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Does reliable electrification reduce gender differences? Evidence from India

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ABSTRACT

This study examines the effect of reliability of electricity on gender differences in socio-economic status using a comprehensive set of labor and non-labor market outcomes in India. Using the temporal variation in household electricity hours from a large gender-disaggregated data set, we examine the effects of electricity reliability with individual fixed effects and instrumental variable regressions. Our analysis reveals contrasting trends with significant progress at the extensive margin of electricity access, but little progress at the intensive margin of reliability, hours of electricity. We find that reliable electrification improves the status of women relative to men through increased employment opportunities and reduced time allocation to home production. For instance, 10 more hours of electricity increases the likelihood of employment in the 'usual status' by 2.8 percentage points (pp) for men, and 4.2 pp for women. The analysis is robust to the use of piece-wise linear regression approaches, as well as alternate specifications of the outcome variables. The study recommends considering electricity as a right, and as part of the broader strategy for reducing gender disparities in India.

1. Introduction

Issues of access and provision of household infrastructure and labor-saving technologies are pertinent in developing economies with lower levels of access to clean drinking water, fuel, safe transportation, and electricity (Dinkelman, 2011; Mensah et al., 2014; Klasen, 2019). These issues affect women disproportionately given that they often spend more time than men at home, and are subjected by social norms to bear the major burden of home production (Ferrant and Thim, 2019; Fletcher et al., 2017; Klasen, 2019). One such issue is that of reliable electrification in India (Kennedy et al., 2019; Aklin et al., 2016; Sedai et al., 2020b; Klasen, 2019), to which very little attention has been paid by policy making, especially from a gendered perspective. The issue of household electrification is more than just the presence or absence of grid connections, or other alternatives; its reliability (e.g. hours of electricity per day) is critical to productive activity and social life, especially in developing countries (Klasen, 2019; Aklin et al., 2016; Fletcher et al., 2017; Dinkelman, 2011).[1] Reliability is a significant determinant of household satisfaction with electrification and has been causing social unrest in India

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[1] Recent studies have shown that increasing electricity connections does not supercharge economic development in developing economies (Lee et al., 2020). In the case of India, a nation-wide act to increase electricity connection from 2005 to 2014, did not increase household and national income (Burlig and Preonas, 2016).

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(Aklin et al., 2016; Klasen, 2019; Sedai et al., 2020a).[2] In this context, this study examines the hours of electricity available per day as the measure of reliability of electrification and analyzes its effects on welfare outcomes stratified by gender.[3]

Studies that have looked at the micro-economic consequences of electrification on women's welfare have focused primarily on electricity connections, and argued that electrification increases female labor force participation (LFP) and empowerment (Rathi and Vermaak, 2018; Samad and Zhang, 2019; Sedai et al., 2020b; Dinkelman, 2011; Winther et al., 2017). However, available literature in developing economies lacks three integral components for a robust understanding of the impact of electrification on women's welfare: (i) addressing endogeneity; self-selection is involved since consumption and supply of electricity are non-random, (ii) reduced form models have used electricity access as the explanatory variables without considering the reliability of electricity, and (iii) existing studies have focused either on the labor force participation, intra-household resource allocations, or women's empowerment instead of a holistic labor and non-labor market analysis. Our study addresses these gaps in the literature through an analysis of the causal effects of reliable electricity on a comprehensive set of labor and non-labor market outcomes for men and women that include both the intensive and extensive margins of work.

Fluctuating voltages, poor maintenance service, frequent power outages, and the appropriation of the limited supply of electricity by elite households have been a norm in India (Rathi and Vermaak, 2018), especially in rural areas (Joseph, 2010; Aklin et al., 2016; Kennedy et al., 2019; Chatterjee and Pal, 2020). Despite tremendous progress at the extensive margin of providing access (Khandker et al., 2014; Rathi and Vermaak, 2018; Samad and Zhang, 2019), as of 2018, six relatively poor states in India have less than 15 h of electricity on a typical day (Kennedy et al., 2019; Sedai et al., 2020a).[4] Analyses of national and regional household surveys and review of available literature shows little progress in the reliability of electricity (measured by hours of electricity available) in the household from 2005 to 2018 in contrast to the substantial progress in providing connections (Sedai et al., 2020a). For households connected to the grid, limited supply may be caused by lack of capacity and rationing.[5] For households using distributed (off-grid) technology, limited hours may, for instance, be related to the availability and affordability of fuel to run the off-grid technologies (Aklin et al., 2016).

Electricity connection is a neccessary but not a sufficient condition to counter energy poverty (Kennedy et al., 2019). Recent studies by Harish et al. (2014) and Sedai et al. (2020a) criticized the frequently used "binary metric" of whether people have/do not have an electricity connection as it can be misleading. Lack of supply reliability, especially during peak periods, acts as an impediment to post electrification decisions, such as the purchase of domestic appliances (TV, fridge, computer, air-conditioner, washing machine, heater, etc.), which lowers the required time for home production, and restricts the efficient allocation of time into labor and home production (Ferrant and Thim, 2019; Klasen, 2019; Sedai et al., 2020b). These time-saving technologies are critical for women, given the norms-based supply side constraints to their LFP, and demands for home production (Fletcher et al., 2017; Ferrant and Thim, 2019; Klasen, 2019; Sedai et al., 2020b).

We examine electricity supply using two household surveys, the India Human Development Survey (IHDS, 2005–2012) and the Access to Clean Cooking Energy and Electricity Survey (ACCESS, 2015–2018), to substantiate lack of reliable electrification as a persistent issue. We then use the balanced sample of households with electricity connections from IHDS data and carry out panel fixed effects and instrumental variable regressions to estimate the effect of electricity reliability on outcomes of interest.[6] Following Bai et al. (2019), Dang and La (2019) and Sedai et al. (2020b,a), we use a geographic instrumental variable: average hours of household electricity at the state level, excluding one's own district. The instrument is strong as shown by the F statistic for the test of excluded instruments (Staiger and James, 1997).

We find that increasing the number of electricity hours in the household increases the likelihood of employment in the usual status[7] ($\geq$ 240 hours or $\geq$ 30 days in a year) for both men and women, with a stronger effect on women. A 10 h increase in household electricity increases the usual employment status by 4.2 pp for women and by 2.8 pp for men. There is no statistical difference in terms of principal employment ($\geq$ 180 days in a year)—the effects are 4.0 pp for men and 3.9 pp for women. We observe an increase in work days for both men and women, and a decrease in work hours

[2] Aklin et al. (2016) find that an increase of one standard deviation (6.5 h) in duration increases the level of satisfaction with lighting by 0.3 points on a 0–2 scale, corresponding to an increase of about 40% of the standard deviation of satisfaction.

[3] Having said this, we acknowledge that hours of electricity available in a day may not reflect the actual supply quality in terms of ample voltage to run appliances on a day to day basis. To attenuate this issue, we control for the electricity payment per hour and state level percentages of peak load surplus/deficit in mega-watts.

[4] Official reports indicate that the objective of 100% electrification of all households has been achieved (Agrawal et al., 2020), yet, only 16% of electrified rural households receive full six hours of electricity during the peak period between 5 PM and 11 PM (Canares et al., 2017). As of 2018, it was reported that "nearly one-fifth of India's rural households still remain in acute darkness" (Singh and Sundria, 2017).

[5] Given the high cost of electricity supply to rural areas and low affordability, electricity utilities serving rural areas resort to the practice of rationing supply by restricting the periods of availability of electricity to match the demand for electricity (Nhalur et al., 2018). Affordability to consumers and the public debt burden due to subsidies to electricity utilities are among other hindrances to complete electrification in India (Venkateswaran et al., 2018).

[6] Dropping the data on households without electricity connections implies our sample is representative of better-off households in terms of income and wealth. Sedai et al. (2020a) find that the likelihood of having electricity is lower among poorer and socially marginalized households and discuss the socio-economic inequalities in electricity access. We instead focus on households with electricity access facing variations in electricity reliability.

[7] The usual status (usual principal plus subsidiary status, UPSS) is applied to a person who pursued some economic activity for 30 days (240 hours) or more during the reference period of 365 days preceding the date of the survey. An individual who has worked for a majority of the 180 days prior to the date of the survey is considered employed by the usual principal activity status (UPS). All those with either UPSS or UPS are considered as being in the labor force through the usual principal plus subsidiary status. We use usual status and at least part-time employment interchangeably, similarly for usual principal status and full-time employment.

(significant for men) with improved electricity reliability. This supports the hypothesis of labor productivity effects, or reduced work hours through time efficient technologies (electric irons, refrigerators, sewing machines), as also found by Rathi and Vermaak (2018) in India and South Africa between 2005 and 2012 and by Dinkelman (2011) in South Africa between 1996 and 2001.

We find significant positive effects of reliable electrification on the annual earnings of both men and women, with higher earning potential for women as compared to men. There is a significant reduction in weekly fuel and water collection minutes for both men and women with larger reductions (respite) for women as compared to men. Increasing reliability of electrification reduces household's expenditure on firewood and increases the likelihood of acquiring basic household amenities such as a household toilet and indoor piped water. We also show that reliable electrification is critical in empowering women in socio-economic and reproductive decision making, and has a positive effect on women's general health. Our results are robust to alternate specifications of dependent variables, and are similar to the results obtained by Rathi and Vermaak (2018) and Van de Walle et al. (2017) on the gendered labor market effects of electrification.

2. Literature and conceptual review

2.1. Gender differences in the labor market and the role of labor saving technologies in india

Recent trends of falling Female Labor Force Participation (FLFP) in India are seen as a challenge that requires immediate policy intervention to protect against deterioration of female well-being and empowerment.[8] Increased FLFP changes the social norms and practices, and introduces a phase where individuals with varying degrees of negotiating power can promote their interests (Winther et al., 2017). Earned income through LFP has been found to have a positive impact on women's bargaining power, and reduce gender disparity in developing economies (Anderson and Eswaran, 2009; Anderson and Baland, 2002). Moreover, it has been estimated that per capita income could be 10 percent higher in 2020, and 20 percent higher by 2030 if India's gender participation gap could be halved from year 2000 levels (Kapsos et al., 2014).

As argued by Sen (1987), in any model of economic development it is crucial to take into account that cooperation and conflict exist simultaneously in gender divisions. These attributes are present not only in the labor market but also within the household and are discussed through the supply and demand side constraints to FLFP. On the supply side, Indian households often require that women prioritize home production, and may even explicitly constrain LFP of married women (Fletcher et al., 2017). Societal expectation of women's role as caregivers and caretakers of the household often mean that women who seek work encounter opposition from their peers and families, leading to lower participation (Kapsos et al., 2014). There is also evidence that these norms are typically more binding among wealthier, educated, upper caste households, suggesting that economic growth alone may not alter their influence (Fletcher et al., 2017; Klasen, 2019). On the demand side, women face legal, normative, and economic constraints to work as they are still subject to laws governing when (i.e. which shifts) and in which industries they can work (Fletcher et al., 2017; Jayachandran, 2019).

The role of labor-saving household technologies in determining LFP of men and women has been understudied in India (Fletcher et al., 2017). This is particularly interesting as there are two contrasting theories of the impact of household technologies in reducing gender inequality. On one hand, labor saving technologies relax time constraints and reduce drudgery. Time saved due to better technology could increase time in paid work, therefore these technologies could increase FLFP (Ferrant and Thim, 2019; Klasen, 2019; Fletcher et al., 2017). On the other hand, as long as the stereotype threats and biases persist, the potential of these technologies in reducing gender inequality will be diminished, even if the technological conditions for an even playing field are met (Kabeer, 1999; Winther et al., 2017; Kapsos et al., 2014). As Klasen (2019) argued, even when the availability of labor-saving technologies is no longer a constraint, the issue of relative bargaining power and distributional equity may still linger.

