Policy Research Working Paper 8796

Electrification and Women's Empowerment

Evidence from Rural India

Hussain Samad
Fan Zhang

WORLD BANK GROUP
South Asia Region
Office of the Chief Economist
March 2019

Policy Research Working Paper 8796

Abstract

Electrification has been shown to accelerate opportunities for women by moving them into more productive activities, but whether improvements in economic outcomes also change gender norms and practices within the household remains unclear. This paper investigates the causal link between electricity access and women's empowerment, using a large gender-disaggregated data set on India. Empowerment is measured by women's decision-making ability, mobility, financial autonomy, reproductive freedom, and social participation. Using propensity score matching, the study finds that electrification enhances all measures of women's empowerment and is associated with an 11-percentage point increase in the overall empowerment index. Employment and education are identified as the two most important causal channels through which electrification enables empowerment.

This paper is a product of the Office of the Chief Economist, South Asia Region. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/research. The authors may be contacted at fzhang1@worldbank.org.

Electrification and Women's Empowerment: Evidence from Rural India[1]

Hussain Samad, Fan Zhang

Key Words: Electrification, Women's Empowerment, Intra-household bargaining power, India

JEL: J16, I14, I3

[1] Hussain Samad is a Consultant and Fan Zhang is a Senior Economist in the World Bank. This paper is part of a broader analytical effort to assess the cost of power sector distortions in South Asia conducted by Office of the Office of the Chief Economist of the World Bank's South Asia Region. Financial support from the South Asia Umbrella Facility for Gender Equality Multi-Donor Trust Fund is greatly appreciated. Authors are grateful to the University of Maryland and the National Council of Applied Economic Research (NCAER) for allowing them to use the IHDS data. Views expressed in this paper are entirely authors' and do not reflect those of the World Bank or its affiliated organizations.

I. Introduction

Women's empowerment has been widely promoted as a key development goal. It is not only desirable in itself, but also has been linked to faster economic growth (World Bank 2011). When women have greater bargaining power to make household decisions, children's education and health outcomes are better and the well-being of families improves (Duflo 2012). Giving women more power also changes communities' choices in important ways, often resulting in higher overall efficiency of the society (Udry 1996; Goldstein and Udry 2005). Recognizing the importance of women's empowerment, the United Nation included "Achieve gender equality and empower all women and girls" in its 17 Sustainable Development Goals. The World Bank too has made gender mainstreaming a priority in development assistance, identifying women's empowerment as a key pathway to sustained poverty reduction and shared prosperity.

Empirical studies show that electrification disproportionally benefits women and girls. In households with electricity, women spend less time on household chores and are more likely to participate in income-generating activities, and girls have higher educational attainment (Samad and Zhang, 2016, 2017, 2018; Kohlin et al. 2012; IEA 2008). What is less understood is whether improvements in welfare outcomes also empower women and change gender norms and practices inside households.

This paper examines whether electricity access enhances women's empowerment at the household level, defined as their ability to make strategic life choices, control resources, and craft decisions that affect important life outcomes (World Bank 2002). To the best of our knowledge, it is the first paper that provides empirical evidence on the causal link between electricity access and a wide range of empowerment indicators. The analysis is based on data from the India Human Development Survey (IHDS) carried out in 2011/2012. This survey provides a broad range of information on women's involvement in household decision making. The survey covers more than 40,000 Indian households, including more than 200,000 individuals.

Empowerment manifests itself in various aspects of life, ranging from women's participation in household decision-making to control over resources and the ability to move freely in public places. To measure different dimensions of empowerment, we construct five empowerment indexes extracted through factor analysis of a wide variety of observed indicators: *decision-making* is measured by a woman's ability to make decisions on her work, household meal choices, children's marriage and other aspects of her and family's choices ; *mobility* is measured by a woman's ability to travel alone to various places outside her home; *financial autonomy* is measured by a woman's ability to make decisions on different purchases and control over financial assets; *reproductive freedom* is measured by contraceptive use and other childbearing decisions; and *social participation* is measured by membership in various social and self-help groups. We also construct an overall empowerment index based on the five indicators.

Analysis of the effects of electrification is generally riddled with concerns about endogeneity at both the household and village levels. To the extent that electrification status is correlated with unobserved factors, such as a woman's ability and family and community background, a correlation between the presence of electricity and rising empowerment would not necessarily indicate causation. To address the potential endogeneity concern, we use propensity-score-weighted estimates to measure the average treatment effects of electrification on various empowerment indexes. Results from the analysis show that electrification has a positive impact on all five latent indexes of women's empowerment and the overall empowerment measure. Gaining access to the electric grid on average increases overall empowerment by 11 percentage points, all else being equal.

We next examine the mechanisms underlying the causal effects of electrification on empowerment. We hypothesize that access to electricity may empower women in several ways. First, it can increase women's labor force participation (Dinkelman 2011; Samad and Zhang 2017; Khandker et al. 2014). Women with an autonomous income are likely to have greater bargaining power and control over assets within the household. Second, electrification may lead to better health outcomes for women. Healthy women are better able to actively participate in society and markets and take collective action to advance their own agency and

empowerment. Third, electrification enables greater exposure to electronic media, such as television and radio. Improved access to information may broaden horizons about opportunities for women's economic empowerment, and social and political participation. Fourth, electrification can lead to better education outcomes for girls (Khandker, Barnes and Samad 2012; Khandker et al. 2014; Samad and Zhang 2016 2017). Better education outcomes for girls could have a catalytic effect on almost all dimensions of development, including women's empowerment over the long term (Duflo 2012).

Using data from the IHDS and a propensity score-weighted method, we find that gaining access to electricity has a positive impact on all four potential enabling factors of empowerment. Moreover, we find that among the four factors, women's employment and education significantly improve almost all measures of women's empowerment, while more exposure to electronic media (such as radio and television) is associated with greater financial and reproductive freedom.

