HOUSEHOLD ELECTRIFICATION AND LABOR SUPPLY: EXPERIMENTAL EVIDENCE FROM EL SALVADOR*

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Abstract

We study the adoption and effects of household electrification in northern El Salvador. Our experimental design, embedded within a grid expansion and intensification program, exploits a $100 security inspection fee that had to be paid by households who wanted to connect to the grid. We randomly allocated time-limited discount vouchers toward this fee, generating household-level exogenous variation in the cost of connections. Despite vouchers were a small fraction of the total cost of adoption, they increased grid connection persistently. In turn, electrification increased female participation in nonfarm employment by 56 percentage points and in the operation of home businesses by 29 percentage points, together with an increase in income of 0.5 standard deviations ($450 per year). Male labor supply was largely unaffected. These effects appear during the first two years and persist towards the end of the study period. We feed the experimental results in an intertemporal choice model and find a parameter of present bias of 0.75, suggesting quasi-hyperbolic discounting as an additional barrier to electricity adoption.

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I INTRODUCTION

In 2017, around 1.1 billion people still lacked access to electricity at home (International Energy Agency, 2017). Providing them with access to electricity could increase the marginal return to labor, leading to income and substitution effects that make net changes in time allocation theoretically ambiguous. For instance, self-employed workers may use power tools, farmers may use electric water pumps, shopkeepers may offer refrigerated goods, and the higher income from these activities may increase in the demand for leisure. Moreover, electricity increases the marginal value of leisure, for instance by providing access to TV, reinforcing the income effect. The outcome is further complicated by the fact that households may decide to increase labor supply because they want to acquire and use new appliances and tools, pushing in the same direction as the substitution effect. Furthermore, the effect of electrification on the marginal return to labor is highly context-dependent. On the one hand, workers need to acquire, maintain and learn how to operate electronic appliances and tools, so the effects depend on the availability of such tools. On the other, the value of the marginal product of labor will be determined by the demand, hence the effects also depend on local economic conditions.

Some evidence suggests that electricity may increase labor supply, particularly female, improve educational outcomes, increase agricultural productivity, and increase consumption and income, foster industrialization (Dinkelman, 2011; Grogan and Sadanand, 2012; Chakravorty, Emerick, and Ravago, 2016; Rud, 2012; Khandker, Barnes, and Samad; van de Walle et al., 2013; Litzow, Pattanayak, and Thinley, 2019). However, other studies find no impacts beyond lighting (e.g. Bernard and Torero, 2013; Bensch, Kluve, and Peters, 2011; Burlig and Preonas, 2016) and Lee, Miguel, and Wolfram (2019) present experimental evidence that electrification can even reduce welfare.

We contribute to the debate on the economic returns to electricity with an experimental study that generated household-level variation in electrification paired with four yearly follow-up surveys. Most previous studies exploit exogenous variation in electrification at the community level, and no previous experimental study has data over four years after roll-out. We embedded our study during a grid extension and intensification program in northern El Salvador that started in late 2009. While the government covered all the costs up to the electric meter, households had to pay for their internal wiring and a \$100 fee for a safety inspection before they could be connected to the grid. We randomly allocated \$50 and \$20 discount vouchers to a subset of study households, generating exogenous variation in connection costs. We interviewed the study households yearly from November 2009 until November 2013.

Our experimental design paired with four years of follow-up surveys allows to shed light on a number of issues. By the first follow-up survey, recipients of the \$50 and \$20 discount vouchers were 17 and 11 percentage points, respectively, more likely to be on-grid than the control group. However, from the second follow-up onwards, the share of on-grid households was similar for both groups of voucher recipients. Second, by the end of the study, four years after baseline, voucher recipients still had a higher connection rate than non-recipients. Given the size of the benefits we discuss below, this persistence is not likely due to the size of the discount, and more likely due to cognitive biases like quasi-hyperbolic discounting, a possibility which we explore in the model in the model developed in section V. Third, similar to Bernard and Torero (2013), we find evidence of spillovers: household adoption is directly affected by the number of vouchers received by their neighbors. Regarding the effects of electrification, we find that electrification increases female -but not male- labor supply. Female participation in home businesses and nonfarm employment increases by 56 and 26 percentage points, respectively. In consequence, female income increases significantly, by \$450 per year (0.5 standard deviations). Analysis of time allocation provides consistent results, showing that females had a large extensive and intensive margin increase in labor activities. As to the type of businesses they operate, electrification increased refrigerator ownership, suggesting that these home businesses were related to home shops selling refrigerated goods. To shed light on the dynamics behind these average effects, we split the study period in two. We find that the effect on female nonfarm employment increases from 0.47 in the first half of the sample to 0.65 in the second. The effect on income is roughly the same in both periods, suggesting that the activities were less profitable on average during the second half of the study period. We also show that workers who engage in nonfarm employment or home business operation are more likely to do so in both periods than to do it only in one, suggesting some stability in the new income generating activities.

Next, we develop an intertemporal model of electricity adoption allowing for cognitive biases and estimate key parameters using the experimental results. First, we show that each voucher allocated to neighbors had at least one-third of the impact on the budget constraint as a voucher allocated to the household. This suggests that households had unexploited income-generating opportunities, something not uncommon in poor areas (Banerjee and Duflo, 2007). Next, we calibrate the model and find that under standard assumptions it is consistent with an average present-bias parameter of 0.75, which is low enough to explain our findings. Finally, we show that offering time-limited discounts may be profitable for the electric utility, since they increase adoption early on in the project despite the need to subsidize households that would have connected even without the subsidy.

To our knowledge, there are two experimental studies on the effects of grid electrification, described in Bernard and Torero (2013) and Lee, Miguel, and Wolfram (2019). The main difference with these studies is the use of multiple follow-up surveys. Four years of follow-up data allows to detect effects that need an incubation period before appearing. Second, while most of the literature studies electrification of the village or community, our approach allows us to study electrification status at the household level. Multiple study periods paired with household-level variation in electrification status allows us to study the role of behavioral biases in connection take-up.

Our study contributes to two more specialized strands of literature. First, to the literature on the long term effects of nudges. The vouchers used in our intervention could be considered "nudges" in the sense of Thaler and Sunstein (2009) because of their small size relative to the cost of electrification. While nudges have been proven to affect a wide variety of behaviors in the short term, less is known about the persistence of these changes. Failing to take long-term effects into account can lead to underestimate a program's cost-effectiveness, as illustrated by Allcott and Rogers (2014) and Bernedo, Ferraro, and Price (2014). Allcott and Rogers (2014) study the effect of household energy reports (HERs) on energy usage. The authors show that if households are exposed to HERs for a two-year period, once the intervention stops the effects decay only at 1020 percent per year. In turn, Ferraro, Miranda, and Price (2011) and Bernedo, Ferraro, and Price (2014), studying the long-term effects of a water conservation intervention, document a similarly low decay rate, of roughly 15 percent per year. Two potential mechanisms for this type of persistent effects are habit formation and technology adoption. The study by Brandon et al. (2017) provides evidence in favor of the latter mechanism in the setting studied by Allcott and Rogers (2014). In the education literature, Castleman and Page (2016) document that text messages encouraging eligible students to file paperwork to maintain financial aid increased their likelihood of remaining enrolled through sophomore year in community colleges, by increasing financial aid effectively allocated to treated students. Our paper fits in this literature by providing evidence that a small, time-limited monetary incentive can affect labor supply and income in the long term by promoting technology adoption.[1]

Second, our paper contributes to the literature on optimal pricing when consumers exhibit cognitive biases. Ellison (2006) and Spiegler (2011) review pricing strategies that must be pursued by firms when their consumers face behavioral biases, highlighting a role for exploiting cognitive biased consumers. In particular, DellaVigna and Malmendier (2004, 2006) and Eliaz and Spiegler (2006) show that firms can exploit present-biased consumers, and that failing to account for sophisticates would reduce profits compared to the case of unbiased consumers. In our model, the existence of present biased consumers implies that the firm profits from offering time-limited connection subsidies to its potential consumers.

