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Long-Term Impacts of Household Electrification in Rural India

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Abstract

India's huge expansion in rural electrification in the 1980s and 1990s offers lessons for other countries today. The paper examines the long-term effects of household electrification on consumption, labor supply, and schooling in rural India over 1982–99. It finds that household electrification brought significant gains to consumption and earnings, the latter through changes in market labor supply. It finds positive effects on schooling for girls but not for boys. External effects are also evident, whereby households without electricity benefit from village electrification. Wage rates were unaffected. Methodologically, the results suggest sizeable upward biases in past estimates of the gains from electrification associated with how past analyses dealt with geographic effects.

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Long-Term Impacts of Household Electrification in Rural India

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1. Introduction

A great many people in the world still do not have electricity. In much of the developing world, households continue to rely on traditional sources of fuel for lighting, heating and cooking. Indeed, it is estimated that 1.3 billion people in 2009 were still without electricity.[2]

Rural households in the developing world can spend a lot of time collecting and preparing fuel for domestic use. Many continue to cook with wood and biomass (mainly dung) with deleterious effects on the health of family members. Across the world, these time and health burdens are thought to be higher for women and the children under their care. Over recent decades, governments and donors have made a concerted effort to bring more efficient sources of energy, particularly electricity, to rural households.

It is often simply assumed that electrification will result in significant welfare gains for households and particularly women within then. Referring to policy discussions in the 1970s and 1980s, Barnes and Binswanger (1986, p.26) note the "blind faith placed in rural electrification." Still, agreement on this faith is not universal, with some observers expressing skepticism on the claimed benefits of electrification over other energy sources.[3] There are concerns about both internal and external validity of past evidence. In an extensive review of the literature, the World Bank's Independent Evaluation Group (2008, p. xvii) concluded that "… the evidence base remains weak for many of the claimed benefits of rural electrification." Similarly, Bernard (2010, p. 41) writes that "While funding for rural electrification programs often rests on their supposed impacts on such outcomes as health, education, or poverty level, there is still very little empirical evidence to substantiate them."

A number of issues make identification of the household welfare impacts of rural electrification difficult. Three stand out. First, there is the potential for electricity acquisition to be jointly determined with outcomes or correlated with omitted variables. Second, non-random placement is likely to entail sensitivity to the choice of regression controls. Third, there are likely to be external effects of electrification in the village, which could well bring benefits to an individual household even if it did not have electricity itself. Indeed, some part of the externality

[2] See World Energy Outlook (WEO) 2011, published by the International Energy Agency. The WEO estimates that in 2009 25% of the population of the developing world was still without electricity, and the proportion rises to 37% in rural areas. In South Asia, the corresponding proportions are 32% and 40%, while in Sub-Saharan Africa they were 69% and 86%.

[3] See, for example, the discussion in Mathur and Mathur (2005) with regard to India's "Electricity for All" program. Also see the discussion in Barnes and Binswanger (1986).

may also be asymmetric in that certain types of benefits accrue to those who do not already have electricity much more than to those who do.

Recent developing-country studies have tackled these issues in different ways, depending on the nature of electricity expansion and related assumptions on how the electricity rollout is related to other factors affecting household labor supply. The studies vary considerably in their treatment of electrification when estimating impacts. A number of studies recognize the endogeneity of placement issue, though sensitivity to controls and external effects are rarely discussed. It has become common to exploit geographic variables for identification under conditional independence assumptions ("exclusion restrictions"). Those assumptions appear to be more plausible in some applications than in others.

Efforts to address the identification problem using single cross-sectional surveys are plagued by concerns about the endogenous placement of electricity. Randomized approaches are difficult with rural electrification because of the large-scale and political nature of such programs.[4] Observational panel data studies help address these concerns, to the extent that the endogeneity can be fully accounted for in the correlation between placement and time invariant factors that can be differenced out using the panel data. However, the acquisition of electricity within the time period is still likely to be endogenous to changes in outcomes at household level. This has been dealt with in the literature by either adding controls for initial conditions that are likely to be correlated with subsequent trajectories or by using an instrumental variables estimator. Both methods require a conditional independence assumption, namely that the error term in the outcomes regression must be conditionally independent of either placement or its instrumental variable (IV).

This paper examines the effects of India's large expansion in rural household electrification on consumption, labor supply and schooling. We distinguish the internal effects of household electrification from the external effect of village electrification. Asymmetry in the external effects between households with and without their own electricity plays a role in our identification strategy, as does (time-varying) proximity to power generating plants.

We find long-term economic welfare gains from household acquisition of electricity, but also show that there are strong positive external effects of village connection to the grid for

[4] Two recent exceptions are ongoing studies that look at specific features of new electricity programs in rural Sub-Saharan Africa, where only 5 percent of households on average have electricity connections. These are ongoing and described in Bernard (2010).

households without electricity themselves. And we show that ignoring these external effects, and latent geographic heterogeneity, substantially biases impact estimates toward over-estimating the gains from rural household electrification. In particular, the use of village placement as an instrument for household placement is also seen to be a source of sizeable bias in some past estimation methods. Indeed, when compared to our preferred estimator, ignoring endogenous assignment across households appears to yield a less biased estimate than obtained by assuming that village placement only alters outcomes via household placement.

After reviewing the literature in the following section, we examine the impacts of electrification in a model of household time allocation. We then discuss our data (Section 4) and method specification (Section 5). Our results are presented in Section 6. Section 7 summarizes the lessons learnt from the study.

2. Arguments and evidence from the literature

The evidence on the economic gains from rural electrification is somewhat mixed. World Bank (2004) and Mathur and Mathur (2005) point to large differences in time allocation between rural Indian households with electricity and those without it, although concerns about endogenous selection clearly cloud the inferences that can be drawn. Some papers have reported evidence of seemingly large impacts of household electrification on household consumption, income and other dimensions of welfare in developing countries (Khandker et al. 2009a, b, 2012, 2013). Using data for India, Khandker et al. (2012) claim proportionate impacts of electrification on income of the order of 25-50%.[5] Other studies, including Bensch et al. (2011) using data for Rwanda, do not find such impacts.