The rest of the paper is organized as follows. Section II briefly describes an intra-household bargaining model to explain the causal link between electrification and women's empowerment. Section III presents the data and descriptive analysis of the observed indicators of women's empowerment. Section IV constructs latent indexes for women's empowerment and provides descriptive analysis of the indexes. This section also analyzes the effects of electrification on the empowerment indexes. Section V provides evidence on the causal channels through which electrification enhances empowerment. Section VI concludes.

II. Gender, bargaining power and intra-household resource allocation

How does the adoption of electricity lead to greater women's empowerment? In this section we first briefly review literature on the bargaining model, which is used to explain intra-household resource allocation and bargaining power; and then discuss how electrification contributes to women's empowerment.

There are two broad types of models for intra-household resource allocation. The first one—the unitary model—considers the household as a collection of individuals, based on the notion

that either all household members have the same preference or that a single decision maker acts for the good of the entire household. Developed by Becker (1981), this model assumes that an "altruistic" head takes into account the preferences of all household members by forming a joint utility function and maximizing it. The unitary model ignores potential differences in individual preferences and is therefore unhelpful in examining the distribution of resources within households (McElroy 1990; Cherchye, de Rock, and Vermeulen 2005).

The alternative to the unitary model, called the collective model, takes into account differences in individual preferences, and views household resource allocation as an outcome of the bargaining process among household members (Chiappori 1988, 1992, 1997; Manser and Brown 1980). The collective model is more suitable in explaining empowerment in the context of gender relationships because it assumes that women may have different preferences from men.[2] One particular type of collective model—the cooperative bargaining model—assumes that individuals can form contracts with each other (as in the case between a husband and a wife) and can reach Pareto efficient allocation of intra-household resources after a bargaining process between each other. There also exists a threat point (or divorce or point of exit) that represents the level of well-being which is the minimum a husband or a wife would attain if they cannot reach a cooperative solution within the marriage.

Based on the collective bargaining model, the consumption of a household consisting of only two members—a husband and a wife—can be described as follows:

$$X = X(x_0, x_h, x_w, l_h, l_w) \qquad (1)$$

where x_0 is the public good shared by both husband and wife; x_h and x_w are the private goods consumed by the husband and the wife, respectively; and l_h and l_w are the quantities of leisure enjoyed by the husband and wife, respectively. The husband and the wife choose their consumption given the respective prices of the goods consumed by each. In a marriage, the utility of the husband depends not only on his own consumption and leisure, but also on his

[2] This is a key assumption because if the preferences of husband and wife were the same, the observed outcome would be the same for both, and accordingly, we cannot determine who has more bargaining power.

wife's consumption and leisure, and vice versa. Accordingly, individual utility function, $U_i = U_i(x_i)$ $(i = h\ or\ w)$, will be strictly quasi-concave and monotonically increasing, with continuous second partial derivative. The household utility function, which is the weighted sum of individual utilities, can be expressed as,

$$U = (1-\mu)U_h(X) + \mu U_w(X) \qquad (2)$$

The maximum utility a household member can reach outside the marriage, $V_i = V(x_0, x_i, l_i)$ $(i = h\ or\ w)$, presents the threat point because marriage may not be sustainable if the utility derived from the marriage is less than V_i. μ and (1−μ) are the weights (ranging from 0 to 1) assigned to the husband or the wife. These weights can be considered as proxies for the bargaining power of the wife and the husband in intra-household resource allocation. μ is generally a function of prices, individual incomes, opportunities outside the marriage, and social perception and gender norms governing marriage.

Assuming the couple plays a cooperative bargaining game with a Nash solution, the utility maximization function is given by

$$Arg\max[U_h - V_h][U_w - V_w]. \qquad (3)$$

In this alternatives-to-marriage structure of the bargaining model, gaining electricity access can increase women's empowerment in three ways. First, electricity increases the efficiency of home production; because women are traditionally responsible for household chores, access to electricity allows women to spend more time on income-generating activities. It therefore increases women's own assets and income prospects outside marriage. Second, by reducing or eliminating the use of alternate sources of lighting (for example, candles and kerosene lighting), electricity reduces indoor air pollution, thereby reducing incidents of respiratory diseases and other health hazards for women (such as the risks of burns and fire). Healthy women are more productive and have greater earning power. Third, access to knowledge and information through electronic media (such as television and radio) can link women to resources they need to achieve economic empowerment and help them participate more fully in public life. All these factors increase V_w relatively to V_h in a fairly

straightforward way and therefore shift cooperatively-bargained household utility along the utility-possibility frontier away from U_h to U_w, leading to greater bargaining power for women within households.

III. Data

The study is based on the second-round of a two-period panel of data collected in the India Human Development Surveys (IHDS), which were jointly carried out by researchers from the University of Maryland and the National Council of Applied Economic Research (NCAER) in New Delhi, India. The nationally representative survey covers all of India's key states and union territories except for Andaman and the Nicobar Islands, and Lakshadweep.

The first round of the survey was carried out in 2004/05 (mostly in 2005). It collected information on 41,554 households in 33 states and union territories, 383 districts, 1,503 villages, and 971 urban blocks. The second survey, conducted in 2011/12 (mostly in 2012), re-interviewed 83 percent of the original households and split households (if located within the same village or town), and also interviewed 2,134 new households, for a total of 42,152 households.[3]

Eligible women from each household (defined as women of age 18–49 who had been married at least once) were interviewed in both rounds. The second-round survey covers substantially more sets of topics on gender relations regarding women's decision-making ability, mobility, financial autonomy, reproductive freedom, and social participation. Analysis of the effects of electrification on women's empowerment is therefore based on the cross-sectional data of 2011/12.

The survey also covered detailed information on households' electrification status, energy use, income, expenditure, education, health, and employment. In addition, the survey included key features of surveyed households' villages. It is important to control for village-level

[3] Some households surveyed during the first round split into multiple households by the time the second round survey was carried out. This is mostly because children became adults and formed separate households. For a detailed description of the survey, see the IHDS website at http://www.ihds.umd.edu.

characteristics in the analysis, because they can directly affect both the level of women's empowerment and the probability of electricity expansion. Although the survey was carried out in both urban and rural areas, village characteristics were collected only for the rural sample. We therefore use only the rural sample, consisting of 28,446 households and 21,896 eligible women in the 2012 survey.

