Electrification and Socio-Economic Empowerment of Women in India

Ashish Kumar Sedai,[a] Rabindra Nepal,[b] and Tooraj Jamasb[c]

ABSTRACT

This study moves beyond the consensus of counting electrified households as a measure of progress in gender energy parity. Using the India Human Development Survey, we examine the effect of reliability of electrification on empowerment of women in terms of economic autonomy, agency, mobility and decision-making abilities, underscoring the labor market and respite effects of service reliability. We develop a comprehensive set of empowerment indices using principal component analysis and assess the causal effects of power outages on the indices with instrumental variable regressions while controlling for individual, household, district and caste characteristics. Results show that reliability of electricity has significant positive effects on all empowerment indices and improves women's labor market outcomes, however, the effects differ at the margin of deficiency, location, living standards and education. The study recommends policy focus on electrification from a gendered lens for cost-effective solutions.

Keywords: Women empowerment, Reliable electricity, Labor Market, Principal Component Analysis, Instrumental Variables

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1. INTRODUCTION

Following the major electricity reforms in 2003 (Thakur et al., 2005), the focus of the discourse on electrification and welfare in India has been on counting electrified households, and investigating the impact of electricity access on households and farm income, labor market and entrepreneurial outcomes (Rao, 2013; Chakravorty et al., 2014; Dinkelman, 2011; Samad and Zhang, 2019). Complimenting the policy impetus, studies have shown that increased access to electricity has effectively empowered women and increased their labor force participation (Samad and Zhang, 2019; Rathi and Vermaak, 2018). However, recent studies have shown stagnancy, redistribution and only marginal improvements in quality of electricity (households electricity hours) on a typical day[1]

1. Between 2005–2012, the mean of household electricity hours stagnated at 15 hours at the national level (derived from the India Human Development Survey), while between 2015–2018 average household electricity hours increased by 2 hours for the six relatively poor and populous states in India (derived from the Access to Clean Energy Survey) (Sedai et al., 2020). This phenomenon occured during to the limited grid capacity which led to rationing of electricity supply to incorporate the thrust to providing new connections (Kennedy et al., 2019).

a Department of Economics, Colorado State University, Colorado, United States: Email: ashish.sedai@colostate.edu.

b School of Business, University of Wollongong, Wollongong, Australia: E-mail: rnepal@uow.edu.au.

c Corresponding author. Department of Economics, Copenhagen Business School, Send correspondence to E-mail: tj.eco@cbs.dk.

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(Sedai et al., 2020; Aklin et al., 2016). Given that some households gained access, while some lost the quality of grid electricity during the wave of mass electrification (Sedai et al., 2020), an empirical analysis on the effect of quality of electricity on women's empowerment is a significant policy question. Our study contributes to the literature by analysing the effect of the quality of electricity on women's empowerment, following a framework of access, agency and achievements laid down by Kabeer (1999).

Connecting households to grid electricity is not the silver bullet for energy poverty and gender based energy disparity if connections do not entail regularity in the service provided, which has been an issue due to the frequent power failure and the poor grid capacity in India (Joseph, 2010; Sedai et al., 2020). In September 2017, the government announced a new scheme, 'Saubhagya', that offers free or heavily subsidized electricity connections to rural households. This scheme reduces the cost of electricity connections, but it does not offer solutions to the problem of low-quality electricity service (Kennedy et al., 2019). Although attempts have been made in improving the quality of electrification in India through the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY, 2014), many relatively poorer states (Uttar Pradesh, West Bengal, Madhya Pradesh, Jharkhand, Bihar and Orissa), on average, have less than half a day of electricity in the household (Sedai et al., 2020). In recent years, the political economy of electrification in India has intensified with electricity being considered in the core basket of necessities requiring public investments, while electricity distribution at the going subsidized rate remains a major loss generating activity (Burgess et al., 2020).

Quality of electrification disproportionately affects women in developing economies, as they spend more time in the household than men (Dinkelman, 2011; O'Dell et al., 2014). Various household activities (such as cooking and cleaning among others) are primarily undertaken by women in India, and elsewhere in developing economies (Ferrant and Thim, 2019). Many of these activities can be performed more efficiently and be less time consuming if the household has electricity all day long, such that time allocations to labor, leisure and home production are more favorable. Fuel and water collection activities, along with the compulsion to stay at home when the electricity is available in the day to perform household activities cripples women's ability to minimize time in home production and maximize time in labor market or entrepreneurial activity[2] (Ferrant and Thim, 2019; Rathi and Vermaak, 2018; Dinkelman, 2011; Gould and Urpelainen, 2018). Gender disparities emanating from the lack of reliable electrification calls for an understanding of the potential benefits of electricity reliability in reducing gender differences, and improving the economic condition at the aggregate level (Samad and Zhang, 2019; Khandker et al., 2014; Rao, 2013; O'Dell et al., 2014).

Our study examines the effects of additional hours of electricity outage, and the non-linear effects on women's empowerment using population weighted quartiles of electricity hours in a day. We analyze the causal effects of electricity deficiency on empowerment outcomes, and discuss the underlying causes through the analysis of the labor market, time allocations and respite effects of reliable electrification. Empowerment indices are derived from the novel framework of women empowerment in terms of 'access, agency and achievements' laid down by Kabeer (1999) and in defining women's autonomy. Following this framework, we create five empowerment indices using a wide variety of observed indicators: (i) economic freedom in terms of regular cash flows, ownership of property, and employment, (ii) economic decision making in terms of major purchases of

2. Home production related work, such as collecting water, firewood, cooking and cleaning are physically intensive and time-consuming, the burden of these activities falls disproportionately on women. In sub-Saharan Africa, women and girls are responsible for over 70% of water collection activity (Ferrant and Thim, 2019). Issues of infrastructure quality are particularly pertinent in developing countries which in general have lower levels of access to clean drinking water and fuel, safe transportation, and electricity (Dinkelman, 2011).

the household and wedding expenditure, (iii) mobility in terms of visiting health center, friends/ relatives, grocery store and short distance travelling alone, (iv) agency in terms of health and reproductive decision making along with membership in social organizations, and (v) household decision making such as of child marriage, fertility, food and account ownership.

We use the India Human Development Survey (IHDS) 2012, as it is the only nationally representative gender dis-aggregated primary survey which has information on both electricity hours and gender relations. We use (i) Ordinary Least Squares (OLS) and (ii) Two Stage Least Squares instrumental variable (2SLS-IV-FE) regressions to derive robust and causal estimates. The instrument used is 'average hours of household electricity in a day at the district level, excluding the district of the household'[3] (Bai et al., 2019). We use Principal Component Analysis (PCA) of nineteen empowerment variables to create five indices[4] and regress them on outages, with the least outage category, 0–4 hours in a day as the base quartile. We conduct our analysis with and without individual and household controls, district and caste controls, and instruments along with different ways of measuring empowerment to arrive at robust estimates.

The study finds significant negative effects of power outages on all indices of women's empowerment, with stronger effects on educated women belonging to middle income households compared to poor and less educated, especially in rural areas. Outages significantly reduce women's mobility and economic decision making compared to other indices. The quartile analysis shows the existence of non-linear relationship between additional hours of electricity and empowerment indices signifying the incremental effects as per the margins of deficiency. Outages significantly reduce women's likelihood of employment, work hours and days, increases fuel and water collection time, and increases the use of inefficient/unhealthy household services and utilities which have a bearing women's bargaining power, and consequently, on their empowerment.

1.1 Reliable electrification and pathways to empowerment

Previous research has shown that reliable electrification empowers women in a myriad ways through economic and non-economic channels (Dinkelman, 2011; Rao, 2013; Khandker et al., 2014; Chakravorty et al., 2014; Rathi and Vermaak, 2018; Dang and La, 2019). The labor supply channel of empowerment through the re-allocation of time from unpaid household work to paid work with better electrification (increases the marginal cost of paid work), increases paid work participation, and consequently, relative income share of the woman in the household (Dinkelman, 2011; Rathi and Vermaak, 2018). Active labor market participation allows women to exercise their agency in economic and social decisions of the family (Kennedy et al., 2019).