Household electrification as a labor saving technology has been argued to disproportionately benefit women and increase FLFP (Ferrant and Thim, 2019; Rathi and Vermaak, 2018; Sedai et al., 2020b). However, electrification also increases household and farm income, and the LFP of men in developing countries which has been associated with falling FLFP (Rathi and Vermaak, 2018; Van de Walle et al., 2017; Chakravorty et al., 2014; Sedai et al., 2020a; Fletcher et al., 2017; Kapsos et al., 2014; Klasen, 2019). In this context, it would be critical to examine the net effect of reliable electrification on LFP across gender. This is important from a policy perspective as there is an ongoing debate on the inefficiencies in the current scheme of subsidized electricity distribution in India, and the need to privatize electricity generation and distribution (Burgess et al., 2020). As Duflo (2012) argued, if the relative effect of a public policy[9] is such that it reduces gender differences in the labor market and in the household, then a continued policy commitment to reliable electrification for its own sake may be needed to bring about more equality between men and women.

[8] The LFP rate for women aged 15 years and above fell by 10.1 pp, corresponding to 22.6 million fewer women in the labor force in 2010 than in 2005 (Kapsos et al., 2014). The drop was higher in rural areas as compared to urban areas, 11.5 and 5.0 pp, respectively. In comparison, male LFP in India declined by only 3.4 pp over the same period.

[9] In the context of this study, the public policy is a thrust to improve the reliability of electricity, hours of electricity available to households in a day.

2.2. Reliable electrification and gender equality

Energy poverty is argued to have various socioeconomic consequences, with implications for social wellbeing, health and productivity, among others (Churchill et al., 2020). Cecelski (2005) used UN gender-related measures, such as the Gender Development Index (GDI) and Gender Empowerment Measure (GEM), to explore if energy consumption is related to gender equity and empowerment. The findings indicate that per capita energy consumption correlates closely with the GDI. The relationship is non-linear (concave), suggesting that even modest increases in energy and electricity consumption could be associated with substantial improvements in gender-related development in terms of women's life expectancy, literacy, and school enrollment.

At the micro level, increasing the reliability of electrification economizes on the time spent in home production, and facilitates the potential reallocation of time from unpaid household labor to paid employment. For example, a study by Kanagawa and Nakata (2008) in Assam, India, showed that the availability of lighting during evening hours extended the effective workday and allowed women to leave certain household chores for the night enabling them to participate in more formal economic activity during the day. In case of erratic power supply, these benefits may fail to materialize. Dinkelman (2011) in a study in South Africa found that the deficiency of electricity led to sub-optimal time allocation to home production hindering the possibilities for paid employment, and increasing the time spent on unpaid home production.

In addition to increased productivity in home production, reliable electrification increases the exposure and social awareness through media (radio, television), which have been found to change gender attitudes[10] and increase women's mobility and autonomy (Sedai et al., 2020b; Jensen and Oster, 2009; Winther et al., 2017). Access to cable television, which is dependent on the reliability of electrification, has been associated with significant decreases in the reported acceptability of domestic violence toward women, preference for a son, and fertility, along with having a positive impact on gender norms and how girls are valued compared to boys (Jensen and Oster, 2009; Winther et al., 2017). Reliable electricity could affect fertility and women's decision making directly through knowledge and information systems, or indirectly, by increasing LFP and relative wages of women as compared to men (Galor and Weil, 1993).

Households, especially in rural India, have depended for years on kerosene and biomass for lighting, cooking and reading, however, these sources of fuel contribute to air pollution and are hazardous for health (Parikh, 2011; Aklin et al., 2016). Use of electricity instead of fuel wood for cooking, heating, reading and lighting reduces household air pollution and leads to decreased risk of respiratory disease, particularly among women and young children (Parikh, 2011), along with reductions in low birth weight and neonatal death (Epstein et al., 2013). Less kerosene and firewood usage implies better health outcomes for women which has a direct effect on their labor supply (Epstein et al., 2013; Sedai et al., 2020b).

According to Rathi and Vermaak (2018), although rural electrification has positive welfare impacts, the benefits of electrification do not accrue universally, but instead depend on gender roles, supporting policies, and the labor absorptive capacity of the economy. Their study concludes that electrification raises the annual incomes earned by those who work in paid employment for both men and women in India and South Africa. Results also show that in India, with respect to the number of paid work-hours, both men and women worked fewer hours, suggesting that electrification raises productivity. In contrast, for South Africa, where the labor market had less absorptive capacity, there were no employment benefits of electrification, but women benefited more in terms of increases in earnings as compared to men.[11]

In studies most closely related to ours, Sedai et al. (2020b,a) and Samad and Zhang (2019) found strong *positive* effects of additional hours of household electricity on household's income, assets, basic amenities and women's autonomy. Sedai et al. (2020a) used panel fixed effects to analyze the impact of electricity reliability on household welfare (consumption, assets and amenities). Samad and Zhang (2019) conducted a cross-sectional analyses of women's empowerment using the spatial variation in access to electrification.[12] Their results show that an additional hour of electricity increases average household's annual consumption by 0.2 percent, income by 0.3 percent, and women's freedom of movement by 2.3 pp. However, their analysis does not discuss the effects of additional electricity hours on gender differences in the labor market and the household. This paper, in contrast, investigates the effects of reliable electrification on gender disaggregated outcomes in the labor market, fuel collection, women's empowerment and energy choices. In addition, examination of the differences between men and women allows us to infer the relative empowerment of women as compared to men.

[10] The assumed mechanism is that individuals, especially in rural areas come in contact with outside world through television and radio, and among other, these services allow individuals to gain knowledge about family planning, contraceptive use, pregnancy, latrine building, perception of own-village status and also learn about and adopt alternative gender norms (Winther et al., 2017; Jensen and Oster, 2009).

[11] Dinkelman (2011) estimated that rural electrification increased rural female's employment by 9–9.5 percentage points in South Africa. Similarly, Grogan and Sadanand (2013) found the probability of women working outside the home increased by 23 percent in Nicaragua as a result of rural electrification. However, to our knowledge, there is no estimate of the effect of electricity reliability on labor market activity by gender.

[12] Sedai et al. (2020b) look at the effect of electricity access on household welfare in terms of consumption, assets, amenities, and status of poverty, but do not look at the means to welfare enhancement- which are gains in employment, productivity and business activity for household members due to better electrification. Sedai et al. (2020b) and Samad and Zhang (2019) use cross-section data to look at the effects of electricity provisioning on variables of women empowerment, however, their outcome variables (such as women's decision-making ability on fertility and personal health) could be indirectly affected by reliable electricity through an increase in women's bargaining power (bargaining power being a function of women's earned income through employment (Anderson and Eswaran, 2009)).

2.3. The context of electrification in India

In the last few decades, the government of India has focused on access to electrification in its national policies. The government allocated substantial resources to increase electricity and these initiatives are expected to contribute significantly to achieving the United Nations' Sustainable Energy for All initiative, which targets to achieve universal access to modern energy services by 2030. However, providing universal access to electricity has not been complemented with policy measures related to affordability, reliability, and quality of service (Sedai et al., 2020a; Aklin et al., 2016). Major reasons behind the lack of reliable electricity despite the policy impetus are (i) poor infrastructure, (ii) policy focus on free connections, (iii) un-affordability and, (iv) poor financial structure of distribution companies (Joseph, 2010; Allcott et al., 2016; Burgess et al., 2020).

In 2003, the landmark "Electricity Act" was implemented to consolidate the laws relating to the generation, transmission, distribution, trading, and use of electricity. The Act outlined measures conducive to the development of the electricity sector, promoting competition, protecting the interest of consumers and supply of electricity to all areas, rationalizing electricity tariffs, and ensuring transparent policies related to subsidies, amongst other provisions. The main objective was the electrification of all villages and habitations with more than 100 people, installing small generators and distribution networks where grid extension is not considered cost-effective, and providing free electricity connections to households below the poverty line. The public program, Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), increased the village electrification rate to 74% by the end of 2010 from 59% in 2000 (Rathi and Vermaak, 2018). In recent times, the central government has been supplementing the efforts of the state governments to achieve universal access to electricity by providing insurance to distribution companies against their losses through various schemes.[13] However, despite significant leaps in providing electricity connections, electricity reliability has been dismal (Sedai et al., 2020a; 2020b).[14]

Figs. 1 and 2 show the reliability and the change in distribution of electricity at the household level between 2005 and 2018. Fig. 1 highlights the lack of reliability electricity spatially and temporally between 2005 and 2012 at the national level. The figure shows that some states had better reliability of electrification compared to others, and as such points to electrification being endogenous with the level of development. Fig. 2 shows the hours of electricity gained or lost by the household during the period 2005–2018.[15] The figure shows that while some households gained hours of electricity, some household's lost in terms of reliable electrification. These different surveys point to the same re-distributive trend in electricity over time. This is probably because of the policy impetus on increasing the connections without corresponding improvements in the grid infrastructures, which might have put pressure on the grid capacity, and led to rationing of supply, as has been pointed out by Aklin et al. (2016) and Sedai et al. (2020a). Therefore, the well-acknowledged trade-off between extending basic access to more people and enhancing the access of those already served (Marzolf et al., 2019) seems to hold in terms of electricity supply in India.