Labor supply responses have figured prominently in past arguments. One popular hypothesis on the benefits of household electrification is that by relieving time burdens spent in collecting and preparing fuel, household electricity results in rural women engaging in market-based work (Wu, Borghans and Dupuy 2009; Dinkelman 2011; Kohlin et al. 2011). A number of studies using US data show that the introduction of household electrical appliances—by raising women's productivity in domestic work—can account for a large share of the increase in married American women's labor force participation in the 20th century (see, for example,

[5] These are coefficients on household electrification in regressions for the log of income, using village electrification rates as the instrumental variable. Estimates vary with the conditional quantile. Impacts were somewhat lower for consumption, but still sizable for the upper consumption groups.

Greenwood et. al., 2005; Coen-Pirani et. al., 2010).[6] Recent papers by Dinkelman (2011) and Grogan and Sadanand (2012) find similar effects on female employment (and not on male employment) for South Africa and Nicaragua, respectively. Dinkelman attributes this to the use of electric stoves and other time saving appliances.

Household electrification presumably increases the productivity of domestic production relative to other uses of time. However, this productivity effect may well be weak in poor rural economies. The evidence suggests that, with the rare exception, rural households in developing countries use electricity first and foremost for lighting, followed by powering televisions and fans (Bernard 2010; Barnes 2007; IEG 2008). Southern Africa appears to be unusual among developing countries in that rural households commonly use electricity for cooking (IEG 2008). The relevance of the Dinkelman (2011) results for South Africa to other developing countries, where most women continue to use traditional fuels and technologies for domestic tasks, is thus unclear. In some contexts, electricity may reduce the cost of lighting and is certain to improve lighting quality over traditional kerosene lighting devices.[7] However, since bio-fuels and firewood continue to be used for cooking in most rural settings, collection time is unlikely to be hugely affected, contrary to some claims (ADB 2010; Mathur and Mathur 2005; Barnes and Sen 2004). In India, there is also evidence that, given the cost and erratic electricity supply, reliance on kerosene for lighting is maintained alongside the use of electricity (Mathur and Mathur 2005; Rehman et al. 2005).

While the productivity effect may be weak in poor rural settings, there is another implication of household electrification that could well be very important. Electric lighting extends the time available for the many activities that need good lighting, thus enabling a rearrangement of tasks to evening hours. Household members can then continue their enterprise work, domestic duties, homework and reading into the evening with potential positive effects on earnings and living standards. For example, studies for Bangladesh suggest that with lighting, women spend a greater share of their evening hours in income generating activities (see Barkat 2002; Chowdhury 2010). Electrification may also foster small home-based enterprises (such as ironing and sewing services) and longer hours for these to be productive. Leisure activities too

[6] Contrast the American view with that of a judge in Japan who famously said: "modern appliances are partly responsible for failed marriages because they give women time to contemplate." (Hendry 2010).

[7] A typical device is a home-made or locally produced wick lamp. This is known to have low luminous efficiency and to generate smoke with potentially adverse health effects.

can be re-allocated, and this may well matter as much for men as for women. The adult male in any society requires a certain amount of leisure time. Without electricity, a significant share of that time will no doubt be in daylight hours, in which case it competes with labor supply. With electric light, there can be a substitution of male leisure from daylight hours to night time; for example, instead of sitting with friends at the tea shop or playing a sport during daylight hours, men can sit at home and watch TV in the evening once electricity is available.

There may well be other ways through which household electrification can increase welfare. Health effects may also result as electric lighting reduces the pollution from using candles or kerosene (IEG 2008). Traditional biomass fuels for cooking and kerosene lamps generate indoor air pollution that is a recognized health hazard, with health costs that are disproportionately borne by women and children.[8] While we do not directly examine impacts on health in this paper, this is a further channel whereby electrification can increase schooling, labor supply and consumption.

The implications for household expenditure on energy have also been prominent in the literature, often with claims about benefits from lower energy expenditures due to electrification (see, for example, Mathur and Mathur, 2005, in the context of rural India). However, while a lower price (per unit of energy consumed) can be expected to generate a welfare gain, there can be no presumption that total expenditure on energy provides an inverse welfare indicator. Spending on energy may increase due to electrification, and this can be a good thing.

Substitution amongst energy sources can also be expected. In India there is evidence that the highly subsidized kerosene ration that most households receive is substituted for cooking once electricity is used for lighting (Heltzberg 2004), although kerosene lamps and candles remain a common back-up given erratic electricity supply (Rehman et al., 2005). Such substitution can still entail welfare gains, of course; for example, even kerosene is considered a cleaner fuel for cooking stoves than traditional biomass.

The role of television is not well understood, but may well be more important than past economic analyses have allowed for. Television viewing may improve women's domestic productivity and welfare through greater knowledge (see, for example, Kohlin et al. 2011; ADB 2010). Research has documented significant effects on fertility from information about modern

[8] See Dasgupta et al (2006), using data for Bangladesh. Also see Duflo et al. (2008) for a review of the evidence on the health effects of indoor air pollution.

contraception gained from watching TV (IEG 2008; Peters and Vance 2010). By the same argument, other health related behaviors may alter and lead to better family nutrition, reduce child morbidity and result in overall health improvements. Television shows, such as popular soap operas, may also have a role in altering the bargaining power and possibly the preferences of women within a traditional rural household.

Any improved productivity for one member is likely to have implications for other members through re-allocations within the household. Schultz (1993), for example, discusses how changes in home-based technology such as electricity can reduce household dependence on girls' labor. This will reduce the opportunity cost to the parents of sending their girls to school.[9] A number of studies also examine whether lighting in the home increases time spent studying and affects student performance, with mixed findings (for example, Aturapane et. al. 2011; Amin and Chandrasehkar 2009; Bensch et al. 2012). On the other hand, increased time spent watching television may well reduce the time on these activities.

