economic autonomy, agency, mobility, decision-making abilities, and time allocation in fuel collection in India. It moves beyond the consensus of counting electried households as a measure of progress in gender parity, and analyzes how the quality of electrification affects women's intra-household bargaining power, labor supply decision and fuel collection time. We develop a set of indices using principal component analysis from a large cross-section of gender-disaggregated survey. We use two stage least squares instrumental variables regression to assess the causal effect of access and hours of electricity on women's empowerment using geographic instrumental variables along with district and caste fixed effects. The results show that quality of electrication has significant positive effects on all empowerment indices. However, the effect differs at the margin of defficiency, location, living standards and education. The study recommends revisiting the paradigm of access to electrification and women empowerment by focusing on the quality of not only extensive but also intensive electrification to enhance life and economic opportunities for women and their households.

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EPRG Working Paper 2012

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Keywords Women Empowerment, Quality of Electrification, Instrumental Variables

JEL Classification D13, D63, H42, Q43

Contact tj.eco@cbs.dk

Publication May 2020

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*Department of Economics, Colorado State University. Email: ashish.sedai@colostate.edu
†Department of Acconting Economics and Finance, University of Wollongong. Email: rnepal@uow.edu.au
‡Department Economics, Copenhagen Business School. Email: tj.eco@cbs.dk

1 Introduction

Gender equality is desirable in itself and is necessary for holistic economic development [Duflo, 2012]. According to the United Nations "achieving gender equality and empowering all women and girls" emphasizes that an economy cannot achieve its potential without equal gender participation [Fukuda-Parr, 2016]. Though there have been several policy initiatives to foster this egalitarian view, a substantial gap still persists [Duflo, 2012, Hendriks, 2019]. In order to promote gender equality, these initiatives have focused on improving women's economic engagement through financial inclusion [World Bank, 2013], political participation as well as equal land and property rights [Cherchi et al., 2019].

Access to electricity and other sources of energy have been widely discussed as an effective pathway to empower women [Samad and Zhang, 2019, Khandker et al., 2014, Gould and Urpelainen, 2018], but the discussion of empowering women through reliable and adequate electricity at the intensive margin has remained elusive [Kennedy et al., 2019]. Thus, empirical evidence on the effect of quality of electricity on women's intra-household resource allocation, bargaining, time allocation and safety has been lacking.

Women in developing countries spend more time in the household than men hence, the quality of household electrification disproportionately affects them [Dinkelman, 2011, O'Dell et al., 2014]. However, the focus in the literature has been whether access to electricity benefits the households, especially women, through increases in labor supply, schooling of children, household income and expenditure as well as women's economic decision making ability and mobility [Samad and Zhang, 2019, Khandker et al., 2014, Rao, 2013, O'Dell et al., 2014].

According to the Government of India reports, there is no scope for improvement as India has already achieved 100% electrification of all villages (Saubhagya Report 2019). However, intensive margin requires policy attention in India because of the official definition of electrification laid down by the government, "a village is electrified if the basic infrastructure is in place; power is being supplied to schools, health centers and other public places; and at

least 10% of households are receiving electricity" [Agrawal et al., 2020].

Despite the micro evidences of the benefits women derive through electrification, a macro examination of the impact of the quality of electrification and its potential for empowering women has remained elusive. This study analyzes quintiles of electricity deficiency within the household and examines the causal effect of falling into those quintiles on women's socio-economic freedom, agency, mobility and decision making ability. We compare the impact of electrification on poor and non-poor, rural and urban women using the novel framework of women empowerment laid down by Kabeer [1999] in defining a woman's autonomy: (i) economic freedom, referring to women's ownership, control and decision making ability over economic resources, allocation and labor supply, (ii) agency in household decision making ability and reproductive freedom and, (iii) mobility, in terms of freedom to travel alone. We operationalizes women's empowerment as a step towards gender equality, access to and control over resources and power to influence matters that concern or affect them [Kabeer, 1999].

We use the India Human Development Survey (IHDS), 2012, which includes hours of electricity in a day, women's engagement in household and personal care activities as well as day to day decision making. We use this data set because it is the only primary survey data which has information electricity hours and eligible women's questionnaire at the national level. We analyze the effect of electrification on women empowerment variables related to economic freedom, reproductive freedom, mobility and decision-making ability. We use (i) Ordinary Least Squares (OLS) with district and caste fixed effects (FE) and (ii) Two Stage Least Squares instrumental variable (2SLS-IV-FE) regressions with a geographic instrumental variable Fang [2003][Khandker et al., 2014]Rao [2013][Chakravorty et al., 2014], average hours of electricity at the village/PSU[1] level except for the hours of electricity of the respondent as an instrument along with district and caste fixed effects [Bai et al., 2019]. We use principal component analyses (PCA) of nineteen empowerment variables to create five

[1]The data used includes observations from rural and urban areas. We denote the regional aggregation of participation through villages in rural areas and through PSUs in urban areas, Desai and Vanneman [2018].

indices and regress them on outages and quintiles of power outages. Power outages in our study refers to the average number of hours of electricity not available in a day, which is not related to a failure, but to network limitations.

The study finds strong positive causal effect of power outages on all empowerment indices at the national level. Outages have the strongest effect on poor women's economic freedom, agency and household decision making. They also have significant effects on women's agency and mobility, but the magnitude of the effect is smaller than the effects of outages on economic and household decision making. The instrument: Mean village/PSU level electrification satisfies the first stage weak, over and under identification tests, and has a strong effect on outages at the household level. The second stage instrumental variable regressions support the hypothesis of differential impacts of energy deficit on women depending on household income, location and women's education. Education matters the most, followed by location and income status for women in conjunction with the quality of electrification at the household level.

Section 2 reviews the literature on the significance of electrification for women with focus on the Indian context. Section 3 presents the theoretical and econometric model, and the data used in the study. Section 4 presents and contrasts the results from the OLS Fixed effects and 2SLS-IV regressions. Section 5 discusses the results. Section 6 concludes.

2 Literature Review

The discussion on the effect of quality o electrification is divided into two sub-sections. The first section reviews the literature on the effects of electrification and its impact on women's social and economic outcomes worldwide. The second section looks at the literature in terms of deficiency of electrification in India and the programs undertaken by the government to address the problem of electrification.

2.1 Background & Literature

Previous research has shown that access to electrification empowers women in myriad ways, first and foremost through improved lighting in rural areas which increases rural household's income, business income and wages [Chakravorty et al., 2014]. A study by Kanagawa and Nakata [2008] in Assam, India, shows that women in households without electricity hardly undertook any reading irrespective of their level of education. Since availability of lighting extends the effective workday, it allows women to leave certain household chores for the night enabling them to participate in more formal economic activity during the day [Kanagawa and Nakata, 2008]. However, these outcomes depend heavily on the reliability of the electricity service. In case of erratic power supply, these benefits may fail to materialise. For instance, electrified households receiving no electricity at night may not be significantly different from households without grid connection. This has a direct bearing on the economic condition of women. Deficiency of electricity through demand or supply channels can both lead to sub-optimal time allocation to home production by women which reduces their labor supply and increases unpaid care work [Dinkelman, 2011].

Lack of electricity dissatisfies women as children have less flexible study time at home [Kennedy et al., 2019]. From a non-economic standpoint, street and household lighting allows women to commute after dark [Standal and Winther, 2016]. Unlike kerosene lighting, electricity provides good quality light required for reading which has potentially long-term productivity impacts [Chakravorty et al., 2014]. Along with electric lighting, electrical appliances reduce time and effort for household chores leaving room for other productive activities [Standal and Winther, 2016]. Time conservation reduces the engagement in intensive household activities allowing leisure and improvement in living standards while providing opportunity to participate in the labour market [Dinkelman, 2011] [Samad and Zhang, 2019]. The study by Standal and Winther [2016] in West Bengal, Uttar Pradesh and Jharkhand finds that electricity affects everyday life in terms of providing important resources and enhancing women's opportunities to perform their role as care workers more efficiently and in

a qualitatively better way.

Often, women spend the majority of their time in cooking and collecting firewood primarily because biomass fuels are perceived to be cost effective, however, they are highly polluting and adversely affect the health of women [Bansal et al., 2013]. Their lower calorific value necessitates prolonged cooking hours thereby enhancing the exposure to hazardous emissions. Although the use of Liquified Petroleum Gas (LPG) has been widely discussed as the alternative to clean cooking, the principal constraint to widespread adoption is the fuel cost [Gould and Urpelainen, 2018] coupled with weak bargaining power of women in rural households for having LPG connections [Bansal et al., 2013]. Household electrification holds tremendous potential for improving the status of women and enhancing their quality of life.

Standal and Winther [2016] show that across all levels of education, women in electrified households were much more likely to read during a day compared to unelectrified households. Virtually no reading by women took place in households without access to electricity which has clear implications for women continuing their education [Kanagawa and Nakata, 2008]. Further, as households add new electrical appliances, the impact on women's life is even greater. They allow women to perform household chores with greater efficiency, for instance, the amount of time required to process food or spices can be considerably reduced through the use of a simple grinder. Aside, electrification is often associated with information by exposure to media such as radio and television, which plays a crucial role in raising awareness and educating women [Samad and Zhang, 2019]. Exposure to radio and television spurs fertility decline via increased use of contraception [Stephenson et al., 2006]. It also enables women to lessen the grip of traditional and cultural norms and participate more actively in the society [Standal and Winther, 2016].