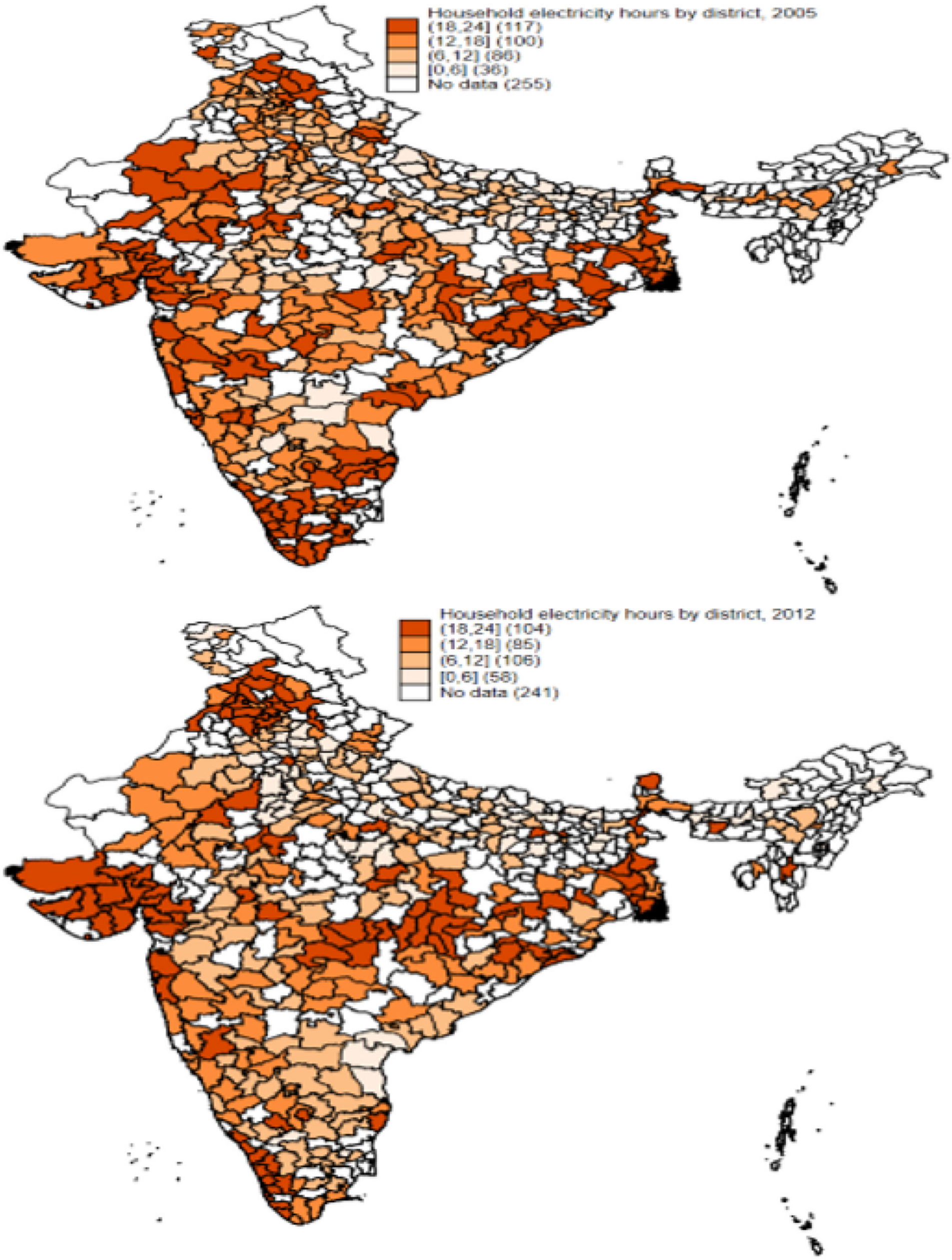
The main reason behind the persistence of outages in India as argued by Pargal and Banerjee (2014) is the lack of commercial viability of the electricity distribution business. After-tax losses, mainly concentrated in the distribution segment, in 2011 were equivalent to nearly 17 percent of India's gross fiscal deficit and around 0.7% of GDP (Pargal and Banerjee, 2014). According to Joseph (2010), electricity utilities are under the ambit of the government authorities, who see electricity users not as consumers but as voters. Hence, under-pricing of electricity is popular for these authorities. As Burgess et al. (2020) argued, it is common to observe electricity costs to be set well below the full recovery cost. This under-recovery is further exacerbated by electricity theft, transmission and distribution losses (Joseph, 2010).[16] Distributional inefficiencies have attracted private players into the electricity market (Joseph, 2010), and there have been arguments for progressive pricing depending on price elasticity (Chindarkar and Goyal, 2019; Harish et al., 2014). However, so far the lack of a gendered understanding of the impact of reliable electrification has overshadowed the true cost-benefit trade-offs within households.

[13] Namely: Deen Dayal Upadhyay Gram Jyoti Yojana (DDUGJY), Integrated Power Development Scheme (IPDS), Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya) and the Ujjwal Discom Assurance Yojana (UDAY).

[14] Government reports indicate 16 to 24 hours of supply in rural areas while consumer surveys and sample measurements report much lower hours. One survey by Smart-Power reports that half of rural households experience eight hours of power cut in a day, and nearly half the rural enterprises use non-grid supply options. The nationwide village survey by the Ministry of Rural Development in 2017, indicates that only half the villages get more than 12 hours of supply (Sreekumar et al., 2019). As per the government reports, India has achieved 100% village electrification (Shrimali and Sen, 2020). However, from 2015 to 2018 average hours of electricity in a day increased from approximately 13 hours a day to 14.5 hours a day. Electricity during night time was relatively stagnant, changing from 3.4 h to 3.5 h a day (Sedai et al., 2020b).

[15] We analyze electricity reliability across all seven regions at the national level between 2005 and 2012. However, due to data limitations, we analyze electricity reliability only across six relatively poor and populous states between 2015 and 2018.

[16] There is under-pricing of electricity to the weaker section of society, almost free electricity to farmers, and pricing above the Average Cost of Supply (ACS) to other consumer groups (commercial and Industrial groups) (Jain and Nandan, 2019). The pricing above ACS to the industry further exacerbates the commercial viability of distribution utilities. Higher pricing charged by distribution utilities prompts the large consumers of electricity (industry) to go for self-generation (Jain and Nandan, 2020). Thus in this way, distribution utilities can lose the lucrative consumer group.



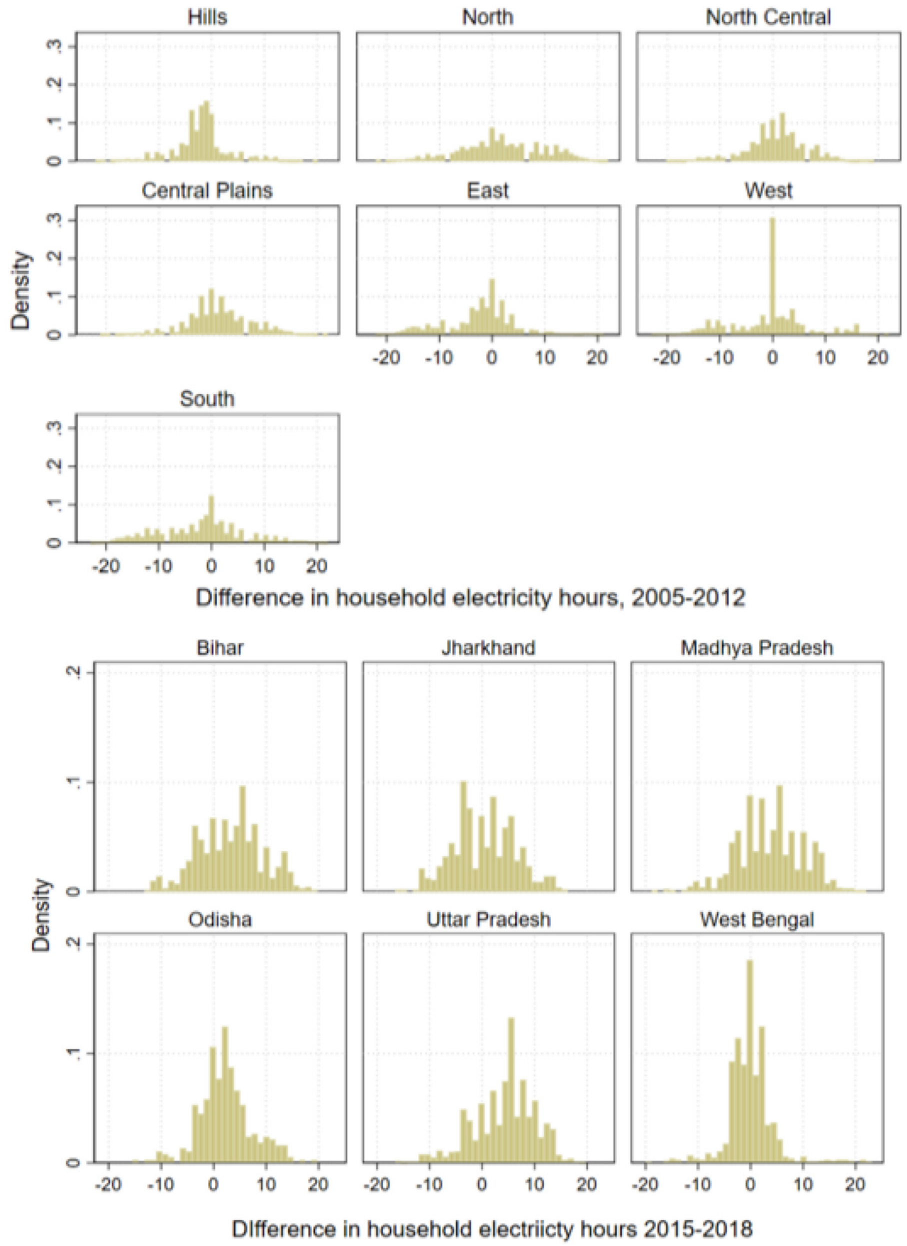
Source: Authors calculations, IHDS, 2005-2012.

Fig. 1. Average hours of electricity in India at the district level, 2005–2012, conditional on electricity access. Source: Authors calculations, IHDS, 2005–2012.

3. Data and empirical framework

3.1. Data

The data used for this analysis is from the second and third wave of the Indian Human Development Survey (2005–2012) (Desai and Vanneman, 2018). IHDS are nation-wide gender-desegregated sample surveys 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). IHDS covers wide-ranging topics at the household, individual and village level on demographic and socio-economic characteristics. The survey covers key gender disaggregated labor and non-labor market characteristics such as: employment for over 240 h in a year (UPSS, usual status), employment for over 180 days in a year (UPS, usual principal



Source: Authors calculations, IHDS, 2005-2012, ACCESS, 2015-2018.

Fig. 2. Difference in the hours of electricity received by households on a typical day by region between 2005 and 2012, and by state between 2015 and 2018, conditional on electricity access. Source: Authors calculations, IHDS, 2005–2012, ACCESS, 2015–2018.

status), work days, work hours, annual earnings, weekly fuel and water collection minutes, basic households amenities, choice of fuel, gender relation variables, energy services, and spending on energy.

Our treatment variable ‘hours of electricity on a typical day’ is derived from the survey item, “Does this house have electricity?”, if yes, “How many hours per day do you generally have power?” It is important to highlight that electricity hours in a day may not reflect the supply quality given the high degree of voltage fluctuations, especially in rural areas. Therefore to attenuate the issue of inability to measure electricity quality (in terms of proper voltage, > 220 Volts), we use two variables to control for supply quality. First, we use the data from the Ministry of Power, India on ‘peak load surplus/deficit’ (%) as a control in the analysis.[17] Second, we control for the electricity payment per hour of electricity available by the household.[18] Due to the inability to accurately quantify the quality of electricity, we restrict our interpretation of the treatment as the effect of reliability of electricity.

In addition to IHDS data, we also use the ACCESS survey (2015–2018) to examine the recent trends in electricity hours in six states (Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand, West Bengal and Orissa). The analysis of descriptive statistics from the ACCESS survey provides inferences of the present state of electrification in relatively poor and populous states in India (Mani et al., 2018; Sedai et al., 2020a). Due to the lack of gender disaggregated data in the ACCESS survey, our regression analysis focuses on the variables in the IHDS survey.

We exclude individuals whose household did not have access to electricity in both waves of the IHDS (observations dropped) as the focus of the analysis is on the intensive margin of reliability of electricity supply. After dropping the observations for households without electricity access and individuals below the age of 17 and above 70, we have a time balanced sample of 33,183 men and 32,275 women in each round of the IHDS survey. The sample for the analysis of employment, work hours, work days, fuel and water collection, energy choices and amenities are drawn from the individual based questionnaire, while the empowerment outcomes are drawn from the women's questionnaire of the survey. It is important to note that the comparison of outcomes between men and women is not necessarily for the same household. The inferences drawn and compared are not for couples, or adults in the same household, but for the overall sample.