Past claims about the household-level impacts of electrification on employment are hard to reconcile with the classic characterization of an under-developed rural economy as having a large labor surplus—as in the famous Lewis (1954) model. In a setting with a large excess supply of labor one would not normally expect a purely supply-side change such as a household's electrification to directly increase employment. If the Lewis model is right, then the channel would have to involve relaxing the external quantity constraints on labor supply at the household level. However, it is important in this setting to distinguish formal (regular or casual) wage work from self-employment. The quantity constraints may well apply to the former but not the latter. For example, Dinkelman (2011) conjectures that the female employment effects she obtains (in a setting with unusually high unemployment rates[10]) are through self-employment, although her data (from census employment questions) do not allow this type of work to be identified.

Externalities appear to be pervasive in this context. It appears to be common that when one family in a village acquires electricity and a TV, other friends and family without a TV come

[9] For example, if schooling displaces child labor one-for-one then parents face a price of schooling equal to the child labor wage rate. While, there is evidence that one-for-one displacement is unlikely in a similar setting (Ravallion and Wodon, 2000), some displacement of activities within the household is plausible.

[10] Around the time period of Dinkelman's (2011) data (1996-2001), the female unemployment rate in South Africa was 40-50% and even higher in the region (KwaZulu-Natal) for which her data pertain (Bhorat and Oosthuizen, 2006). However, these are unusually high unemployment rates compared to other developing countries.

to watch the current favorite soap opera (say). Note that this externality is asymmetric, in that a household without electricity (and hence, quite probably, a TV) will benefit much more from a neighbor's acquisition than a household who already has electricity. The same is true of lighting. Khandker et al. (2013) separate the internal from the external gains from connection to the electricity grid in Vietnam and find evidence of external effects on household consumption, labor earnings and the schooling of girls (but not boys).

Geographic variables have played an important role in past efforts to identify the household-level impacts of electrification. Grogan (2012) uses distance to the power source, namely hydroelectric dams. Khandker et al. (2009a) use household proximity to an electricity line. Coen-Pirani et al. (2010) and Khandker et al. (2012) use the local geographic mean electrification (or appliance-ownership) rate as the IV for household electrification. A number of papers have been influenced by the identification strategy used by Duflo and Pande (2007) exploiting geological/topological features of the land; Duflo and Pande used local land gradient as an IV (in their case for dam placement). Dinkelman (2011) and Grogan and Sadanand (2012) use local land gradient as the IV for electricity placement.[11] Barham et al. (2013) use an estimated cost of hydropower dam placement based on geological features relevant to the cost of dam construction.

While all these variables are plausible predictors of household placement, the validity of the required exclusion restrictions is never beyond question. For example, the slope of the land influences agricultural productivity (positively for some crops, negatively for others) and so may shift domestic production functions in this setting; it may also influence the local prices of other goods and access to other infrastructure.[12] And, as we have noted, household electrification in a geographic area could well have an external benefit (including to non-electrified households), such as through greater employment opportunities or general equilibrium price effects on the village economy.[13] Geographic proximity to an electricity line is questionable given endogenous placement of those lines. However, this is of less concern in using long lags of proximity to the primary power source (from which the lines emanate). While the cables and sub-stations that

[11] Flatter land makes it cheaper to lay cables (Dinkelman, 2011).

[12] See Ravallion's (2008) comments on the use of land gradient as an IV for dam placement by Duflo and Pande (2007). This is arguably of less concern in some settings than others; for example it is arguably of less concern in the region of South Africa from which Dinkelman's (2011) data derive than in an all-India application (as here and in Duflo-Pande).

[13] Evidence on the effects on rural industrialization in India can be found in Binswanger, Khandker, and Rosenzweig (1993) and Rud (2012).

emanate from that source are endogenously placed, the source itself can more plausibly be treated as independent of household outcomes conditional on placement and other covariates. However, objections can still be raised about this identification strategy and indeed any of the various geographic IVs found in the literature. Of course, judgments on the plausibility of the identification strategy must also depend on what other control variables are used, given that the estimator is making a conditional independence assumption. Logically, the choice of controls should get as much attention as the choice of IV, though that is rarely the case in the literature.

3. Theoretical model of the impacts of household electrification

We adapt the long-standing economic model of household time allocation to the question of how electrification would alter work and consumption in a poor rural economy. In the light of the literature reviewed above and our own observations we focus this discussion on three areas: the productivity effects on domestic production, the budget effects on the amount of lighted time available and prices, and the external effects. Under the assumptions of our model, household electrification generates welfare gains, but these do not necessarily entail higher market labor supply or even higher consumption. That will emerge as an empirical issue.

Following Becker (1965) a key feature of the following model is the existence of production within the household, interpreted as either a self-employment activity (including farming) or domestic work, such as preparing meals. We modify the standard model to allow for two types of time, namely under light and in darkness. Labor supply to the market and domestic work (within the household) are more difficult in the darkness. Leisure is possible in either, but leisure in darkness is not a perfect substitute for leisure in the light. Domestic labor time is combined with market goods (including energy) to produce a commodity that is at least partly consumed within the household, though some can be sold in a competitive market. The household is also free to supply as much labor to the market as it likes, though we also consider the implications of a quantity constraint (generating involuntary unemployment).

Output of the domestic good is given by:

$$Z = Z(D, C_e, C_o, E) \tag{1}$$

Here D denotes domestic work, C_e denotes consumption of energy, C_o is a composite commodity representing consumption of other goods; the function Z is strictly increasing and quasi-concave in these inputs. We also allow access to electricity to shift the production function in (1); this is denoted by *E* and is taken as exogenous to household choices on work and consumption (although we relax this in the empirical work). We can also allow for heterogeneity in the quality of the domestic good, such that when it is produced using electricity its improved quality allows it to command a higher market price. For example, when an electric sewing machine is available, higher quality products are possible. For mathematical convenience (to permit use of the calculus) we will treat *E* as a continuous variable, rather than discrete (as will be the case in the empirical work).

The domestically produced good can either be consumed within the household (in amount Z_H) or sold (Z_M), $Z = Z_H + Z_M$. Market consumption goods only give a derived utility through the consumption of domestically produced goods. (For example, energy and purchased food must be combined with domestic labor time to produce a final consumption good.) We thus write the utility function as:

$$U = U(Z_H, R_L, R_D) \quad (2)$$

where R_L, R_D denote leisure ("*R*" for recreation) in the light and darkness respectively. Utility is taken to be a strictly increasing and strictly quasi-concave function of (Z_H, R_L, R_D) .