Empowerment of women through electrification underscores the need for adequate access to energy as a means towards inclusive development. The principal question is the discovery of an optimal price and quantity given the constraints. Burgess et al. [2020] show how treating electricity as a freebie creates economic inefficiency because it develops a social norms that

everyone deserves power independent of payment, subsidies, theft, and nonpayment. This creates a sinking circle whereby electricity distribution companies lose money, government-owned distribution companies restrict access and hours of supply is no longer governed by market forces [Burgess et al., 2020]. The link between payment and supply is severed, thus reducing customers' incentives to pay, hence the equilibrium outcome is uneven, and sporadic access undermines growth [Burgess et al., 2020].

Policy makers face a dilemma wherein electricity supply is quintessential for household welfare, especially women's empowerment, but providing electricity for free does not seem to be a feasible solution. In this context, this study contributes to understanding how additional hours of electricity affects women's empowerment depending on the income levels in rural and urban areas. Better knowledge of the marginal benefits and costs to women of hours of electricity could provide policy makers with better understanding of appropriate pricing mechanisms depending on the margin of deficiency and the objective of gender parity. Faults in the existing structures of the public-private distribution grid cannot sidestep the significance of electrification for women and understates the potential impact of providing energy services to women who would not sit idly. Although designing appropriate pricing mechanisms is important and energy supply to women through targeted measures is a justified concern, it is beyond the scope of this study.

2.2 The Context in India

Domestic energy concerns loom large for women in a country where 65% of the population resides in rural areas with uneven and often unreliable access to electricity supply [Samad and Zhang, 2019], also shown by figure 1. Despite making great strides to improve the access to electricity supply since 2005, reliability of the supply has largely been neglected by the government which can be the potential actor to empower women by enabling them to be more efficient in household activities, enhance their educational and awareness levels, enter

workforce and start businesses [2]. Often seasonal fluctuations and irregular access acts as a serious impediment to welfare outcomes that electrification holds for women in terms of labor supply and leisure.

Over 1/3 of the 840 million people lacking access to electricity globally reside in India [ECOSOC, 2019]. This figure underlines the scarcity and bottlenecks of energy supply and the inability of various households to afford electrification for the whole day. With only 5.4% electricity generated from renewable sources , the supply gap is highest in India among the developing economies. India is dependent on the use of biomass in rural areas. Further, the country has the highest share of world annual consumption of biomass – 22% – significantly higher than that of other continental-size countries with similar social inequality.

In terms of the progress in electrification, there are two contradicting evidences the extensive and the intensive margin. At the extensive margin in terms of access, the World Bank micro data shows that the percentage of population having access to electricity has increased from 67.2% in 2005 to 92% in 2017. One of the the latest household survey (ACCESS 2015-2018) of six most populous states of India [Jain, 2018], shows that there has been an increase from 72% grid connection to 85% grid connections in the six states. This figures shows huge improvements in the accessibility of electricity however, a closer look at the hours of electricity and the hours of electricity in the night (after sunset until 12 o'clock midnight) shows improvements, but the deficiency still persists. From 2015-2018 average hours of electricity in a day increased from approximately 13 hours a day to 15 hours a day. Electricity at the night time stagnated from 3.4 hours to 3.5 hours a day. A huge gap in reliable electrification still persists.

The early focus on electrification in India had been on building up industrial capacity and facilitating the use of electric pumps for irrigation purposes. It was only in the 1980s that the central planning system started considering electricity as a basic input to household

[2]Authors elaboration from the average hours of electricity in a day at the household level from IHDS, 2005-2012. In 2005, the average household electricity hours in a day was 16 hours in 2005 which stagnated, even reduced to 15.68 hours a day in 2012.

production [Palit et al., 2014]. A major impetus was observed in 2005 following the forward-looking Electricity Act of 2003 (EA), when the government launched Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) which led to a large increase in the village electrification rate from 59% in 2000 to 74% by 2010, albeit at the expense of massive losses to distribution companies due to subsidies and thefts [Pargal and Ghosh Banerjee, 2014]. Though the reforms succeeded in increasing the rate of electrification, it failed at ensuring the reliability of the service as evidenced through the IHDS survey 2005-2012 and also shown through high frequency satellite images by [Min et al., 2017]. In fact, Min et al. [2017] found that many villages that were officially deemed as 'electrified' under RGGVY remained in dark for years after completion of electrification projects.

In 2015, RGGVY was subsumed in Deen Dayal Upadhyay Gram Jyoti Yojana (DDUGJY) which aimed to provide continuous power supply to the households [Jain, 2018]. In 2019, India achieved 100% village electrification as per the Saubhagya, government of India report [Mehra and Bhattacharya, 2019]. A village is deemed 'electrified' if at least 10% of the households along with public spaces like school, post office, and basic infrastructure have access to electricity [Nouni et al., 2008]. However, according to Smart Power India report (2017), approximately 237 million Indians lacked access to reliable electricity. In the government's efforts to electrify communities, the emphasis has been on providing grid connections to increase the count of electrified households while the reliability concerns have largely escaped the attention of policy makers. Not only does it mask the problem of poor household's access, it also does not consider the quality of electricity service provided which is essential for improving the quality of life for women. As a result, the impetus has been on counting the electrified households, neglecting the reliability of the service. However, to reap the socio-economic benefits of electrification, it is important to move beyond the binary of classifying households as either having access to electricity or not and argue for a richer definition which also incorporates the quality of the provided service.

In India, fuel wood collection and cooking forms a large part of household work whose

burden primarily falls upon women. According to Sharma et al. [2019], women in rural areas in Jharkhand spend an average of 2hrs 45 mins on cooking activities and 2 hrs 30 mins on an average to collect firewood on a typical day. Not only is it arduous, the usage of traditional fuel is extremely hazardous to health, especially for inhabitants who stay inside the house for longer duration, and additionally, environmentally degrading. In India, the ambient pollutant (PM10) concentration was drastically high around $20000\mu g/m^3$, even higher near the cooking locations Sharma et al. [2019]. This is higher than the benchmark set by Environmental Protection Act, 1986 around $150\mu g/m^3$. Further, health tests to measure smoke levels in the lungs found that women had an average carbon monoxide (CO) reading of 7.77ppm, while children had CO levels similar to those from smoking about seven cigarettes per day Parikh [2011]. These findings show grave impacts of using biomass fuels on women's health and wellbeing, in light of the fact that 80% of energy needs are met by biomass fuels. Electrification is often found to spur the switch to cleaner fuels such as Kerosene, Liquified Petroleum Gas and electrical cooking which saves women from the collection and usage of biomass, and allows them to use their time in more productive activities.

Exposure to electronic media, especially television has made women more assertive, thereby, increasing their autonomy in the household. Jensen and Oster [2009] find that the access to cable television results in lower acceptance of spousal abuse, lower preference for sons and greater likelihood of sending girls to school in rural India. Television viewing may also improve women's domestic productivity and welfare through greater knowledge. Home-based technology such as electricity can reduce household dependence on girls' labor and reduces the opportunity cost of sending girls to school Köhlin et al. [2011]. However, for energy access to translate into empowerment, it needs to be reliable and affordable. According to Köhlin et al. [2011], benefits emerging from the improved access to energy are substantial for women but the size of benefits is constrained by frequent power cuts. Therefore, providing reliable electricity supply, instead of merely counting electrified households, should be an important policy priority.

3 Methodology

The model is based on the intra-household resource allocation and uses a Nash bargaining solution [Cohen and Glazer, 2017] under the assumption that an additional hour of electricity at the margin of electricity deficiency has significant effects on the socio-economic outcomes of women in the household where the modelled household consists of a wife and husband. Following gender disparity in relative bargaining power and the unequal time spent by women in the house [Duflo, 2012, Kabeer, 1999], we assume that household electrification disproportionately benefits women, and that the path to increased household welfare is largely through the wife [Duflo, 2012, Mayoux and Anand, 1995]. Thus, the women in the household have a higher preference for more electricity hours compared to their husband.

The objective is to maximize the joint utility of the household, the husband and wife who live for two periods. The husband's preferences for the indivisible good are positive but lower than the wife's. We test the comparative static effect of additional electricity hours on the wife's bargaining power in intra-household resource allocations. The model shows that if the wife's preference $\delta \geq 0.5$ for household electricity is more than the husband's, then a marginal increase in expenditure on the purchase of an additional hour of electricity increases the wife's bargaining power. This model has been extensively used in the field of micro-finance and women empowerment but has been relatively under explored in the field of energy and women empowerment.

3.1 Theoretical Model

In the first period, the wife expresses demand for an electricity D for which her preference $\delta\epsilon(0,1)$ is higher than the preference of the husband $(1-\delta)$. To acquire more hours of electrification the household must save S (we alternatively use savings to reflect expenditure on the purchase of electricity). For simplicity, we assume that the household earns the same income in both periods, although the assumption can be relaxed to account for inflation

adjusted income. Both the husband and the wife are risk averse and have utility functions that exhibit Constant Relative Risk Aversion (CRRA).

Wife's utility function: $U_W = U(c_1) + U(c_2) + \delta D$. Husband's utility function: $U_H = U(c_1) + U(c_2) + (1-\delta)D$. CRRA utility function implies: $U(c_1) = c_1^{(1-\theta)}/(1-\theta)$ and $U(c_2) = c_2^{(1-\theta)}/(1-\theta)$. Household utility function is derived from the Nash bargaining model:

$$U_{HH} = (U_W)^{\gamma}(U_H)^{(1-\gamma)} \tag{1}$$

where γ is the relative bargaining power of the wife and $(1-\gamma)$ is the relative bargaining power of the husband in intra-household resource allocations. Given that the preference for the indivisible good D is higher for the wife, we have $\delta > (1-\delta)$. The household faces the following constraints: (i) $S \geq 0$; savings in the first period has to be positive to acquire the indivisible good D, (ii) $Y \geq C_1 + S$; income in the first period should be equal to consumption in period 1 and savings in period 1, (iii) $Y + S \geq C_2 + D$; income and savings from the first period must be more or equal to consumption in period 2 and the expenditure on the purchase of higher hours of electricity D.