Table 1 shows the distribution of sample households across six geographic regions as well as the union territories as a group. The rural electrification rate varies widely by region. The union territories and the rural vicinity of the national capital have the highest electrification rate (almost 100 percent). East India, which includes the states of Bihar, Jharkhand, Orissa, and West Bengal, has the lowest rate (less than 65 percent). For rural India as a whole, the electrification rate was 77 percent in 2012.

Table 2 presents summary statistics of various observed indicators of women's empowerment. Almost all the variables indicate stronger empowerment for women in households with electricity supply from the grid and the differences are statistically significant. For example, compared with women in off-grid households, women in grid-connected households are more likely to have decided alone on their work, traveled out of state, had a bank account, and participated in women's self-help groups.

IV. Measuring empowerment and the effects of electrification

a. Measuring latent indicators of empowerment

Empowerment is an abstract concept and manifests itself in multiple aspects of life. For example, whether a woman is empowered to make decisions may be reflected by whether she can decide on her own work, medical treatment or how many children to have. In such a case, it is difficult to measure empowerment directly using one single indicator. One way to resolve this issue is to use an indexing or scoring approach in which individual attributes are combined to form an index or score.[4]

[4] The use of indexes is common in development practices. For example, the World Bank's Doing Business index combines multiple variables into scores. In a study of reproductive behavior, Beegle, Frankenberg, and Thomas

In this study, we use a factor analysis approach to construct composite indexes from observed indicators on gender relations reported in the IHDS. Factor analysis uses correlations among measurable (observed) indicators to infer a latent behavior. By creating a single score from multiple indicators, it offers insights into underlying trends that would otherwise be difficult to measure.

Factor analysis starts with all the variables assumed to measure different dimensions of a given concept. It reduces them to a smaller number of variables that are correlated with the original variables but are themselves orthogonal to one another. In arriving at a solution, factor analysis uses only the variance a variable shares with other variables; it then divides this common variance into factors (Child 1990; Conway and Huffcutt 2003; Thompson 2004). The factors obtained thus focus only on what is common to all variables.

In order to analyze these factors, factor-score correlation coefficients (also called *factor loadings*) are calculated using regression. The factor score is then estimated as the linear combination of products of the response on each of the original variables and the corresponding correlation coefficient, as shown in the following equation:

$$score_{dm} = a_1x_1 + a_2x_2 + a_3x_3 + \cdots + a_nx_n \qquad (4)$$

where, $x_1, x_2, x_3, \ldots, x_n$ are original variables such as the ability to make decisions about one's education, decide whether to have children, and so on; $a_1, a_2, a_3, \ldots, a_n$ are correlation coefficients between the score and each of the x's. Each of the correlation coefficients takes a value between 0 to 1; they show the extent to which change in one indicator is associated with the change in the overall score. A correlation factor of 0.70, for example, implies that the score increases by 0.70 percent with a 1 percent increase in the value of the original indicator (alternately, one could say that the original indicator increases by 0.70 percent with a 1 percent increase in the score).

(2001) show that women's bargaining power is captured by a combination of multiple aspects as opposed to a single factor.

Based on gendered indicators included in the 2012 survey, we group empowerment into five factors indicating five types of latent abilities: [5]

(1) *Decision-making* is the ability to make decisions about various aspects of one's own life and household affairs. We combine five indicators to construct this ability: whether a woman can make decisions alone about her own work, about her medical treatment, about her children's medical treatment, about children's marriage, and about items to cook on a daily basis.

(2) *Mobility* is the ability to move about independently. It is based on the ability to visit various places, including health centers and friends' or relatives' homes; to travel a short distance by trains or buses; having traveled outside a rural area to a city or town during the 5 years preceding the survey; and having traveled outside the state during the five years preceding the survey.

(3) *Financial autonomy* is the ability to make purchase decisions and access assets or finance. It is based on four attributes: the ability to purchase expensive household durables, such as a refrigerator or television set; the ability to purchase land or other real estate; possession of a bank account; and having her name on the ownership or rental document of her domicile.

(4) *Reproductive freedom* is the ability to make reproductive choices. We consider three measures for this ability: whether a woman uses any contraceptives; whether she can decide how many children to have; and whether the actual or desired number of children is less than three. Literature on gender equity and reproductive outcomes mostly suggests that there is an inverse relationship between a woman's empowerment and the number of children she has (Upadhyay et al.).[6] The third indicator is measured by: i) the number of children for those who would not conceive any more children (either by choice, or because of sterilization), or ii) the total of current and additional desired number of children for those who want more children.

[5] This categorization is not set in stone; alternate combinations of indicators are possible.

[6] We use a cut-off point to convert a continuous variable (number of children) to an indicator variable (yes-no). The choice of cut-off point is arbitrary. Use of other cut-off points, such as 4 children, does not change the results.

(5) *Social participation* measures awareness of socio-political issues and membership in social groups. It is captured by membership in each of the following organizations: *Mohila Mandals*, self-help groups, and credit or savings groups. *Mohila Mandals* work to empower women in a number of ways, such as making them self-reliant and aware of their human and constitutional rights, nurturing their physical and emotional health, and providing them with vocational training and credit facilities for self-employment. A self-help group is a village-based financial organization in which members regularly save small amounts of money to create a common fund that can be used to meet their emergency needs, pool resources to become financially stable, and take out loans to support self-employment. Credit or savings groups are similar to self-help groups but more inclusive. For example, in some states ultra-poor members of the society are not covered by self-help groups but may join credit or savings groups.

We also create an overall empowerment measurement from the five latent abilities, using factor analysis.