Notice that the only direct effect of electrification in this formulation is via the production function for the domestic good. One might also allow a direct effect on utility in (2). This could arise from the "role model effect of TV" as discussed in the last section. However, such a shift in preferences associated with electrification would cloud welfare assessments. Instead we ask here about the welfare effect as judged by a fixed set of preferences over commodities.

There is a time endowment *T*, which is fully absorbed as either time in light (T_L) or darkness (T_D) $(T = T_L + T_D)$. The time in light is determined by access to electricity. We write this as $T_L(E)$, with $T_L'(E) > 0$. The household faces an additional constraint on time allocation whereby it is assumed that market labor supply is not possible in the darkness, i.e., time in darkness can only be used for leisure in darkness ($R_D = T_D$).Thus the value of time in darkness drops out of the budget constraint and can be treated as fixed in the utility function. In other words, although leisure in darkness can raise welfare its amount is exogenously determined by the total daily time in darkness, and the later time cannot be used for anything else. It is assumed that the household is constrained to have too much darkness; more precisely, $U'_{R_L} > U'_{R_D}$ (using subscripts to denote partial derivatives).

Time in light is then allocated between market labor supply (*L*), domestic work (*D*) and lighted recreation, as:

$$T_L(E) = L + D + R_L \tag{3}$$

It can be immediately noted that electrification can allow all three uses of time to increase. For example, women may end up doing more work within the home as well as more wage labor.

Market labor supply earns a gross wage rate of *w* and the labor market is competitive. The price of energy is denoted p_e and electrification reduces (or at least does not increase) this price; we write this as $p_e(E)$ for which $p'_e(E) \le 0$. Utility is maximized subject to (2) and the budget constraint:

$$C \equiv p_e(E)C_e + C_o = wL + p_Z(E)Z_M + \pi \tag{4}$$

where $p_Z(E)$ denotes the market price of the domestically produced good, with $p'_Z(E) \ge 0$, and π denotes any other (exogenous) source of income. The composite "non-energy" good is the numéraire. Equation (4) can also be written as the "full income" budget constraint, which we can write as follows (after netting out the imputed value of R_D from both sides):

$$p_e(E)C_e + C_o + w(D + R_L) - p_Z(E)Z_M = wT_L(E) + \pi \tag{5}$$

This makes clear the three budget effects of electrification: the income effect of the new opportunities through the extra lighted time and the two price effects.

Under our (standard) curvature assumption for the utility function, an optimum requires that the marginal rates of transformation (MRT) in domestic production are equated with the relevant input prices ($Z'_D / Z'_{C_o} = w$; $Z'_{C_e} / Z'_{C_o} = p_e$), that the marginal rate of substitution (MRS) between lighted leisure and consumption of the numéraire good is equated with the wage rate $(U'_{R_L} /(U'_Z / Z'_{C_o}) = w)$ and that the marginal revenue product of extra consumption of the numéraire good is equated with its price of unity ($p_Z Z'_{C_o} = 1$). The solutions can then be written in the form:

$$Y = Y[p_e(E), p_Z, w, wT_L(E) + \pi, T - T_L(E), E] \tag{6}$$

where $Y = (C_e, C_o, D, R_L, L)$.

Under our assumptions, there is a welfare gain from household electrification ($dE = 1$) as given by:

$$dU = U'_Z[Z'_E + Z'_{C_o}(p'_Z(E)Z_M - p'_e(E)C_e)] + (U'_{R_L} - U'_{R_D})T'_L(E) > 0 \qquad (7)$$

Notice that a welfare gain is also possible when the price of energy rises with electrification as long as there is sufficient gain in domestic output (namely that the first term in brackets in (7) is positive). However, there is nothing to guarantee that consumption and market labor supply would both increase; we cannot rule out the possibility that the welfare gains may be due entirely to greater (lighted) leisure and domestic labor time. This remains true even when we introduce some seemingly reasonable extra assumptions. For example, it is reasonable to assume that both energy consumption and other consumption are normal goods, but there is also own and cross-effects of the price changes that can (in principle) work in the opposite direction, and the direction of the effect on labor supply is indeterminate. For example, the higher market price for domestic output may induce a switch from external wage work to domestic labor. The same outcome is possible if domestic labor time and energy are complements in domestic production.

There are a number of special cases of this formulation that deliver unambiguous comparative static results for the effects of electrification on consumption and labor supply. To give one example, suppose that the household simply maximizes output of the domestic good. (None of which is sold, and leisure has no value.) Output is assumed to be additively separable between the variable inputs and electrification is assumed to increase the marginal product of domestic labor.[14] Then it is readily verified that consumption, and both domestic and external work are increasing in *E*. Note that the extra lighted time is shared between domestic and market work; the increase in the latter does not come with less of the former.

Now modify this special case by assuming instead that utility is derived from lighted leisure but linearly so (without diminishing, or increasing, marginal utility) and that the marginal product of domestic labor is unaffected by electrification.[15] Then it is readily verified that all of the extra lighted time will be devoted to leisure, without any change in labor supply or consumption.

[14] Thus the problem is to maximize $Z(D,C,E)$ s.t. $C = w(T_L(E) - D)$ which requires that $Z_D(D,E) = wZ_C(C)$.

[15] So the problem is now to maximize $Z(D,C,E) + R_L$ s.t. $C = w(T_L(E) - D - R_L)$ which requires that $Z_D(D) = wZ_C(C) = 1$.

So far we have assumed that the household is free to choose its market labor supply. Suppose instead that the household faces a constraint, $L < \bar{L}$, on how much market wage employment it can find (as in the Lewis model). The constraint is taken to be binding (the household will supply as much labor to the market as it can sell), i.e., $U'_{R_L} / (U'_Z / Z'_{C_o}) < w$. The solutions can be written in the form:

$$Y = \tilde{Y}[p_e(E), p_Z(E), w\bar{L} + \pi, T_L(E) - \bar{L}, T - T_L(E), E] \qquad (8)$$

(Notice that the relevant budget parameter is now $w\bar{L} + \pi$ since the household is no longer free to choose its market labor supply.) Also note that the household's "discretionary time" allocation is now constrained by $T_L(E) - \bar{L}$, which also appears as a parameter in (8). However, the expression for the welfare gain in equation (7) remains valid for this case, and a welfare gain is still implied, though (again) it remains ambiguous in theory as to whether this implies higher consumption.