Identifying consumption as a function of income and savings, the household maximization problem with choice of savings S and purchase the reliable electricity D is given by the household utility function (1) with the constraints:

$$Log(U_{HH}) = (1-\gamma)[U(Y-S)+U(Y+S-D)+(1-\delta)D]+\gamma[U(Y-S)+U(Y+S-D)+\delta D]$$

subject to

$\mathrm{S} \geq 0$

$\mathrm{Y} \geq C_1 + S$

$Y + S \geq C_2 + D$

(2)

First order conditions of the maximization exercise $\partial U_{HH}/\partial S$ in equation 3.1 gives the

neccessary condition for the household to purchase the available electricity $(C_1)^{-\theta} = (C_2)^{-\theta}$. The savings neccessary to buy electricity is given by $S = D/2$. The marginal effect of purchasing electricity on the joint utility shows that the optimal savings rate is given by

$$S = Y - (2\delta\gamma + 1 - \delta - \gamma)^{-1/\theta} \tag{3}$$

Here θ is the parameter of relative risk aversion. Marginal effect of bargaining power on the savings function $\partial^2 Log(U_{HH})/\partial S \partial\gamma$ in equation 3 shows that with an increase in the bargaining power of women in the household, the savings for electrification in period 1 also increases.

$$\partial S/\partial\gamma = 1/\theta[2\delta\gamma + 1 - \delta - \gamma]^{(\theta-1)/\theta}(2\delta - 1) \tag{4}$$

Equation 4 is a positive for any value of $\gamma\epsilon(0, 1)$ if $\delta > 0.5$. Partial derivative of wife's bargaining power with changes in the savings

$$\partial\gamma/\partial S = [\theta(Y - S)^{-\theta-1}]/2\delta - 1 \tag{5}$$

Equation 5 shows that an increase in savings for electrification increases women's bargaining power in intra-household resource allocations.

3.2 Empirical Model

We are interested in estimating the causal effect quality of electricity on women empowerment. We consider that the outcomes are conditional daily hours of electricity and power outages, the baseline estimate is as follows:

$$Y_i = \alpha_i + \delta QE_i + \beta X_i + \gamma d_i + \theta c_i + \epsilon_i \tag{6}$$

Where, Y_i represents the outcome of interest, empowerment for women i of caste c_i in district d_i. X_{ij} is a vector of individual and household observable socioeconomic and demographic characteristics: real income, household adult education, women education, age, number of children, household size, age of the household head, sex of the household head, rural/urban and caste. QE_i is the hours of electricity outage in the house of the i-th women of c-th caste in the d-th district. We control for geographic and cultural characteristics at the district and caste levels with district and caste dummy variables. The error term ϵ_i is assumed to be randomly distributed. α, β, and δ are the unknown parameters to be estimated. The interest in the analysis is to estimate the effect of hours of electrification, measured by the coefficients δ.

If villages/PSUs were randomly selected, and electricity distribution happened randomly then the baseline estimation in equation 6 would have provided unbiased estimates of the impact of electrification. However, in practice individuals and households are not randomly assigned to hours of access to electricity. There is an element of self-selection and sorting involved. The decision to acquire electrification is based on both observed (income, household size, age, sex, caste and locality) and unobserved characteristics at the village/PSU level. There are unobserved characteristics such as household preference for electricity, the relative bargaining power of the women in the household, productive potential of the household and the ability to perceive benefits from electrification. These issues lead to endogeneity, self-selection and sorting in acquiring reliable electrification. Households that are likely to be excluded and left to be subsidized with irregular electricity, such as poor and the less educated, are more inclined to acquire higher hours of electricity indicating a positive selection bias, especially in households where women have strong bargaining power Donoso et al. [2011].

Endogeneity can manifest in various ways. For example, it could be due to time varying omitted variable bias motivated by unobserved factors at an individual and household level, or that individual's perception about potential benefits of electrification leads to a positive

self-selection bias. There could be reverse causality with positive or negative self selection. Household could stop bargaining for electrification once they reach a certain threshold of income and be able to afford alternate sources of electrification causing a negative selection bias. Hence, a proposition could be made that households who are at the extreme ends of electricity deficiency may have low marginal benefits from an additional hour of electrification. Endogeneity may also arise from simultaneity if outcomes such as household income and electrification are jointly determined. Thus equation 6 would yield biased impact estimates. To this effect, we expect the baseline estimate to underestimate the coefficients.

To address this problem of endogeneity, we instrument household hours of electricity with average hours of electricity at the village/PSU level. The same instrument has been used previously on the effect of electrification on household and non-farm income [Khandker et al., 2014, Chakravorty et al., 2014]. These studies have used the average access of electricity at the village level. In our study we substitute average access by average hours of electricity at the village/PSU level. A technical view of access vs. hours of electricity is potential power (capacity) vs. energy (power*hours). Some systems are capacity constrained and some are energy constrained. In this case, the system is mostly energy constraint. For example, in the case of water with only two hours of access one can store some water but with electricity this is not possible.

We use average hours of electricity at the village/PSU as this would affect a household's choice of electricity hours through peer-effects and demonstration effects. Higher hours of electricity at the village level could induce a household which is below the average level to acquire more hours of electricity. In India, where caste and religion form the basis of social structure, this social structure influences how a particular village/PSU is populated [Newman and Thorat, 2010]. The structure of social organization influences a household's choice of electricity hours given the local hours of electricity [Khandker et al., 2014, Rao, 2013]. The first stage estimate of instrumental variables (IVs) regression is obtained by

estimating the following equation

$$QE_i = \alpha_i + \lambda I_{ij} + \beta X_i + \gamma d_i + \theta c_i + \epsilon_i \tag{7}$$

Where I_{ij} is the vector of instruments of mean hours of electricity in village/PSU j [3]. λ is the vector of coefficient of the effect of average hours of electricity at the village/PSU level on household's hour of electricity. If neighbors acquire more hours of electricity and realize economic and social gain of better quality of electrification, then the status of fewer electricity hours may signals lower socioeconomic standing and a case for social depravity, which we expect households would want to avoid.

We expect that the higher the hours of electricity in a village/PSUs, the higher will be the likelihood of a household in that village/PSUs to acquire more hours of electricity, provided the household can afford the cost. The exogeneity condition for the instrument also holds because mean village/PSUs level electricity does not directly affect a woman's economic and social agency in household decision making processes. Women's financial autonomy, mobility, agency and socio-economic decision making ability depends on their education, economic and social condition at home, and the relative intra-household bargaining power [Kabeer, 1999]. We expect a negative self selection bias as empowered women already have higher household income and education would have an alternate source of electricity, the outcome of which is that they do not need to acquire state/agency provided electricity.

We follow a two stage least squares linear probability instrumental variable (2SLS-IV) equation Semykina and Wooldridge [2010], with cross-section data as it permits for unspecified correlation between I_i and α_i, but requires I_i to be uncorrelated with the error u_i.

$$y_i = \alpha_i + \delta QE_i + \beta X_{1i} + \gamma d_i + \theta c_i + \epsilon_i \tag{8}$$

[3]There are 1503 villages in the survey with 42152 household level observations, hence there is sufficient variation of approx 28 observations at the village/PSU level, see Khandker et al. [2014] for geographic instrumental variables using IHDS, (2012).

Where, y_i is the dependent variable. For our study, these are the 5 empowerment indices created by classifying 19 empowerment variables of women i in village/PSU j based on the IHDS, 2012 survey using a principal component analysis (see Table 2). QE_i is the hours of power outage and allowed to be correlated with the ϵ_i, all other notations are similar to equation 7. The model does not reject the hypothesis of no selection bias and allows for arbitrary correlation between the unobserved effect and the explanatory variables. We use caste and district fixed effects in the instrumental variables to derive a more robust casual effect by controlling for the observed time invariant characteristics as these have significant impact on women's empowerment in India [Chandrasekhar and Ghosh, 2018]. The model allows for any type of correlation between unobserved effects, explanatory and instrumental variables, and does not require any specification of the reduced form equations for endogenous variables. It makes no assumptions about errors distribution.

4 Data

The data used for this analysis is mainly from the third wave of the Indian Human Development Survey (2012) [Desai and Vanneman, 2018]. IHDS are nation-wide random sample surveys covering all 28 states of India except Meghalaya and Union Territories of Andaman and Nicobar Islands and Lakshadweep, depending on population density [4]. IHDS have representative individual, household and gender disaggregated survey and wide-ranging topics at household and individual level on demographic and socio-economic characteristics. The survey also covers key features of the households at aggregated level including caste, religion and village level infrastructure. These features help control for community and district level characteristics in the analyses as they can directly affect the outcomes of interest. The survey covers 13,706 households from urban areas and 28,446 households from rural areas. We use only the third wave of the survey by combining the Individual, Household and Eligible

[4]The surveys are jointly carried out by researchers from the University of Maryland and the National Council of Applied Economic Research (NCAER) in New Delhi [Desai and Vanneman, 2018].

women's questionnaire (IHDS, 2012), since the IHDS 2005 does not include all the variables to create the indices of empowerment. We select 19 variables relating to gender relations, all of which are only available for the third wave of the survey with 1,503 villages and 42,152 households.

The survey covers key socio-economic aspects of gender relations, agency, mobility and decision making processes as shown in table 1.