Table 3 shows how the original variables load on each of the five factors. For example, the ability to make decisions about children's medical treatment or children's marriage loads strongly and positively on decision-making ability, with a factor loading of more than 70 percent. The ability to visit health centers, visit friends or relatives, and travel a short distance by train or bus loads strongly on mobility with factor loadings greater than 80 percent. Visiting towns or cities or going out of state has a weak association with freedom of mobility. Use of contraceptives or lower optimum number of children have a strong association with reproductive freedom whereas the ability to decide to have certain number of children has a weaker association with reproductive freedom. All three component indicators of social participation have a strong association with the factor.

To what extent are these latent abilities associated with one another and to the overall empowerment index? Table 4 shows the correlation matrix. All the correlation coefficients reported in table 4 are positive. The correlations of the five latent abilities are weak (less than 0.25), implying that they are independent (that is, having one ability is not related to having

another). However, the correlations between these abilities and the overall empowerment are moderate to strong. The correlation with overall empowerment is strongest for decision making (0.54), making it the most dominant component of women's empowerment. Mobility comes next, with a correlation coefficient of 0.46.

Table 5 reports descriptive statistics of the five composite indexes of empowerment and the overall empowerment measure by electrification status. Women in households with grid electricity have higher index values in all cases, and all differences are statistically significant. For example, 45 percent of women in households with access to electricity have financial autonomy, compared with 37 percent of women in households without electricity access. The overall empowerment index is 0.5 in grid-connected households; among women in off-grid households, the figure is 0.37.

b. Measuring the effects of electrification on women's empowerment

These findings provide evidence on the correlation between women's empowerment and household electrification. However, they do not yet imply any causality. Families in grid-connected households are likely to be different from households that have no electricity. For example, women from wealthier families or women with higher earning abilities are more likely to marry wealthier or more progressive men who have preferences similar to the women's. These families are also more likely to adopt electricity. Furthermore, electricity expansion may first take place in areas that are more developed and have more favorable environments for gender equality.

We use the propensity-score weighting method (also known as inverse-probability-weighted or IPW estimates) to address the potential endogeneity issue. The literature suggests that unobserved heterogeneity is correlated with initial conditions (Heckman 1981; Chamberlain 1984; Arulampalam, Booth, and Taylor 2000). Initial conditions can therefore be used as controls for unobserved characteristics that may lead to endogeneity bias in the estimation.

To implement IPW, we first estimate the probability of being connected to the grid using a wide range of household and village characteristics observed in the base year (2005). These variables

include sex, age and education of household head; the number of adult males and females in the household; the amount of household agricultural land; and measures of the household's sanitation status, such as access to running water, a flush toilet, and a separate kitchen. Village-level control variables include dummy variables measuring the presence of schools, paved roads, markets, banks, nongovernmental organizations (NGOs), and development programs, as well as village prices of alternative fuels (firewood, kerosene, and liquefied petroleum gas) and essential food items (such as staples, meat, fish, vegetables, and so on). We then use the estimated probability (propensity score) to create a weight. In the second-stage estimation, we use the weight to estimate the effects of electrification on empowerment. Following Hirano, Imbens, and Ridder (2003), we give each variable a weight of 1 for households with electricity and p/(1 – p) for households without electricity, where p is the propensity score. The outcome equation can be written as follows:

$$Y_i = \alpha X_i + \beta V_i + \gamma E_i + \varepsilon_i \qquad (5)$$

where, Y_i is a binary variable denoting the empowerment status of women in household *i*. To ease the interpretation of the estimation results, we convert continuous scores for each of the latent dimensions (and the overall index) of women's empowerment to a binary variable based on the following criteria:

$$Y_{ij} = \begin{cases} 1, & f_{ij} \geq \widehat{f_J} \\ 0, & f_{ij} < \widehat{f_J} \end{cases} \qquad (6)$$

where, Y_{ij} is the binary empowerment indicator of woman *i* to be constructed; *j* is the type of ability such as decision-making, mobility and so on; f_{ij} is the continuous-value score generated from observed variables through factor analysis, $\widehat{f_J}$ is the median value of the continuous score in the sample. A woman can be considered empowered (Y_{ij} =1) with decision-making if she had a decision-making empowerment score of or above the median value, and unempowered otherwise.[7]

[7] There are different conventions of generating the threshold value $\widehat{f_t}$. We also tried a few alternatives: mean value, 75 percentile, and 80 percentile of the score. While the value of Y_i obviously varies, the direction and statistical significance of the estimation results remain the same.

X_i is a vector of household-level characteristics and V_i is a vector of village-level characteristics. Besides the control variables that are included in the equation for electricity adoption at the first stage, a few extra variables are included in the outcome equation, which are expected to influence women's empowerment. They are education of woman's father, mother and husband; her age at marriage; if her marriage was arranged or she chose her husband; and if she had known her husband for over a year before marriage. These variables can shape a woman's mental make-up and influence her post-marriage outlook. At the village-level, we included the distribution of different religions in the community, which can be a proxy for the social norm that sets the expected behavior of men and women in a society. E_i is a dummy variable measuring the electrification status of *i*-th household—E_i equals 1 if households have access to electricity and 0 otherwise; ε_i is a randomly distributed error term; and α, β, and γ are unknown parameters to be estimated. For comparison, we also estimate equation (6) using ordinary least squares (OLS).

Table 6 reports the estimation results. It shows that gaining access to electricity has positive impacts on all five dimensions of women's empowerment and the overall empowerment index. The magnitude of the effects varies slightly across models. In the propensity-score-weighted (p-weighted) model, which is our preferred specification, gaining access to electricity is associated with a 10.7 percentage point increase in the overall empowerment index. It is also associated with a 4.6 percentage point increase for decision-making, 10 percentage point increase for mobility, 6.9 percentage point increase for financial autonomy, 2.7 percentage point increase for reproductive freedom, and 8.0 percentage point increase for social participation.

These findings also show that while electrification in general improves women's empowerment, the size of improvement varies by index. Improvement in reproductive freedom is the smallest. Improvement in decision-making, a key measure of intra-household bargaining power, is only statistically significant at the 10 percent level. Improvement in bargaining positions primarily involving a women's own well-being, such as travel alone, having a bank account, and participating in social groups, are higher and of similar magnitude.