3.2. Empirical model

3.2.1. Baseline model and endogeneity

The baseline individual fixed effect estimation is given as

$$Y_{it} = \beta EH_{it} + X_{it}^{'}\delta + \theta_i + \gamma_t + \alpha D_{jt} + \lambda P_{jt} + \epsilon_{it} \tag{1}$$

where Y_{it} represents the outcome of interest for individual i at time t: employment, work hours, work days, annual earnings, fuel and water collection minutes, energy choices, basic household amenities, and women's empowerment. EH_{it} is the hours of electricity available in the household of individual i at time t. In addition to the effect of additional hours, we create survey sample weighted quartiles of electricity hours and analyze a piecewise linear model with 0–9 h of electricity in a day as the base category. $X_{it}^{'}$ is a vector of individual and household observable socioeconomic and demographic characteristics: household: wealth, measured by total assets and size, and individual: education, age, and marital status. In addition, in all the analyses, we control for household's payment for electricity per hour available, and percentage of PLD % of electricity at the state level. The unobserved θ_i is modeled as a fixed effect with no restriction on the correlation with other model regressors. γ_t is a survey wave intercept. In addition, we control for geographic time-varying characteristics at the district level through the average district level household income D_{jt}, and average district level household poverty P_{jt}. The error term ϵ_{it} is assumed to be randomly distributed in the fixed effects analysis while any heterogeneity is accounted for in the instrumental variables regression.

The main argument for endogeneity in the baseline model is that the supply, consumption and distribution of electricity in India are non-random, there is self-selection and sorting involved. According to Lee et al. (2020), "electricity grid infrastructure is costly and long-lived, and its planning and construction requires the inputs of multiple stakeholders, therefore, it is rarely randomized, instead it is endogenous to a variety of economic and political factors" (p. 131). From the supply side, energy infrastructure projects target relatively wealthy or quickly-growing regions, as has been found in India by Burlig and Preonas (2016). Selection of this kind would bias econometric estimates of treatment effects. However, Joseph (2010) argued electricity connection through the local grid based transmission infrastructure in India does not distinguish between richer and poorer households in a given area. From the demand side, electrification decisions are dependent on household income, location, and social-cultural factors (Sedai et al., 2020b; Khandker et al., 2014; Dang and La, 2019). Higher employment and income levels could lead to a higher consumption of electricity.[19] Therefore, while remaining agnostic about the nature of the self-selection bias, our empirical analyses seeks to address the possibility of endogeneity.

More specific examples of the general arguments of endogeneity in the Indian context relate to, (i) reliable electrification at the household level being associated with reliable electrification at the regional level, this could increase employment opportunities in the region thus leading to higher LFP and could be the potential cause for reverse causality, as was found by Rao (2013), (ii) if electrification is more cost-effective in areas that already have unmeasured economic advantages, which are correlated with individual labor market outcomes, then household electrification status may suffer from omitted variable bias (Rathi and Vermaak, 2018), (iii) household electrification status may be endogenous to labor market outcomes via

[17] PLD is obtained from the annual reports of the Central Electricity Authority, India, Annual Reports (2005 & 2012, https://cea.nic.in/l-g-b-r-report/?lang=en). Peak load surplus/deficit (PLD) data is derived at the state level for 2005 and 2012 and merged with the IHDS panel. It is percentage value which hypothetically ranges from −100 to 100. The variable is derived as: (availability – requirement)/requirement of electricity in mega-watts by state for 2005 and 2012.

[18] Dividing the monthly electricity bill by hour of electricity available controls for the potential quality but does not bias the treatment effect which is the quantity of hours of electricity.

[19] Time varying characteristics are hard to account for because there could be confounding trends in wealth as well as economic and infrastructural developments in districts which could simultaneously affect electricity variables and household outcomes (Dang and La, 2019).

the unmeasured political economy motivations rather than customer demand or the cost-effectiveness of grid expansion.[20] Endogeneity could also be due to time-varying omitted variable bias motivated by unobserved factors at the household level: household's perception about potential benefits or costs of electricity (Khandker et al., 2014).

In previous work, Rathi and Vermaak (2018) capture time-invariant unobserved heterogeneity using individual fixed effects to examine the extensive margin of electricity access and labor market outcomes across gender. However, they do not capture the correlation between time-variant unobserved heterogeneity and the error term (such as an employment shock, like the Mahatma Gandhi National Rural Employment Guarantee Program, the global financial crisis, a pandemic, or a medical emergency, among others).[21] The cross-sectional estimation by Sedai et al. (2020b) provides causal estimates of empowerment, but their analysis does not focus on labor market outcomes which is the main outcome of interest in our analysis. Moreover, the study does not take into account the temporal variations which are crucial to the analysis of electrification in India, especially in the time frame of our study (2005–2012) when major strides were made in electrifying households.

3.2.2. Instrumental variable

We use average household electricity hours at the state level, excluding one's home district, as an instrument to address the remaining endogeneity.[22] By excluding households from an individual's home district, the instrument takes into account local spill-over effects at the district level (electrification in own district could be correlated with higher LFP through, for example, higher economic activity or price changes).[23] It measures the district level variation temporally which allows us to capture the time-variant unobserved heterogeneity for each wave. The same instrument has been used previously on the effect of electrification on household welfare and empowerment by Dang and La (2019) and Sedai et al. (2020b,a).

The first stage estimation using the instrumental variables approach is given by:

$$EH_{it} = \lambda I_{jt} + X_{it}^{'}\delta + \theta_i + \gamma_t + \alpha D_{jt} + \lambda P_{jt} + \epsilon_{it} \tag{2}$$

where I_{jt} is the average household electricity hours in household i's state at time t, excluding their home district. λ is the coefficient of the instrument. All other variables and specifications remain the same as in the baseline estimation.

If neighboring districts acquire more hours of electricity and realize the economic and social gains of better reliability of electrification, then the status of fewer electricity hours may signal lower socioeconomic standing, therefore more electricity hours in the neighboring districts is expected to increase one's own electricity hours (Dang and La, 2019). We argue that the exogeneity condition for the instrument also holds because electricity availability in other districts should not directly affect labor market differences across genders in one's home district. Following the existing literature, we argue that gender differences in the labor market are affected by household's income, relative bargaining power of the individuals, education, age and occupational segregation (Fletcher et al., 2017; Klasen, 2019; Duflo, 2012). As discussed in the potential threats to identification, we do anticipate that household's own district level electrification and the availability of other infrastructures will have an impact on individual LFP, hence excluding one's home district from the instrument is key to the exclusion restriction.

3.3. Analysis of descriptive statistics

Table 1 shows the descriptive statistics from the two household surveys.[24] There have been huge improvements in access to electricity between 2005–2018. On average, the six relatively poor states used in the ACCESS survey had 66% of the observations having household electricity in 2015, which increased to 85% in 2018. At the national level, between 2005 and 2012, there was a 11% (76–87%) increase in total electricity connections at the household level. However, in terms of electricity hours, there was stagnation at the national level between 2005 and 2012, and an increase of approximately 2.5 h from a relatively low base of 12.28 h in the six states between 2015 and 2018.[25] Overall, at the national level, in 2012, households had electricity supply for 62% of the day. Despite the claims of progress, in 2018, households from the

[20] Political economy may explain the location and timing of public interventions, such as subsidies and industrial parks, which are likely to affect the chosen labor market indicators directly (Rathi and Vermaak, 2018).

[21] In addition, the sample size used by Rathi and Vermaak (2018) is small (29,614 for men and 9813 for women) compared to our study (32,288 for men and 31,925 for women). Their sample is skewed towards male respondents potentially leading to biased estimates (Semykina and Wooldridge, 2010). Our sample is more balanced by gender, hence minimizing participation bias.

[22] We estimate the instrument using the IHDS data by averaging hours across all households in one's home state, excluding households in one's home district. Therefore, the instrument varies at the district level, by year.

[23] Higher electricity hours at the district level could create an indirect impact on economic activity in the district due to the reaction of prices. Higher electricity hours might imply higher demand for goods and appliances, especially electronic appliances, leading to an increase in prices for those goods, and overall. Therefore, the positive consequences of higher electricity hours through spill-overs in LFP might be off-set by higher prices overall. Bias from these general equilibrium effects is avoided when we exclude the average electricity hours of the household's district in our instrument.

[24] Although these surveys have different respondents and are not directly comparable, we can infer about the intensity of electricity supply as these surveys ask the same question about the reliability of electricity in the households, as described in the data section.

[25] 8% of individuals reported using solar and other alternative electricity sources as of 2018. There has been a huge reduction in kerosene lighting as reported in the sample between 2015 and 2018.The period from 2005 to 2012 saw a huge increase in households who had subsidized electricity connection (9% in 2005 to 15% in 2012), while there was a decline in subsidized electricity connections 2015–2018 (21% to 17%).

Table 1
Trends in electricity access, reliability, costs, energy choice and household amenities (2005–2018).

	2005		2012		2015		2018	
	Mean	sd	Mean	sd	Mean	sd.	Mean	sd
Access to grid electricity	0.76	0.42	0.87	0.33	0.66	0.47	0.85	0.36
Hours of electricity in a day	15.89	6.74	15.05	6.86	12.28	6.27	14.74	5.48
Sources of Electricity								
Bill company/department	0.84	0.36	0.75	0.43	0.72	0.22	0.69	0.33
Neighbors	0.03	0.17	0.02	0.15	0.02	0.15	0.02	0.14
No bill	0.09	0.16	0.15	0.34	0.21	0.41	0.17	0.37
Own generator	0.01	0.03	0.02	0.05	0.02	0.15	0.07	0.25
Monthly fuel (USD, 2005, PPP).	32.88	37.49	36.34	61.21				
Firewood for cooking (0/1)	0.497	0.499	0.526	0.499				
Household Toilet (0/1)	0.414	0.492	0.534	0.498				
Indoor Water (0/1)	0.266	0.442	0.302	0.459				
Sample size (all adults)	40,018		40,018		7890		7890	

Source: Authors calculations using IHDS (2005–2012) and ACCESS survey (2015–2018). Samples are at the household level. The data from 2005 to 2012 is the national sample and from 2015 to 2018 is for six states: Uttar Pradesh, Madhya Pradesh, West Bengal, Orissa, Bihar and Jharkhand. Monthly fuel expenditure is the expenditure on LPG, firewood, and cowdung converted to U.S dollar purchasing power parity equivalent in 2005.

Table 2
Electricity Access, Reliability and Monthly Payment by Income levels, India, 2005–2012, IHDS.

	Poor		Lower Middle Income		Middle Income		Upper Middle Income		Rich	
	2005	2012	2005	2012	2005	2012	2005	2012	2005	2012
Electricity Access	0.57	0.72	0.63	0.79	0.73	0.88	0.85	0.93	0.95	0.97
	0.50	0.44	0.48	0.40	0.44	0.32	0.36	0.24	0.21	0.14
Electricity Hours	14.40	13.79	14.79	14.03	15.69	14.59	16.39	15.47	16.94	16.56
	6.78	6.74	6.61	6.73	6.69	6.72	6.68	6.84	6.65	6.84
Monthly Electricity Payment, Rs.	199.37	136.83	221.42	166.05	270.26	207.58	329.36	278.06	512.89	449.95
	344.26	220.15	382.99	319.27	373.89	304.38	397.48	383.51	601.85	551.65

Source: Authors elaboration, IHDS, 2005–2012.

six relatively poor states of the ACCESS survey, had electricity for 61% of the day. Therefore, reliable electricity is still well below the threshold of continuous and complete electrification.

There has been a marginal increase in monthly fuel expenditure (constituting of LPG, firewood and cowdung) and a marginal increase in the use of firewood for cooking, but these differences were not statistically significant across the time period.[26] Significant increases are observed for household toilet facilities given the strong policy impetus during the time period (Kumar, 2015).[27] There was a marginal increase in the availability of indoor pipe drinking water in the household across the survey period.