Insert Table 1 here

It shows the descriptive statistics for the sub groups classified by quintiles of power outage with difference in means tests across the quintiles to compare these samples. There are significant differences among women in economic decision making, mobility, agency and household decision making ability between the quintiles of deficiency. A pronounced difference can be seen between women in the first and the second quinitile of deficiency, highlighting that the having less that 5 hours of outage of electricity in a day does not substantially affect women's empowerment, but the second quinitile 5-14 hours and third quintile 15-24 hours of deficiency have a strong bearing on the empowerment variables. We explore the correlation between the empowerment variables and use these variations to create empowerment indices as shown in table 2 using Principal Component Analysis (PCA).

We choose the component which has an eigen value greater than one as is the common practice with PCA [Fang, 2003]. Component loading for economic empowerment includes four variables: cash in hand for household expenditure, women's ownership of property, and women's employment and women's decision making ability about their work. PCA analysis in Table 2 shows that cash in hand for expenditure has significantly higher weight than property ownership and employment in terms of determining the economic freedom for women.

Insert Table 2 here

The analysis assigns ranks and factor loads (weight) to each variable within each empow-

erment category. We have five standardized empowerment indices with a mean of zero and a standard deviation of one namely: economic freedom, economic decision making ability, agency, mobility and household decision making ability. For simplicity, we use empowerment indices instead of individual variables with the district and caste fixed effects and treat the OLS model in equation 6 as the baseline model following the fixed-effects estimation in normal linear models [McCaffrey et al., 2012]. Coefficients in all regression tables are deviations from zero as the indices are standardized with mean zero and standard deviation of one.

5 Results

For expositional purposes, we start the analysis at the extensive margin with an instrumental variable regression of the access to electricity on women's empowerment indices. We use mean access to electricity at the Village/PSU/District/State level as an instrument for the analysis at the extensive margin following the save IV used by Khandker et al. [2014], Rao [2013], Chakravorty et al. [2014]. Table 3 shows that reliable access to electricity has strong positive effects on women's economic freedom, economic decision making, agency, mobility and household decision making.

Insert Table 3 here

Access to electricity increases women's economic freedom by 0.34 standard deviations, women's economic decision making by 0.25 standard deviations, women's agency by 0.58 standard deviations, women's mobility by 0.38 standard deviations and household decision making ability by 0.44 standard deviations. Samad and Zhang [2019] have carried out a similar analysis and have shown the effects of access to electricity on women's socio-economic agency at the extensive margin only. We start the analysis at the intensive margin using an OLS fixed effects regression with district and caste fixed effects as shown in equation 6. Specification 1 in Table 4 shows the index of women's economic freedom created by the PCA of cash in hand for expenditure, current employment, decision making ability about work and property

ownership.

Insert Table 4 here

An additional hour of power outage in a day reduces women's economic freedom by -0.02 SD. Once we add additional controls in specification 2, the effect of power outage on women's economic freedom is still significant at 1% but the magnitude of effect decreases to -0.01 SD. Comparing specification 3, 4 and 5 shows that power outage at the second quinitile (5-14 hours of outage a day) has the strongest negative effect on women's economic freedom. Although any power outage has a negative effect on women's economic freedom, it is the second quintile of outage that has the strongest bearing on economic freedom. Household income has a positive effect on women's economic freedom. Further, women's education has a positive effect on economic freedom. Women's age has a positive effect on their economic freedom. Given that the poorest population have the lowest access to electricity [Samad and Zhang, 2019], the number of children for these women have a positive effect on their economic freedom. Women headed households have a positive effect on women's economic freedom. Household size has a negative effect and except for the Brahmin caste which is the base of the analysis for caste, belonging to any other caste does not individually have any bearing on women's economic freedom in the sample.

Figure 2 shows the effect of an additional hour of power outage on women's empowerment and fuel collection time of girls for the poor and non-poor. Figure 3 shows women's empowerment with interactions at income levels and education of women. The results of the non-linear OLS fixed effect regression shows that poor women expectedly have lower levels of empowerment with additional hours of power outage. Education is more important than their economic status in terms of determining the effect of power outage on their economic freedom, economic decision making ability, agency, mobility, household decision making ability and fuel collection time. Overall, the figures show that income and education are key in determining empowerment with electrification. Empowerment indices are affected differently by income and education interacted with electrification.

Table 5 compares the effect of margins of electricity deficiency on women's economic decision making, agency, mobility, household decision making and fuel collection time for girls using the baseline OLS fixed effects model in equation 6.

Insert Table 5 here

An additional hour of outage has a strong negative impact on all the variables in the bivariate and multivariate regression. As in economic freedom, households belonging to the second quinitile of electricity deficiency bear the strongest negative effect on women's empowerment: -0.01 SD on economic decision making, -0.01 SD on women's agency, -0.03 SD on mobility and a significant but smaller effect on women's household decision making ability. Quintile 1 of power outage has a stronger effect than quintiles 2 and 3 in terms of women's agency. An additional hour of outage increases the fuel collection time of young women under the age of 15 by approximately 2 minutes. In comparison with other indices, women's agency in terms of use of contraceptives, membership in social organizations, decision in own sickness and the illness of the child is most affected by power outages and is significant across all quintiles of power outage.

Given the presence of endogeneity in the relationship between electricity and women empowerment, as well as self-selection in electrification, we use instrumental variables regression to examine the intensive margin of electricity deficiency. The instrumental variable regression in Table 6 shows the causal effect of an additional hour of outage on women's empowerment indices and fuel collection time in the household of adult women and children under the age of 15 in the household.

Insert Table 6 here

Results show that power outage affects all facets of women's empowerment under consideration. An additional hour of power outage in a day reduces women's economic freedom, agency, mobility and household decision making by 0.02 SD and the effect is significant. Power outage reduces women's economic decision making by 0.01 SD. Household income

has a negative effect on women's economic and household decision making which confirms to the de-feminization theory with higher incomes in India [Abraham, 2013]. An additional hour of outage increases the woman's fuel collection time by 1.06 minutes, the boy's by 4.96 minutes and the girl's by 2.56 minutes. Apart from income which shows a strong negative selection bias in the IV regression, all other covariates exhibit similar signs as the baseline model in equation 6, but the significances are different correcting for selection bias in the baseline estimates.

Table 7 shows the effect of moving from one quinitile of electricity deficiency to the next quintile on women's economic empowerment for poor and non-poor households in rural and urban areas.

Insert Table 7 here

One quinitile increase power outage on an average reduces poor women's economic freedom by 0.14 SD and non-poor women's economic freedom by 0.20 SD. In rural areas a quintile increase in outage reduces economic freedom of women by 0.15 SD and in urban areas the effect is negative but the coefficient is insignificant. In terms of economic decision making of poor women, an increase in the quintile of power outage reduces poor women's economic decision making by 0.10 SD, and for the non-poor women by 0.12 SD. In rural areas the economic decision making is reduced by 0.16 SD and in urban areas by 0.10 SD. Overall, an additional quinitle of power outage reduces economic freedom and economic decision making more for the non-poor women than for poor women. Outage negatively affects women's economic freedom and decision making in rural areas as compared to urban area. Results show that non-poor and more educated women in rural households are likely to suffer more from power outage as compared to poor women in urban areas with lower education levels.

Table 8 shows the effect of an additional quintile of power outage on women's agency, mobility and household decision making ability.

Insert Table 8 here

Outage does not have a significant effect on poor women's agency. It has a negative and significant effect on non-poor women's agency by 0.15 SD. Women's agency is reduced by 0.17 SD in rural areas and 0.27 SD in urban ares. In terms of women's mobility, an additional quintile of power outage reduces poor women's mobility by 0.25 SD and non-poor women's mobility by 0.15 SD. Mobility for rural women is reduced by 0.18 SD, for urban women the effect is negative but insignificant. Household decision making for poor women is reduced by 0.22 SD. For non-poor women the household decision making ability reduces by 0.14 SD. The household decision making ability for rural women reduces by 0.15 SD and in urban areas it decreases by 0.20 SD. Overall, similar to the effect on economic empowerment, an increase in quintile of outage affects rural non-poor women's agency, mobility and decision making more than poor and non-poor women in urban areas.

6 Conclusion

This study analyzes how empowerment of women is affected by the quality of electricity outages at the household level. We investigate the causal link between access and quality of electricity and women's empowerment using a large gender-disaggregated survey from the India Human Development Survey, 2012. We use principal component analysis to combine 19 variables that elicit information on women's economic freedom, intra-household decision-making and resource allocation into five indices of empowerment: economic freedom, economics decision-making ability, agency, mobility and household decision making ability.

The study finds that an additional hour of power outage and the quintiles of outages reduce women's empowerment and bargaining power, but the effect is not homogeneous across all women population. An hour of electricity is more beneficial for women in the second quintile of electricity deficiency where household on average has no electricity between 5-14 hours a day. There is not much difference in the effect of electrification for those who the second and third quintiles of outage where on average the household faces outages for

15-24 hours a day.

A number of factors in conjunction with electricity deficiency affect women's empowerment in India. Educated women tend to lose the most from outages in rural and urban areas conforming the loss of labor supply by educated women with energy deficiency [Chakravorty et al., 2014, Dinkelman, 2011]. Household income has a strong impact on women's empowerment associated with electricity deficiency, as also suggested by [Kanagawa and Nakata, 2008], [Khandker et al., 2014]. The analysis shows that having access to electricity is not sufficient to empower women and the quality of electricity affects women's position on all five dimensions of empowerment.

Women's labor force participation, education, health and exposure to electronic media are key intermediary factors through which electrification enhances women's empowerment. We find that the quality of electricity is associated with positive improvements in all five enabling factors for empowerment. We then investigate how the intermediate factors may affect women's empowerment depending on education and household characteristics such as income and location. We find suggestive evidence that women's labor force participation and education are the most important determinants of their intra-household bargaining power.