These models can be readily extended to allow schooling as an activity by postulating that schooling enters the utility function (reflecting expected future welfare gains to parents) and has its own price in the budget constraint, combining out-of-pocket expenses and the foregone wages of children. We do not develop this formally but the analysis is straightforward.

The above discussion has focused on the "internal" effect of electrification. There will also be external effects of village-level electrification. The external effect can be expected to operate through wages, prices or other income (π), and also through the quantity constraint on labor supply in a model with a labor surplus. We can distinguish two types of external effects. Symmetric external effects exist when village electrification gives similar gains to households who are themselves electrified and to those who are not. Examples include potential benefits such as safer streets, changing social norms, and general equilibrium effects on wages and employment opportunities. Some of these, such as enhanced security, will no doubt benefit households with electricity, but we are unable to measure them. By contrast, asymmetric external effects are substantially greater for households without electricity. An example is shared lighting. If your household already has its own lighting, it may matter rather little whether or not your neighbors have light, but if you do not have light yourself, having neighbors with light can make a big difference; for example, you can send your child to study in the evening at the home of a friend or relative with good lighting. Other examples include being able to watch the (electrified) neighbor's TV, or store your perishables at a neighbor's house which has a refrigerator. The village externality can also operate through domestic production possibilities. The domestic production activity need not be physically located within the household in question but might reside instead with a friend or neighbor's dwelling. Thus a household still without electricity can benefit by using the electric sewing machine (say) of a neighbor who has acquired an electric connection, possibly with some compensation to the neighbor. This is another example of an asymmetric external effect. We will not be able to disentangle the various "internal" effects identified above, but we will be able to separate out the external effect.

Village-level external effects can also arise through status-seeking behavior. Having electricity in one's home in a typical Indian village is conspicuous, and conveys a sense of status. Those without electricity (for some exogenous reason) may then respond by changing their own consumption behavior, spending more on other status-conveying goods to compensate; Frank (1997) discusses such behavior and points to supportive evidence. These goods would clearly need to also be conspicuous goods, rather than (say) food consumed within the home. Spending on celebrations and festivals is a plausible example. The welfare implications of such behavior are unclear. As Frank (1997) argues, such social effects on consumption behavior may have little or no lasting effect on welfare, because everyone keeps trying to keep up their relative status in a race that leaves everyone spending too much on such goods. Rao (2001) describes the importance of status-related spending in South Indian villages, though Rao describes more positive roles that such spending can play in building social capital, which can be interpreted as a welfare enhancing role. We will look for signs of spending shifts in response to both household and village-level electrification.

4. Setting and data

India's early, post-independence, economic plans had given priority to the use of electricity for urban industry, in an effort to develop capital-intensive domestic production. As a result, efforts to bring electricity to rural households were delayed until the 1970s. Based on India's National Sample Surveys, only around 18 percent of rural households had an electricity connection for household use in 1982, while close to 70 percent did so 20 years later, although access continues to vary widely across regions. The expansion of the grid was initially influenced by population density (households in large cities were among the first to be connected), but also favored areas where natural resources were abundant for generating electricity (rivers for hydroelectric power, and coal for thermal power). Connections in dwellings expanded rapidly during the 1980s and 1990s. While some rural households use diesel generators to create electricity. The bulk get their electricity from a wired connection to above-ground power lines, which in turn are connected to village transformers that are linked via a feeder (or medium-voltage) line to power substations further away on the grid.

According to official statistics, more than 90 percent of villages are currently electrified, in that they have a feeder connection to the grid (International Energy Agency, 2002). However, far from all households in these villages are connected to the electricity grid, and the extent of household connections varies widely on a regional basis. Grid management in India has been carried out on a regional basis since the 1960s, with five main regions comprising the grid, namely the North, East, West, Northeast, and South (Pandey 2007). Each state and union territory of India falls in one of these regions; power is also shared across regions.

During the same period there was a pronounced increase (although starting from a low base) in non-agriculture wage and self-employment work (Foster and Rosenzweig 2003). Both men and women experienced a large gain in non-agricultural wage employment over the period, although much of this has been attributed to a rise in rural public expenditure promoting rural nonfarm industries in the 1980s (Sen 1998). The period also experienced rising rural consumption levels and primary school enrollment.

A key question is how India's dramatic increase in household-level electrification impacted household economic behavior. The India Rural Economic and Demographic Survey (REDS) covers this key period of rising household level electrification and includes detailed information for a panel of households. This appears to be the only long-period household panel data set available for a rural economy that underwent extensive electrification. While providing a unique opportunity for assessing the long-term impacts of electrification, the use of the data for this purpose still requires a number of assumptions, which we outline later.

We use the 1981-82 and 1998-99 (henceforth 1982 and 1999) rounds of the REDS, conducted by the National Council for Applied Economic Research (NCAER).[16] The two

[16] There was a first round of the REDS (called ARIS) in 1970-71 which was nationally representative of rural areas excluding households residing on the Andaman and Nicobar, and Lakshadwip Islands (Foster and Rosenzweig 2001). However, its questionnaire was more restricted in scope than that for the subsequent rounds. There is also a

rounds form a panel of 6,008 households across 242 villages in 15 states; a village-level survey also accompanied the household survey in both rounds, which included wage rates by activity for men and women. The REDS was designed to be representative of rural India, excluding states in significant conflict.[17]

For both rounds, the survey collected data on education, health, marital status, labor supply (main and secondary occupations) and sources of farm and non-farm income, access to infrastructure and facilities, consumption expenditure and assets, agricultural production, and land owned and inherited.[18] Village surveys across both rounds elicited community access to facilities, infrastructure, prices, as well as population characteristics.