Table 2 shows the access, reliability and payment of electricity for households belonging to different income levels for the raw household sample across the survey period. Poor households have lower access to electricity as compared with economically better off households, and the trend is linear across income groups. Households from all income levels saw an increase in electricity access. However, the same is not true for electricity reliability, all households irrespective of income levels saw a decline in electricity reliability during the survey period. Also, all households irrespective of the income level saw a decline in monthly electricity payment across the survey period.

From an analytical standpoint, our study does not take into account the households who do not have electricity, and therefore the sample could be biased towards higher income households. From a policy standpoint, our results would apply to households with electricity access in both periods and more towards relatively higher income households as compared to the poorest households.[28]

Table 3 shows the IHDS survey wave based labor and non-labor market indicators by gender. These statistics are for households with electricity connections, hence they are expected to be higher than the National Sample Survey estimates, as also argued by Rathi and Vermaak (2018). It is known that LFP in the UPSS saw a rebound between 2010–2012, after falling from 2005 to 2009, termed as the 'rebound effect' (Shaw, 2013), potentially due to increased impetus on employment guarantee program. Therefore, we see some marginal improvements in the LFP for both men and women across the

[26] Authors elaboration using T test for statistical differences in the mean.

[27] Absolute number of households having latrine facility within the household premises rose by 21.2 million (from 30.3 million in 2001 to 51.6 million in 2011), a decadal growth of 70.1% (Kumar, 2015). To account for the policy impact on household toilet construction, we control for any past five years participation or benefit derived from social/insurance schemes to build household toilets.

[28] In this context, Sedai et al. (2020a) have extensively discussed the differences in electricity access and reliability across income levels, and analyzed the impact of electricity reliability on consumption, assets, amenities and debt.

Table 3
Descriptive statistic of labor market activity by gender, India, 2005–2012, conditional on electricity access.

	Men			Women		
	Obs.	2005 Mean (sd)	2012 Mean (sd)	Obs.	2005 Mean (sd)	2012 Mean (sd)
Employment UPSS (>240 hours in a year)	32,397	0.841 (0.365)	0.886 (0.317	32,028	0.488 (0.499)	0.498 (0.500)
Employment UPS (>180 days in a year)	32,397	0.451 (0.497)	0.495 (0.499)	32,028	0.077 (0.269)	0.091 (0.282)
Annual Work Days	27,598	252.92 (86.07)	267.04 (90.40)	13,031	180.34 (95.92)	188.54 (107.66)
Annual Work Hours	27,127	2042.84 (912.00)	2065.26 (960.54)	13,031	1207.28 (832.29)	1166.06 (880.83)
Real Earnings p.a (USD, 2005, PPP).	32,398	3352 (5245)	4764 (9320)	32,028	572 (2141)	984 (3354)
Fuel Collection Minutes/Week	8196	127.54 (201)	95.56 (253)	8443	260.315 (292)	215.242 (377)
Water Collection Minutes/Day	9698	37.94 (54.91)	32.46 (36.87)	12,883	72.14 (71.11)	49.62 (46.19)
Most say in: purchase decisions (0/1)				18,471	0.111 (0.314)	0.131 (0.337)
Permission to visit health center (0/1)				18,404	0.740 (0.438)	0.768 (0.422)
Most say in: number of children (0/1)				17,739	0.210 (0.403)	0.265 (0.441)
General Health (1–5)				18446	2.19 (0.791)	2.09 (0.843)

Source: Authors calculations using IHDS (2005–2012), conditional on electricity access. Standard errors in parentheses. Base, 2011 Indian rupees. General health is coded as 1 being very poor health and 5 being very good health.

Table 4
Descriptive statistics of covariates, 2005–2012.

	2005			2012		
	Obs	Mean	sd	Obs	Mean	sd
Total assets (0–33)	64,426	14.35	5.43	64,398	17.33	5.17
Respondent's age in years (18–70)	64,426	35.96	11.85	64,426	43.03	12.05
Respondent's sex (male=1, female=2)	64,426	1.49	0.50	64,426	1.50	0.50
Highest male adult education (0–15)	62,990	8.59	4.68	62,990	9.24	4.56
Highest female adult education (0–15)	62,990	5.80	5.12	62,990	7.11	5.17
Household size	64,426	6.21	3.07	64,426	5.60	2.73
Log average district income	64,426	12.16	0.42	64,426	11.84	0.45
Average district poverty (0–1)	64,426	0.22	0.18	64,426	0.16	0.13
Peak Load Surplus/Deficit (%)	65,674	-17.76	17.92	65,674	-11.85	17.81
Electricity payment per hour (Rs.)	64,160	0.999	1.904	65,362	0.844	1.382

Source: IHDS, authors calculation, observations for individuals with electricity access. Peak Load Surplus/Deficit (%) is percentage value which hypothetically ranges from -100 to 100. The variable is derived as: (availability – requirement)/requirement of electricity in mega-watts by state.

time period. In terms of the usual principal status, IHDS estimates shows similar statistics to the NSS, 13.5% workforce participation rate (WPR) for women in rural areas and 4.5% (WPR) in urban areas (Srivastava and Srivastava, 2010).

Between the survey period, hours worked per year in paid employment decreased by 23 h for men and 39 h for women, and there was a decrease in real earnings for both men and women.[29] Weekly fuel collection minutes reduced from 127 min to 95 min per week for men, and from 260 min to 215 min for women. In terms of women's empowerment, we look at: 'most say in economics decisions, mobility and reproductive freedom'. In all these variables, there have been marginal improvements over time. Women's general health as measured by an index on a scale from 1 to 5, with 1 being very poor health to 5 being very good health remained relatively constant over the 7 years.

Table 4 shows the covariates used in the analysis. Observations from 2005 to 2012 are 87% matched, which is slightly above official match level of the IHDS data set (83%) (Desai and Vanneman, 2018). This is probably because the raw IHDS data is matched unconditionally, while our matching is based on electrified households. During the survey period, there has been no systematic progress in the reliability of electricity. Households either gained some hours of electricity or lost some

[29] The decrease in real earnings for both men and women is attributable to the high level of inflation in 2012 with the base as 2005, as the deflator used in IHDS divides the monetary values in 2012 by 1.81.

hours of electricity.[30] There has been a small increase in household's total assets which in our study is used as a proxy of wealth. We use district level household income and district level standard of living measured by average district poverty rate. We do not use household income as a control as it is highly correlated with the LFP and other outcome variables of our analysis.

4. Results

All regression specifications have individual and year fixed effects along with additional independent variables as described in the empirical model. Standard deviations of all regressions are clustered at the individual level. All tables show fixed effects and IV results for all outcome variables. The strength of the instrument is tested using F-statistic (Sanderson-Windmeijer multivariate *F* test of excluded instruments), and is considered to be strong at 5% level of confidence if the F-statistic is larger than 10 (Staiger and James, 1997). We also present fixed effects results in all tables where electricity hours are divided into four quartiles (0–9 h is base quartile 1, 10–16 h is 2, 17–22 h is 3 and 23–24 h is 4) based on survey probability weights. Even though time-varying endogeneity could be an issue, these results provide insight into possible non-linearity of effects and serve as robustness check to our main analyses.

4.1. Labor market effects of reliable electrification

Table 5 shows the linear and piece-wise analyses of the effects of additional hours of electricity on the usual principal and subsidiary status of employment for the whole sample, and across men and women (panel (a) shows outcomes for usual status ($\geq$ 30 days in a year) employment and panel (b) shows full-time employment ($\geq$ 180 days in a year)). The fixed effects results in column 2 and 3 of panel (a) shows that 10 more hours of electricity increases the probability of men's employment in the usual status by 1.1 pp and that of women by 1.2 pp. As the fixed effects estimates without IV do not capture the time varying unobserved heterogeneity, we focus on the causal estimates provided by the IV results. The instrumental variable results in column 9 shows that 10 more hours of electricity leads to 4.2 pp increase in the likelihood of women being in the labor force.[31] In comparison, column 8 shows that 10 more hours of electricity increases men's LFP by 2.8 pp.[32]

The piece-wise analysis across all quartiles in the usual status category shows a stronger and significant effect of additional hours of electrification on women's LFP compared to men. Moving from the base quartile of electricity hours (0–9) to the 2nd or the 3rd quartile does not increase the likelihood of men's employment but it increases women's employment by 2.3 and 1.8 pp, respectively. Moving from the base quartile to the 4th quartile of complete electrification increases men's employment in the usual status category by 2.2 pp and that of women by 2.6 pp. Fixed effect analysis in piece-wise regression shows that gains from additional hours at higher levels of electricity deficiency are stronger for women as compared to men.

In panel (b), we look at full-time employment ($\geq$ 180 days) as the criteria for LFP. Here the coefficients of the IV regression, after correcting for the selection bias, shows that 10 more hours of electricity increases women's LFP by 3.9 pp and men's LFP by 4.0 pp. These coefficients in comparison with panel (a) show that in absolute terms, reliable electrification improves women's employment in the usual status more than men, while there are no significant differences in the impact of reliable electrification on full-time employment between men and women.[33]

Panel (c) shows the intensive margin of annual work days in all employment or business activity, for men and women, conditional on working in both periods. The IV results show that women increased work days more than men—10 more hours of electricity increases women's annual work days by 28 days, while it increases men's annual work days by 17 days. Results at the intensive margin of work days are similar to the extensive margin of LFP for men and women, that is, women gain more in terms of LFP (work days) as compared to men. This is probably because women gain more than men in terms of employment in the usual status and gained equivalent to men in terms of employment in the usual principal status (full-time employment), therefore, the overall effect could be higher work days for women as compared to men.

To underscore the significance of electricity reliability and not just electricity access, we compare our results with studies that have focused solely on electricity access and gendered outcomes. Rathi and Vermaak (2018) looked at the extensive margin of electricity access and found no effect on men's usual status of employment but a positive effect on women. Our study finds a positive effect of additional hours of electricity on LFP for both genders, with a stronger effect on women. Van de Walle et al. (2017) also looked at electricity access in India and found no significant change in women's full-time

[30] So far, to our knowledge there is no study that shows the relative change in electricity hours in the Indian households between 2005–2018. In Fig. 2, we show that some households gained more hours of electricity while some households lost. The redistribution in electricity hours seems to be true for both the IHDS and the ACCESS surveys, which indicates that these trends are not due to survey measurement techniques.

[31] The coefficient of 4.2 pp when contrasted with the average LFP of women in the usual status ($\geq$ 240 h) in Table 3 which is around 49% in 2012, shows that women's LFP in the usual status increases by approximately 9 percent.

[32] The coefficient of 2.8 when contrasted with the average LFP of men in the usual status ($\geq$ 240 h) in Table 3 which is around 88% in 2012, shows that men's LFP in the usual status increases by approximately 0.45%.

[33] Since panels (a) and (b) are iterations of the categorical variable (extensive margins of employment), both panels have the same observations and statistic for the F test for excluded instrument.

Table 5
Effects of additional hours of electricity on the likelihood of employment, 2005–2012, India. Linear probability analysis with individual fixed effects.