Our results suggest that counting the electrified households is not sufficient and quality is an important policy lever for empowering women. However, electrification alone is unlikely to ensure significant progress in important dimensions of women's empowerment, in particular, for decision-making ability and economic freedom. Sustained efforts in improving women's earning opportunities, education, household income and urbanization are important for improving their agency and empowerment. These enabling factors can be improved in other ways besides electrification. One possible approach is the use of micro-finance in provisioning of energy access to women. Policy measures targeting pervasive social norms and gender stereotypes are also needed to reduce gender inequality.

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Table 1: Descriptive Statistics and Mean Difference at Three Quinitles of Power Outage, India, IHDS, 2012

Variables	Obs	Mean	sd	Obs	Mean	sd	Obs	Mean	sd	Mean Diff.	Mean Diff.
	Q1 (Power Outage (0-4) hours)			Q2(Power Outage (5-14) hours)			Q3(Power Outage (15-24) hours)			p (Q1-Q2)	p (Q2-Q3)
Real Income (base 2005)	14830	92957.84	135116.50	11660	65648.32	105620.60	10100	66827.43	134304.60	***	
Women Education	12397	1.30	0.63	9841	1.16	0.48	8594	1.14	0.44	**	
Women Age	12398	37.32	9.22	9842	36.46	9.57	8594	36.33	9.57		
Number of Children	12395	2.36	1.32	9837	2.59	1.48	8593	2.72	1.62	*	*
Household Head Education	14829	9.74	4.66	11660	8.35	4.94	10093	8.21	5.09	***	
Household Head Sex	14828	1.15	0.36	11656	1.14	0.34	10100	1.13	0.34		
Household Head Age	14828	50.62	13.20	11656	49.66	13.49	10100	49.56	13.60		
Household Size	14830	4.74	2.15	11660	4.89	2.36	10100	5.07	2.46	*	*
Urban	14830	0.55	0.50	11660	0.32	0.47	10100	0.22	0.41	***	***
Electricity Hours	14830	22.17	1.57	11660	14.23	3.01	10100	6.19	1.88	***	***
Hours of Power Outage	14830	1.83	1.57	11660	9.77	3.01	10100	17.81	1.88	***	***
Women Knowledge of Health	14683	2.60	0.63	11530	2.51	0.70	9964	2.34	0.76	*	**
Fuel Collection Minutes											
Adult Women	3031	153.54	109.23	3559	157.72	104.29	3148	155.14	107.52		
Boys Under 15	176	129.48	82.89	323	133.21	96.96	406	111.45	82.96	*	***
Girls under 15	236	134.13	81.04	408	130.28	87.15	527	123.41	89.20	*	**
Girl Harassment (0/1)	12241	0.25	0.43	9632	0.26	0.44	8356	0.34	0.47		***
Empowerment for Women (0/1)											
Cash in hand for expenditure	12377	0.93	0.26	9827	0.93	0.25	8577	0.90	0.30		
Ownership of Property	11996	0.19	0.39	9499	0.17	0.38	8168	0.16	0.37	*	
Current Employment	12381	0.40	0.49	9828	0.45	0.50	8579	0.40	0.49		
Permission to visit health center	12303	0.80	0.40	9729	0.69	0.46	8440	0.65	0.48	***	*
Permission to visit friends/relatives	12257	0.84	0.36	9695	0.76	0.43	8443	0.70	0.46	***	***
Permission to visit grocery stores	11964	0.86	0.34	9287	0.80	0.40	8008	0.73	0.45	***	***
Permission for short distance travel	12274	0.64	0.48	9706	0.49	0.50	8462	0.47	0.50	***	
Use of Contraception	11167	0.80	0.40	8791	0.79	0.41	7648	0.69	0.46		***
Ownership of Joint Bank Account	9653	0.62	0.49	7119	0.54	0.50	5553	0.53	0.50	***	
Membership in Social Organizations	12383	0.08	0.27	9832	0.05	0.21	8581	0.05	0.22	***	
Decision on number of children	12044	0.94	0.24	9451	0.94	0.24	8247	0.90	0.30		*
Decision making ability about work	10579	0.50	0.50	8462	0.46	0.50	6706	0.40	0.49	*	**
Decision-Purchase of Expensive items	12314	0.81	0.39	9792	0.80	0.40	8543	0.76	0.43		*
Decision-Purchase of Property/Land	12194	0.79	0.41	9652	0.77	0.42	8485	0.73	0.45		*
Decision-Wedding Expenditures	12352	0.84	0.36	9783	0.83	0.38	8522	0.78	0.41		**
Decision-Children Marriage	11779	0.92	0.27	9391	0.90	0.30	8147	0.84	0.36		**
Decision-Food items	12374	0.69	0.46	9827	0.60	0.49	8582	0.55	0.50	***	***
Decision-Child Illness	11827	0.94	0.24	9422	0.92	0.27	8234	0.88	0.33		*
Decision-Own Sickness	12369	0.89	0.31	9821	0.88	0.32	8571	0.82	0.38		***

$***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Table 2: Descriptive Statistics: Principal Component Analysis (PCA) of empowerment variables, IHDS, 2012

Indices	Rank	Empowerment Variables (0/1)	Obs.	Mean	sd	Weight (PCA)	Interval
Economic Freedom	4	Cash in hand for household expenditure	39460	0.91	0.29	0.31	
	3	Name on home ownership papers	38023	0.17	0.37	0.39	
	2	Currently Employed	39461	0.42	0.49	0.58	
	1	Decision about Work	39461	0.42	0.49	0.63	(-2.81 1.77)
Mobility	1	Can visit health center alone	39079	0.71	0.45	0.52	
	2	Can visit friends/relatives alone	38966	0.77	0.42	0.52	
	3	Can go to grocery shop alone	37358	0.8	0.4	0.48	
	4	Can go short distance travel alone	38980	0.53	0.5	0.47	(-2.20 0.85)
Agency	3	Currently use contraceptives	35101	0.74	0.44	0.11	
	4	Membership Social Organization	27769	0.55	0.5	0.09	
	2	Decision Child Illness	39481	0.06	0.23	0.69	
	1	Decision Own Sickness	38042	0.92	0.27	0.70	(-3.96 0.91)
Economic Decisions	3	Decide purchasing expensive item	39243	0.77	0.42	0.57	
	1	Decides whether to buy land/property	38867	0.75	0.44	0.59	
	2	Decide wedding expense	39294	0.8	0.4	0.57	(-2.13 0.56)
Household Decisions	1	Decision Child Marriage	37261	0.88	0.32	0.67	
	3	Decision Food Shopping	39465	0.58	0.49	0.30	
	2	Decision Number of Children	37474	0.91	0.29	0.65	
	4	Ownership of Joint Bank Account	39430	0.85	0.35	0.18	(-3.30 0.53)

Factor loads are the score of individual variables in the empowerment indices and all indices are standardized with mean zero and standard deviation one

Table 3: Extensive Margin: Instrumental Variable Regression: The Effect of Access to Electricity on Women's Empowerment in India, IHDS, 2012

	(1)	(2)	(3)	(4)	(5)
Variables	Economic Freedom	Economic Decision	Agency	Mobility	Household Decision
Access to Electricity	0.34***	0.25***	0.58***	0.38***	0.44***
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)
Log Real Income	0.06***	-0.01**	0.01	0.02***	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Women Education	0.10***	0.04***	0.01	0.14***	0.06***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Women Age	0.02***	0.02***	0.01***	0.02***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of Children	0.00	0.04***	0.03***	0.03***	0.01**
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
Household Head Sex	0.51***	0.13***	0.13***	0.25***	0.14***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
Household Head Age	-0.00***	-0.01***	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household Size	-0.03***	-0.06***	-0.04***	-0.02***	-0.04***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Forward Caste	-0.00	-0.07***	-0.05**	-0.02	-0.03*
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Other Backward Caste	-0.04	-0.07***	-0.07***	-0.14***	-0.07***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Scheduled Caste	-0.09***	-0.12***	-0.10***	-0.00	-0.08***
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Constant	-1.84***	-0.13**	-0.57***	-1.22***	-0.58***
	(0.11)	(0.06)	(0.09)	(0.07)	(0.07)
District FE	370	370	370	370	370
Observations	13,622	33,381	29,324	31,992	22,024
R-squared	0.085	0.084	0.016	0.044	0.033

Robust standard errors in parentheses

$***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Number of observations are reduced in Table 3 due to the variable women's current employment which has 13,622 observations.