For each round, we construct a binary indicator of whether the household has electricity for household use. Only the 1999 survey directly asked whether the household had electricity in the home. In the earlier survey, households were asked about their ownership of consumer durables that use electricity. We construct an indicator of household electricity over time that is equal to one in 1982 if the household reports having an electric appliance, and equal to one in 1999 if the household said they had an electricity connection in the home or if it incurred consumption expenditures on electricity.[19] In a few cases, it is unclear whether an appliance requires electricity to run. For example, early radios and sewing machines were run without electricity. The evidence for rural India in 1982 leads us to believe that such appliances were typically not electricity driven then. We constructed alternative definitions of household

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more recent round for 2006 which is not yet for public access. However, for the questions of interest to us, the 1982-1999 panel covers the key period.

[17] The 1982 round excluded Assam because of an insurgency at the time. It surveyed a total of 4,979 households across 250 villages. The 1999 round excluded Jammu and Kashmir due to unrest there. It covered all surviving 1982 households and added a small random sample of new households from the same villages. Together with household division since 1982, this results in a sample of 7,474 households. The increase in the number of households with baseline information in 1982 and hence in the 1982-1999 panel is explained by household splits over time. Current representativeness of the survey data for rural India can be questioned and we can only make inferences for the baseline panel sample at subsequent dates.

[18] Both survey rounds also collected data from women on their time allocation and that of their children. This is likely to be quite noisy data, especially in measuring changes over time (not helped by changes in the questionnaire for reporting time allocation). We decided that the data were not usable for our purpose.

[19] Note that expenditures on electricity for production are reported in a different survey module. In the 1999 round, 366 households (out of the sample of over 6,000) incur electricity expenditures but don't report having electricity. The vast majority (322 households) own at least one electric appliance. We therefore define these 366 households as being electrified in 1999. There are 74 households for which our electricity indicator is positive in 1982 and zero in 1999. Of these, 21 split off from a mother household that maintains its electricity status over time; 31 split off from an initial household with electricity to a number of households of which none have electricity in 1999. The remaining 22 households did not split between rounds and we can only conclude that they became un-electrified over the period studied, perhaps through loss of a private generator or an illegal connection.

electrification ─ both conservative (assuming such appliances were not electricity dependent) and liberal (assuming they were). In this paper we will use the more conservative definition which we believe is more likely to approximate the correct measure. However, we tested sensitivity to using the broader measure as well and found this made negligible difference to the main results.

We do not know whether the household's electricity was obtained from a private generator or through connection to the grid. We do not include households that report just having an electricity connection for purely agricultural purposes, since we are interested specifically in the effects of the use of electricity in the home. Using this indicator on the panel, 17.3 percent of rural households have electricity for household use in 1982, while 69.6 percent do so in 1999. Our figures accord reasonably well with national trends as reported in other sources.[20]

Table 1 presents the share of panel households with electricity in the home across the 15 states in the 1982 and 1999 rounds. There is considerable regional variation. In 1982, household electrification was less common in the East than elsewhere, especially the North (where many hydropower stations are located). By 1999, although many more households across regions had received electricity, access was still limited in the Eastern region, especially Bihar, eastern parts of Madhya Pradesh, and Uttar Pradesh.

Table 2 gives the number of households in the panel that acquired electricity over the period. 53.6% of households went from being non-electrified in 1982 to being electrified by 1999. (Very few went in the other direction.)

We are also interested in the impacts of village electrification separately from those of household access. Both survey rounds asked what year the village was electrified. Using these data, we construct a variable for the years since the village has been electrified. Given discrepancies in dates across the two rounds, we rely primarily on the 1982 data which we deem likely to be more reliable given recall bias, but use information from the later survey when the information is missing in the baseline and whenever electrification occurred more recently.

We first examine the impact of electrification on real total consumption per capita

[20] Using National Sample Survey (NSS) data for India, Pachauri and Muller (2008) estimate that 18% of rural households had electricity in 1981 (for both household and agricultural use). Restricting their sample to just those 15 states in the REDS panel, the share is 20%. The comparable figure in our analysis is a bit higher at 24% for households with electricity connections for agriculture and owning an electric appliance. The 55th NSS round (1999-00) indicates that 66% of rural households across the 15 states in the REDS panel use electricity for domestic lighting, while our figure based on the REDS 1999 is 71%.

expressed in 1998 rupees. We also examine impacts on components of spending including fuel expenditures per capita.[21] The consumption variables are fully comparable across the two survey rounds. (The Statistical Addendum provides more information on the construction of these variables.) Whether electricity has an impact on the ownership of kerosene run stoves is also of interest in the context of the claims that subsidized kerosene is substituted to cooking when electricity powers lighting.

For each household, we have information on the primary and secondary activities of adult household members. We construct household level variables for the average number of 8 hour work days per individual male or female adult member in casual wage work, regular wage work and non-agricultural and agricultural self-employment during the year preceding the survey round.[22] For our purposes here, we define adults to be those aged between 16 and 55.

We also examine effects on children's schooling, namely the share of children aged 5-18 who are in school by gender, and the average years of completed schooling divided by the maximum possible years (defined as the age of each child minus 4) for all children in the 5-18 age range in a given household. The last variable is expressed not only as a household average, but also as the household's minimum and maximum values.

Table 3 presents summary statistics for our outcome variables against household electrification status across both rounds.

In choosing controls, we have been guided in part by past literature. In the closest prior study for India, Khandker et al. (2012) controlled for household demographic characteristics, maximum education, land and non-land assets and infrastructure. The REDS allows a similar set of controls. Our base-year household level controls include demographic characteristics (age, age squared and marital status of the household head, disability/illness in the household, household size and age/gender composition, religion and caste); maximum years of schooling of any adult in the household; and wealth variables (dummies for landownership and whether the house is built with bricks, and inherited land amounts). Community variables include access to facilities and infrastructure, local agricultural and non-agricultural wages for men and women, the Muslim population share, characteristics of land tenure and cultivable land, a dummy indicating below

[21] We are not able to examine fuel expenditures net of that spent on electricity as these expenditures were not disaggregated in the first survey round. Fuel expenditures include the value of own produced fuel.