V. Potential causal channels between electrification and women's empowerment

What are the mechanisms through which electrification brings about changes in women's empowerment? Section II discussed several hypotheses, including the effects of increased earning opportunities, better health outcomes, enhanced media exposure, and better education attainment for girls in the long run. This section provides suggestive evidence on the roles of these causal channels. We first investigate to what extent women's employment, health, education and media consumption are affected by grid electrification. We then examine the potential causal effects of these outcome variables on women's empowerment.

Table 7 presents summary statistics of several outcome variables that may affect empowerment. Girls in households with grid connection spend more time studying than those in off-grid households. More specifically, girls from households with grid electricity on average spend about 6.7 hours per week in study, compared to 4.6 hours per week spent on study by girls in households with no access to electricity. This pattern is also reflected in girls' grade attainment, with those in grid-connected households do better than those in off-grid households. The differences are both statistically significant.

No clear pattern emerges with regard to electrification and women's employment based on simple mean comparison. While employment hours of women in grid-connected households are higher, their labor force participation is lower than women in off-grid households. Similarly, a simple mean comparison shows a mixed correlation between electrification and exposure to electronic media. Women in households with access to electricity watch TV slightly more often than those in households without electricity, while they listened to radio slightly less.

Women in grid-connected households had a lower incidence of illnesses (fever, coughing and diarrhea) and fewer sick days than women in off-grid households. For example, 17.2 percent of the women in grid-connected households reported having had a fever during the 30 days preceding the survey, compared with 25.3 percent of the women in off-grid households. The number of days of illness during the 30 days preceding the survey were 1.32 for women in grid-connected households, compared to 2.42 days for women in off-grid households.

The correlation between electrification and welfare outcomes does not indicate the causal effect of electricity access because of potential non-random adoption of electricity at both household and village level. To address the potential endogeneity issue, we use the following model to estimate the causal effects of electrification:

$$W_i = \theta X_i + \pi E_i + \rho T + \eta_i + \varepsilon_i \qquad (7)$$

where W_i denotes the outcome variables of interest, including women's monthly employment hours, labor force participation, health outcomes, and media exposure at home; X_i is a vector of household- and village-level characteristics, as in equation (6); E_i is a dummy variable measuring access to electricity; T is common yearly shocks; η_i represents unobserved household- and village-level determinants of outcome variables; ε_i is an idiosyncratic error term.

To control for unobserved variable η_i, we rely again on propensity score matching and exploit the correlation between initial characteristics and unobserved heterogeneity. Specifically, we estimate a two-stage propensity score-weighted model. In the first stage, a weight variable is created based on the probability of a household adopting electricity given household and village-level characteristics in 2005. In the second stage, the effect of electrification is estimated using *p*-weighted OLS model using 2012 data.

Table 8 reports estimation results of equation (7). For comparison, we also report findings from a simple OLS estimation. Based on our preferred specification, the p-weighted model, electrification is associated with almost one hour increase in girls' study time each week. In addition, with access to electricity, girls' grade attainment on average increases by 0.48. Women's labor force participation increased 3.8 percentage points, and women's employment hours increased 36.3 percent because of electrification. Electrification also brought positive health benefits for women. The probability of having a fever, cough, or diarrhea for women falls when a household is connected to the grid. Also, the number of sick days of women falls by 12.5 percent because of grid connectivity. Electrification also increased women's exposure to electronic media—radio and television. The probability of listening to radio and watching

television rose by 5.1 percentage points and 2.5 percentage points, respectively, among women with grid connection.

The above results provide evidence that gaining access to electricity has a positive impact on all four potential enabling factors for women's empowerment.

Next, we explore the relationship between women's empowerment and the aforementioned outcome variables on women's employment, health, education, and media exposure. The estimation model is described as

$$Y_i = \vartheta X_i + \sum_{j=1}^{n} \varphi_j C_{ij} + \theta_i + \varepsilon_i \qquad (8)$$

where, Y_i is the indicator variable for empowerment status of woman *i* as defined in equation (5); X_i is a vector of household- and village-level control variables (but no variable on electrification status)[8]; C_{ij} is the *j*-th hypothesized causal variable for women's empowerment. We consider the following causal variables (*n*=5): woman's grade attainment, whether a woman is employed, log of number of days woman was ill during last 30 days, whether a woman listens to radio regularly and whether a woman watches TV regularly.[9] θ_i is unobserved women's characteristics. It should be noted that although we have included a wide range of control variables, there could still be unobserved factors that are correlated with both empowerment indicators and their hypothesized causal variables (C_{ij}). If this is the case, then the following OLS estimation of equation (8) would be biased. ε_i is an idiosyncratic error term.

Table 9 reports results from OLS estimation of Equation (8). It shows that women's employment has the most consistent and significantly positive correlation with empowerment. If a woman

[8] Control variables are the same as those included in equation (5): age of the woman; sex, age, and education of household head; the number of adult males and females in the household; household agricultural land; household access to running water and flush toilets; presence of schools, paved roads, markets, banks, nongovernmental organizations (NGOs), and development programs in the village; prices of alternative fuels and essential food items in the village; education of woman's father, mother and husband; her age at marriage; if her marriage was arranged or she chose her husband; and if she had known her husband for over a year before marriage, and the distribution of different religions in the community.

[9] To avoid collinearity, we only include women's labor force participation (that is, whether a woman is employed) as an explanatory variable to estimate the effects of women's employment on empowerment. Using women's employment hours as an explanatory variable gives the same conclusions. Similarly, we use the number of sick days instead of dummy variables for specific illness such as fever, cough or diarrhea as an explanatory variable to estimate the effects of women's health on empowerment.

is employed, all measures of her empowerment would be higher, with an increase in empowerment index ranging from 1.5 percentage points in reproductive freedom to 9.5 percentage points in financial autonomy. The second most important explanatory variable is women's education. Each additional year of education achieved is associated with a 1.8 percentage point increase in mobility, 1.1 percentage point increase in financial autonomy, 0.6 percentage point increase in social participation, and 0.9 percentage point increase in overall empowerment. Regular listening to radio is found to slightly increase reproductive and financial autonomy, while regular TV watching is associated with an increase in financial autonomy and social participation. Being sick during the last 30 days is negatively correlated with mobility but does not have any statistically significant impact on other empowerment indexes, possibly because it may be an imperfect approximation of a woman's general health.