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[1] See Rogers and Frey (2015) for a more detailed discussion on this literature.

Offering connection subsidies increases its customer base early on, strengthening the revenue stream. The optimal subsidy is increasing in average degree of present bias in the population. Even if consumers are naive about their bias, failing to take their present bias into account would hurt the firm's profits.

The next section describes the study setting and the experimental design, and reports the main descriptive statistics in our sample. Section 3 details our empirical approach. Section 4 presents the results. Section V we develop a model and estimate its key parameters using the results from the experiment. Section VI concludes.

II STUDY SETTING

II.A THE ELECTRIFICATION PROGRAM AND EXPERIMENTAL DESIGN

The study took place during a grid extension and intensification program in northern El Salvador, designed to be rolled-out in three phases according to construction costs and accessibility. The study design is described in detail in Barron and Torero (2017). In this program, the El Salvadorian government covered all the installation costs up to the electric meter, and households had to pay for their internal wiring and a US$ 100 fee for a safety certification.

The experimental sample consists of 500 off-grid households located in subdistricts that were scheduled to be covered by the program during its first year. We generated experimental variation in the connection fee by offering discount vouchers to a randomly selected subsample. We randomly allocated 200 low-discount vouchers (20% discount), 200 high-discount vouchers (50% discount), and left the remainder households as control group (N=100). The exogenous variation in the connection fee generated by the random voucher allocation deals with self-selection in connection to the grid. Vouchers were valid for a discount towards the safety certification to be reimbursed after paying the full cost. Each voucher showed the name and address of the beneficiary, it was non-transferable, and it was valid for nine months.

Random voucher allocation also creates exogenous variation in the number of voucher recipients in a given neighborhood of household i (controlling for the number of eligible neighbors). This generates variation in the number of new connections around household i, which allows to estimate the effects spillovers on grid connection. The sign of the effect is theoretically ambiguous. On the one hand, observing their neighbors connect to the grid may make households more prone to connect, through a combination of social learning and imitation effects.[2] In addition, from a prospect theory approach, having more connected neighbors could shift a household's reference point, so adopting a grid connection becomes the reference point, while remaining off-grid is perceived as a loss. On the other hand, higher formal connection rates in a neighborhood reduce the cost of getting an informal connection, so the number of vouchers around a household may increase the number of informal connections, crowding out the adoption of formal grid connections. To estimate the role of spillovers on adoption, we use the number of household i's neighbors that received a voucher in a given radius (0-100 meters, 100-200 meters, 200-300 meters), controlling by the number of eligible households in that radius. Eligible households are households with no electricity at baseline.

EHEIPCER, the household survey used in this study,[3] is a household survey that collected data on demographic characteristics, health, education, housing characteristics, energy use, income, consumption, among others. In particular, it includes a detailed module on time allocation for up to four household members: the male head, the female head, and up to two school-age children. Strict training sessions were conducted to ensure high quality in

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[2] Social learning would occur if households observed the private benefits of electrification (better illumination, less smoke at night, better food availability, more enjoyable leisure time) from their neighbors. Imitation effects (also known as "preferences interactions" in the literature) are similar to a "keeping-up with the Joneses" story: a household wants electricity because its neighbors have it.

[3] The survey was collected as part of a larger project that included 4,800 households from northern El Salvador, and includes 500 households from San Miguel and Chalatenango, the experimental study sites. This paper uses the 500 households from the experimental sites.

data collection, which was conducted with handheld computers. Enumerators were trained and recruited by the authors with the assistance of *DIGESTYC* (the Salvadorian Bureau of Statistics) and *IFPRI* staff. The sampling framework was the 2007 Population Census. The baseline survey was collected in November and December 2009. Follow-up surveys were collected in the same months in 2010, 2011, 2012, and 2013. The multiplicity of follow-up surveys is an important contribution of this study. It allows to test which outcomes changed immediately and which took longer, and whether changes are persistent in time.

II.B DESCRIPTIVE STATISTICS AND BALANCE

[INSERT TABLE I ABOUT HERE]

Table I shows descriptive statistics split by treatment arm. Column 1 shows the means for the control group, column 2 shows the means for the households that received a 20% discount, and column 4 shows the means for households that received a 50% discount. Columns 3 and 5 test for differences between each of the treatment arms and the control group. Household heads are on average 50 years old, 60-70% of them are male and have 2 years of schooling on average. Literacy rates among household heads are low, with only 50% of them reporting being literate. Average household size is 4.5 members, with a total dependency ratio of roughly 0.45. Around 30% of households own or operate a home business. Nonfarm income is around US$ 1000, while farm income is around US$ 500. The main cooking fuel is wood, used by 75% of households.

Thirty-eight percent of households had informal access to electricity at baseline. Informal connections consist on a series of extension cables connected to each other and plugged into a neighbor's sockets. They are at most enough for two lightbulbs and some times a television set, but cannot power larger appliances like refrigerators. Thus, we consider households with informal connections as off-grid.

Households were also balanced regarding their ex-ante perceptions towards energy sources. The vast majority of interviewees agreed that electricity illuminates better than kerosene

(96%) and that woodsmoke generates respiratory problems (87%). Between 30 to 40% of respondents said that kerosene is not an expensive source of lighting, and 20-30% said it as the best way to illuminate their household.

III EMPIRICAL APPROACH

Our main specification is an IV estimation. The first stage regression is given by:

$$\text{conn}_{it} = \alpha_0 + \beta' \text{voucher}_{ik} \times \text{Post}_t + \lambda \text{s100}_i \times Post_t + \gamma' X_{0i} + \mu_t + u_{it} \tag{1}$$

, where conn_{it} is an indicator that takes the value of 1 if the household i has a formal connection to the grid at time t and 0 otherwise. $voucher_{ik}$ indicates whether household i received a voucher for a reimbursement of US\$ k off the connection cost (k=20,50), $Post_t$ is a dummy that turns on in the follow-up surveys, s_{100} is the share of i's eligible neighbors that received a voucher within a 100 meter radius, while μ_t are year fixed effects. The X_{0i} vector contains the baseline characteristics that were unbalanced across treatment arms as well as *voucher* and s_{100}.

The second stage is given by:

$$y_{it} = \beta_0 + \delta \widehat{\text{conn}}_{it} + \omega' X_{0i} + \mu_t + \varepsilon_{it} \tag{2}$$

y_{it} is the outcome of interest and the other variables are as before. Since vouchers were allocated at the household level, standard errors are clustered at the household level.

Due to random allocation, voucher and s_{100} are uncorrelated with the disturbance terms in equations (**??**) and (**??**). Under the assumption that vouchers affected the outcome variables only through their effect on the adoption of electric connections, IV renders consistent estimates of δ for the population of compliers.

IV RESULTS

IV.A ADOPTION

Figure 1 plots the yearly evolution of connection rates by encouragement arm (with 95% confidence intervals). The figure shows three main results: (i) high-discount vouchers had higher take-up than low-discount vouchers by the first follow-up (ii) this difference faded by the second follow-up, resulting in similar connection rates across groups, and (iii) discount vouchers had persistent effects on the probability of adoption over the whole study period. Given the small magnitude of the subsidy relative to the cost of connection, we find this indicative of the prevalence of cognitive biases, which we explore formally in section V. Fourth, there is a feature that sets our setting apart from most other studies in this literature: take-up among non-encouraged households was high. Almost 40% of non-encouraged households connected to the grid one year after baseline; by the end of the study this figure was close to 75%. This high take-up reveals high willingness to pay paired with sufficient resources.