The study on benefits of rural electrification in South Africa showed that women's employment rate grew by 9.5 percent because of the 'Eskom' project, a community electrification program (Dinkelman, 2011). Rathi and Vermaak (2018) examined gender differences through electrification in India and South Africa and found that the policy impetus on electrification increased women's likelihood of work, earnings and reduced the hours of work through increased productivity, with stronger for women compared to that of men. Reliability of electricity in addition to labor market

3. Dang and La (2019) use the same instrument to study the effect of electrification on household welfare in rural Vietnam. The instrument controls for general equilibrium effects of electrification on empowerment at the district level by excluding the district of the household. Following Desai and Vanneman (2018), we denote the regional aggregation of participation through villages in rural areas and through PSUs in urban areas.

4. PCA calculates the factor-score correlation coefficients, also called component loadings. The component score is then estimated as the linear combination of products of the response on each of the original variables and the corresponding correlation coefficient (Samad and Zhang, 2019).

improvements also increases the use of more efficient household services, which provides a respite from the ardous process of home production (Ferrant and Thim, 2019). Dinkelman (2011) found that electrification in South Africa from 1996–2001 reduced the likelihood of cooking with firewood, increased the likelihood of having a flush toilet and indoor water, and reduced the expenditure on fuel-wood.

Continuous power supply extends the effective workday by allowing women to leave certain household chores for the night enabling them to participate in paid labor activity during the day (Kanagawa and Nakata, 2008). In case of erratic power supply, these benefits may fail to materialize. The gap in demand or supply in South Africa lead to sub-optimal time allocation to labor market activities (Dinkelman, 2011). 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.

In rural India, women often spend a considerable amount of time daily in collecting firewood for cooking, which is highly polluting, more ardous, and adversely affects health[5]. Firewood has lower calorific value which necessitates prolonged cooking hours, 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 has been the fuel cost (Gould and Urpelainen, 2018), poor infrastructure, especially in rural areas (Allcott et al., 2016), coupled with weak bargaining power of women in rural households for having LPG connections (Bansal et al., 2013).

Having electricity all day allows households to add new electrical appliances, thereby improving the efficiency in home production. Exposure to radio and television spurs fertility decline via increased use of contraception (Stephenson et al., 2006).[6] It also enables women to lessen the grip of traditional and cultural norms, and participate more actively in the society (Standal and Winther, 2016). Many important events, news and information broadcasted through radio, television and mobile, which are crucial in raising awareness and providing valuable information could be missed if electricity is lacking during broadcast hours, which is mostly true, as power outages are common during peak load periods in India (Joseph, 2010).

Given the frequency of power outages during the evening hours (Sedai et al., 2020), kerosene-based lighting have been used as an alternative, one that emits a dull light and is inadequate for reading or close work (Kennedy et al., 2019). Availability of electricity during peak periods (5pm–10pm) allows school-going children to study during evening hours, thus encouraging more hours of study and consequently yielding long term benefits (Khandker et al., 2014). 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. Reliable electrification can reduce household dependence on girls' labor, and reduces the opportunity cost of sending girls to school (Köhlin et al., 2011).

5. According to Sharma et al. (2019), women in rural areas in Jharkhand spend an average of 2 hours 45 mins on cooking activities and 2 hours 30 mins on an average to collect firewood on a typical day. In India, the ambient pollutant (PM10) concentration was drastically high around 20000 $\mu g/m^3$, much higher near the cooking locations (Sharma et al., 2019). This is higher than the benchmark (150 $\mu g/m^3$) set by Environmental Protection Act, 1986. 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).

6. The assumed mechanism is that women gain knowledge about family planning through television and learn about and adopt alternative gender norms, which reduces their likelihood of having many children (Winther et al., 2017).

1.2 The context of reliable electrification in India

Burgess et al. (2020) in their study of 'the consequences of treating electricity as a right'[7] in India posit that policy makers face a dilemma: on the one had, the government considers electricity in the core basket of necessities for household welfare, on the other, providing electricity at the present rate[8] given the subsidies and threat, does not seem to be a feasible solution, and distorts the equilibrium in the market, thus leading to under provisioning. According to Burgess et al. (2020), treating electricity as a right undermines the aim of universal access to reliable electricity because (i) subsidies, theft, and nonpayment are widely tolerated and become an accepted part of the system, (ii) distribution companies lose money with each unit of electricity sold, even with government's support, at some point, budget constraints start to bind, and consequently, (iii) distribution companies have no option but to ration supply by limiting access and restricting hours of supply. As discussed in the previous section, effects of quality of electricity on women's autonomy could provide policy makers with broader understanding of welfare implications of reliable electrification through a gendered lens.

Figure 1 depicts the distribution of district level electricity hours in a day of the households. The figure highlights regional inequality between and within states in the distribution of electricity, with some states doing relatively better than the others. With only 5.4% electricity generated from renewable sources, and less than 8% of the population using alternative sources of energy, the supply gap is highest in India among the developing economies (Jain, 2018). 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.

Given the present state of electricity generation, distribution and consumption, provisioning more hours of electricity would imply increasing costs for the consumers (Kennedy et al., 2019). However, considering electricity as an essential commodity creates a downward spiral whereby electricity distribution companies lose money, government-owned distribution companies restrict access and hours of supply, and market forces cease to govern (Burgess et al., 2020). Thus, the link between payment and supply of electrification gets severed, reducing customers' incentives to pay, and the equilibrium outcome is uneven and sporadic, undermining the economic potential. For instance, the cost of household lighting per lighting unit (lumen) with electricity is much less than that it is with kerosene lamps, but due to upsurge in demands during peak periods, distribution companies have to cut back the grid load to avoid a transmission failure (Khandker et al., 2014), thus resulting in a sub-optimal outcome both from the demand and the supply side.

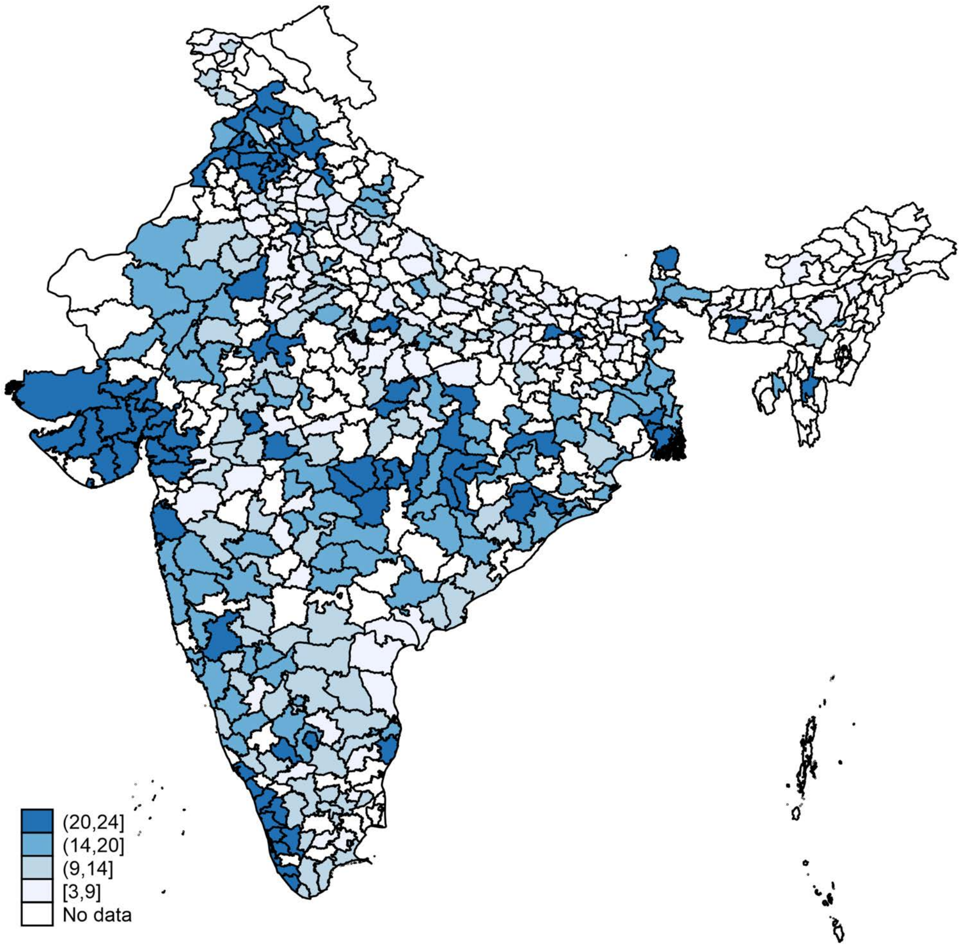
In 2010, India had 174 gigawatts of utility-scale power generation capacity, or about one-sixth of the US total, of which, 53% was coal, 10% was natural gas, and 22% was hydroelectric[9] (Allcott et al., 2016). The study by Allcott et al. (2016) found that, conditional on state and year effects, there is no correlation between the the shortage of electricity variable and the median electric-