VI. Conclusion

This paper investigates the causal link between access to electricity and women's empowerment using a large gender-disaggregated data set from the India Human Development Survey. To measure the multidimensional aspects of empowerment, we use factor analysis to combine an array of information on women's intrahousehold decision-making and resource allocation into five indicators of empowerment: decision-making ability, mobility, financial autonomy, reproductive freedom, and social participation. We also construct an overall empowerment index based on the five factors.

The analysis shows that getting access to electricity enhances women's positions on all five dimensions of empowerment and the overall empowerment measure. However, the magnitude of improvement is small for women's decision-making ability and reproductive freedom. Gaining access to electricity is associated with a 4.6 percentage point increase in women's decision-making ability on intra-household resource allocation and 2.7 percentage point increase in their reproductive freedom. Women's bargaining power, primarily involving her own well-being (such as traveling alone, having a bank account, and participating in social groups), increases by 6.9–10 percentage points because of electrification.

We also examine the potential causal mechanisms through which electrification affects women's opportunities and empowerment. Women's labor force participation, education, health and exposure to electronic media are identified as key intermediary factors through which electrification enhances women's empowerment. We find that gaining access to electricity is associated with positive improvements of all four enabling factors for empowerment. We then go on to investigate how the intermediate factors may affect women's empowerment. We find suggestive evidence that women's labor force participation and education are the most important determinants of women's intra-household bargaining power. Media exposure and health outcomes during the last 30 days are also found to have positive impact on financial autonomy, reproductive freedom, and mobility.

These results suggest that electricity access can be an important policy lever for empowering women. However, electrification alone is unlikely to ensure significant progress in important dimensions of women's empowerment, in particular, their decision-making ability and reproductive freedom. Sustained efforts in improving women's earning opportunities, education and health are important for improving women's agency and empowerment; these enabling factors can be improved in other ways besides electrification.[10] Policy actions targeting pervasive social norms and gender stereotypes are also needed to reduce gender inequality.

[10] For example, girls' education in developing countries can get a boost from a wide range of incentive programs. In Pakistan, a stipend program for primary school girls was found to increase school enrollment (Kim, Alderman, and Orazem 1999). In Colombia too, school voucher programs targeted to girls were found to increase enrollment rates (King, Orazem, and Wohlgemuth 1999).

References

Agarwal, Bina. 1997. "'Bargaining' and Gender Relations: Within and beyond the Household." *Feminist Economics* 3(1): 1–51.

Arulampalam, W, A. L. Booth, and M. P. Taylor. 2000. "Unemployment persistence," *Oxford Economic Papers*, 52: 24–50.

Becker, G. S. 1981. *A Treatise on the Family.* Harvard University Press. Cambridge, Massachusetts.

Beegle, Kathleen, Elizabeth Frankenberg, and Duncan Thomas. 2001. "Bargaining Power within Couples and Use of Prenatal Delivery and Case in Indonesia," *Studies in Family Planning.* Vol. 32, no. 2: 130–46.

Chamberlain, G. 1984. "Panel Data," in Handbook of Econometrics, S. Griliches, M. Intriligator (eds), North-Holland, Amsterdam.

Cherchye, Laurens, Bram de Rock, and Frederic Vermeulen. 2005. "Opening the Black Box of Intra-Household Decision-Making: Theory and Non-Parametric Empirical Tests of General Collective Consumption Models." IZA Discussion Papers 1603.

Chiappori, P. A. 1997. "Introducing Household Production in Collective Models of Labor Supply." *Journal of Political Economy* 105(1), 191–209.

_____. 1992. "Collective Labor Supply and Welfare." *Journal of Political Economy* 100 (3), 437–467.

_____. 1988. "Rational Household Labor Supply." *Econometrica* 56: 63–89.

Child, D. 1990. The Essentials of Factor Analysis (Second Edition), London: Cassel Education Limited.

Chowdhury, Shyamal K., 2010. "Impact of Infrastructures on Paid Work Opportunities and Unpaid Work Burdens on Rural Women in Bangladesh," Journal of International Development 22 (2010) pp. 997-1017.

Conway, James M., and Allen I. Huffcutt. 2003. "A Review and Evaluation of Exploratory Factor Analysis Practices in Organizational Research," *Organizational Research Methods*, Vol. 6, No. 2: 147-168.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review* 101(7), 3078–3108.

Duflo, Esther. 2012. "Women Empowerment and Economic Development." Journal of Economic Literature, 50(4): 1051-1079.

Goldstein, Markus, and Christopher Udry. 2005. “The Profits of Power: Land Rights and Agricultural Investment in Ghana.” Yale University Economic Growth Center Discussion Paper 929.

Grogan, Louise, and A. Sadanand. 2009. "Electrification and the Household." Working Paper, University of Guelph.

Heckman, James J. 1981. “The Incidental Parameters Problem and the Problem of Initial Conditions in Estimating a Discrete Time - Discrete Data Stochastic Process,” in Structural Analysis of Discrete Data with Econometric Applications, C. Manski, D. McFadden (eds), MIT Press, Cambridge, MA.

Hirano, Keisuke, Guido Imbens, and Geert Ridder. 2003. “Efficient Estimation of Average Treatment Effects Using the Estimated Propensity Score.” *Econometrica* 71 (4): 1161–89.

Independent Evaluation Group (IEA). 2008. The Welfare Impact of Rural Electrification : A Reassessment of the Costs and Benefits. Washington, DC.

Khandker, Shahidur R., Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes. 2014. “Who Benefits Most from Rural Electrification? Evidence from India.” *Energy Journal* 35(2): 75–96.