Variables	(1) All	(2) Men	(3) Women	(4) All	(5) Men	(6) Women	(7) IV-All	(8) IV-Men	(9) IV-Women
Panel (a) (>30 days)									
10 Electricity Hours	0.012***	0.011***	0.012***				0.034***	0.028***	0.042***
	(0.000)	(0.000)	(0.000)				(0.001)	(0.001)	(0.001)
Base quartile (0–9)									
2nd quartile (10–16)				0.013***	0.004	0.023***			
				(0.005)	(0.006)	(0.008)			
3rd quartile (17–22)				0.011**	0.005	0.018**			
				(0.005)	(0.006)	(0.008)			
4th quartile (23–24)				0.024***	0.022***	0.026***			
				(0.006)	(0.007)	(0.009)			
Panel (b) (>180 days)									
10 Electricity Hours	0.010**	0.012***	0.011**				0.039***	0.040***	0.039***
	(0.00)	(0.00)	(0.00)				(0.00)	(0.00)	(0.00)
Base quartile (0–9)									
2nd quartile (10–16)				0.008	0.005	0.010**			
				(0.01)	(0.01)	(0.01)			
3rd quartile (17–22)				0.017***	0.016*	0.018***			
				(0.01)	(0.01)	(0.01)			
4th quartile (23–24)				0.016**	0.025***	0.017**			
				(0.01)	(0.01)	(0.01)			
F test (instrument)							17,442	8429	8998
Observations	122,971	63,018	59,953	122,971	63,018	59,953	120,876	61,957	58,919
No. of Individuals	63,620	32,283	31,347	63,629	32,283	31,347	62,553	31,774	30,810
Panel (c) Work days p.a									
10 Electricity Hours	4.081***	4.771***	2.634*				18.005***	16.519***	28.011***
	(0.921)	(1.110)	(2.521)				(1.539)	(2.511)	(5.357)
Base quartile (0–9)									
2nd quartile (10–16)				5.911***	5.836***	5.060***			
				(1.532)	(1.751)	(3.117)			
3rd quartile (17–22)				9.447***	6.965***	10.934**			
				(1.532)	(1.744)	(3.204)			
4th quartile (23–24)				4.4801**	8.017***	7.827***			
				(1.816)	(2.023)	(4.703)			
Work both periods	Y	Y	Y	Y	Y	Y	Y	Y	Y
F test (instrument)							8453	6862	1551
Observations	66,497	48,817	17,680	66,497	48,817	17,680	65,509	48,074	17,435
No. of Individuals	34,348	24,992	9357	34,348	24,992	9357	33,841	24,614	9228

Robust standard errors (clustered at individual level) in parentheses $***p < .01$, $**p < .05$, $*p < .1$. Additional independent variables in all regressions.

employment ($\geq$ 180 days) but an increase in part-time employment ($\geq$ 30 days and $\leq$ 180 days) of 4.6 days per year. For men, they found a 14.6 days increase in full-time employment and 8.9 days reduction in part-time employment. Their study argued that electricity access triggered men to pursue formal work, reducing their part-time work which in part was taken over by women. Results in panel (a) and (c) supports the hypothesis by Van de Walle et al. (2017) that women gain part-time employment and men gain full-time employment.

The differences in these findings could be due to the differences in margins—Van de Walle et al. (2017) and Rathi and Vermaak (2018) looked at the access, while our focus is on reliability. As Aklin et al. (2016) argued, electricity connections with poor reliability may limit individual's time allocations and hinder the efficient redistribution of labor and leisure. The difference in results with Van de Walle et al. (2017) could also be because of the study period. Their study period was between 1982–1999, while ours is more recent (2005–2012), and in between this period, substantial improvements in women's education have taken place (Srivastava and Srivastava, 2010), along with meaningful infrastructural developments (Kumar, 2015), providing a potential foundation to utilize the benefits of reliable electrification in translation to higher LFP. Given that electricity access is not the silver bullet to energy security (Aklin et al., 2016), we argue that our analysis of the intensive margins of deficiency is also important in understanding the gendered effects of electricity as a labor saving technology.

Table 6 using IV-FE specifications show the effect of additional hours of electricity on the likelihood of employment in usual subsidiary status ($\geq$ 30 days) and usual principal plus subsidiary status ($\geq$ 180 days) for men and women in rural and urban areas, and for poor and non-poor households. Panel (a) shows that 10 more hours of electricity increases men's likelihood of employment in rural areas by 3.3 pp, and in urban areas by 2.9 pp. Whereas for women, the increase in urban areas is substantially higher than the increase in rural areas, 9.1 and 1.3 pp, respectively. The effects of additional hours of electrification is more pronounced for non-poor households as compared to poor households for both men and women.

Table 6
Effects of additional electricity hours on subsidiary and principal status of employment for rural/urban and poor/non-poor in India, 2005–2012. All specifications are IV-linear probability model.

Variables	(1) Men	(2)	(3) Women	(4)	(5) Men	(6)	(7) Women	(8)
	Rural	Urban	Rural	Urban	Non-Poor	Poor	Non-Poor	Poor
Panel (a) (>30 days)								
10 Electricity Hours	0.033***	0.029*	0.013	0.091***	0.029***	-0.002	0.044***	0.025
	(0.010)	(0.015)	(0.015)	(0.016)	(0.009)	(0.025)	(0.011)	(0.0036)
Panel (b) (>180 days)								
10 Electricity Hours	-0.002	0.103*	0.030*	0.055***	0.036***	0.071*	0.044***	0.009
	(0.009)	(0.014)	(0.013)	(0.014)	(0.008)	(0.022)	(0.010)	(0.022)
F test (instrument)	3271	2464	3100	2199	5272	1011	5101	978
Observations	37,581	25,243	36,596	23,159	54,740	8066	52,016	7721
No. of individuals	19,388	13,145	19,074	12,052	27,671	4075	26,858	3981

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. Additional independent variables in all regressions.

Table 7
Effects of additional hours of electricity on log of annual work hours, 2005–2012. Log-linear model, conditional on working in both waves.

Variables	(1) All	(2) Men	(3) Women	(4) All	(5) Men	(6) Women	(7) IV-All	(8) IV-Men	(9) IV-Women
10 Electricity Hours	0.015***	0.016***	0.006				0.040**	0.045***	0.043
	(0.007)	(0.008)	(0.019)				(0.017)	(0.018)	(0.046)
Base quartile (0–9)									
2nd quartile (10–16)				0.007	0.004	0.014			
				(0.011)	(0.012)	(0.024)			
3rd quartile (17–22)				0.020	0.021**	0.054**			
				(0.013)	(0.014)	(0.030)			
4th quartile (23–24)				0.033***	0.019	0.075**			
				(0.015)	(0.017)	(0.037)			
F (test) instrument							8450	6887	1551
Observations	66,444	48,777	17,667	66,444	48,777	17,667	65,456	48,034	17,422
No. of individuals	34,321	24,972	9350	34,321	24,972	9350	33,814	24,594	9221

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. Additional independent variables in all regressions.

For non-poor households there is a 2.9 pp and 4.4 pp increase in the likelihood of employment for men and women, respectively.[34] Wile, for poor households, women have a stronger but insignificant effect on usual status employment as compared to men. In panel (b) the same analysis is conducted for the principal plus subsidiary status of employment. With additional hours of electricity, men in rural areas do not gain regular employment while men in urban areas have a significant increase of 10.3 pp. Women in rural areas have a 0.30 pp increase in regular employment while in urban areas the increase is 5.5 pp. Non-poor households tend to gain in terms of regular employment with additional hours of electrification, but only poor men gain regular employment with additional electricity hours.

Table 7 shows the effect of additional hours of electricity on the annual work hours for paid work. We use a log-linear specification with the dependent variable being log of annual work hours. Columns 8 and 9 show the instrumental variable results stratified by gender: 10 more hours of electricity in the household significantly reduces annual work hours by 4.5% for men, while the effect on women's work hours is positive (4.3 pp) but insignificant. Allowing the functional form to be piece-wise using individual fixed effects shows that moving from 0 to 9 h to 17–22 h (approximately 10 h of increase) reduces annual work hours by 2.1% for men, while it has a positive and significant effect on work hours for women, 5.4%. The IV estimations, after controlling for the time varying unobserved heterogeneity shows strong labor productivity effects in reducing work hours for men but not for women. According to Rathi and Vermaak (2018), household electrification might have improved the productivity of home businesses by facilitating time efficient technologies thus reducing the labor supply hours. Given that men work hours are substantially more than that of women (see Table 3), we expect the effect to be stronger for men as compared to women.

Table 8 shows the effect of additional hours of electricity on log of annual earnings from all work activities, after controlling for annual work hours. We control for work hours in order to isolate any productivity gains. The IV-specifications show that 10 more hours of electricity increases the annual earnings of men and women by 15.6% and 16.7%, respectively.

[34] Note our sample consists of only electrified households, hence it does not take in account the majority of poor households, especially in rural areas, that do not have electricity.

Table 8
Effect of additional hours of electricity on log of annual earnings, 2005–2012, India. Log-linear model, conditional on hours worked.

Variables	(1) All	(2) Men	(3) Women	(4) All	(5) Men	(6) Women	(7) IV-All	(8) IV-Men	(9) IV-Women
10 Electricity Hours	0.035***	0.035***	0.010				0.162***	0.156***	0.167***
	(0.008)	(0.010)	(0.022)				(0.019)	(0.020)	(0.061)
Base quartile (0–9)									
2nd quartile (10–16)				0.043***	0.042**	0.040*			
				(0.013)	(0.014)	(0.026)			
3rd quartile (17–22)				0.080***	0.079***	0.080**			
				(0.015)	(0.016)	(0.039)			
4th quartile (23–24)				0.074***	0.067***	0.120***			
				(0.019)	(0.021)	(0.045)			
Work Hours	Y	Y	Y	Y	Y	Y	Y	Y	Y
F (test) instrument							14,169	11,246	2876
Observations	48,441	35,203	12,562	48,441	35,203	12,562	46,924	34,587	12,337
No. of individuals	32,285	22,823	9463	32,285	22,823	9463	21,694	22,412	9283

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. Additional independent variables in all regressions.

Panel analysis in column 1–6 without accounting for the time varying unobserved heterogeneity shows no significant differences in the effect of additional hours of electricity on the annual earnings between men and women, except in the 4th quartile, where it is significantly higher for women. Rathi and Vermaak (2018) using a panel fixed effects model also found no significant differences in the earnings between men and women with access to electrification.

4.2. Reliable electrification, fuel and water collection

Fuel and water collection activity are primarily undertaken by women in India, and elsewhere in developing countries (Fletcher et al., 2017; Dinkelman, 2011; Kapsos et al., 2014; Ferrant and Thim, 2019). The burden of these time consuming activities is disproportionately borne by women (Ferrant and Thim, 2019), as is also shown the Table 3, where women, on average, spent approximately twice as much time as men in fuel and water collection activities. Time intensity in these activities could be reduced, or the burden could be done away with reliable electrification, as is also argued by Dinkelman (2011), Sedai et al. (2020b) and Ferrant and Thim (2019), the benefits of which would accrue more to women than men.

Table 9 shows the effects of additional hours of electricity on weekly fuel collection minutes (panel a) and daily water collection minutes (panel b) for men and women. IV results show that 10 more hours of electricity significantly reduces women's weekly time spent on fuel collection by 37 min, and men's weekly fuel collection by 26 min. The piece-wise analysis also confirms the disproportionate effects on women. Moving from the base quartile to the 3rd quartile of electricity hours reduces the weekly fuel collection time for women by 66 min, and that of men by 37 min. Results in the fourth quartile show positive but insignificant effects of reliable electrification on fuel collection minutes for both men and women, this highlights the significance of capturing the time varying unobserved heterogeneity in estimating the effect of electrification on time allocations, and the selection bias in the fixed effect models.

Panel (b) shows the effect on daily water collection minutes. 10 more hours of electricity reduces daily time spent on water collection by 31 min for women and 12 min for men. The piece-wise analysis corroborates the estimates of the IV-specifications, and shows that at all levels of deficiency, reliable electricity reduces the gender differences in water collection time between men and women. For example, moving from the base quartile to the 4th quartile reduces the daily time spent on water collection by 14 min for women and 0.6 min for men. Reliable electricity is crucial in reducing fuel and water collection time for both men and women, with stronger reductions for women as compared to men. The time freed up from these activities could be critical in improving the labor market outcomes for both men and women.