7. By a "right to electricity" Burgess et al. (2020) refer to the social norm that all people deserve electricity regardless of payment. "This entitlement has driven universal electrification programs around the world for decades and remains salient in developing countries investing in electrification today" (Burgess et al., 2020).

8. For instance, the average revenue obtained per unit of power supplied in Bihar, excluding subsidies and accounting for losses from billing inefficiencies, theft, and technical losses, was 2.3 cents per kilowatt-hour compared to the average cost of 6.8 cents per kilowatt-hour in 2018–2019 (Burgess et al., 2020).

9. Although, power generation has been open to private investment since India's 1991 liberalization, 80% of electricity supply in 2010 remained government owned: 51% by states and 29% by the central government, retail distribution companies are state-run and rely on grid systems of distribution (Allcott et al., 2016).

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



ity price paid by plants in the Annual Survey of Industries. They argue that the disconnect between retail price and market conditions is common to nearly all power systems around the world, including many that do not experience endemic shortages. Their analysis of the state of electrification in India finds the following electricity based impediment to sectoral growth in India: (i) infrastructure quality and subsidy trap,[10] (ii) underinvestment in new generation capacity, supply is not keeping up with rapid demand growth, and (iii) underutilization of existing capacity.

Demand for electricity in rural India is primarily met by extending the grid (Sedai et al., 2020; Amutha and Rajini, 2016). But the costs of extending lines to rural facilities are prohibitively expensive and vary in cost on the distance to be covered, the land, utility and the size of the load (Amutha and Rajini, 2016). In the Indian context, for example, spending on power plants does not necessarily translate into electricity provision, because plants are frequently offline due to mechani-

10. According to Allcott et al. (2016), subsidy traps in India are pertinent because distribution companies provide low-quality electricity, consumers tolerate this low quality because they pay low prices, government subsidies cover distribution companies' losses from the low prices, and politicians support the subsidies to avoid voter backlash.

cal failure or fuel shortages (Allcott et al., 2016). Considering these challenges, improving the quality of electrification will require considerable skill in the selection and implementation of technical and economic strategies for electrification.

In rural areas where power supply is expensive or insufficient, renewable energy alternatives may be the only option (Amutha and Rajini, 2016). A modelling approach using the HOMER software by Amutha and Rajini (2016) found that a hybrid combination of solar/wind/hydro/battery is a cost effective, sustainable, techno-economically and environmentally viable alternative to grid extension in rural India. This is visible through a preliminary observation of the ACCESS 2015–2018 panel (Sedai et al., 2020), where the uptake of solar power for lighting, cooking and cleaning increased from 4% of the population to 8% of the population in the relatively poorer states in India.

2. EMPIRICAL MODEL

Empowerment is an abstract concept and manifests in multiple aspects of life, thus using an indicator or variable as a measure of either social or economic autonomy is not reflective of the multi-faceted nature of empowerment. Hence, following Kabeer (1999) and Samad and Zhang (2019), we resolve this issue by using principal component analysis (PCA) to construct composite indices from observed variables of gender relations reported in the IHDS, 2012. Although IHDS has two waves (2005, 2012) and could be used as a panel, we limit our analysis to cross-sectional estimations as the 2005 wave does not have composite list of gender relations variables of interest. We use the framework of empowerment derived from Kabeer (1999) as a standard for defining women's empowerment and define five indices which reflect women's access to economic and social capital, agency to make and exercise their decision, and ability to achieve economic and social independence.

PCA uses correlation among observed indicators to infer a latent behavior. It creates a single composite score from multiple indicators and offers insights into the trends that would otherwise be difficult to measure (Samad and Zhang, 2019). It reduces the multi-dimensionality of variables and produces correlates that are orthogonal to one another (Abdi and Williams, 2010). We use the PCA to (i) extract a composite score from each set of economic, social, household and agency based gendered relations variables through component loadings, (ii) compress the number of variables by aggregating them into an index given the sample weighted relative rankings, (iii) simplify the analysis of empowerment variables (19 variables condensed in 5 indices), and (iv) analyze the structure of the observations and the variables.[11]

The objective of our empirical analysis is to examine the effect of reliability of household electricity on indices of women's empowerment and substantiate the coefficients with underlying causes of the effects. We use OLS and instrumental variable regressions to analyze the margins of empowerment outcomes with additional hours of electricity in a day. The baseline regression is as follows:

$$Y_i = \alpha_i + \delta QE_i + X_i'\beta + \gamma d_i + \theta c_i + \varepsilon_i \tag{1}$$

Where, Y_i represents the outcome of interest, empowerment for women i. For our study, these are the 5 empowerment indices created using PCA of 19 empowerment variables (see Table 2)[12]. QE_i is the hours of electricity outage in the household of the $i-th$ women. X_i is a control vector of individ-

11. For more detailed explanation of PCA and component loadings, see Abdi and Williams (2010).

12. PCA is carried out using the framework for women's empowerment as laid down by Kabeer (1999), to determine the socio-economic agency of women in the household in developing economies.

ual and household observable socio-economic and demographic characteristics: wealth (proxied by total assets), adult male and female education in the household, marital status, age, household size, urban/rural. We control for geographic and cultural characteristics at the district and caste level with district and caste dummy variables for each individual d_i and c_i, respectively. The error term ε_i is assumed to be randomly distributed. α, β, and δ are the unknown parameters to be estimated, with δ being the coefficient of interest.

If districts were randomly selected, and electricity distribution happened randomly then the baseline estimation in equation 1 would have provided unbiased estimates of the impact of reliable electrification. However, in practice the quality of electricity received by households is not randomly assigned. There is self-selection and sorting involved. The decision to acquire a certain level of electrification is based on both observed (income, household size, age, sex, caste and locality) and 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 the demand and distribution of reliable electrification.

Households that are likely to be excluded due to the costs and transmission capacities are inclined to acquire more electricity, causing a positive selection bias. While poor and less educated households in remote areas could be less inclined to acquire higher hours of electricity due to limited benefits, indicating a negative selection bias (Burgess et al., 2020). Women who exhibit strong preferences due to their bargaining power and economic autonomy in the household could already afford better quality of electrification. Given that over 20% of generated electricity is lost in transmission primarily due to theft (Joseph, 2010), the selection bias is evident.

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. 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, it could be proposed that households 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 1 would yield biased 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 district level in the state except for the district of woman *i*'s household. The same instrument has been used to study the effect of reliable electrification on household welfare and non-farm income in Vietnam by Dang and La (2019). The instrumental variable affects a household's choice of electricity hours through peer-effects and demonstration effects at the district level. Higher hours of electricity in neighboring district induces higher hours of electricity in the $i-th$ woman's district, and consequently induces the household i to acquire more hours of electricity[13]. We discount the average hours of electricity in the district of the $i-th$ woman to get rid of any general equilibrium effects of district level electrification on woman's socio-economic agency. A similar approach is used by Sedai et al. (2020) when examining the effect of reliable electrification on household welfare in India using the same data-set as in this study.