_____. 2012. “The Welfare Impacts of Rural Electrification in Bangladesh.” Energy Journal 33(1): 199–218.

Khandker, Shahidur, M. A. Baqui Khalily, and Hussain Samad. 2012. “Seasonal Hunger and Its Mitigation in North-West Bangladesh.” *Journal of Development Studies* 48(12): 1750-1764.

Kim, Jooseop, Harold Alderman, and Peter Orazem. 1999. “Can Private School Subsidies Increase Enrollment for the Poor? The Quetta Urban Fellowship Program.” *World Bank Economic Review* 13 (3): pp. 443–65.

King, Elizabeth, Peter Orazem, and Darin Wohlgemuth. 1999. “Central Mandates and Local Incentives: The Colombia Education Voucher Program.” *World Bank Economic Review* 13 (3): pp. 467–91.

Kohlin, Gunnar; Erin O. Sills, Subhrendu K. Pattanayak, Christopher Wilfong. 2012. Energy Gender and Development. What are the Linkages? Where is the Evidence? Background Paper to the 2012 World Development Report. Washington DC.

Lipscomb, Molly, A. Mushfiq Mobarak, and Tania Barham. 2013. “Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil,” *American Economic Journal: Applied Economics* 5(2): 200-231.

Manser, M. and M. Brown. 1980. “Marriage and Household Decision-Making: A Bargaining Analysis.” *International Economic Review* 21 (1), 31–44.

McElroy, M. B. 1990. “The Empirical Content of Nash-Bargained Household Behavior.” *Journal of Human Resources* 25(4), 559-583.

Samad, Hussain, and Fan Zhang. 2017. “Heterogenous Effects of Rural Electrification: Evidence from Bangladesh.” World Bank Policy Research Working Paper 8102. Washington DC.

_____. 2016. “Benefits of Electrification and the Role of Reliability: Evidence from India.” World Bank Policy Research Working Paper 7889. Washington, DC.

Udry, Christopher. 1996. “Gender, Agricultural Production, and the Theory of the Household.” *Journal of Political Economy* 104 (5): 1010–46.

Ushma D. Upadhyaya,g, Jessica D. Gipsonb, Mellissa Withers, Shayna Lewise, Erica J. Ciaraldib, Ashley Fraserd, Megan J. Huchkof, and Ndola Pratad. 2014. “Women’s empowerment and fertility: A review of the literature.” Social Science & Medicine. 115: 111-120.

World Bank. 2011. *World Development Report 2012: Gender Equality and Development.* Washington, D.C.

-- 2002. Measuring Women’s Empowerment as a Variable in International Development. Background Paper Prepared for the World Bank Workshop on Poverty and Gender: New Perspectives.

Table 1 Distribution of sample households and percent of households with access to electricity, by region

Region	States and union territories	Sample size	Access to electricity
Union territories and the capital[a]	Dadra and Nagar Haveli, Daman and Diu, Delhi, Pondicherry	242	99.8
North	Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan, Uttarakhand, Uttar Pradesh	9,334	66.8
South	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu	5,985	95.5
East	Bihar, Jharkhand, Orissa, West Bengal	4,530	64.5
West	Goa, Gujarat, Maharashtra	3,448	92.6
Central	Chhattisgarh, Madhya Pradesh	3,572	91.9
Northeast	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura	1,335	67.8
Total		28,446	76.7

Note: Union territories are administrative divisions that differ from states. Each state is ruled by its own elected government; union territories are ruled by the central government.

Table 2. Descriptive statistics of observed women's empowerment indicators by electrification status

Indicators	Households with grid electricity	Households without grid electricity	t-statistics of the difference
Can decide alone on own work	0.360	0.317	5.43
Can decide alone on own medical treatment	0.178	0.141	5.97
Can decide alone on children's medical treatment	0.222	0.217	0.77
Can decide alone on children's marriage	0.096	0.078	3.88
Can decide alone what to cook	0.634	0.561	9.21
Can visit alone health centers	0.662	0.611	6.56
Can visit alone friends and relatives	0.729	0.718	1.55
Can use alone trains or buses to go short distance	0.474	0.364	13.57
Has been to a town or city in last five years	0.813	0.756	8.72
Has been to a different state in last five years	0.159	0.083	13.37
Can decide alone on the purchase of expensive household items	0.070	0.077	-1.70
Can decide alone on the purchase of real-estate properties	0.045	0.036	2.86
Has a bank account	0.349	0.262	11.42
Has her name on the ownership/rental document of the house	0.131	0.094	6.95
Currently use contraceptives	0.685	0.574	14.54
Can decide alone how many children to have	0.214	0.195	2.92
Optimum number of children is less than or equal to 2	0.069	0.049	5.04
Is a member of women's group	0.068	0.031	9.58
Is a member of self-help group	0.169	0.091	13.42
Is a member of credit/savings group	0.098	0.022	17.13
No. of Obs.	18,266	3,630	

Table 3 Latent indexes for women's empowerment and their components

Empowerment indicators	Factor loading
Decision-making	
Can decide alone on own work	0.361
Can decide alone on own medical treatment	0.737
Can decide alone on children's medical treatment	0.800
Can decide alone on children's marriage	0.684
Can decide alone what to cook	0.474
Mobility	
Can visit alone health centers	0.850
Can visit alone friends and relatives	0.803
Can use alone trains or buses to go short distance	0.808
Has been to a town or city in last 5 years	0.020
Has been to a different state in last 5 years	0.109
Financial Autonomy	
Can decide alone on the purchase of expensive household items	0.845
Can decide alone on the purchase of real-estate properties	0.841
Has a bank account	0.263
Has her name on the ownership/rental document of the house	0.211
Reproductive freedom	
Currently use contraceptives	0.779
Can decide alone how many children to have	0.206
Optimum number of children is less than or equal to 2	0.772
Socio participation	
Is a member of women's group	0.727
Is a member of self-help group	0.670
Is a member of credit/savings group	0.771
No. of Obs.	21,896