[INSERT TABLE II ABOUT HERE]

Table II reports the first stage results. The first two columns use dummies indicating the size of the voucher (US$ 20 or 50) and the share of eligible neighbors within a radius of 100 meters that received a voucher. Consistent with Figure 1, low- and high-discount vouchers had similar effects on connection rates, of around 12 percentage points over the course of the study. As in Bernard and Torero (2013) we find evidence of spillovers. The share of eligible neighbors receiving a voucher also increased connection rates: a 10 percentage point increase in this variable boosted connection rates by 1.3 percentage points. Since both types of voucher had similar effects on the likelihood of connection, in columns 3 and 4 we pool them together to increase power. Given the stronger first stage results indicated by a larger F-statistic, we use the latter in the IV specifications that follow. The fact that the coefficient estimates in this table do not vary with the inclusion of the unbalanced baseline controls is reassuring and suggests that the voucher variables have no relation with the disturbance term. These results hold if the "post" period is split round by round (Table A.1) and if the explanatory variables are the household's connection fee and the average fee in 100m radius (Table A.2). We use the results in Table II as the base for our IV estimation because of the larger F-statistic resulting from this specification.

To shed light on the characteristics of adopters, Table III analyzes effect heterogeneity by baseline dwelling characteristics, income, and characteristics of the household head. The first columns shows that, as one would expect, vouchers induced take-up of connections almost exclusively among households with adequate walls (concrete or adobe) at baseline. The second column shows that vouchers were taken-up almost exclusively by households that had an informal grid connection at baseline, while households with no connection at baseline responded only to vouchers allocated to their neighbors. This is consistent with spillovers working through information or imitation. If imitation where the channel, effects should be stronger among better-off households. The lack of heterogeneity by household income shown in the third column suggests this is not the case, indicating that the spread of information may be a more prevalent channel. We find no heterogeneity by the age or schooling of the household head.

[INSERT TABLE III ABOUT HERE]

IV.B EFFECTS ON LABOR SUPPLY AND INCOME

Table IV shows the effects of electrification on nonfarm employment. These are the main results in the paper. The first row reports the extensive-margin effect on nonfarm employment. All discussion about statistical significance in this section refers to the FDR q-values, which reported in brackets below the standard errors. Individual significance is reported in the table for reference. Electrification increased participation in nonfarm employment by 41 percentage points. The effect on operation of home business is positive but not significant (q-value of 0.15). The next row shows that electrification increased individual income by US$374 per year on average over the duration of the study. This is a large effect, amounting to 0.4 standard deviations of baseline income. The next two rows show that gains in household income are due to higher earnings, while non-labor income was largely unaffected by electrification. This is a key fact to establish in our study setting, since international remittances amount to 29% of household income in our sample. It is possible that migrant workers could increase their remittances to newly electrified households for a number of reasons. Therefore, income gains could be due to higher remittances, not to the new income generating activities, which is a possible scenario given recent evidence on the lack of productive uses of electrification.

[INSERT TABLE IV ABOUT HERE]

Previous studies have found that changes in labor supply and income are concentrated among females, so the next columns split the sample by sex. Electrification increased female participation in nonfarm employment by 56 percentage points while it had no statistically significant among males, although we lack precision to conclude null results in the latter group. Given that participation in nonfarm employment was balanced across genders at baseline, electrification increased female participation in nonfarm employment over and above male participation in these activities. The break-down by sex shows that electrification increased operation of home businesses significantly by 26 percentage points among females, and had no effect on males. In line with changes in labor supply, electrification boosted female income by US$450 per year (0.5 standard deviations), with most of the effect stemming from earnings, and no statistically or economically significant effects on non-labor income. As in the case of nonfarm employment and business operations, male income did not change significantly, but the estimated effects are too noisy to conclude null effects.

We next analyze time-use data to check for consistency and to shed light on labor supply changes along the intensive margin, although with an important caveat. The time allocation module was responded by 358 adult females (70% of the targeted sample), 269 adult males (54%) and 192 children (38%). To standardize the recall period, survey respondents were asked to report time allocation on the Monday prior to the survey. Odd columns report changes in the extensive margin, while even columns report changes in the intensive margin. Children's time is split in education, household chores, work and leisure. Adults' time is split in chores, work, and leisure. Electrification did not lead to significant changes in time allocation among children or males, but there are important changes among females. Results are reported in Table A.3. Consistent with the previous table, electrification increased labor supply along the extensive margin (by 47 percentage points) and along the intensive margin (by 3.9 hours per day). There are no statistically significant reductions along the extensive margin of leisure or chores. Time allocated to these activities did not change individually, but the effects add up to a reduction 3.3 hours which is almost equivalent to the increase in labor. The changes among males and children are imprecisely estimated.

Table V analyzes effects on appliance ownership to shed light on the type of activities households in our study setting could be performing because of electrification. The table shows that electrification increased ownership of refrigerators by 59 percentage points (q-value = 0.02), followed by stereo (42 percentage points, q-value = 0.07) and washing machines (14 percentage points, q-value = 0.07). The effect on TV ownership is not statistically significant, although this is likely because a high ownership rate at baseline (56%, mainly powered by informal connections and car batteries). Increased refrigerator ownership is consistent with households opening small shops at home and selling refrigerated products. This is consistent with the authors' field observations, and with the magnitude of the effect on income (approximately US$1.25 per day).

[INSERT TABLE V ABOUT HERE]

Summing up, our evidence shows that electrification increased female nonfarm employment along the extensive margin, largely through the operation of home businesses, leading to economically and statistically significant increases in female income. The changes on males, however, are uncertain, as the coefficients are not statistically significant but their confidence intervals are too wide to conclude null results.

IV.C TIMING

A central question in the literature of the effects of electrification relates to the timing of the effects of electrification. Households need complementary inputs -and demand for their products - before they can use electricity for productive purposes. In the previous section we showed that in our setting electrification lead to shifts in labor supply and income on average over the four years after electrification. As this average effects can mask increasing or decreasing patterns, we turn to analyze the timing of the effects. To do so, we split the sample periods in half and estimate effects for the first and second follow-up surveys (which we label "first period") and for the third and fourth ("second period"). Table VI reports the results.

[INSERT TABLE VI ABOUT HERE]

Electrification increased participation in nonfarm employment by 31 percentage points in the first period and by 51 percentage points in the second (FDR q-values of 0.06 in both cases). As in Table IV, the effect on operation of home businesses is not saignificant. In this table, the effects of electrification on total income, earnings, and nonlabor income are not statistically significant. As in the previous analysis, the overall effects, however, mask effect heterogeneity by gender. The effects of electrification on female participation in nonfarm employment appeared from the first period, a 47 percentage point increase. The effect increased to 65 percentage points in the second period. While the effect on operation of home businesses also appeared in the first period, it did not increase markedly in the second, with coefficients of 0.23 and 0.29 respectively (FDF q-value 0.10). Consistent with these patterns, the effects on income and earnings appeared in the first period, suggesting that the new employment activities were profitable from early on, pointing to a US$ 445 increase in income and US$ 330 in earnings). These effects remained practically unchanged in the second period, at US$ 470 and US$318, respectively. Given the larger share of females participating in nonfarm activities during the second period, this suggests that during the second period those that joined nonfarm employment as a consequence of electrification experienced lower returns than in the first period. Consistently with our previous findings, the effects on males are not statistically significant, although the confidence intervals are too wide to conclude null effects.