Results from the analysis on fuel and water collection highlights a concrete channel by which electrification ameliorates the time constraint on women's participation in paid employment and reduces the burden of unpaid household labor. While this amelioration is by no means an adequate basis for gender empowerment in the absence of complementary policies that directly address norms and institutions that perpetuate gender disparities, it shows a potential avenue to address gender disparities.

4.3. Reliable electrification, empowerment and energy choices

We examine the effects of additional hours of electricity on indicators of (i) women's empowerment and (ii) energy choices and household amenities that could affect women's health and well-being. First, we look at empowerment outcomes in terms of economic decision making, mobility, reproductive freedom and health of women, which are viewed to be the key components in agency, resource and achievements of women (Kabeer, 1999). Instead of looking at whether women have a say in major economic decisions, which might be inconsequential if the preferences of other members of the family are stronger, and could be an incomplete representation of women's economic autonomy (Kabeer, 1999), we look into whether

Table 9
Effects of additional hours of electricity on fuel and water collection time, 2005–2012.Linear probability model with individual fixed effects and instrumental variables.

Variables	(1) Men	(2) Women	(3) Men	(4) Women	(5) Men	(6) Women
Panel (a) Weekly fuel Collection minutes						
10 Electricity Hours	15.794**	26.337**			26.633***	37.697***
	(3.964)	(6.476)			(7.991)	(12.286)
Base quartile (0–9)						
2nd quartile (10–16)			2.606	29.047***		
			(6.624)	(10.810)		
3rd quartile (17–22)			37.163***	66.623***		
			(7.043)	(9.456)		
4th quartile (23–24)			13.474	20.891		
			(8.799)	(14.453)		
F (test) instrument					11,295	11,293
Observations	43,452	43,456	43,452	43,456	43,041	43,055
No. of individuals	32,050	32,053	32,050	32,053	31,724	31,727
Panel (b) Daily Water Collection Minutes						
10 Electricity Hours	0.093	-5.870***			-12.105***	-31.519***
	(0.098)	(0.096)			(0.205)	(0.212)
Base quartile (0–9)						
2nd quartile (10–16)			-0.234	-4.948***		
			(1.791)	(1.596)		
3rd quartile (17–22)			-0.928	-3.256**		
			(1.674)	(1.613)		
4th quartile (23–24)			0.613	-14.062***		
			(1.367)	(1.704)		
F (test) instrument					2438	4491
Observations	38,335	51,460	38,335	51,460	318,002	51,013
No. of individuals	28,988	35,208	28,988	35,208	28,757	34,822

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**\,p < 0.05$, $*p < 0.1$. Additional independent variables in all regressions.

women have the most say in major purchase decisions, which highlights their 'agency' more strongly as a 'first order choice' (Kabeer, 1999). Similarly instead of a say on fertility decisions, we look at the 'most say' in deciding the number of children.

To analyze the impact of reliable electrification on women's mobility, we look at effects on electricity hours on women's need to ask permission to visit health center alone. In addition, women's health is considered to reflect 'agency' in the empowerment framework of 'access agency and achievements' (Kabeer, 1999), therefore, we analyze the impact of reliable electrification on health as a measure of women's empowerment. To do so, we create a binary health variable from the discrete variable 'general health', 1–5 (1 very good—5 very poor), by assigning '1' to good and very good health and '0' to poor, very poor and OK.

Between 2005 and 2012, there were significant improvements in health infrastructure in the country through government's National Rural Health Mission, new construction of heath sub-centres, primary health centres, community health centres, and district hospitals (Agarwal et al., 2019). Public and Private health infrastructure, and knowledge and connections with doctors and health care workers also expanded during the same phase. This could affect women's visitation to health centers alone, and also health in general. Therefore, our analysis accounts for the effect of health care expansion on women's freedom to visit to health center, and self-rated health. We control for the household's acquaintance with doctors and health care workers during the time period.[35] In addition, we control for any health insurance that the household acquired through a public or private source.[36] In addition, results are presented with and without controls for employment and annual earnings to examine the magnitude of indirect effects.

Using a linear probability model, the IV estimates in column 3 of panel (a) in Table 10 show that 10 more hour of electricity increases women's agency in major purchase decision of the household by 4.8 pp. Similarly, column 6 shows that 10 more hours of electricity increases women's autonomy over their fertility by 6.6 pp. Moving from the base quartile to the 4th increases the autonomy on women's fertility by 5.1 pp. Controlling for employment and earnings, the coefficients are consistent for both outcomes. Our results are consistent to the findings by Samad and Zhang (2019) and Sedai et al. (2020b): electricity access and reliability have positive effects on women's decision making agency.

[35] Network with doctor/health-workers variables is derived from the IHDS income and social capital questionnaire. The questionnaire item is "Do you or any members of your household have personal acquaintance with someone who works in any of the following occupation"– (i) Doctors, (2) Health Care Workers.

[36] We observe health insurance at the household level. The likelihood of heath insurance either public or private increased from 3.5 to 11% at the national level, authors elaboration from IHDS, 2005–2012.

Table 10
Effects of additional hours of electricity on women's economic decision, mobility, reproductive freedom, and health, 2005–2012. Linear probability model.

	(1) FE	(2) FE	(3) IV-FE	(4) IV-FE	(5) FE	(6) FE	(7) IV-FE	(8) IV-FE
Panel (a)	Purchase Decision				Number of Children			
10 Electricity Hours	0.001		0.048***	0.042***	0.034***		0.066***	0.063***
	(0.009)		(0.012)	(0.023)	(0.014)		(0.012)	(0.034)
Base quartile (0–9)								
2nd quartile (10–16)		0.018***				0.013		
		(0.007)				(0.010)		
3rd quartile (17–22)		0.001				0.051***		
		(0.007)				(0.010)		
4th quartile (23–24)		0.004				0.054***		
		(0.009)				(0.012)		
Employment $\geq$30 days				0.006***				0.007***
				(0.021)				(0.032)
Log annual earnings				0.004				0.004
				(0.004)				(0.006)
F (test) instrument			15,713	7182			15,142	7002
Observations	34,768	34,768	34,196	15,880	33,921	33,921	33,358	15,422
Number of individuals	18,237	18,237	17,942	10,797	18,159	18,159	17,865	10,591
Panel (b)	Permission to visit health center				General Health			
10 Electricity Hours	0.087***		0.133***	0.172***	0.041***		0.092***	0.071**
	(0.013)		(0.014)	(0.034)	(0.012)		(0.016)	(0.037)
Base quartile (0–9)								
2nd quartile (10–17)		0.003				0.014		
		(0.009)				(0.010)		
3rd quartile (17–22)		0.102***				0.016		
		(0.009)				(0.011)		
4th quartile (23–24)		0.128***				0.074***		
		(0.012)				(0.013)		
Know Doctor/H.Workers	0.028***	0.029***	0.027***	0.057***	0.029***	0.027***	0.030***	0.042***
	(0.007)	(0.007)	(0.007)	(0.012)	(0.007)	(0.007)	(0.007)	(0.013)
Any health insurance	0.016	0.016	0.021*	0.016	0.011	0.010	0.010	0.022
	(0.012)	(0.012)	(0.013)	(0.023)	(0.012)	(0.012)	(0.013)	(0.022)
Employment $\geq$30 days				0.056*				0.009
				(0.031)				(0.034)
Log annual earnings				0.007				0.002
				(0.006)				(0.006)
F (test) instrument			15,602	7823			15,001	6911
Observations	34,599	34,599	34,037	15,840	34,646	34,646	34,080	15,858
Number of individuals	18,227	18,227	17,933	10,781	18,230	18,230	17,936	10,790

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. Additional independent variables in all regressions.

In terms of mobility, we look at the effect of additional hours of electricity on whether women have to ask for permission to visit health centers. Results in column 3 of panel (b) shows that 10 more hours of electricity reduces the likelihood of women having to ask for permission from family members to visit a health center by 13.3 pp. After controlling for the expansion in health care infrastructure, the effects are stronger on mobility. In terms of general health, the IV estimation shows that 10 more hours of electricity increases the likelihood of reporting good health by 9.2 pp. After controlling for employment and earnings, the effect is reduced to 7.1 pp.

Table 11 shows the effect of electricity reliability on energy choices and basic infrastructure in the household. For this analysis, we restrict the sample to the household head responding for the household, and consequently have fewer observations. First, in panel (a), we look at the effect of additional hours of electricity on the log of the monthly expenditure on fuel-wood. On one hand, common Property Resource (CPR) in India has been reducing at a rate of 1.9 percent every five years due to encroachment, as per the National Sample Survey Organisation (Kaur, 2011), while on the other, the reliance of poor households on CPR for fodder and fuel is higher as compared to richer households in India (Jodha, 1986).[37] Therefore, the use of instrumental variables is critical in capturing the time varying unobserved heterogeneity in the use of fuel-wood in India. The IV analysis shows that 10 h of electricity reduces the expenditure on fuel-wood by 12.2%. Ten more hours of electricity reduces the likelihood of using wood for cooking by 7.3 pp. Similar, but smaller effects of electricity access on fuel use for cooking was found by Dinkelman (2011) and Parikh (2011) in South Africa and India.

[37] Also, Parikh (2011) in a study of Himachal Pradesh, India, found that cooking with firewood was correlated with higher proportion of respiratory symptoms among girls below 5 and females in 30–60 age-groups than males of similar age-groups.

Table 11
Effects of additional electricity hours on energy choices and household amenities, 2005–2012. Linear probability model except for column 1,2,3 in panel (a).

	(1) FE	(2) FE	(3) FE-IV	(4) FE	(5) FE	(6) IV-FE
Panel (a)	Log of fuel expenditure			Cooking with fire-wood		
10 Electricity Hours	0.031		0.122***	0.014***		0.073***
	(0.003)		(0.008)	(0.001)		(0.004)
Base quartile (0–9)						
2nd quartile (10–16)		0.031**			0.010*	
		(0.002)			(0.001)	
3rd quartile (17–22)		0.018			0.016***	
		(0.002)			(0.001)	
4th quartile (23–24)		0.013			0.012*	
		(0.002)			(0.001)	
F (test) instrument			1877			2112
Observations	30,172	30,172	29,666	40,884	40,884	40,122
Number of households	21,279	21,279	20,933	23,974	23,974	23,549
Panel (b)	Household Toilet			Indoor Pipe Water		
10 Electricity Hours	0.021***		0.016**	0.031***		0.019**
	(0.004)		(0.003)	(0.004)		(0.004)
Base quartile (0–9)						
2nd quartile (10–16)		0.003			0.002	
		(0.008)			(0.008)	
3rd quartile (17–22)		0.017***			0.038***	
		(0.007)			(0.007)	
4th quartile (23–34)		0.041***			0.036***	
		(0.010)			(0.010)	
Public/Private Toilet Prog.	0.233**	0.240**	0.243***			
	(0.003)	(0.003)	(0.003)			
Water in House	0.028**	0.028**	0.028***			
	(0.007)	(0.008)	(0.006)			
F (test) instrument			1676			1698
Observations	40,433	40,433	39,687	40,875	40,875	40,113
No. of households	23,927	23,927	23,503	23,971	23,971	23,546

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.
Additional independent variables in all regressions.