13. The structure of social organization and community in India influences a household's choice of electricity at the household level (Khandker et al., 2014; Rao, 2013).

We address the issue of endogeneity by using a two stage least squares regression approach, the first stage of which is obtained by estimating the following equation

$$QE_i = \alpha_i + \lambda I_{-j} + X_i'\beta + \gamma d_i + \theta c_i + \varepsilon_i \tag{2}$$

Where I_{-j} is the average hours of electricity outage at the district level in the state excluding the district of the $i-th$ woman's household. λ is the coefficient of average hours of electricity outage in other districts, $i = 1,2,3,...,-j,...,n$ on household i's hour of electricity outage in a day. We allow for any type of correlation between unobserved effects, explanatory and instrumental variables, and the model does not require any specification of the reduced form equations for endogenous variables. It makes no assumptions about errors distribution.

We expect that the higher the hours of electricity in other districts of the state, the higher will be the likelihood of the household's district to have higher hours of electricity, and consequently higher will be the hours of electricity in house of the $i-th$ women, provided the household can afford the cost. We expect a negative self selection bias as empowered women would have alternate sources of electricity, the outcome of which is that they do not need to acquire state/agency provided electricity.

As a robustness check, we carry out a panel fixed effects regression analysis

$$Y_{it} = \delta QE_{it} + X_{it}'\beta + \theta_i + \gamma_t + \varepsilon_{it} \tag{3}$$

Where, Y_{it} are empowerment outcomes for $i-th$ woman at time t. QE_{it} is the quality of electricity (hours of electricity in a day) in $i-th$ women's household in time t. Following Sedai et al. (2020), we use X_{it}' is a vector of control variables, observable time varying individual and household characteristics: household wealth, women's age and marital status, men and women's education in the household, household size, average district level household income and average district level household poverty. θ_i is the unobserved individual-level effect, modeled as a fixed effect with no restriction on the correlation with other model regressors. γ_t is a survey round intercept capturing the time trend effect, and ε_{it} is the error term. We assume the error term is independent and identically distributed across individuals and independent across survey waves.

3. DATA

The data used for this analysis is mainly from the third wave of the Indian Human Development Survey (2012) (Desai and Vanneman, 2018).[14] The survey covers 13,706 households from urban areas and 28,446 households from rural areas. We only use the third wave of the survey by combining the adult individual, household and eligible women's questionnaire (IHDS, 2012). IHDS 2005 does not include all the variables to create the indices of empowerment following the framework of empowerment given by Kabeer (1999), and so we do not carry out a panel analysis. With the progress in the quality of household electrification post the DDUGJY, 2014, (Sedai et al., 2020), it would be important to analyze recent trends, however, the IHDS, 2012 is the most recent data-set that has the variable hours of electricity in a day in the household and the gender dis-aggregated variables of interest. We select 19 variables relating to gender relations, all of which are exclusive to IHDS, 2012.

14. 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).

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

Table 1 shows the descriptive statistics for the sub-groups classified by quartile of power outage. There are significant differences across quartile in women's economic freedom, economic decisions, mobility, agency and household decision making ability. A pronounced difference can be seen between the variables in the first and the second quartile of deficiency, highlighting the non-linear effects of deficiency in electrification.

We explore the correlation between the empowerment variables and use these variations to create empowerment indices as shown in Table 2 using PCA. We choose the component (rankings of variable) 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.

The analysis assigns ranks and factor loads (weight) to each variable within each empowerment 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. Coefficients in empowerment regression tables are deviations from zero as the indices are standardized with mean zero and standard deviation of one.

4. RESULTS

First stage results of the two stage least squares estimation are given in Table 3. The results show that the instrument, 'average district level power outage in the households, excluding the district of the household' has strong correlation with the hours of power outage in the household. Coefficient from the first specification (economic freedom) indicates that an hour of power outage at the district level excluding the district of the household correlates with a 0.77 hours reduction in the hours of electricity in the household. Expectedly, living in urban areas leads to a significant increase in hours of electricity available in the household, as reliable electrification has been noted to be a rural phenomenon in India (Rathi and Vermaak, 2018; Khandker et al., 2014; Chakravorty et al., 2014). The F test for excluded instrument for all the empowerment indicators are greater than 10 (generally accepted minimum criteria for the instrument to be strong (Staiger and Stock, 1994)) indicating that the instrument we have used is strong. The Hansen *J* statistic of over-identification has values ≤ 0.05 in all specifications which implies that all empowerment equations are exactly identified.

To understand the the magnitude of the selection bias and the corrections done through the instrumental variables approach, we first analyze the baseline OLS regression estimates. Table 4 shows the baseline OLS estimates of the correlation between power outages and women's economic freedom, economic decision making, agency, mobility and household decision making. All empowerment indices are standardized, and the coefficients are interpreted as standard deviations from the mean.[15]

15. Outages and additional hours of electricity yield exactly opposite effects, the sigh of the coefficients with an additional hour of outage can be understood as the sign of the coefficient of an additional hour of electricity with the sign of the coefficient reversed.

Table 1: Descriptive Statistics: Variables classified as per quartile of electricity outages in India, IHDS, 2012

	Quartile 1		Quartile 2		Quartile 3	
Variables	Mean	sd	Mean	sd	Mean	sd
Power outage in hours	1.832	1.573	9.768	3.013	17.809	1.882
Electricity hours in a day	22.168	1.573	14.232	3.013	6.191	1.882
Socio-economic and Demographic characteristics						
Real Income (base 2005)	92960.600	135212.100	65529.520	105090.300	66917.570	134568.500
Assets (0–33)	18.755	5.745	15.771	5.838	14.878	5.701
Highest Adult Male Education (0–15)	9.101	4.687	7.901	4.894	7.878	5.044
Highest Adult Female Education (0–15)	7.429	5.216	5.472	5.130	5.135	5.146
Age in years	50.637	13.201	49.654	13.497	49.575	13.609
Household Size	4.740	2.151	4.886	2.361	5.068	2.461
Urban (0/1)	0.549	0.498	0.321	0.467	0.217	0.412
Labor Market characteristics						
Annual Work Hours	516.834	853.674	645.619	848.957	565.664	794.074
Annual Work Days	82.544	121.284	102.673	119.797	92.187	114.451
Household Services and Energy characteristics						
Flush toilet in the house (0/1)	0.576	0.494	0.387	0.487	0.345	0.475
Indoor pipe water (0/1)	0.472	0.499	0.303	0.460	0.253	0.435
Cooking with wood (0/1)	0.397	0.489	0.492	0.500	0.562	0.496
Weekly Fuel Collection Minutes	153.499	108.995	157.702	104.239	155.203	107.418
Daily Collection Minutes	288.490	285.383	367.630	321.941	333.821	347.914
Empowerment Variables (0/1)						
Cash in hand	0.925	0.264	0.934	0.249	0.904	0.295
Property Ownership	0.186	0.389	0.173	0.378	0.162	0.369
Employed	0.394	0.489	0.450	0.498	0.398	0.490
Can visit health center alone	0.795	0.404	0.694	0.461	0.654	0.476
Can visit friends/relatives alone	0.843	0.364	0.755	0.430	0.700	0.458
Can visit grocery store alone	0.864	0.343	0.798	0.402	0.725	0.447
Can travel alone	0.636	0.481	0.489	0.500	0.473	0.499
Use contraception	0.796	0.403	0.790	0.407	0.686	0.464
Bank account	0.616	0.486	0.539	0.499	0.527	0.499
Membership social organization	0.081	0.273	0.047	0.212	0.052	0.223
Fertility decision	0.938	0.241	0.939	0.240	0.897	0.304
Work decision	0.497	0.500	0.461	0.499	0.403	0.491
Decision major household purchases	0.812	0.391	0.798	0.402	0.757	0.429
Decision major asset/land purchases	0.787	0.409	0.768	0.422	0.726	0.446
Decision wedding expenses	0.842	0.365	0.829	0.376	0.781	0.414
Decision child marriage	0.920	0.272	0.896	0.305	0.843	0.364
Decision food shopping	0.686	0.464	0.598	0.490	0.545	0.498
Decision child illness	0.939	0.239	0.919	0.272	0.875	0.330
Decision self illness	0.891	0.311	0.880	0.325	0.822	0.382
Observations	14766		11611		10056	

Source: Authors calculations from India Human Development Survey, 2012. Quartile 1,2,and 3 are households with an average power outage of 0–4 hours, 5–14 hours and 15–24 hours in a day, respectively.