This analysis, however, does not indicate to what degree the females that participated in nonfarm employment in the first period did so in the second, and how many quit after the first period. The same concern applies to home businesses. Answering this question is important because one could be concerned that employment opportunities created by electrification could have been only temporary. To investigate this issue we constructed dummy variables that indicate whether that the female participated in nonfarm employment in both periods, and a similar variable for home businesses. The results are presented in Table VII. Electrification increased the probability of engaging in nonfarm employment in both periods by 37 percentage points (q-value 0.03) and the probability of operating a home business by 12 percentage points (q-value 0.10). As in the preceding analysis, the results are concentrated among females, with effects of 51 and 21 percentage points, respectively. These point estimates are remarkably close to those in Table IV, suggesting that the income generating activities that arose due to electrification were not temporary, but persisted over the course of the study. Following the previous patterns, the point estimates for males are not statistically significant. While the coefficient on nonfarm employment is large and noisy, the coefficient on operation of home business is close to zero.

[INSERT TABLE VII ABOUT HERE]

V HOUSEHOLD RESPONSE TO DISCOUNT VOUCHERS

In this section we develop an intertemporal model of technology adoption allowing consumers to be present-biased. We show that in our setting, vouchers allocated to neighbors had a large effect on the household's effort to connect. Next, we estimate the present bias parameter. Finally, we show that offering time-limited discounts towards the connection costs can be profitable for the electric utility, even as it must subsidize households that would have connected without the subsidy.

V.A HOUSEHOLD PREFERENCES

We set up a multiple period model where households decide when (and whether) to connect to the electric grid. Households derive utility from leisure and an aggregate consumption good, which they purchase with labor income. Access to electricity improves utility from consumption of the aggregate good (e.g. with refrigeration, households are able to store perishable goods, reducing food losses) and leisure (TV) but it also allows performing productive activities (nonfarm activities, and allowing household members to study and perform business-related activities at night) that raise income and thus allow to increase consumption. Consistent with most rural settings in developing regions, these are small businesses and may start quickly, for instance by using the home refrigerator to sell refrigerated goods or using kitchen appliances prepare food for sale.

Hence, when evaluating whether to connect to the electric grid, off-grid households take into account both the utility they expect from consumption and the additional consumption derived from productive activities. These benefits are measured by a variable b that follows some unknown distribution with finite mean and variance. Adopting an electric connection requires incurring in an immediate cost c_F, which includes monetary and non-monetary costs (c_M and c_N, respectively). Monetary costs include internal wiring, inspection fee, and large appliances (refrigerator and leisure equipment like TV), while non-monetary costs include the cognitive effort of learning about the application process and of planning ahead, finding a contractor, deciding which appliances to purchase, and so on.

Empirically, there is a time lag between the moment a household decides to connect to the grid and the moment it can use electricity. For instance, in our study setting, once households decide they want to get a grid connection, they need to install wiring and may need to upgrade the materials on their walls and ceiling, after which they need to schedule and pass the inspection. Once this is done they need to submit paperwork to the utility and wait for it to be processed and approved. Upon approval of the paperwork a certified technician visits the home and connects it to the grid. The whole process may take a few months. We model the lag between the decision to connect and the moment the grid connection is operative by assuming electricity takes one period to work after the investment is done. Starting one period after households pay c_F, electricity generates consumption benefits b each period, net of variable costs and measured in units of the consumption good. Household utility is increasing in its expected value and decreasing in its variance. Let $E_t[b]$ and $E_tV[b]$ denote the expected value and expected variance of b, respectively, from period t's perspective.

Before the grid becomes available, households start from an equilibrium in which each period they work l hours and earn income $m(l)$ which they allocate to the aggregate consumption good e. Thus, each period without electricity, household utility is $U(e, l)$, which we normalize to zero. There are no credit markets, so households need to finance the connection cost c_M with their own resources, either reducing consumption or increasing labor supply. Let e_I denote the reduction in consumption and l_I the increase in labor, such that $e_I + m(l_I) = c_M$. Household consumption and labor supply will adjust in order to finance the monetary costs of grid connection, so in the period when households connect the budget constraint becomes: $(e - e_I) + c_M \leq m(l + l_I)$.

In the period when households adjust their consumption and labor supply to afford the electric connection, their utility reduces to $U(e - e_I, l + l_I)$. We assume $U(e - e_I, l + l_I) = U(e, l) - \nu(c_F) = -\nu(c_F)$. Households may be present-biased ($\beta \leq 1$) and discount across periods in the future at a rate $0 \leq \delta \leq 1$. Let $U^j(\tau)$ be the expected utility from adopting a connection at time τ from the perspective of period j (O'Donoghue and Rabin, 1999), and let l_E be total labor supply once the household is connected to the grid. Then,

$$U^j(\tau) = \beta \sum_{t=\tau+1}^{T} \delta^{t-1} U(e+b, l_E) - \nu(c_F) \qquad \text{if } \tau = j \tag{3}$$

$$U^j(\tau) = \beta \sum_{t=\tau+1}^{T} \delta^{t-1} U(e+b, l_E) - \beta\delta^{\tau-1}\nu(c_F) \qquad \text{if } \tau > j \tag{4}$$

Households adopt electricity in period 1 if $U^1(1) \geq U^1(\tau)$, $\forall \tau > 1$ and if the connection is affordable. The former condition holds when:

$$\beta \sum_{t=2}^{\tau} \delta^{\tau-1} U(e+b, l_E) \geq (1 - \beta\delta^{1-\tau})\nu(c_F) \tag{5}$$

Intuitively, for households to adopt in the first period, the net present value of profits from periods 2 through τ must outweigh the cost of paying c_F in the first period instead of τ periods into the future.

To keep the model tractable, we will assume that $U^1(t) > U^1(t+1)$, $\forall t \geq 2$.[4] Thus, households for whom it is optimal to adopt in the future prefer to adopt earlier rather than later. Under this simplifying assumption, the problem collapses to deciding between connecting in the first or second period. Households prefer to connect in the first period when

$$V = \left(\frac{\beta\delta}{1-\beta\delta}\right) U(e+b, l_E) - \nu(c_F) \geq 0 \tag{6}$$

Thus, the probability of connecting in the first period is given by:

$$\Pr(\text{connect in t=1}) = \Pr\left(\frac{\beta\delta}{1-\beta\delta} U(e+b, l_E) - \nu(c_F) \geq 0\right) \times \Pr(e - e_I + c_M \leq m(l + l_I)) \tag{7}$$

and otherwise, from period 1's perspective, they defer adoption to t=2. However, naive

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[4] This holds mechanically in the special case of $\delta = 1$.

households who find it optimal to adopt in the second period ignore their preferences will be updated at the start of that period, so they will postpone the adoption indefinitely.

To simplify notation, let Θ denote the probability that (6) holds, and Γ the probability that the budget constraint is satisfied. Then, the probability of connecting in the first period is:

$$\Psi = \Theta \times \Gamma \tag{8}$$

Since connection is observed, it is possible to estimate Ψ empirically, but not its components separately.