Table 4 Correlation matrix of latent indexes of women's empowerment (N=21,918)

	Decision-making	Mobility	Financial autonomy	Reproductive freedom	Social participation	Overall empowerment
Decision-making	1.000					
Mobility	0.179	1.000				
Financial autonomy	0.143	0.097	1.000			
Reproductive freedom	0.228	0.099	0.105	1.000		
Social participation	0.071	0.028	0.201	0.035	1.000	
Overall empowerment	0.538	0.462	0.305	0.293	0.258	1.000
No. of Obs.	21,896					

Table 5. Descriptive statistics of empowerment indexes by electrification status

Empowerment index	Households with access to grid	Households without access to grid	t-statistics of the difference
Decision-making	0.439	0.388	6.37
Mobility	0.462	0.332	16.24
Financial autonomy	0.453	0.365	10.94
Reproductive freedom	0.150	0.118	5.69
Social participation	0.242	0.114	19.23
Overall empowerment	0.497	0.366	16.20
No. of Obs.	18,266	3,630	

Table 6 The effects of electrification on empowerment indexes

Empowerment index	OLS	p-weighted OLS
Decision-making	0.074**	0.046*
	(3.22)	(1.95)
Mobility	0.083**	0.100**
	(4.64)	(4.32)
Financial autonomy	0.047**	0.069**
	(2.83)	(3.24)
Reproductive freedom	0.025**	0.027**
	(2.26)	(2.19)
Social participation	0.067**	0.080**
	(5.13)	(6.17)
Overall empowerment	0.104**	0.107**
	(6.07)	(4.08)
No. of Obs.	21,896	

Note: Figures in parentheses are *t*-statistics based on robust standard errors clustered at the village level. ** and * represent statistically significant at 5 and 10 percent level, respectively.

Table 7 Summary statistics of women's outcomes by electrification status

Outcome variable	HHs with grid	HHs without grid	t-stat of the diff.
Education outcome (age 5–18)			
Total time spent in studies (hours/week)	6.71	4.64	19.29
	(6.79)	(5.21)	
Girls' grade attainment (years)	5.03	3.61	24.73
	(3.59)	(3.21)	
No. of Obs.	14,991	3,934	
Employment (age 15–65)			
Labor force participation	0.526	0.565	-7.21
	(0.499)	(0.496)	
No. of Obs.	38,822	7,131	
Employment by all women in HH (hours/month)	69.5	51.1	15.25
	(89.9)	(72.0)	
No. of Obs.	23,496	5,050	
Incidence of illness in last 30 days (age>=15)			
Had fever	0.172	0.253	-18.91
	(0.377)	(0.435)	
Had cough	0.116	0.174	-15.73
	(0.320)	(0.379)	
Had diarrhea	0.025	0.031	-3.67
	(0.156)	(0.175)	
Days lost due to illness	1.320	2.416	-23.99
	(3.745)	(5.392)	
No. of Obs.	45,526	7,739	
Exposure to media (age>=15)			
HH women listen to radio regularly	0.167	0.176	-1.70
	(0.373)	(0.381)	
HH women watch TV regularly	0.287	0.271	2.47
	(0.452)	(0.445)	
No. of Obs.	23,496	5,050	

Note: Figures in parentheses are standard deviations.

Table 8 The effects of electrification on potential causal channels of women's empowerment

Outcome variable	OLS	p-weighted OLS
Girls' education (age 5–18)		
Total time spent in studies (hours/week)	0.976**	0.966**
	(5.00)	(4.65)
Girls' grade attainment (years)	0.486**	0.482**
	(6.69)	(5.73)
N=18,303		
Employment (age 15–65)		
Labor force participation	0.039**	0.038**
	(2.63)	(2.40)
N=43,876		
Log employment by all women in HH	0.354**	0.363**
(hours/month)	(4.94)	(5.14)
N=21,969		
Incidence of illness in last 30 days (age>=15)		
Had fever	−0.022**	−0.003
	(−2.06)	(−0.31)
Had cough	−0.018**	−0.026*
	(−2.05)	(−1.67)
Had diarrhea	0.003	−0.024*
	(0.79)	(−1.78)
Log of number of days woman was ill	−0.164**	−0.125*
during last 30 days	(−2.28)	(−1.89)
N=47,940		
Exposure to media (age>=15)		
Women listen to radio regularly	0.013	0.051**
	(0.76)	(2.98)
Women watch TV regularly	0.038**	0.025*
	(2.30)	(1.71)
N=21,969		

Note: Figures in parentheses are *t*-statistics based on robust standard errors clustered at the village level. ** and * represent statistically significance at 5 and 10 percent level, respectively.

Table 9 Estimated effects of causal channels on empowerment indexes (N=21,896)

Causal channels	Decision-making	Mobility	Financial autonomy	Reproductive freedom	Social participation	Overall empowerment
Woman's grade attainment	0.004*	0.018**	0.011**	0.001	0.006**	0.009**
(years)	(1.89)	(8.58)	(5.39)	(0.49)	(3.84)	(4.52)
Woman's labor force	0.057**	0.043**	0.095**	0.015**	0.077**	0.057**
participation	(4.68)	(3.56)	(7.93)	(1.99)	(8.01)	(4.88)
Log number of days woman was	−0.007	−0.012**	0.003	0.004	0.013	−0.004
ill during last 30 days	(−1.19)	(−2.00)	(0.50)	(0.90)	(0.74)	(−0.71)
Woman listens to radio regularly	−0.011	0.019	0.067**	0.022*	−0.011	0.002
	(−0.65)	(0.99)	(3.64)	(1.73)	(−0.86)	(0.09)
Woman watches TV regularly	0.004	−0.009	0.019*	0.008	0.010*	0.016
	(0.28)	(−0.74)	(1.76)	(0.98)	(1.91)	(1.28)

Note: Figures in parentheses are *t*-statistics based on robust standard errors clustered at the village level. ** and * represent statistically significance at 5 and 10 percent level, respectively.

Source: Based on IHDS 2012