Table 4: Intensive Margin: Baseline Result of OLS Fixed Effects Regression, Dependent Variable: Women's Economic Freedom

	(1)	(2)	(3)	(4)	(5)
Variables	Economic Freedom	Economic Freedom	Quintile-1	Qunitile-2	Quintile-3
Power Outage	-0.02***	-0.01***	-0.00	-0.02***	-0.02
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Log Real Income		0.05***	0.06***	0.05***	0.02
		(0.01)	(0.02)	(0.02)	(0.02)
Women Education		0.09***	0.05*	0.12***	0.21***
		(0.02)	(0.03)	(0.04)	(0.06)
Women Age		0.02***	0.02***	0.02***	0.02***
		(0.00)	(0.00)	(0.00)	(0.00)
Number of Children		0.01	-0.01	0.01	0.05***
		(0.01)	(0.01)	(0.01)	(0.01)
Household Head Sex		0.49***	0.45***	0.46***	0.54***
		(0.02)	(0.04)	(0.04)	(0.05)
Household Head Age		-0.01***	-0.01***	-0.01***	-0.01***
		(0.00)	(0.00)	(0.00)	(0.00)
Household Size		-0.02***	-0.02**	-0.01	-0.03***
		(0.01)	(0.01)	(0.01)	(0.01)
Urban			0.11**	0.05	-0.02
			(0.05)	(0.05)	(0.09)
Forward Caste		0.01	0.01	0.00	-0.00
		(0.03)	(0.05)	(0.05)	(0.06)
Other Backward Caste		-0.03	-0.01	-0.01	-0.07
		(0.03)	(0.05)	(0.05)	(0.06)
Scheduled Caste/Tribe		-0.02	-0.07	0.04	-0.01
		(0.04)	(0.06)	(0.06)	(0.08)
Constant	0.18***	-1.32***	-1.46***	-1.25***	-1.21***
	(0.02)	(0.13)	(0.21)	(0.22)	(0.32)
District FE	370	370	370	370	370
Observations	11,949	11,621	4,464	4,099	3,058
R-squared	0.198	0.262	0.272	0.355	0.304

Robust standard errors in parentheses

$***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Note: For Table 4, the number of observations are listed from the baseline bivariate specification

Table 5: Intensive Margin: OLS Fixed Effect Regression: Effect of an additional hour of power outage on Women's Economic Decisions, Agency, Mobility, Household Decisions and Fuel Collection time of Girls

	(1)	(2)	(3)	(4)	(5)
Variables	Economic Decision	Agency	Mobility	Household Decision	Fuel Collection Girls
OLS (Bivariate)	-0.01***	-0.02***	-0.01***	-0.01***	2.1***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.60)
OLS (Multivariate)	-0.01***	-0.02*	-0.01***	-0.01***	2.45***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.69)
Quintile 1	-0.01	-0.03***	0.00	-0.01***	
	(0.00)	(0.01)	(0.00)	(0.07)	
Quintile 2	-0.01*	-0.01**	-0.03***	-0.00**	
	(0.00)	(0.00)	(0.00)	(0.00)	
Quintile 3	-0.00	- 0.01**	-0.00	-0.00	
	(0.01)	(0.00)	(0.00)	(0.00)	
Controls	Y	Y	Y	Y	Y
District FE	370	370	370	370	370
Caste FE	4	4	4	4	4
Observation	30205	26571	29030	20637	1171

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

Table 6: Intensive Margin: Instrumental Variable Regression: Causal effects of an additional hour of power outage on Women Empowerment and Fuel Collection Time.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Economic Freedom	Economic Decision	Agency	Mobility	Household Decision	Fuel Girls	Fuel Boys	Fuel Women
Power Outage	-0.02***	-0.01***	-0.02***	-0.02***	-0.02***	2.59***	4.96***	1.06**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.99)	(1.25)	(0.48)
Log Real Income	0.04***	-0.02***	-0.00	0.01	-0.02**	-1.52	3.72	-1.05
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(2.71)	(2.87)	(1.29)
Women Education	0.09***	0.04***	0.02	0.12***	0.06***	4.44	5.92	-7.60**
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(13.20)	(12.60)	(3.47)
Women Age	0.02***	0.02***	0.01***	0.02***	0.01***	0.26	0.32	0.25*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.40)	(0.50)	(0.15)
Number of Children	0.01	0.05***	0.03***	0.03***	0.02***	2.09	0.72	0.04
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(1.85)	(2.25)	(0.89)
Household Head Sex	0.49***	0.12***	0.09***	0.21***	0.12***	7.45	11.04	-4.75*
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(7.40)	(7.62)	(2.82)
Household Head Age	-0.01***	-0.01***	-0.01***	-0.01***	-0.00***	-0.08	0.05	0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.25)	(0.24)	(0.10)
Household Size	-0.02***	-0.05***	-0.02***	-0.02***	-0.02***	1.55	0.61	1.34**
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.98)	(1.10)	(0.59)
Urban	0.05	0.01	-0.03	0.03	-0.01			
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)			
Forward Caste	0.01	0.03*	0.04*	-0.02	0.03	-3.23	19.78**	4.12
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(7.96)	(8.94)	(3.86)
Other Backward Caste	-0.03	0.01	0.01	-0.06***	0.00	-0.47	28.50***	-3.75
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(7.59)	(9.39)	(3.78)
Scheduled Caste/Tribe	-0.02	0.03	0.04	-0.04**	0.02	-13.68	-0.01	-12.39***
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(8.93)	(10.50)	(4.18)
Constant	-1.15***	0.07	0.43***	0.35***	0.29***	-17.64	-46.00	182.72***
	(0.33)	(0.12)	(0.12)	(0.10)	(0.11)	(40.96)	(55.28)	(54.36)
District FE	370	370	370	370	370	370	370	370
Observations	11,621	29,343	25,819	28,203	20,054	1,043	788	8,193
R-squared	0.262	0.303	0.282	0.216	0.291	0.475	0.494	0.347

Robust standard errors in parentheses

$***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Table 7: Intensive Margin: Instrumental Variable Regression: The Effect of Quintile of Power Outages on Women's Economic Freedom and Decision Making

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Ec. Freedom Poor	Eco Freedom Non-Poor	Eco Freedom Rural	Eco Freedom Urban	Ec Decision Poor	Eco Decision Non-Poor	Eco Decision Rural	Eco Decision Urban
Quinitle of Power Outage	-0.14*	-0.20***	-0.15***	-0.13	-0.10*	-0.12***	-0.16***	-0.10**
	(0.07)	(0.03)	(0.04)	(0.10)	(0.05)	(0.02)	(0.02)	(0.04)
Log Real Income	0.01	0.03**	0.03**	0.01	-0.01	-0.03***	-0.03***	-0.04***
	(0.03)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Women Education	0.13	0.07***	0.14***	0.02	-0.07	0.02**	-0.03	0.04***
	(0.10)	(0.02)	(0.03)	(0.03)	(0.06)	(0.01)	(0.02)	(0.01)
Women Age	0.02***	0.02***	0.01***	0.02***	0.01***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of Children	0.02	0.02**	0.02***	0.02	0.08***	0.07***	0.07***	0.07***
	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Household Size	-0.03**	-0.05***	-0.04***	-0.04***	-0.06***	-0.08***	-0.08***	-0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Forward Caste	-0.01	-0.01	-0.01	-0.05	0.08*	0.03	0.06***	0.00
	(0.06)	(0.04)	(0.03)	(0.07)	(0.05)	(0.02)	(0.02)	(0.03)
Other Backward Caste	0.01	-0.06*	-0.06**	-0.07	0.04	-0.01	0.01	-0.01
	(0.06)	(0.03)	(0.03)	(0.06)	(0.04)	(0.02)	(0.02)	(0.03)
Scheduled Caste/Tribe	-0.05	-0.04	-0.07	-0.02	0.05	0.01	0.00	0.03
	(0.09)	(0.04)	(0.04)	(0.07)	(0.06)	(0.02)	(0.03)	(0.03)
Constant	-1.08**	-0.31	-0.55	-0.21	0.50*	0.31**	0.42***	0.42*
	(0.42)	(0.34)	(0.39)	(0.64)	(0.26)	(0.13)	(0.15)	(0.22)
District FE	370	370	370	370	370	370	370	370
Observations	2,177	9,440	8,247	3,375	4,161	25,178	18,054	11,292
R-squared	0.365	0.226	0.255	0.250	0.348	0.294	0.284	0.312

Robust standard errors in parentheses

$***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Table 8: Intensive Margin: Instrumental Variable Regression: Effect of Electricity Deficiency on Women's agency, mobility and household decision making ability for poor, non-poor, rural and urban areas, India, IHDS 2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Variables	Agency Poor	Agency Non-Poor	Agency Rural	Agency Urban	Mobility Poor	Mobility Non-Poor	Mobility Rural	Mobility Urban	HH Decision Poor	HH Decision Non-Poor	HH Decision Rural	HH Decision Urban
Quinitle of Power Outage	-0.09	-0.15***	-0.17***	-0.27***	-0.25***	-0.15***	-0.18***	-0.03	-0.22***	-0.14***	-0.15***	-0.20***
	(0.06)	(0.03)	(0.03)	(0.06)	(0.06)	(0.02)	(0.03)	(0.04)	(0.05)	(0.02)	(0.03)	(0.05)
Log real income	0.02	-0.01	-0.01	-0.00	-0.01	0.01	0.01	-0.02*	-0.01	-0.02***	-0.03***	-0.02**
	(0.03)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Women Education	-0.09	0.01	-0.01	0.02	0.11*	0.11***	0.10***	0.12***	0.02	0.05***	0.04**	0.06***
	(0.08)	(0.01)	(0.02)	(0.02)	(0.07)	(0.01)	(0.02)	(0.01)	(0.05)	(0.01)	(0.02)	(0.01)
Women Age	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of Children	0.05***	0.04***	0.05***	0.05***	0.03***	0.04***	0.04***	0.04***	0.03***	0.03***	0.03***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Household Size	-0.02***	-0.04***	-0.04***	-0.03***	-0.03***	-0.03***	-0.03***	-0.03***	-0.04***	-0.04***	-0.04***	-0.03***
	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Forward Caste	0.20***	0.02	0.05*	0.05	0.12**	-0.03	-0.01	-0.03	0.14**	0.01	0.06**	-0.00
	(0.06)	(0.03)	(0.03)	(0.04)	(0.05)	(0.02)	(0.03)	(0.04)	(0.06)	(0.02)	(0.02)	(0.03)
Other Backward Caste	0.14**	-0.01	0.03	-0.02	0.07	-0.08***	-0.06**	-0.07**	0.10**	-0.02	0.03	-0.04
	(0.06)	(0.02)	(0.03)	(0.04)	(0.05)	(0.02)	(0.03)	(0.03)	(0.05)	(0.02)	(0.02)	(0.03)
Scheduled Caste/Tribe	0.17**	0.01	0.06*	-0.01	0.01	-0.06***	-0.07**	-0.04	0.12*	0.01	0.04	-0.01
	(0.07)	(0.02)	(0.03)	(0.04)	(0.06)	(0.02)	(0.03)	(0.03)	(0.07)	(0.02)	(0.02)	(0.03)
Constant	0.13	0.73***	0.75***	1.05***	0.52	0.73***	0.81***	0.52**	0.67**	0.55***	0.52***	0.95***
	(0.31)	(0.14)	(0.16)	(0.23)	(0.37)	(0.12)	(0.14)	(0.21)	(0.28)	(0.12)	(0.14)	(0.20)
Observations	3,747	22,068	15,920	9,901	4,048	24,150	17,272	10,933	2,340	17,714	11,928	8,129
District FE	370	370	370	370	370	370	370	370	370	370	370	370 R-squared
0.326	0.290	0.251	0.347	0.289	0.208	0.207	0.237	0.379	0.295	0.286	0.312	