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: First stage estimation results, effect of average district level household power outage in hours, excluding the district of the household on the power outages in hours in the household, IHDS, 2012.

Variables	(1) Economic Freedom	(2) Economic Decision	(3) Agency	(4) Economic Mobility	(5) Household Decision
	Hours of Power Outage in a day				
Average district level household power outage, excluding the district of the household (instrument)	0.77***	0.72***	0.73***	0.81***	0.73***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.00)
Age	0.00	0.00	0.02	0.00	0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Assets (0–33)	–0.09***	–0.08***	–0.010***	–0.011**	–0.09***
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Male Education (0–15)	0.006	0.002	0.002	0.001	0.005
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Female Education (0–15)	–0.005	–0.005	–0.005**	0.001	–0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household Size	0.00	0.00	0.01	0.03	0.01
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Urban	–2.32***	–2.11***	–2.49**	–2.01**	–2.01***
	(0.15)	(0.34)	(0.21)	(0.22)	(0.12)
F test for excluded instrument	70	91	82	88	74
Hansen J statistic (Over-identification)	***	***	***	***	***
Caste	4	4	4	4	4
Marital Status	Y	Y	Y	Y	Y
District Control	373	373	373	373	373
Observations	10,895	28,089	25,339	26,978	19,271

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: Hansen J statistic for over-identification is *** if the equations are exactly identified (coefficient ≤0.05). The F test for excluded instrument is larger than 10 implying the instrument is strong (see Staiger and Stock, 1994).

Table 4: Baseline OLS estimates: effect of electricity outages on women's empowerment, IHDS, 2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variables	Economic Freedom		Economic Decision		Agency		Mobility		Household Decision	
Additional hour of outage	–0.02***	–0.01**	–0.01***	–0.01***	–0.02***	–0.02***	–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)
Baseline outage (0–4) hours										
2nd Quartile outage (5–14) hours	–0.05	–0.01	–0.04**	–0.04**	–0.08***	–0.08***	–0.07***	–0.05**	–0.01	–0.01
	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
3rd Quartile outage (15–24) hours	–0.19***	–0.15***	–0.14***	–0.15***	–0.20***	–0.19***	–0.17***	–0.13***	–0.19***	–0.19***
	(0.03)	(0.04)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Individual and household controls	N	Y	N	Y	N	Y	N	Y	N	Y
Observations	11,936	10,895	30,189	28,089	26,558	25,339	29,017	26,978	20,623	19,271
R-squared	0.200	0.221	0.229	0.264	0.268	0.276	0.183	0.196	0.269	0.285

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: All regression specifications include the individual district dummies and specifications 2,4,6,8,10 include individual dummies for caste and marital status along with the full set of control variables.

Table 5: Instrumental variable regression: Effect of household electricity outages on women's empowerment indices, India, IHDS, 2012

Variables	Economic Freedom		Economic Decision		Agency		Mobility		Household Decision	
Additional hour of outage	–0.02***	–0.02**	–0.01***	–0.01***	–0.02***	–0.02***	–0.02***	–0.02***	–0.02***	–0.02***
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Quartile of electricity outage	–0.20***	–0.14**	–0.11***	–0.12***	–0.16***	–0.17***	–0.20***	–0.16***	–0.18***	–0.19***
	(0.00)	(0.06)	(0.03)	(0.06)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Individual and household controls	N	Y	N	Y	N	Y	N	Y	N	Y
Observations	11,949	10,905	30,205	28,102	26,571	25,349	29,030	26,988	20,637	19,282
R-squared	0.197	0.219	0.229	0.264	0.268	0.276	0.181	0.196	0.267	0.283

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: All regression specifications include the individual district dummies and specifications 2,4,6,8,10 include individual dummies for caste and marital status along with the full set of control variables. Standard errors are clustered at an individual level.

An additional hour of electricity outage reduces women's economic freedom by 0.02 standard deviation, women's economic decision making by 0.01 standard deviations, women's agency by 0.02 standard deviations, women's mobility by 0.01 standard deviations and household decision making ability by 0.01 standard deviations. Adding individual and household controls, district and case fixed effects does not change the significance of the coefficients. We look at non-linearity in the effect of electricity hours on women's empowerment by classifying power outages into three categories according to the population weights. Non-linearities suggest that power outages have a convex relationship with dis-empowerment. Moving from the base category of power outage, 0–4 hours in day to the second quartile of outage, 5–14 hours correlates with a reduction of 0.05 SD in the economic freedom index, it also correlates with a 0.08 SD reduction in women's agency. Moving from the base category to the third quartile of outage, 15–24 hours correlates with significant decreases in all empowerment indices. For instance, having more than 15 hours of outage in a day correlates a 0.15 SD reduction in women's economic decision making ability.

The estimates in Table 5 correct for the issue of endogeneity and self-selection and show the causal effects of power outages on women's empowerment. Since we do not have an instrument for all quartile of outages, we restrict the quartile analysis to be a super-category that has three quartile as mentioned above. As such the quartile analysis is used to assess the robustness of the quartile regression in the baseline model.

Instrumental variable results show that an additional hour of power outage in a day reduces women's economic freedom by 0.02 SD, the coefficients in all specifications are similar to the OLS estimates with marginal differences which are corrections to the selection bias. Adding household, individual, district and caste controls do not alter the significance of additional hours of electricity. quartile regressions are similar to those as the baseline estimations, with marginal decrease in coefficients controlling for the selection bias. The strongest effect of not having electricity is realized in the realm of household decision making ability and mobility.

Figure 2 shows the effect of an additional hour of power outage on women's empowerment and weekly fuel collection minutes for the poor and non-poor. Figure 3 shows women's empowerment with interactions at income levels and women's education. The results of the non-linear OLS regression with district and caste controls show 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 6 provides the labor market effects through which electricity could affect women's empowerment. We estimate the effect of electricity outage on work days in a year, work hours in a year and the binary of employment for at least 240 hours a year. The analysis is carried out using OLS and instrumental variable regressions. Specifications 1, 2 and 3 show that an additional hour of outage reduces women's work days by 1 percentage point, this translates to approximately 1 less working day and 5 less working hours, on average (referred through the averages in Table 1). The Quartile regression shows that having electricity outages between 5–14 hours a day correlates to a reduction of 4 working days in a year and 22 working hours, with a 3 percentage point decrease in the likelihood of employment. Having outages for 15–24 hours in day reduces the work days and work hours by approximately 9 working days and 50 work hours in a year. The instrumental variable