[22] There are some measurement errors as person-specific days worked in certain activities run in excess of 365 days in a year. We restrict the number of potential person-days to 365 for each activity as well as the total person-days spent in all activities combined for every individual household member.

normal crop yields in the preceding year and inequality as measured by the mean log deviation of household consumption in the community. We also include controls for some changes in household characteristics (including size and composition, and the maximum education) and some changes in community characteristics over time. However, we do not control for changes in whether the house is built with bricks and land inheritance amounts, which are clearly affected by access to electricity. For the same reason, we do not control for changes in village access to facilities. Finally we include a dummy variable to indicate whether the household split between the survey rounds.

There are endogeneity concerns about some of our controls. For example, following Khandker et al. (2012) we control for the household's maximum years of education when explaining the schooling attainments of children and we control for the change in this variable. Over a long period of time, as in our study, if electrification influences children's schooling then one might expect it to also influence the gain over time in the maximum years of schooling. Similarly, there are concerns about the possible endogeneity of changes in household size. We will test the effect of dropping these controls. However, we acknowledge that there is always a trade-off between dropping variables to address endogeneity concerns and omitted variable bias.

For identification purposes, we also use data on the location of power generating plants obtained from the 2004-5 CO2 Baseline Database for the Indian Power Sector, published by the Central Electricity Authority of India. This public database has detailed information on each power generating plant in India, across different types of power (hydropower versus thermal, for example), and generating capacity. The data include the date at which each power plant became active. Using the GPS locations of the REDS survey villages, we calculated the straight-line distance from each village to the nearest power plant for 1965 (as a benchmark before the REDS survey, during the time when rural electricity generation capacity was beginning to expand), and 1975.

5. Specification and identification

We postulate two distinct ways that a rural household can benefit from electrification. First, it can gain from village electrification, even if it does not have electricity itself, though we allow for the possibility that the extent of that gain may depend on whether the household itself has electricity. Second, the household can gain directly from having electricity inside the home. We first outline the model specification and then discuss identification.

Model specification: To quantify these two factors we exploit the unusually long time period in the REDS panel. This allows us to observe household consumption at a base date (1982), denoted C_{ij82} for household *i* in village *j*, and at the follow-up survey date 17 years later (1999), denoted C_{ij99}. We postulate that village electrification allows household consumption to grow at a rate G_{ij} for household *i* in village *j* that has been connected to the electricity grid for T_j years. Thus the consumption level at the end of the period attributable to the returns from village electrification is given by:

$$C^*_{ij99} = (1+G_{ij})^{T_j} C_{ij82} \tag{9}$$

We do not observe either C^*_{ij99} or G_{ij}. To address this problem we make two assumptions:

Assumption 1: The proportionate deviation of observed consumption from C^*_{ij99} is:

$$\ln(C_{ij99} / C^*_{ij99}) = \alpha + \gamma(E_{ij99} - E_{ij82}) + \pi X_{ij} + \eta_j + \varepsilon_{ij} \tag{10}$$

Here we allow household electrification (whether grid-supported or private) to yield a consumption gain—represented by the term $\gamma(E_{ij99} - E_{ij82})$—relative to the consumption level attributable to village electrification. We also allow for a vector of household and community characteristics as controls, denoted X_{ij} (which can include changes in characteristics), and geographic effects, η_j. The innovation error term is ε_{ij}.

Assumption 2: The return to having the village connected to the electricity grid depends on the household's own access to electricity (such as through a private generator) at the time the connection becomes available. Thus we write:

$$G_{ij} = \beta_0 + \beta_1 E_{ij99-\tau_j} \tag{11}$$

where $E_{ij99-\tau_j} = 1$ if the household has electricity at the time of connection to the grid τ_j years earlier and $E_{ij99-\tau_j} = 0$ otherwise.

Notice that if $\beta_0 + \beta_1 = 0$ then $G_{ij} = \beta_0(1 - E_{ij99-\tau_j})$, in which case the private return to village grid connection is zero if one already has electricity privately. This is the asymmetric externality discussed in section 3. We do not, however, assume that this is the case. As a practical matter, we do not observe whether the household had electricity at the time of the grid connection, as we only observe this for the initial and the final survey dates. We replace $E_{ij99-\tau_j}$ by E_{ij99}, whether the household had electricity at the final survey date.[23]

Combining these assumptions we have the following estimable model of consumption growth between the beginning and final survey dates:[24]

$$\Delta \ln C_{ij99} = \ln(C_{ij99} / C_{ij82}) = \alpha + (\beta_0 + \beta_1 E_{ij99})T_j + \gamma(E_{ij99} - E_{ij82}) + \pi X_{ij} + \eta_j + \varepsilon_{ij} \quad (12)$$

We use the same specification for all outcome variables including labor supply and schooling.

In equation (12) we see the two distinct ways that electrification can matter. The first is through village electrification, the benefits of which can depend on own-electrification; this is the term $(\beta_0 + \beta_1 E_{ij99})T_j$. We interpret this as the external effect. The second (partial equilibrium) channel is the direct idiosyncratic effect of the household acquiring electricity within the period ($\gamma(E_{ij99} - E_{ij82})$). (Notice that, in the absence of the external effect, we would have a standard difference-in-difference specification with controls for initial conditions.)

Identifying assumptions: A key identifying assumption is:

Assumption 3: The endogeneity of household electrification is assumed to be confined to the acquisition of electricity over the time period. In other words, E_{ij99} is endogenous but E_{ij82} is assumed to be exogenous and excludable from the vector X_{ij} in (12). Thus E_{ij82} is used as an IV for $E_{ij99} - E_{ij82}$.

Exogeneity of E_{ij82} might be questioned over relatively short time periods, although it is more plausible over the 17 year period used here. However, the length of the time period also makes it more likely that the returns to electrification may have changed, casting doubt on the excludability of the initial value in a difference-in-difference specification. In view of this concern, we use a second IV to test Assumption 3. For this purpose we draw on the practice in the literature of using geographic variables as a source of IVs:

[23] Alternatively we could replace $E_{ij99-\tau_j}$ by E_{ij82}. However, we will be using E_{ij82} as the instrumental variable for E_{ij99} so this choice is a moot point.