We examine the impact of reliable electrification on collective amenities in the households: household toilet and indoor piped drinking water. These collective household amenities have been argued to have a strong impact on women's empowerment (Fletcher et al., 2017), and could be critical in the Indian context, especially in rural areas. To analyze the effect of reliable electrification, we control for the government programme to improve sanitation and hygiene as there has been tremendous increases in access to toilets during the survey period, owing majorly to the Nirmal Bharat Abhiyan, 2005, (Kumar, 2015).[38] The IV linear probability model in panel (b) shows that 10 hours of electricity increases the likelihood of having a toilet in the house by 1.6 pp. Moving from the base quartile to the 4th quartile increases the likelihood of having a household toilet by 4.1 pp. In terms of indoor piped drinking water, 10 hours of electricity increases the likelihood of having indoor piped drinking water by 1.9 pp. Similarly, moving from the first quartile to the 4th quartile increases the likelihood of having indoor piped drinking water by 3.6 pp.

We further examine the impact of electricity hours on access to a household toilet and indoor piped drinking water in rural/urban areas and poor/non-poor households. Table 12 shows that electricity hours have a stronger effect in increasing access to a toilet in rural areas as compared to urban areas, and for non-poor households as compared to poor households. Electricity reliability increases the likelihood of having access to indoor water in rural areas by 4.7 pp, but there is no significant effect in urban areas. Non-poor households have a 2.3 pp likelihood of gaining access to indoor water as compared to 0.007 pp for the poor households.

4.4. Analysis of the extensive margin of electricity

As a check of our data and to facilitate comparison to existing literature, we look at the extensive margin of electricity access and examine its effects on employment and earning outcomes. Given our results show that the effect at the intensive margin (reliable electrification) holds, we anticipate similar effects using a binary independent variable. As such we move from a continuous independent variable to a discrete independent variable. Rathi and Vermaak (2018) using the same panel from IHDS, 2005–2012, look at the effects of electricity access on employment (usual subsidiary status) and earnings (log of

[38] In addition, with regards to access to household toilet, we control for household's access to water within the household premises, as these outcomes could be correlated.

Table 12
Effects of additional electricity hours on household toilet and indoor piped drinking water by rural/urban and poor/non-poor, India, 2005–2012.

VARIABLES	(1) Rural	(2) Urban	(3) Poor	(4) Non-Poor	(5) Rural	(6) Urban	(7) Poor	(8) Non-Poor
	Household Toilet				Indoor Pipe Drinking Water			
10 Electricity Hours	0.023***	0.009***	0.011*	0.027***	0.047***	0.001	0.007**	0.023***
	(0.010)	(0.014)	(0.026)	(0.010)	(0.004)	(0.005)	(0.009)	(0.003)
Public/Private Toilet Prog.	0.281***	0.045*	0.322***	0.226***				
	(0.03)	(0.06)	(0.06)	(0.03)				
Water within house	0.022***	0.011***	0.021	0.021***				
	(0.01)	(0.02)	(0.03)	(0.01)				
Observations	24,087	16,346	4658	35,346	24,316	16,559	4669	35,737
No. of households	14,585	9777	2812	20,692	14,617	9,796	2816	20,722

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. Additional independent variables in all regressions.

Table 13
Extensive margin: effects of electricity access on employment and earnings, 2005–2012.

	(1) All	(2) Men	(3) Women	(4) All	(5) Men	(6) Women
	Employment UPSS			Log of Annual Earnings		
Electricity Access (0/1)	0.003	0.014***	0.020***	0.071***	0.074***	0.077**
	(0.00)	(0.00)	(0.01)	(0.02)	(0.02)	(0.03)
Highest Adult Education	0.000	0.002***	0.002***	0.001	0.002	0.006*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household Size	0.007***	0.006***	0.008***	0.026***	0.028***	0.020***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Wealth (Assets, 0/33)	0.001	0.001*	0.003***	0.036***	0.039***	0.028***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Monthly HH Con. Exp.	0.000***	0.000***	0.000***	0.000***	0.000***	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age in years	0.004***	0.005***	0.004***	0.009***	0.012***	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Year fixed effects	0.035***	0.029***	0.038***	0.203***	0.165***	0.301***
	(0.00)	(0.01)	(0.01)	(0.02)	(0.02)	(0.03)
House Rented	0.003	0.002	0.004	0.005	0.001	0.004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Marital Status						
Married	0.018	0.052**	0.005	0.075	0.050	0.105
	(0.01)	(0.03)	(0.01)	(0.06)	(0.09)	(0.07)
Unmarried	0.206***	0.186***	0.054*	0.534***	0.468***	0.224
	(0.01)	(0.03)	(0.03)	(0.06)	(0.09)	(0.15)
Widowed	0.044***	0.061**	0.041**	0.053	0.145	0.036
	(0.02)	(0.03)	(0.02)	(0.07)	(0.11)	(0.09)
Separated	0.019	0.035	0.036	0.099	0.066	0.024
	(0.02)	(0.04)	(0.03)	(0.08)	(0.12)	(0.11)
No gauna	0.062	0.065	0.222	0.400*	0.329	0.164
	(0.05)	(0.06)	(0.18)	(0.21)	(0.23)	(0.31)
Constant	0.908***	1.041***	0.744***	10.031***	10.473***	9.023***
	(0.02)	(0.04)	(0.04)	(0.10)	(0.12)	(0.17)
Observations	170,397	85,392	85,005	115,308	74,201	41,107
Number of Individuals	86,391	43,582	43,020	69,320	41,822	27,499

Robust standard errors (clustered at individual level) in parentheses $***p < 0.01$, $**p < 0.05$, $*p < 0.1$.

annual earnings) for men and women. The sample size used by Rathi and Vermaak (2018) is smaller (29,614 for men and 9813 for women) compared to our study (69,024 for men and 69,496 for women) and is skewed towards male respondents which could potentially be leading to biased estimates (Semykina and Wooldridge, 2010). Our sample is balanced with nearly equal observations for men and women, which corrects for the potential participation bias. We use the exact same covariates as used by Rathi and Vermaak (2018) as shown in Table 13.

Coefficients in Table 13 are similar to the estimates of Rathi and Vermaak (2018). They find a significant positive effect of electricity access on women's employment (UPSS), and so do we. In contrast to their analysis, we find a smaller magnitude of effect on earnings. Their analysis finds a 10 log points increase in annual earnings for women with electricity access, while in our analysis, the coefficient is 7 log points. This could be due to their smaller sample of women (9,813) as compared to our sample, which may have certain characteristics that led to overestimation of the coefficients.

5. Discussion and conclusion

This study contributes to the literature in understanding the gendered effects of reliable electrification. First, we move beyond quantifying electrified households as a policy objective and look at the effects of electricity reliability (hours of electricity supplied) on gender differences in the labor and non-labor outcomes. Second, we tackle the endogeneity between employment and electrification, and arrive at robust point estimates. Third, instead of focusing either on labor market outcomes or empowerment, we seek to provide a holistic picture of the effect of electrification on 'access, agency and achievements' for women following the framework of empowerment by Winther et al. (2017) and Kabeer (1999). Fourth, unlike previous studies which have looked at the effect of reliable electrification on women's outcomes only (Sedai et al., 2020b; Samad and Zhang, 2019), we analyze the gender differences in labor market and fuel collection activities, which allows us to highlight a significant channel through which electrification helps in reducing gender differences. Through these analyses, we posit that the gender differences in the labor market and in the household reduce with reliable electrification by reducing the time-burden of labor intensive activities like fuel and water collection.

We analyze two household surveys and posit that there has been redistribution of electricity hours between 2005 and 2018, with many households gaining access to electricity, while other losing hours of electricity on a typical day. We use the variation in the reliability of electricity between 2005 and 2012 and study its impact on multi-dimensional framework of labor and household outcomes between men and women to understand the causal effects of reliable electrification in increasing LFP and reducing the burden and drudgery of household labor. We find that reliable electrification reduces the time spent on home production disproportionately more for women than men. Relaxing the time constraint that hinders labor market participation could lead to increased LFP. In addition to labor market outcomes, we examine non-labor market outcomes such as household activities of fuel and water collection, women's economic and reproductive agency, mobility, health, and household's use of amenities (toilet and piped water) and energy choices (fuel-wood expenditure and usage).

We find that the reliability of household electricity is a significant factor in reducing household and labor market differences between men and women. We analyze both the extensive and intensive margins of employment, activities of home production (fuel and water collection), economic and social decision making ability, health related fuel choices and the provisions of basic household amenities and find that reliable electrification generally benefits women more than men. Given our findings, reducing the inefficiency in electricity supply could be a significant policy lever in reducing gender disparities in the labor market and in the household.

This study uses two identification strategies (IV-FE and FE) and examines the empirical evidence on electricity's gendered impacts in India, where electricity provisioning is sub-optimal (Burgess et al., 2020; Chindarkar and Goyal, 2019), and extant gender inequality is a serious concern (Duflo, 2012; Fletcher et al., 2017; Jensen and Oster, 2009). Drawing on the framework of 'access agency and achievements' laid down by Kabeer (1999), and contextualizing it with regards to labor saving technologies, we situate the lack of reliable electrification as a potential obstacle to policies seeking to reduce gender disparities. We measure the direct effects of reliable electrification on gender differences in the labor markets and investigate the mechanisms through which these effects operate. Addressing the endogenous placement of infrastructure and confounding trends, we show that gender differences in employment opportunities and within the household are reduced when households receive additional hours of electricity.

Results from the labor market analysis show that 10 more hours of electricity increases women's likelihood of usual status employment (4.2 pp) more than that of men (2.8 pp), while both women and men gain similar levels of full-time employment, 3.9 pp and 4.0 pp, respectively. This study underscores the role reliable household electrification could play in increasing the employment opportunities for women, and in reducing the gender differences in LFP. In addition, increasing the reliability of electricity supply lowers the time spent on fuel and water collection, more for women than men, reduces unhealthy fuel choices, and increases the likelihood of having basic amenities. It also improves women's general health and increases their say in economic decisions, mobility and reproductive choices.

Additional hours of electricity lowers the annual work hours for both men and women, presumably through the channels of improvements in labor productivity, as argued by Rathi and Vermaak (2018). Relatively better employment opportunities for women with additional electricity hours is reflected in annual earnings. The fact that reliable electrification increased the real annual earnings for both men and women provides evidence that an improvement in the reliability of electricity supply could spark large increases in the demand for labor, primarily through promotion of enterprise and industry.

Given the disproportionate effects electrification has on women's agency, resources and achievements, we argue for considering reliable electrification as a right. In conjunction with other measures, reliable electrification would help relieve the time constraints that ties women to the home and pre-empts their labor force participation, in a context where social norms place the primary responsibility of unpaid household work on women. Reliable electrification is important for a variety of reasons but one aspect that is less acknowledged in the literature is the gendered impact, which we document in this work. The argument against considering 'electricity as a right' on the grounds of inefficiencies in generation and distribution of electricity (Burgess et al., 2020) can therefore be challenged on the additional basis of its potential role in enabling a reduction in gender disparities.

There is an evident under-provisioning of electricity in India (Sedai et al., 2020a; Aklin et al., 2016) and there are price adjustments that could be optimal (Chindarkar and Goyal, 2019). Policy impetus should be on providing continuous affordable electricity to households, identifying households or localities where willingness to pay exceeds the supply; designing price per units accordingly, with appropriate and timely calculations of costs, surplus and losses. Where neccessary, appropriate public spending should be undertaken to recover the costs of generation and distribution intended to increase household reliable electrification.

Declaration of Competing Interest

None. The authors did not receive any funding for the project. There are no competing interests.

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