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

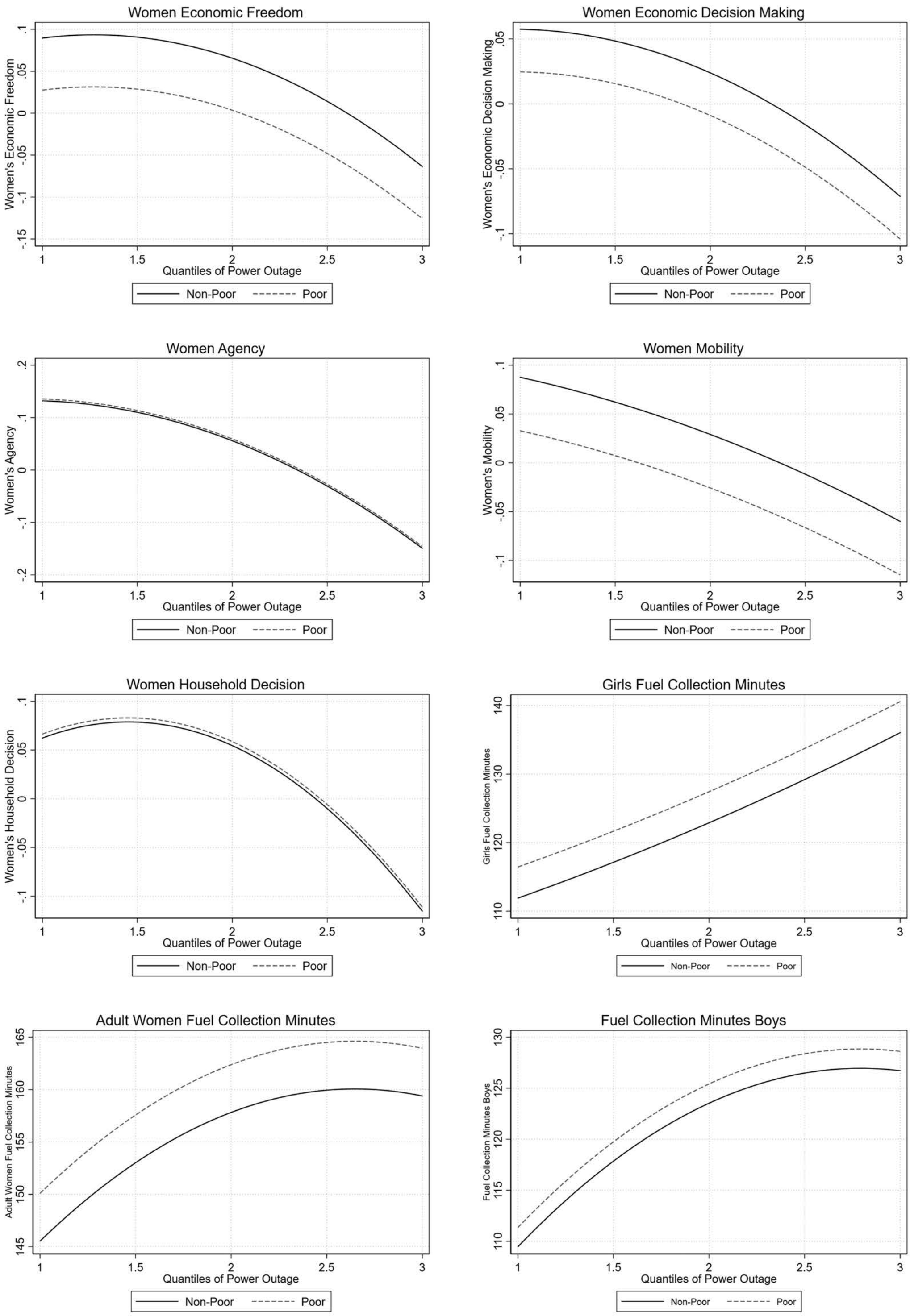
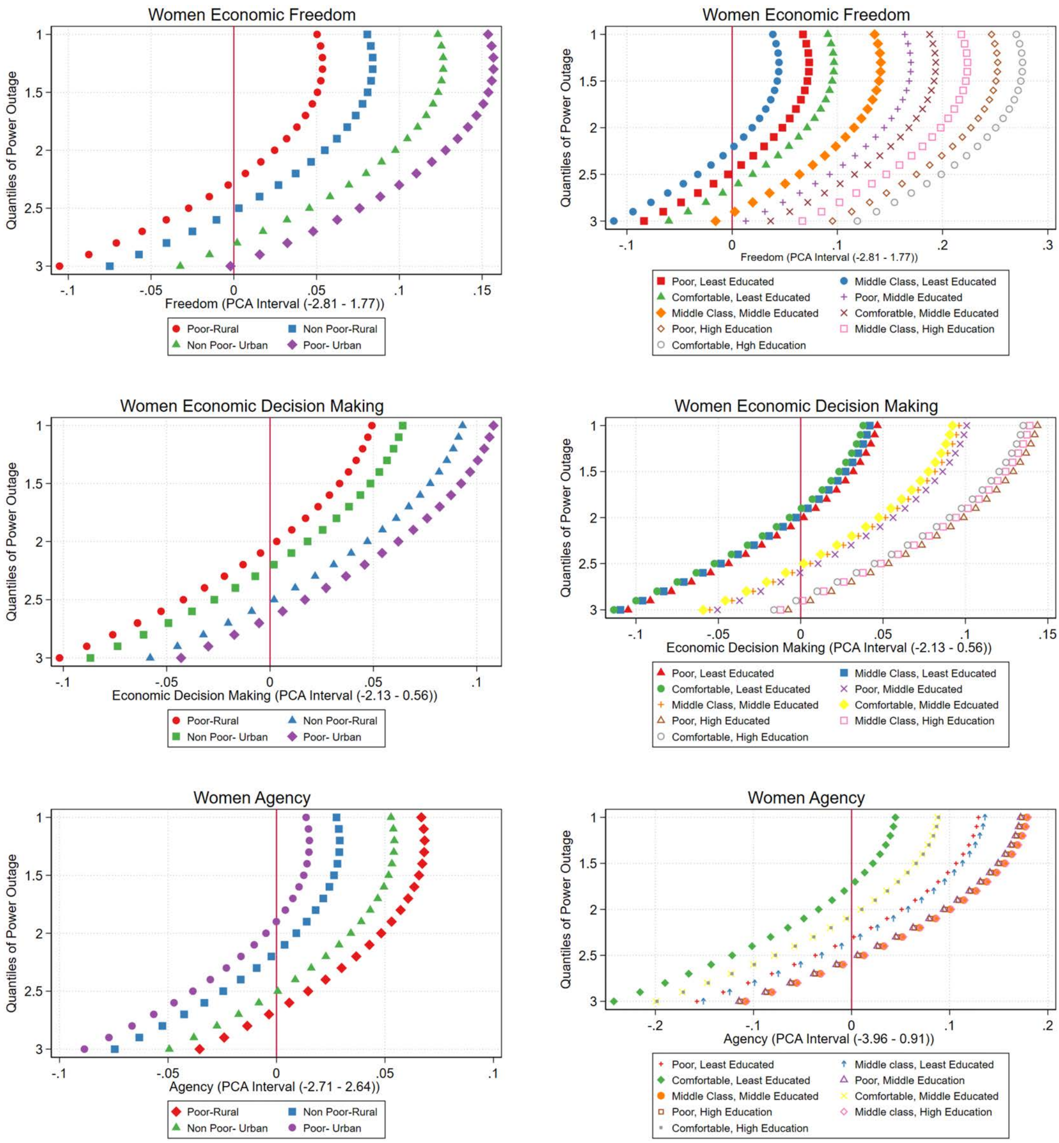


Figure 3: Quintile of Power Outages and Women's Empowerment.



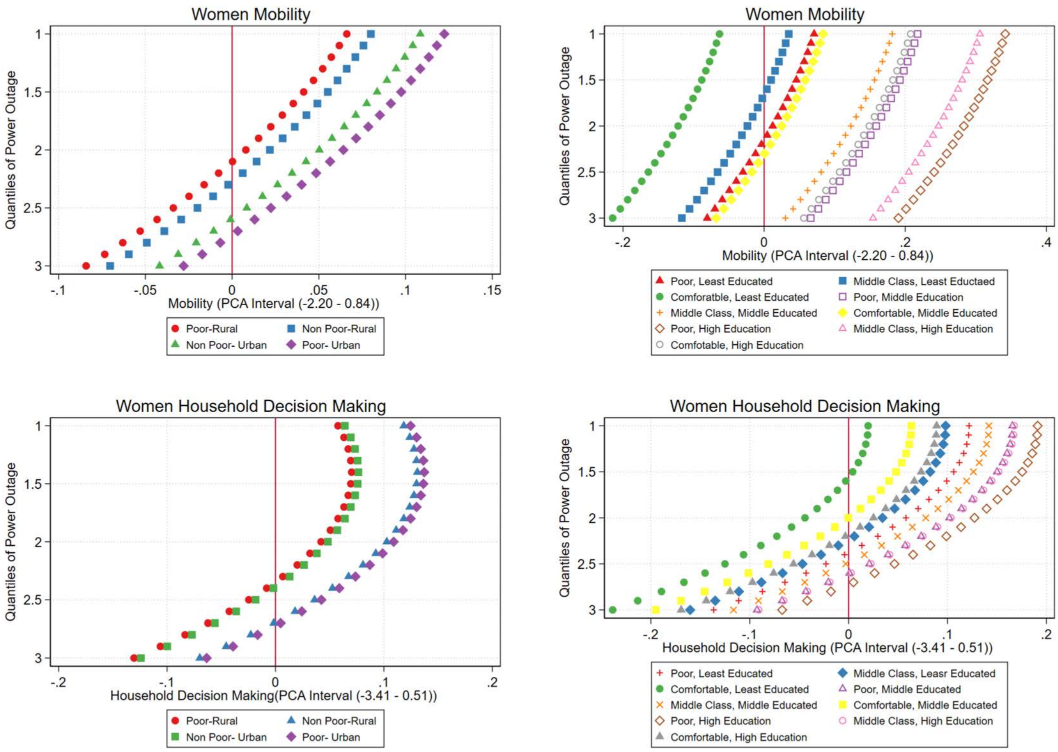
(continued)