V.B FLEXIBILITY OF THE BUDGET CONSTRAINT

Our experiment induced exogenous variation in the inspection fee by offering discounts to randomly selected households if they connected early (within nine months of the project start date). Vouchers allocated to a household acted as a discount of x off the connection fee. This can induce households to adopt earlier by lowering the monetary connection cost c_M (relaxing their budget constraint) and reducing $\nu(c_F)$.[5] In addition, vouchers allocated to neighbors (s_{100}) increase knowledge of benefits from electricity for consumption and productive activities, lowering $E_t V[b]$. More knowledge about the benefits of electricity can also induce households to exert additional effort to finance their connection early, by reducing consumption or increasing income. Let $\omega = m - e$ denote the difference between household income and consumption. These resources are to be allocated to electrification. Then $\partial\omega/\partial s_{100}$ is the marginal response of the budget constraint to an increase in vouchers allocated to neighbors, and $\partial\omega/\partial x$ measures how the budget constraint responds to reductions

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[5] The second mechanism gains importance if c_F perceived as a loss and the household is loss averse, or if there is narrow bracketing.With narrow bracketing, households perceive a \$20 discount as large because they compare it to the \$100 inspection fee. If they compare it to the total cost of electrification, the \$20 are less salient.

in c_F, in line with the goal-gradient hypothesis (Hull, 1932, 1934).[6]

Deriving (8) with respect to x and s_{100}, we obtain the following system:

$$\frac{\partial \Psi}{\partial x} = \Gamma\theta\frac{\partial V}{\partial x} + \Theta\gamma\frac{\partial \omega}{\partial x} = \hat{\psi}_x \tag{9}$$

$$\frac{\partial \Psi}{\partial s_{100}} = \Gamma\theta\frac{\partial V}{\partial s_{100}} + \Theta\gamma\frac{\partial \omega}{\partial s_{100}} = \hat{\psi}_{100} \tag{10}$$

where lower case greek letters denote the density functions. Equation (9) shows that the marginal effect of a discount on connection is a weighted sum of the marginal utility and the marginal slack generated by the discount. The discount increases the probability of connection because it reduces the value of $\nu(c_F)$ and increases the likelihood that the budget constraint is satisfied. A similar reasoning applies regarding the marginal effect of a discount allocated to a neighbor using equation (10). The theoretical model allows decomposing these effects into density functions, cumulative functions, marginal utilities, and marginal budget responses. Our experiment allows estimating the left-hand-side expressions in each equation, but not the marginal effects separately.

Dividing (9) by (10) we can solve for the marginal rate of substitution between s_{100} and x:

$$MRS_{s_{100},x} = \frac{\frac{\partial V}{\partial x}}{\frac{\partial V}{\partial s_{100}}} = \frac{\hat{\psi}_x - \Theta\gamma\frac{\partial \omega}{\partial x}}{\hat{\psi}_{100} - \Theta\gamma\frac{\partial \omega}{\partial s_{100}}} \tag{11}$$

Since the numerator is the marginal utility of a discount we assume it to be positive. Hence,

$$\frac{\hat{\psi}_x}{\frac{\partial \omega}{\partial x}} \geq \Theta\gamma \tag{12}$$

Plugging this in the denominator, which we also assume positive, we get a lower bound on

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[6] The goal-gradient hypothesis states that humans exert more effort in a task when they are closer to completing it.

the marginal rate of response of the budget constraint to one dollar allocated to a neighbor relative to a one dollar discount allocated to the household:

$$\frac{\frac{\partial \omega}{\partial s_{100}}}{\frac{\partial \omega}{\partial x}} \geq \frac{\hat{\psi}_{100}}{\hat{\psi}_{x}} \tag{13}$$

Estimating this expression from our results provides a lower bound of 0.36, which means that providing a discount to a neighbor has at least one-third of the effect of providing the discount to the household. To provide a sense of the magnitude of this figure, assume that $\partial\omega/\partial x = 1$, meaning that if households receive a one dollar subsidy for connection, their budget increases by one dollar and they do not exert additional effort to finance their connection as would predict the goal-gradient hypothesis. In this case, $\partial\omega/\partial s_{100} \geq 0.36$, meaning that \$20 discount allocated to a neighbor increases the slack in the household's budget constraint by at least \$7.20. This sizable effect indicates that in our study setting, the budget constraint was highly responsive to discounts received by neighbors, suggesting that in this setting, households had either unexploited income-earning opportunities available, were able to cut consumption, or a combination of both. This bound can be estimated from the findings in Bernard and Torero (2013), which results in a lower bound of 0.03. This is suggestive that our setting is considerably more dynamic than their study, potentially explaining the lack of effects of electrification in the authors find in Ethiopia.

The natural question is then why were our study subjects not taking advantage of these income earning opportunities. The next subsection argues this is largely because of present bias.

V.C PRESENT BIAS

Four years after baseline, households that received a \$20 discount were still 10 percentage points more likely to be on the grid than households that had to pay the full price. This is especially surprising given the large benefits found in our setting together with the evidence from the previous section. Given our experimental design, this gap can be attributed to the \$20 discount. The persistence of this gap suggests present bias may be important. In this section we calibrate a model to estimate β, the present bias parameter. In this subsection we use connection rates for the period when the vouchers were valid (the first follow-up). In addition, we make a few additional assumptions.

First, we focus on households for whom the budget constraint is satisfied in period 1. This limits the scope of our conclusions, but avoids the need for distributional assumptions about Γ. In line with our findings from section IV.B, we assume that, if the household gets a grid connection, a female will engage in productive activities and obtain benefits of \$450 per year. In our data, c_F is approximately US\$ 400. This includes the inspection (\$100) wiring and lighting (\$100) and a large appliance (\$200).

Following Duflo, Kremer, and Robinson (2011), we simplify the utility function so that it is equal to the consumption in that period, but we incorporate loss aversion. We assume the payment of c_F is perceived as a loss, so we incorporate a loss-aversion parameter of λ. Thus, a household connects if:

$$\left(\frac{\beta\delta}{1-\beta\delta}\right) b - \lambda c_F \geq 0 \tag{14}$$

where we have used our previous assumption that $U(e) = 0$, so $U(e + b) = U(b) = b$. In line with the literature review by Kremer, Rao, and Schilbach (2019) let $\lambda = 2.5$, $\delta = 0.9$.

Now, assume $\beta \sim U[\beta_L, \beta_H]$. Let $p = \Pr(\beta\delta b - (1-\beta\delta)\lambda c_F \leq 0) \equiv Pr(\lambda \leq 0)$. Thus, $\lambda \sim$ uniform $[\beta_L\delta(b+\lambda c_F) - \lambda c_F, \beta_H\delta(b+\lambda c_F) - \lambda c_F]$. To ease notation, let $\beta_L\delta(b+\lambda c_F) - \lambda c_F = \gamma_L$ and $\beta_H\delta(b + \lambda c_F) - \lambda c_F = \gamma_H$. We assume that $\gamma_L < 0 < \gamma_H$, so that some households find it profitable to connect and others do not. Under these assumptions, the probability that a household remains off-grid is:

$$\int_{\gamma_L}^{0} \frac{dx}{\gamma_H - \gamma_L} = \frac{-\gamma_L}{\gamma_H - \gamma_L} = \frac{-\beta_L\delta(b + \lambda c_F) + \lambda c_F}{(\beta_H - \beta_L)\delta(b + \lambda c_F)} = p_1 \tag{15}$$

By the first follow-up survey, the connection rate among households facing the full cost was 40%, which gives the value for p_1. Households with connection costs of $c_F - 20$ and $c_F - 50$ had connection rates of 50 and 60%, respectively. This provides three equations to estimate two unknowns: β_L and β_H. Rather than estimating a third parameter, we use the third equation to test the fit. Using the unsubsidized group and the group with the \$50 voucher, we find $\hat{\beta}_L = 0.67$ and $\hat{\beta}_H = 0.83$, implying $\hat{E}[\beta] = 0.75$.[7] A present bias parameter of 0.75 is in line with the value of 0.8 commonly used in the literature (Kremer, Rao, and Schilbach, 2019).This degree of present bias can certainly explain the persistence of the difference between voucher recipients and non-recipients four years after baseline. We see this by using $\hat{\beta}_L$ and $\hat{\beta}_H$ to estimate the connection rate for the group that received the \$20 discount, which was excluded in the calculation of these parameters. Doing so results in a predicted rate of 0.52, close to the observed rate of 0.48. The accuracy of this prediction is reassuring in that the assumptions used in the exercise are adequate in our study setting, at least to some extent.