Robust standard errors in parentheses

$***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Figures

Figure 1: Hours of electricity in India at the district level, 2012, Legend is average hours of electricity at the district level in 2012. Source: India Human Development Survey 2012

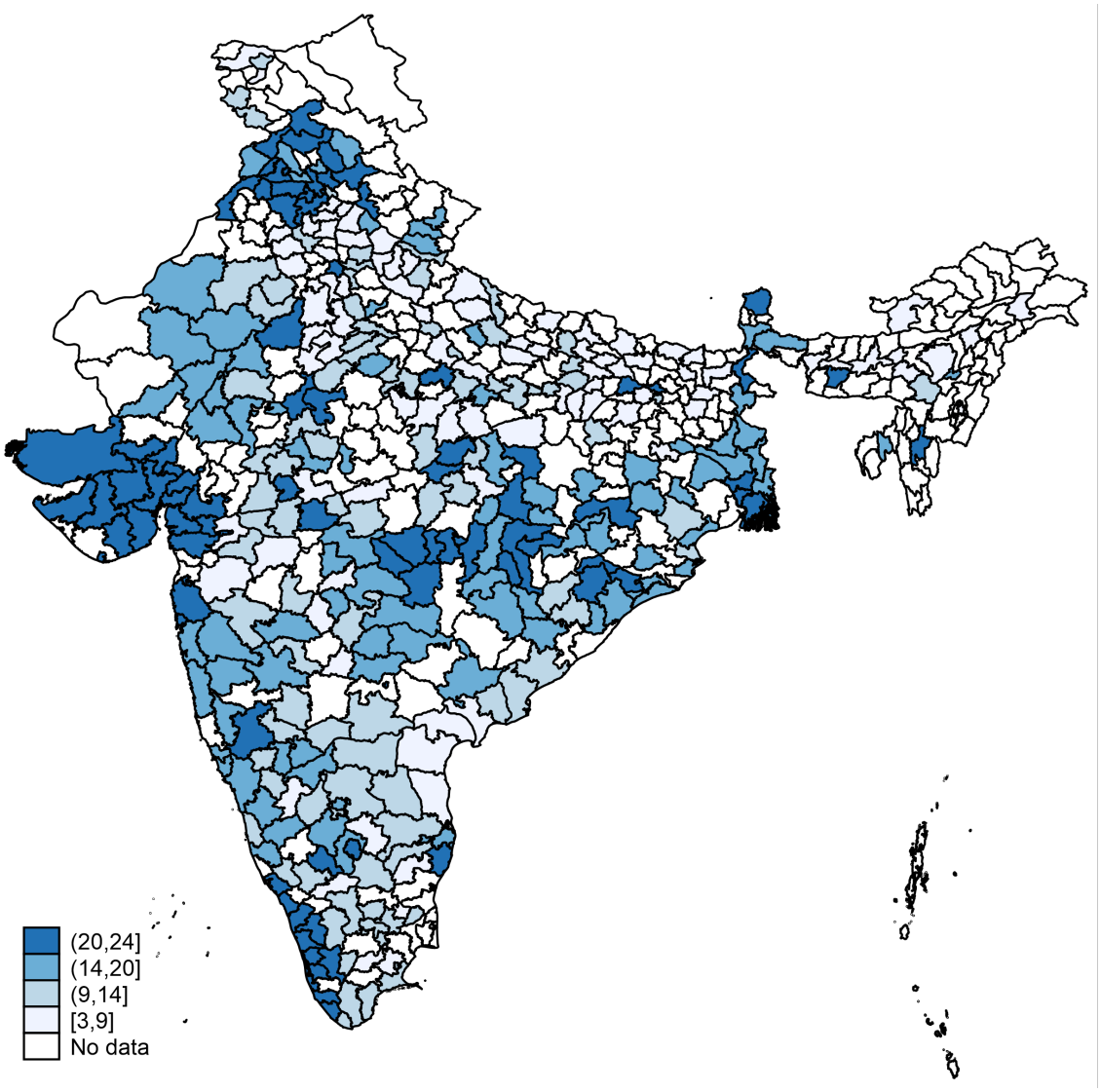


Figure 2: Quintile of Power Outages and Women's Empowerment for the Poor and Non-Poor, result from OLS fixed effects regression. Quintile 1: 0-4 hours of power outage, Quintile 2: 5-14 hours of power outage, Quintile 3: 15-24 hours of power outage, IHDS, 2012

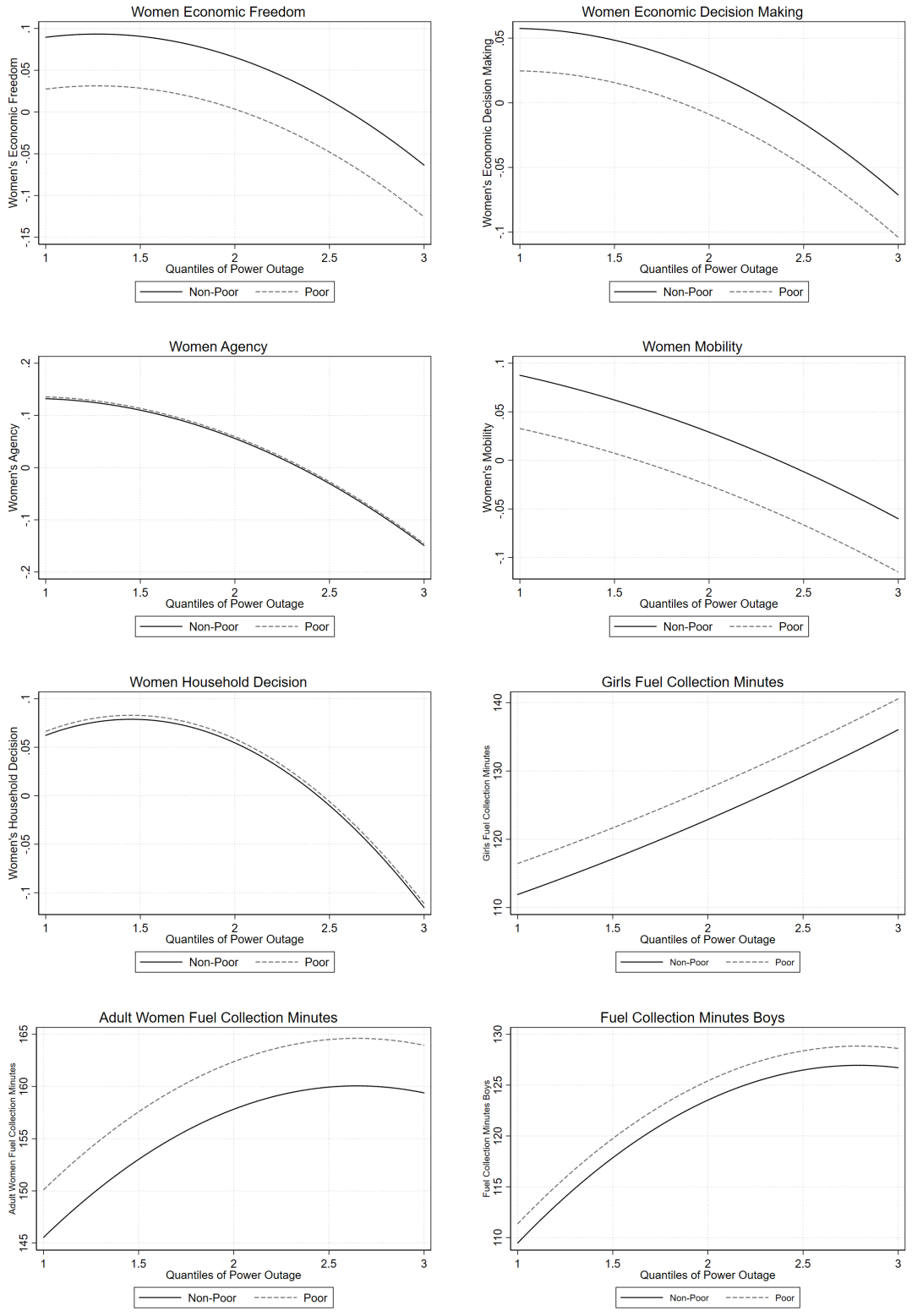
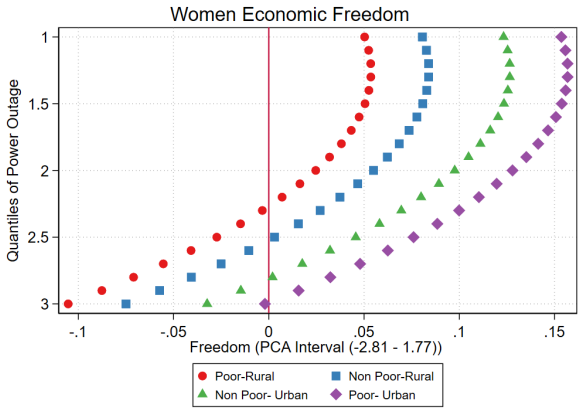
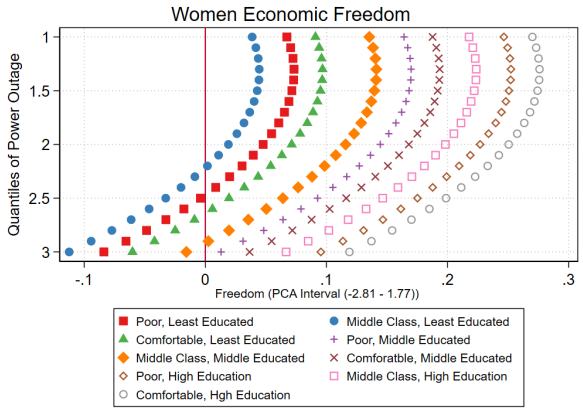
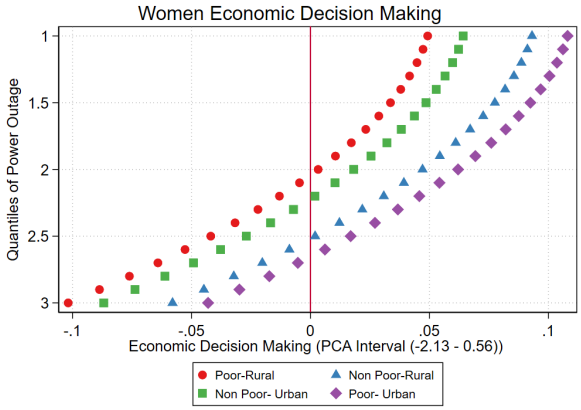
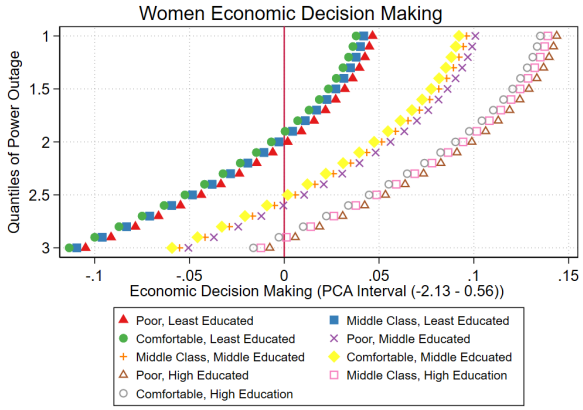