regression shows that an additional hour of outage reduces work days by 1.8 days and work hours by 12 hours. An additional hour of outage reduces the likelihood of employment by 1 percentage point.

Next, we look at the respite effects of reliable electrification (respite from the activity of fuel and water collection).

Table 7 shows the effects of additional hours of outage and quartile of power outages in the OLS and IV specifications. An additional hour of outage increases the time spent on weekly fuel collection activity by 1 minutes. Compared to the base quartile of outage, if the household has electricity outages between 5 to 14 hours in a day, this correlates with 13 more minutes of time spent on weekly fuel collection activity. In terms of water collection minutes, an additional hour of power

Figure 3: Quintile of Power Outages and Women's Empowerment *(continued)*.



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

outage increases the daily time spent on water collection activity by 2.5 minutes.[16] Power outages between 5–14 hours in day correlates with a 36 minutes increase in daily water collection activity.

Table 8 shows the effect of quality of electrification on the use of household services and energy resources. We follow the analysis of household services and energy resources through electrification as carried out by Dinkelman (2011) in determining their impact on home production, health and labor market activity of women. Given the IHDS data-set, we analyze the impact of the quality of electrification on the following household services and energy resources: (i) flush toilet in the house, (ii) indoor pipe drinking water, and (iii) cooking with firewood.

Results in Table 8 of the OLS and IV regressions show that an additional hour and quartile of power outages have significant effects on the outcome variables. An additional hour of outage reduces the likelihood of having a flush toilet in the house by 1 percentage point, the IV specification shows similar effects. Having 5–14 hours of power outage in a day reduces the likelihood of having a flush toilet by 2.4 percentage points. An additional hour of outage reduces the likelihood of having indoor pipe drinking water by 1 percentage point, similarly having 5–14 hours of outage reduces

16. Fuel and water collection activities add up to 3.5 minutes. We anticipate higher time costs of daily activities, however due to the lack of time diary data, conducting a comprehensive analysis of the time costs is not possible with the IHDS data-set.

Table 6: Effect on household electricity outages on labor market outcomes for adult women in India, IHDS, 2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS—Outage in hours			OLS—Quartile of Outage			2SLS-IV—Outage in hours		
Variables	Work Days	Work Hours	Employment	Work Days	Work Hours	Employment	Work Days	Work Hours	Employment
Additional hour of outage	–0.010***	–0.014***	–0.004*				–0.015***	–0.023***	–0.010*
	(0.00)	(0.00)	(0.00)				(0.00)	(0.01)	(0.00)
Baseline Quartile of Outage (0–4)									
nd Quartile of Outage (5–14)				–0.033	–0.023	0.033**			
				(0.02)	(0.03)	(0.01)			
rd Quartile of Outage (15–24)				–0.082***	–0.091***	–0.010**			
				(0.03)	(0.03)	(0.02)			
Observations	13,889	13,889	11,516	13,889	13,889	11,516	13,889	13,889	11,516
R-squared	0.209	0.246	0.216	0.209	0.246	0.217	0.206	0.242	0.216

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

Note: All regression specifications include the baseline individual and household controls, district and caste dummies.

Table 7: Effect of household electricity outages on weekly fuel and daily water collection minutes of adult women, India, IHDS, 2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	2SLS-IV	OLS	OLS	OLS	2SLS-IV
Variables	Weekly Fuel Collection Minutes				Daily Water Collection Minutes			
Additional hour of outage	0.595**	0.626**		1.070**	2.190***	2.850**		2.494**
	(0.25)	(0.29)		(0.51)	(0.55)	(0.64)		(1.23)
Baseline Quartile of Outage (0–4)								
nd Quartile of Outage (5–14)			13.228***				35.575***	
			(3.57)				(7.42)	
rd Quartile of Outage (15–24)			16.945***				29.672***	
			(4.39)				(9.17)	
Individual and household controls	N	Y	Y	Y	N	Y	Y	Y
Observations	9,704	7,705	7,705	7,705	16,709	13,192	13,192	13,192
R-squared	0.334	0.345	0.346	0.344	0.285	0.315	0.316	0.313

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

Note: All regression specifications include district and caste dummies.

the likelihood of piped water by 4 percentage points. On the contrary an additional hour of outage increases the likelihood of cooking with firewood by 1 percentage point and having 15–24 hours of outage increases the likelihood of firewood based cooking by 8.4 percentage points.

4.1 Robustness checks

Following the evidence of stronger effects of electrification in rural areas compared to urban ares (Khandker et al., 2014; Rathi and Vermaak, 2018), we analyze the effect of quality of electrification in Table 9 as robustness checks of our estimates.

Results show the effect of an additional quartile of power outage on empowerment indices using the instrumental variable regressions in rural and urban areas. The analysis in Table 9 provide strong evidence of significantly higher effects of power outages on economic freedom, economic and household decision making and mobility in rural areas compared to urban areas. An additional hour of outage reduces economic freedom by 0.02 SD in rural areas and 0.01 SD in urban areas. An additional hour of outage reduces women's mobility by 0.023 SD in rural areas and 0.012 SD in urban areas.

Another robustness check that we conduct is the effect of additional hours of electricity on the variables with highest PCA ranks for each of the empowerment variables.

Table 10 presents the results of OLS and IV regressions where we flip the independent regressor to additional hours of electricity and look at individual variables of empowerment from each of the five indices. The quartile regression is based on three categories of power supply in the household (i) base category with 0–10 hours of electricity in a day, (ii) second quartile with 11–20 hours of electricity hours in a day, (iii) third quartile with 21–24 hours of electricity in a day. Having 21–24 hours of electricity increases the likelihood of women being able to decide their labor supply by 4 percentage points. The instrumental variable regression estimate shows that an additional hour increases the likelihood of work decision by 1.4 percentage points. An increase in the quality of electrification has positive effects in the likelihood being able to visit health center, deciding what to do in sickness, having a say in household's major economic purchases and wedding decisions.

To capture the longitudinal aspect of the effect of quality of electricity on women's empowerment we examine the estimates from a panel fixed effects regressions using the IHDS survey (2005–2012). We look at a few indicators that are available in both the 2005 and 2012 waves: (i) most influence in the purchase decisions of the household, (ii) ask permission to visit health center, and (iii) most influence in the number of children. We use the time varying observed characteristics as controls: age, household wealth (assets), male and female education, household size, and capture the time trend using a year dummy for each wave. Individual fixed effects captures the time invariant unobserved heterogeneity.

Results from the panel analysis confirms the estimates derived from the cross-sectional OLS and IV estimations. An additional hour of electricity increases women's decision making ability in major household purchases by 1 percentage points. The non linear analysis with the base category of electricity hours (1–9) in a day shows that moving from the base category to the 4^{th} quartile (23–24) of hours of electricity in a day leads to a 3.3 percentage point increase in women's decision making in major household purchases. Additional electricity hours reduces the need to ask permission to visit health center and increases women's say in the number of children in the household.