V.D IMPLICATIONS FOR INFRASTRUCTURE FINANCING

In this section we study the conditions under which the electric utility would benefit by offering to share connection costs with the beneficiaries (for a limited time), by increasing its client base early on in the project. Note that the electric company is a natural monopolist that cannot set price, which is determined by the regulator, or costs. However, it could increase its customer base by paying a fraction of the connection fee.

Let household benefits from electrification be given by γ, defined as in the previous subsection, which follows some density function $f(\gamma)$. In this model, households that can afford the connection will connect if $\gamma > 0$, and otherwise will remain off-grid.

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[7] Any combination of equations renders essentially the same results. Using the \$20 off instead of the \$50 group renders $\hat{\beta}_L = 0.69$ and $\hat{\beta}_H = 0.81$, implying $\hat{E}[\beta] = 0.75$. Using the two voucher recipients results in $\hat{\beta}_L = 0.65$ and $\hat{\beta}_H = 0.86$, implying $\hat{E}[\beta] = 0.76$.

The utility's profits are given by

$$\Pi = \sum_{i=1}^{N} T_i(x)\left(R(q_i)q_i - x\right) - G_F \tag{16}$$

N is the total number of households within reach of the grid, $T_i = 1$ if household i is connected to the grid, 0 otherwise, $R(q_i) = p(q_i) - c(q_i)$ is the net present value of profits obtained from household i (net of household connection costs), q_i is the quantity of electricity consumed, x is the part of the connection fee paid by the firm, and G_F is the fixed cost of grid extension.

At each round households can be classified as follows: Always-Takers, Never-Takers, and Compliers, based on their reaction to receiving a voucher of x. *Always-takers* are households that would have connected even without the discount ($\gamma_H \geq \gamma \geq 0$). *Never-takers* are households that would not connect even if they received the discount ($\gamma_L \leq \gamma < -x$). *Compliers* are households that would connect if and only if they receive the discount ($-x \leq \gamma < 0$). Note that $\frac{\Delta T_i}{\Delta x}$ can take only one of two values. It is zero for always takers and never takers, and one for compliers.

$$\frac{\Delta T_i}{\Delta x} = \begin{cases} 1 & \text{if } -x < \gamma < 0 \\ 0 & \text{otherwise} \end{cases} \tag{17}$$

Theoretically, x could have an effect along the extensive and intensive margins, but we assume there is no effect along the intensive margin. This simplifies the algebra at little cost in terms of insights. This assumption is perhaps more appealing if we think of intertemporal extensions to this model, where, conditional on having a grid connection, lifetime electricity consumption would vary little by receiving a \$20 or \$50 discount on the connection fee.

Furthermore, assume that q_i is constant among compliers. Thus,

$$R(q_i)q_i = \widehat{Rq} \quad \forall i : x < \gamma_i < 0 \tag{18}$$

With this, we can write a first order condition for x, setting the expected revenue equal to the expected cost:

$$\widehat{Rq}\int_{-x^*}^{0} df(\gamma) = x^*\left(\int_{-x^*}^{0} df(\gamma) + \int_{0}^{\gamma_H} df(\gamma)\right) \tag{19}$$

Equation (19) requires that the marginal revenue obtained by the utility from the compliers when offering a discount of x^* must be sufficient to face the cost of x^* for compliers and always-takers.

If we impose a uniform distribution for γ like in the previous subsection, we get

$$\widehat{Rq}\int_{-x^*}^{0} \frac{dy}{\gamma_H - \gamma_L} = x^*\int_{-x^*}^{\gamma_H} \frac{dy}{\gamma_H - \gamma_L} \tag{20}$$

Solving for x^*:

$$x^* = \widehat{Rq} - \beta_H\delta(b + \lambda c) - \lambda c \tag{21}$$

Thus, the utility benefits from offering time-limited discounts if $Rq > \beta_H\delta(b + \lambda c) - \lambda c)$. The optimal discount is increasing in the revenue obtained from compliers (Rq), decreasing in β_H, δ, b, λ and c, as a higher values of these parameters imply more always takers that need to be financed with $\widehat{Rq}$. An increasing dependence on β_H means that the optimal subsidy is directly proportional to the average degree of present bias in the population.

VI CONCLUSIONS

This paper studies the effects of rural electrification in El Salvador in an experimental setting. Our findings are based on data from four yearly follow-up surveys, spanning from 2009 to 2014, which allows to look at the long term effects of electrification. We have a number of key findings. The evidence we present in this paper complements the findings in Barron and Torero (2017), where we show that electrification leads to improvements in indoor air pollution, which reduced the incidence of acute respiratory infections among children.

Our experimental design paired with four years of follow-up surveys allows to shed light on a number of issues. Our first important finding is that even four years after baseline, recipients of time-limited discounts still had a higher connection rate than the non-encouraged grouop. Given the size of the benefits we discuss below, this is not likely due to the size of the discount, and more likely due to quasi-hyperbolic discounting. Our theoretical model confirms this by providing a present bias estimate of 0.75, which indicates a relatively high degree of present bias. Therefore, our evidence shows that nudges can have long term effects on electricity adoption. Second, in line with Bernard and Torero (2013), we find evidence of spillovers: household adoption is directly affected by the number of vouchers received by their neighbors. Using their estimates provides an income elasticity measure of 0.03, an order of magnitude lower than estimate of 0.36 found in this study. This difference indicates stark differences in economic opportunities across settings, potentially explaining why electricity had no effects in their paper. Third, in line with Dinkelman (2011) we find that electrification increases labor supply among females in the extensive margin, not among males. Female participation in home businesses and nonfarm employment increases by 56 and 26 percentage points, respectively. In consequence, female income increases significantly, by $450 per year (0.5 standard deviations). Most of this increase arises from earnings, while non-labor income is unaffected. Analysis of time allocation shows that children and adult males had no discernible activity changes in the extensive or intensive margin, while females had a large extensive and intensive margin increase in labor activities. As to the type of businesses they operate, electrification increased refrigerator ownership, suggesting that some of these home businesses were related to home shops selling refrigerated products.

We analyze the timing of the labor market effects and show that they appear in both halves of the study period. The effect on engagement in nonfarm income generating activities appeared in the first half of the study period and increased towards the second half. Since the effect on income is unchanged, this suggests that the profitability decreased towards the second half of the period. Finally, our model shows that the electric utility can actually increase its revenues by providing discount vouchers in a similar fashion as in this study, given that vouchers increase the utility's customer base and revenue flows, despite the need to subsidize households that would have connected without the subsidy.

Overall, our results suggest that electrification may increase household income by allowing access to nonfarm employment. This is possible because our study setting has some degree of economic dynamism and households had income generating opportunities at hand, which were not being exploited.