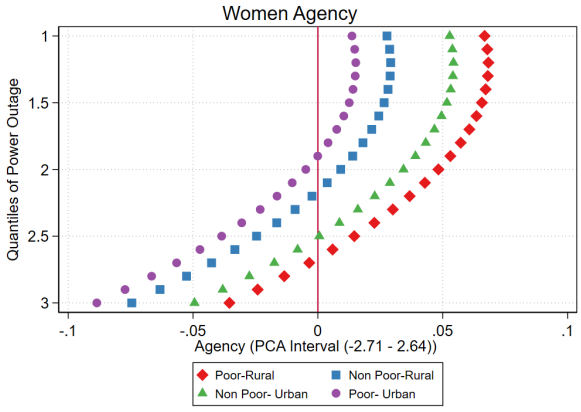
Figure 3: Quintile of Power Outages and Women's Empowerment. Categories: Poor, Non Poor, Urban, Rural, Education, Living Standards. Result from OLS fixed effects regression with interactions. Quintile 1: 0-4 hours of power outage, Quintile 2: 5-14 hours of power outage, Quintile 3: 15-24 hours of power outage. Education: 0-9th grade is grouped as 1, Matriculation (10th grade) to Higher secondary is grouped as 2, Bachelors and above is grouped as 3. Poverty line is derived from Tendulkar's (2012) cut-off line of poverty. Living standard is classified into Poor, Middle Class and Comfortable following the survey codebook, IHDS, 2012.
Note: The index is standardized with Mean=0 and Standard Deviation=1

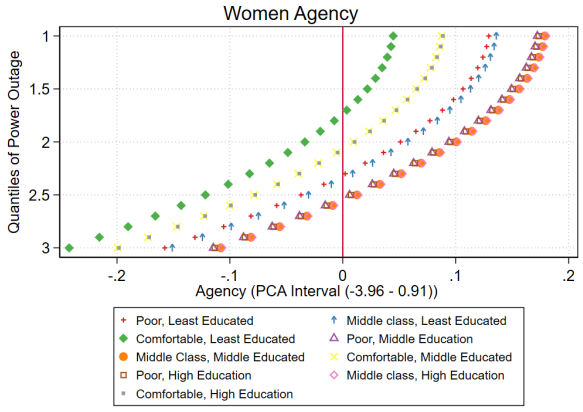


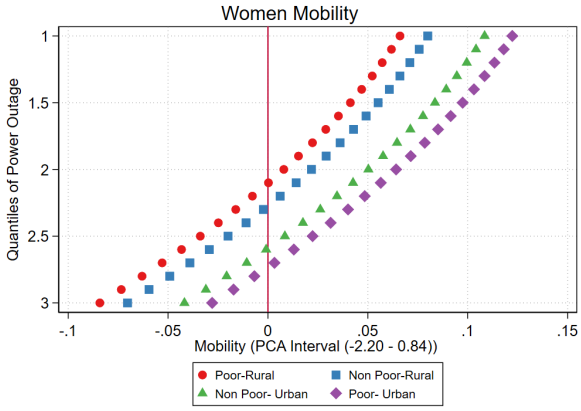


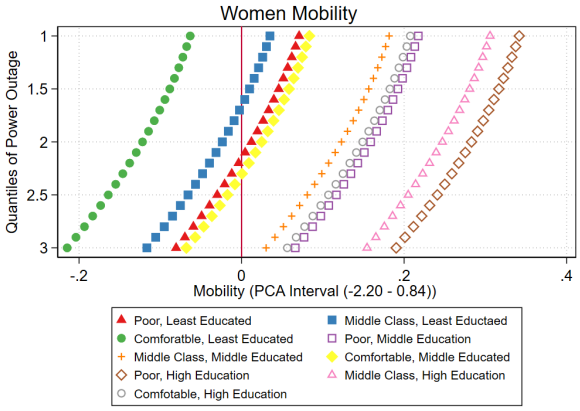


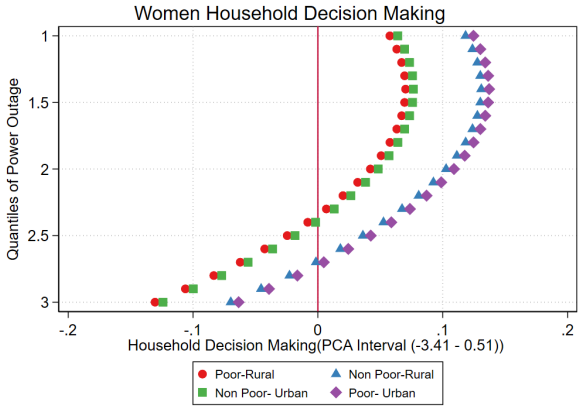


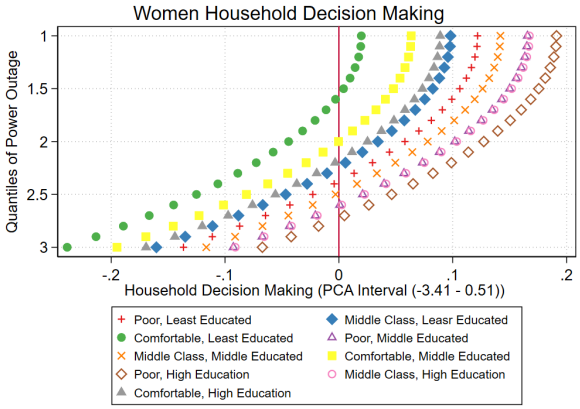





Women Mobility
Quantiles of Power Outage
1
1.5
2
2.5
3
-.1
-.05
0
.05
.1
.15
Mobility (PCA Interval (-2.20 - 0.84))
Poor-Rural
Non Poor-Rural
Non Poor- Urban
Poor- Urban


Women Mobility
Quantiles of Power Outage
1
1.5
2
2.5
3
-.2
0
.2
.4
Mobility (PCA Interval (-2.20 - 0.84))
Poor, Least Educated
Middle Class, Least Eductaed
Comforatble, Least Educated
Poor, Middle Education
Middle Class, Middle Educated
Comfortable, Middle Educated
Poor, High Education
Middle Class, High Education
Comfotable, High Education


Women Household Decision Making
Quantiles of Power Outage
1
1.5
2
2.5
3
-.2
-.1
0
.1
.2
Household Decision Making(PCA Interval (-3.41 - 0.51))
Poor-Rural
Non Poor-Rural
Non Poor- Urban
Poor- Urban


Women Household Decision Making
Quantiles of Power Outage
1
1.5
2
2.5
3
-.2
-.1
0
.1
.2
Household Decision Making (PCA Interval (-3.41 - 0.51))
Poor, Least Educated
Middle Class, Leasr Educated
Comfortable, Least Educated
Poor, Middle Educated
Middle Class, Middle Educated
Comfortable, Middle Educated
Poor, High Education
Middle Class, High Education
Comfortable, High Education