Table 8: Effect of household electricity outage on household services and energy source

	(1) OLS	(2) OLS	(3) 2SLS-IV	(4) OLS	(5) OLS	(6) 2SLS-IV	(7) OLS	(8) OLS	(9) 2SLS-IV
Variables	Flush toilet in the house			Indoor piped drinking water			Cooking with wood		
Additional hours of outage	–0.013***		–0.011***	–0.012***		–0.014*	0.012***		0.014***
	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)		(0.00)
Baseline Quartile of Outage (0–4)									
nd Quartile of Outage (5–14)		–0.024***			–0.040***			0.036***	
		(0.01)			(0.01)			(0.01)	
rd Quartile of Outage (15–24)		–0.049***			–0.049***			0.084***	
		(0.01)			(0.01)			(0.01)	
Individual and household controls	N	Y	Y	N	Y	Y	N	Y	Y
Observations	36,412	28,529	28,529	36,421	28,535	28,535	36,433	28,543	28,543
R-squared	0.297	0.464	0.464	0.316	0.394	0.394	0.378	0.464	0.462

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: All regression specifications include district and caste dummies.

Table 9: Instrumental variables regression: Effects of an additional hour of power outage on women's empowerment indices in rural and urban areas, India, IHDS, 2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variables	Economic Freedom		Economic Decision		Agency		Mobility		Household Decision	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Additional hour of outage	–0.019***	–0.010	–0.019***	–0.014*	–0.021***	–0.025***	–0.023***	–0.012*	–0.025***	–0.020***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	7,770	3,084	17,187	10,796	15,558	9,703	16,432	10,444	11,390	7,815
R-squared	0.266	0.252	0.263	0.299	0.248	0.352	0.198	0.223	0.282	0.321

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: All regression specifications include individual and household controls, district and caste dummies.

Table 10: OLS and Instrumental variables: Effects of additional hours of electricity on major women empowerment variables, India, IHDS, 2012

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Variables	Work Decision		Visit Health Center		Decision in Sickness		Land Purchase Decisions		Wedding decisions	
Additional hours of electricity		0.014**		0.010***		0.013***		0.010***		0.013***
		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)
Baseline electricity hours (0–10)										
nd Quartile (11–20)	0.03***		0.03***		0.05***		0.04***		0.04***	
	(0.01)		(0.01)		(0.01)		(0.01)		(0.01)	
rd Quartile (21–24)	0.04***		0.02*		0.07***		0.07***		0.06***	
	(0.01)		(0.01)		(0.01)		(0.01)		(0.01)	
Observations	23,777	23,777	28,237	28,237	28,477	28,477	28,095	28,095	28,386	28,386
R-squared	0.213	0.212	0.157	0.156	0.242	0.242	0.249	0.249	0.214	0.214

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: All regression specifications include individual and household controls, district and caste dummies.

Table 11: Panel fixed effects regression: Effect of additional hours of electricity on indicators of empowerment, 2005–2012, IHDS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Most say in purchase decisions			Permission for health center			Most say in the no. of children		
Electricity hour in a day (1–24)	0.01***	0.01*		–0.02***	–0.01***		0.01***	0.01***	
	(0.00)	(0.00)		(0.00)	(0.00)		(0.00)	(0.00)	
Base Quartile of electricity hours (1–9)									
nd Quartile of electricity hours (10–16)			0.019***			–0.05***			0.024**
			(0.01)			(0.01)			(0.01)
rd Quartile of electricity hours (17–22)			0.031**			–0.104***			0.049***
			(0.01)			(0.01)			(0.01)
th Quartile of electricity hours (23–24)			0.033			–0.132***			0.062***
			(0.01)			(0.01)			(0.01)
Household and individual controls	N	Y	Y	N	Y	Y	N	Y	Y
Observations	41,018	39,027	39,027	41,114	39,114	39,114	39,841	38,033	38,033
Number of Households	22,647	22,046	22,046	22,670	22,066	22,066	22,449	21,842	21,842

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: All regression specifications include individual and year fixed effects. Standard errors are clustered at the individual level, in parenthesis. The model captures for time invariant unobserved heterogeneity at the individual level and the time trend.

5. CONCLUSION

This study moves beyond counting electrified households, and looks at the effects of electricity deficiency in electrified households on women's empowerment underscoring the mechanisms through which reliable electricity improves the labor and leisure conditions of women. Given the demand supply gap (Sedai et al., 2020), and the political economy around appropriate pricing and provisioning of electricity (Burgess et al., 2020; Joseph, 2010), the theoretical model understates our hypothesis of how household's collective savings to acquire a better quality of electrification improves women's bargaining power in the household, and how in assessing the potential benefits and costs, the issue of disproportionate effects of better electrification on women is ignored. The empirical analysis provides causal implications of power outages on welfare outcomes of the woman in the household by controlling for the endogeneity and self-selection in the choice of electrification. We discuss the reliability effects on women's labor supply, home production and leisure to substantiate the potential effects we observe on empowerment outcomes.

Using the gender dis-aggregated data at the national level in India, we confirm the importance of high-quality service on the welfare effects on women. The results show that this association is robust: in households where daily hours of electricity availability are high and outages or voltage fluctuation rare, women experience better labor market outcomes and more respite from arduous home production activities even when controlling for other determinants such as household wealth, educational attainment, regional variation and caste status. Women's labor force participation, education, health and exposure to electronic media are key intermediary factors through which electrification enhances women's empowerment.

Our first important contribution is methodological. By applying the instrumental variables model, we have corrected for the bias stemming from the fact that empowerment outcomes are meaningless for households with 24*7 electrification. As we demonstrate, the correction has a substantial impact on the results: quality of electricity service, have a large and robust effect on empowerment outcomes. In the models that fail to correct for sample selection, this important result disappears because of selection bias.

This study finds that an additional hour of power outage and the quartile of outages reduce women's welfare outcomes, but the effect is not homogeneous across all women population. An hour of electricity is more beneficial for women in the second quartile of electricity deficiency where household on average has no electricity between 5–14 hours a day. There is not a significant difference in the effect of electrification on women's autonomy moving from the second and third quartile of outage. However, moving from the first quartile of outage (0–4) hours to the third quartile of outage (15–24) hours reduces working days for women by 9 days in a year which translates to loss of 1,080 (at the daily minimum compensation of 120 through the rural employment guarantee scheme, MNREGA, as of 2011 (Narayanan et al., 2017).

The policy implication of our analysis is clear: improving the quality of service is essential, also been noted by Kennedy et al. (2019). India's problems with electricity service stems from the poor financial performance of distribution companies, and our results show that improving the quality of service would allow for improvements in women's opportunities in the labor market, income, and decision making, which consequently leads to greater economic activity. These outcomes could help distribution companies to charge cost-recovering prices for electricity through the normal mode of the market, or leverage for more support from the government to distribute more reliable electricity depending on whether the government perceives electricity as a right, or as a marketable commodity.

India's recent electrification efforts have neither emphasized on service quality nor tried to target communities and households where the willingness to pay are underestimated due to the lack of awareness of how electrification affects women's welfare (Rathi and Vermaak, 2018; Kennedy et al., 2019). As the lack of women's representation in labor market mars the objective of India's sustainable development (Duflo, 2012; Abraham, 2013), the need to focus on service quality and the value of electricity service, as opposed to increased connectivity alone has becoming increasingly important. As improving the quality of service increases the potential avenues for increases in willingness to pay, policymakers may have a solution to the financial problems that electrification creates under heavily subsidized schemes.

Our analysis offers a comprehensive approach to measuring the welfare effects of quality of electricity service for women in developing countries. This approach can inform efforts such as the Sustainable Development Goal 5, women's influence in international development agendas and policy processes effectively through equality, inclusion and participation in societies structured around grave inequalities and exclusions (Gabizon, 2016). Future research, in our view, should continue to pursue this line of inquiry by considering the implications of service quality on gender differences in economic and non-economic outcomes.

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