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Figure 1: Connection Rates by Treatment Arm

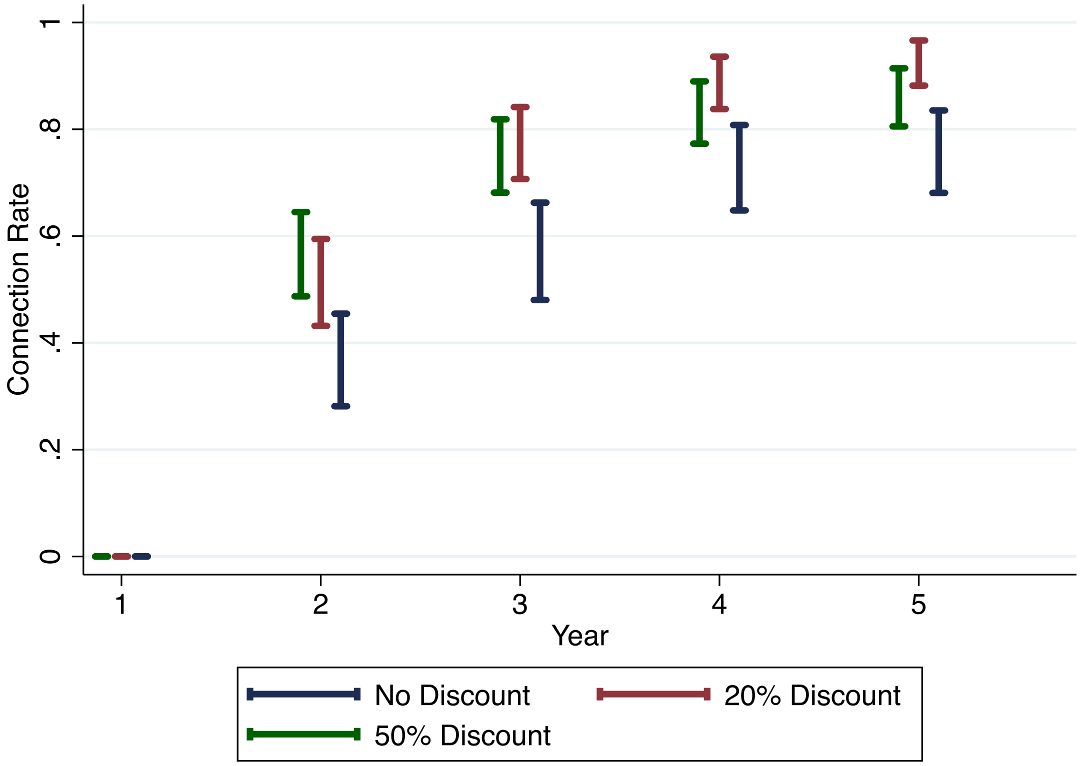

Table I: Descriptive Statistics and Balance

Variable	Control Group	20% Discount	Diff C-20%	50% Discount	Diff C-50%
Age of household head	49.12	50.80	1.68	48.99	-0.13
	(1.48)	(1.95)	(1.95)	(1.94)	(1.94)
Household head is male	0.61	0.72	0.11**	0.72	0.11**
	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)
Schooling of the household head	1.93	2.03	0.11	2.23	0.31
	(0.29)	(0.38)	(0.38)	(0.38)	(0.38)
Household head is literate	0.49	0.49	0.00	0.52	0.03
	(0.04)	(0.06)	(0.06)	(0.06)	(0.06)
Household size	4.21	4.65	0.44	4.82	0.61**
	(0.21)	(0.27)	(0.27)	(0.27)	(0.27)
Total dependency ratio	0.47	0.44	-0.02	0.43	-0.03
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Maximum schooling in the household	5.47	5.76	0.29	5.76	0.29
	(0.36)	(0.48)	(0.48)	(0.48)	(0.48)
Nonfarm Income (USD/year)	999.77	791.87	-207.90	1,124.73	124.96
	(275.60)	(363.94)	(363.94)	(351.73)	(351.73)
Farm Income (USD/year)	491.37	657.59	166.21	676.19	184.81
	(139.80)	(184.61)	(184.61)	(178.42)	(178.42)
Cooks with wood	0.76	0.73	-0.03	0.73	-0.03
	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)
Informal connection at baseline	0.38	0.50	0.12**	0.48	0.10*
	(0.04)	(0.06)	(0.06)	(0.06)	(0.06)
Perceptions on traditional and modern energy					
Electricity illuminates better than kerosene.	0.96	0.95	-0.01	0.97	0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Powering a TV is cheaper w/elect than battery.	0.79	0.74	-0.06	0.81	0.02
	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)
Cooking with electricity is not convenient	0.62	0.46	-0.16***	0.50	-0.12**
	(0.04)	(0.06)	(0.06)	(0.06)	(0.06)
Electricity is very expensive	0.54	0.43	-0.10*	0.47	-0.06
	(0.04)	(0.06)	(0.06)	(0.06)	(0.06)
Woodsmoke generates respiratory problems	0.88	0.84	-0.04	0.87	-0.00
	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)
Kerosene is not an expensive source of lighting	0.42	0.35	-0.08	0.32	-0.11*
	(0.04)	(0.06)	(0.06)	(0.05)	(0.05)
Kerosene is the best way to illuminate my household	0.28	0.20	-0.08*	0.20	-0.08*
	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)

Notes: Column (1) reports the mean in the control group. Columns (2) and (4) report the means in the 20 and 50% discount voucher groups. Columns (3) and (5) test the difference between the control and the voucher recipient groups. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*

Table II: First Stage: Voucher Allocation and Connection

	(1) Connected	(2) Connected	(3) Connected	(4) Connected
20 USD Voucher x Post	0.122***	0.126***		
	(0.045)	(0.046)		
50 USD Voucher x Post	0.116**	0.117**		
	(0.045)	(0.047)		
Voucher x Post			0.119***	0.121***
			(0.041)	(0.042)
s100 x Post	0.132***	0.129***	0.133***	0.130***
	(0.038)	(0.039)	(0.037)	(0.038)
Baseline Covariates	No	Yes	No	Yes
Observations	2269	2205	2269	2205
Number of Households	494	481	494	481
F-Stat	10.0	9.7	15.0	14.4

Notes: Dependent variable is household electric connection. All regressions control for voucher, s100, and round fixed effects.Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*

Table III: Effect Heterogeneity

	(1) Walls	(2) Low Income	(3) Informal Connection	(4) Age>50	(5) Schooling
Voucher x Post	0.017	0.116**	-0.003	0.124**	0.075
	(0.060)	(0.053)	(0.048)	(0.052)	(0.049)
... x Interacted	0.122*	0.005	0.285***	-0.017	0.092
	(0.065)	(0.057)	(0.052)	(0.057)	(0.056)
s100 x Post	0.085	0.172***	0.149***	0.130**	0.181***
	(0.069)	(0.051)	(0.051)	(0.054)	(0.052)
... x Interacted	0.068	-0.075	-0.104	-0.001	-0.099
	(0.079)	(0.072)	(0.067)	(0.072)	(0.071)
Observations	2269	2252	2269	2254	2259
Number of Households	494	490	494	491	492

Notes: Dependent variable is household electric connection. All regressions control for voucher, s100, and round fixed effects.Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*

Table IV: Effects on Labor and Income

		All			Female			Male	
	Baseline Mean	IV	q-val	Baseline Mean	IV	q-val	Mean Mean	IV	q-val
Engages in nonfarm employment	0.19	0.410***	0.02	0.20	0.564***	0.02	0.18	0.267	0.55
		(0.137)			(0.192)			(0.169)	
Owns or operates home business	.	0.116	0.15	.	0.259**	0.04	.	-0.022	0.81
		(0.074)			0.122			(0.90)	
Income (1000 USD / year)	0.26	0.374**	0.04	0.19	0.452**	0.03	0.33	0.219	0.81
		(0.155)			(0.193)			(0.249)	
Earnings (1000 USD / year)	0.18	0.244*	0.11	0.10	0.329**	0.03	0.26	0.128	0.81
		(0.131)			(0.132)			(0.230)	
Non-labor income (1000 USD / year)	0.07	0.081	0.31	0.09	0.078	0.52	0.06	0.040	0.81
		(0.079)			(0.120)			(0.094)	
Households		481			456			454	

Notes: Dependent variables indicated in the row. Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Columns 3, 6, and 9 report the FDR q-values. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*

Table V: Appliance Ownership

Appliance	Baseline Mean	IV	q-val	Appliance	Baseline Mean	IV	q-val
Blender	0.20	0.166 (0.141)	0.32	Microwave	0.04	0.083 (0.068)	0.32
Computer	0.02	0.109 (0.070)	0.28	Radio	0.71	0.041 (0.172)	0.81
DVD player	0.17	0.193 (0.119)	0.28	Sewing machine	0.08	-0.069 (0.071)	0.40
Fan	.	0.111 (0.088)	0.32	Stereo	0.25	0.420** (0.175)	0.07
Fridge	0.31	0.592*** (0.195)	0.02	TV	0.56	0.242 (0.184)	0.32
Iron	0.31	0.099 (0.164)	0.60	Washing machine	0.03	0.136** (0.057)	0.07

Notes: Dependent variables are indicators of ownership of the appliances indicated in the column title. Fan was not included in the baseline survey. Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*

Table VI: Timing

	All		Female		Male	
	Rounds 2 & 3	Rounds 4 & 5	Rounds 2 & 3	Rounds 4 & 5	Rounds 2 & 3	Rounds 4 & 5
Engages in nonfarm	0.306***	0.514**	0.466***	0.654**	0.175	0.355
employment	(0.113)	(0.205)	(0.173)	(0.277)	(0.144)	(0.247)
FDR q-value	[0.060]	[0.060]	[0.046]	[0.046]	[0.748]	[0.748]
Owns or operates	0.090	0.150	0.232*	0.289*	-0.047	0.012
home business	(0.080)	(0.099)	(0.130)	(0.166)	(0.096)	(0.114)
FDR q-value	[0.325]	[0.186]	[0.103]	[0.103]	[0.748]	[0.913]
Income	0.306**	0.437**	0.445**	0.471*	0.128	0.290
(1000 USD / year)	(0.153)	(0.219)	(0.190)	(0.267)	(0.243)	(0.349)
FDR q-value	[0.118]	[0.118]	[0.046]	[0.103]	[0.748]	[0.748]
Earnings	0.235*	0.251*	0.330**	0.318**	0.138	0.170
(1000 USD / year)	(0.132)	(0.132)	(0.144)	(0.137)	(0.227)	(0.235)
FDR q-value	[0.124]	[0.118]	[0.046]	[0.046]	[0.748]	[0.748]
Non-labor income	0.051	0.081	0.138	0.078	-0.065	0.040
(1000 USD / year)	(0.062)	(0.079)	(0.098)	(0.120)	(0.081)	(0.094)
FDR q-value	[0.416]	[0.339]	[0.177]	[0.515]	[0.748]	[0.748]

Notes: Dependent variables are indicated by the row title. Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. FDR q-values in brackets. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence.

Table VII: Timing

	All	Female	Male
Engages in nonfarm employment in both periods	0.371**	0.508**	0.191
	(0.151)	(0.236)	(0.179)
	[0.030]	[0.061]	[0.568]
Owns or operates a home business in both periods	0.115	0.210*	0.010
	(0.070)	(0.112)	(0.072)
	[0.103]	[0.061]	[0.890]
Number of households	456	421	390

Notes: Dependent variables are indicated by the row title. Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. FDR q-values in brackets. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence.

Online Appendix

Table A.1: First stage estimates, round by round

	(1) Connected	(2) Connected	(3) Connected	(4) Connected
Voucher x Round 2	0.172***	0.167***	0.140**	0.138**
	(0.052)	(0.051)	(0.054)	(0.054)
Voucher x Round 3	0.190***	0.161***	0.145***	0.120**
	(0.051)	(0.052)	(0.055)	(0.055)
Voucher x Round 4	0.131***	0.106**	0.098**	0.079
	(0.044)	(0.046)	(0.047)	(0.049)
Voucher x Round 5	0.133***	0.108**	0.093**	0.074
	(0.042)	(0.044)	(0.043)	(0.045)
s100 x Round 2			0.119**	0.110**
			(0.055)	(0.053)
s100 x Round 3			0.161***	0.149***
			(0.051)	(0.049)
s100 x Round 4			0.113***	0.095**
			(0.041)	(0.041)
s100 x Round 5			0.139***	0.121***
			(0.036)	(0.036)
Baseline Covariates	No	Yes	No	Yes
Observations	2269	2205	2269	2205
Number of Households	494	481	494	481
F-Stat	4.15	9.74	4.39	7.78

Notes: Dependent variable is household electric connection. All regressions control for voucher, s100, and round fixed effects.Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*

Table A.2: Connection rates and connection fee

	(1) Connected	(2) Connected	(3) Connected	(4) Connected
Fee x Post	-0.237***	-0.194**	-0.207**	-0.169*
	(0.086)	(0.088)	(0.086)	(0.087)
Fee100 x Post			-0.349***	-0.316***
			(0.100)	(0.096)
Baseline Covariates	No	Yes	No	Yes
Observations	2269	2205	2269	2205
Number of Households	494	481	494	481
F-Stat	7.55	13.70	9.81	13.69

Notes: Dependent variable is household electric connection. All regressions control for voucher, s100, and round fixed effects.Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*

Table A.3: Effects of Electrification on Time Allocation, IV Estimates

	Chores		Labor		Leisure		Education	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Pr(t>0)	t	Pr(t>0)	t	Pr(t>0)	t	Pr(t>0)	t
Adult females	-0.012	-1.957	0.471**	3.890**	-0.046	-1.376		
	(0.109)	(1.264)	(0.207)	(1.626)	(0.066)	(1.377)		
Observations	1548	1548	1548	1548	1548	1548		
Households	358	358	358	358	358	358		
Mean Dep Var at baseline	0.97	6.59	0.36	1.92	1.00	6.25		
First Stage F-stat	7.10	7.10	7.10	7.10	7.10	7.10		
Adult males	-0.307	-1.097	-0.452	0.418	-0.228*	-1.743		
	(0.258)	(1.111)	(0.283)	(2.498)	(0.118)	(2.065)		
Observations	1144	1144	1144	1144	1143	1143		
Households	269	269	269	269	269	269		
Mean Dep Var at baseline	0.39	1.03	0.85	6.97	1.00	6.77		
First Stage F-stat	3.26	3.26	3.26	3.26	3.18	3.18		
Children	0.231	1.011	0.008	-0.688	0.048	0.313	0.001	-0.547
	(0.251)	(1.249)	(0.220)	(1.734)	(0.083)	(1.942)	(0.181)	(1.203)
Observations	765	765	765	765	765	765	765	765
Households	192	192	192	192	192	192	192	192
Mean Dep Var at baseline	0.67	2.36	0.19	1.12	1.00	8.84	0.23	1.32
First Stage F-stat	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76

Notes: Dependent variable: odd columns are indicators of participation in the activities indicated in the column title; even columns are hours per day. Both are in relation to the Monday preceding the survey. Baseline covariates are sex of the household head, household size, informal access to electricity, and agreeing that cooking with electricity is not convenient. Standard errors clustered at the household level, reported in parentheses. Significantly different than zero at 90(*), 95(**), and 99(***) percent confidence. Source: *Household Electrification Survey.*