[24] We use the approximation that $\ln(1+G_{ij}) = G_{ij}$, which holds well for sufficiently small G_{ij}.

Assumption 4: Access to electricity depends in part on physical proximity to power generating plants, which we assume do not influence outcomes independently of electrification or the other controls, including other exogenous geographic variables.

As noted in section 2, the exclusion restriction is never beyond question and whether or not it is accepted must depend crucially on what other controls are available since one is making a conditional independence assumption. By exploiting the relatively rich REDS data on village attributes and the (long) panel structure we believe that the exclusion restriction in Assumption 4 is defensible.

Armed with the extra IV, we test the null hypothesis that electrification has the same effect at each date, conditional on other factors in the controls. It is this homogeneity restriction that allows us to use E_{ij82} as an IV for E_{ij99}. (In other words, this is the test of the exclusion restriction for this IV, which is only possible given that we have the second IV.) If the test fails then we will not employ our estimator.[25]

In implementing Assumption 4, we use the distance in kilometers from the village to the nearest power generating plant within the state. As noted in the last section, this is measured at two points in time, namely 1965 and 1975. (We expect these to have opposite signs in the first-stage when explaining the change in household electrification.) As compared to distance to the nearest power substation (which supplies feeder lines to villages and is hence located closer to villages), distance to the nearest power generating plant is more likely to be orthogonal to unobserved factors affecting household outcomes and electricity access. Villages do not shift location in rural India, and even by 1999, power generating plants were often several hundred kilometers away from villages (see Table A1). Furthermore factors affecting plant location (such as access to natural resources) can be controlled for in the regression framework. Distance to the nearest power generating plant for the different years we examine also has a strong significant impact on household electrification.

To address concerns about the validity of the exclusion restriction stemming from the possibility of omitted geographic factors we allow a complete set of district fixed effects, as well as control variables for village characteristics, in the vector *X*. We include initial conditions (1982 values) of the household and community characteristics detailed in Section 3 as well as

[25] Strictly, our model is still identified if the test fails. However, with only the second, geographic, IV left (namely the distance to power stations) we naturally do not feel that this would adequately capture the exogenous variation in household electrification.

changes in their value over time. We test separate specifications dropping variables that are potentially endogenous (such as changes in household land and housing material, and in community access to facilities). The Addendum gives supplementary summary statistics including for the control variables.

6. Results

Table 4 reports our estimates of the key parameters for consumption and labor supply. We first give the simple difference-in-difference (DD) estimates. This is the difference between the mean outcome variable for those with electricity in 1999 and for those without it, less the corresponding difference for 1982. We allow for a time effect, but there are no controls. As discussed, we expect these simple DD estimates to be biased due to endogeneity in the household acquisition of electricity and confounding effects due to other differences in initial conditions and time varying variables, including village-level electrification. Next, Table 4 gives our estimates of the same parameter based on equation (12), allowing for the village-level external effect with controls, and treating the household's acquisition of electricity by 1999 as endogenous. The last column of Table 4 gives the corresponding estimates of the external effect.

Consumption: The DD method attributes a 17.5% increase in consumption to household acquisition of electricity.[26] Evaluated at the mean consumption of those households who did not have electricity in 1982, this represents a gain of Rp 611.6 per person per year. Regular wage work increases by 11 days for men, but with no gain for women. Casual wage work decreases for both men and women, though with a larger impact on men. Agricultural self-employment increases for men, but with little effect for women. Non-agricultural work falls for women, but with no effect on men. As we will see, the simple DD method appears to greatly over-estimate the consumption gains attributable to electrification, and gives a distorted picture of the effects on labor supply.

Turning to our IV estimator, we could not reject the null hypothesis of homogeneity ($\beta_0 + \beta_1 = 0$) in all but one of the regressions so we give results with this restriction imposed (or note its rejection). This implies that village electrification had no significant effect if the household already had electricity. The external benefits of village electrification are largely

[26] Note that the regression coefficient of 0.161 is the change in log consumption. Then the ratio of consumption in 1999 to 1982 is exp(0.161) =1.175

confined to those households without electricity. (Addendum Table A2 provides the detailed total consumption regression results for the various specifications, as well as the homogeneity tests.[27] The first stage regressions for electrification are given in Table A3. The instruments perform well.)

Focusing first on total consumption, the OLS estimate of the impact of household electrification represents about a 11% increase in consumption over the study period (Addendum Table A2). This falls by about one third when we use our IV estimator in Table 4, which gives an implied consumption gain of 7%, representing a gain of Rp 242 per person per year or Rp 1450 per household. These numbers suggest sizeable bias due to endogenous acquisition of electricity by more (latently) wealthy families.

There are possible concerns with these results related to the other control variables. In particular, we have included controls for the change in (log) household size and the change in the maximum years of schooling (the Addendum provides details). The assumption that these variables are exogenous can be questioned. And it could be argued that these are also channels of influence for electrification, leading us to underestimate the impact. Against these concerns, there is a potential omitted variable bias in excluding these controls.

We tried dropping the control for the change in log household size, and instead using the change in log consumption per equivalent single person as the dependent variable, where the number of equivalent persons was assumed to be the square root of household size. This assumption was motivated by the fact that the coefficient on the change in log household size was close to -0.5.[28] This made little difference to the results for electrification; the coefficient on the change in household electrification in the IV estimate rose slightly (to 0.072 with a t-ratio of 2.18), while the coefficient on the village effect and its standard error were almost identical.

There was greater sensitivity to dropping the controls for changes in the household's maximum education. Then the coefficient on household electrification fell to 0.051 with a t-ratio of 1.52, though (again) the coefficient and standard error for the village effect were almost identical (0.011; t=2.22). However, not controlling for education (a key factor in other income sources) may well be imparting a downward bias on the estimated impact of electrification. This

[27] For all outcome variables we run various specifications including with and without controls for some potentially endogenous household and community change variables. Addendum Table 2 gives results both including and excluding the community change controls. Our preferred model and the one we will focus our discussion on omits these variables.
[28] The coefficient in the restricted IV regression was -0.42 (t=18.72); the Addendum provides further details.

bias stems from a "catching up" process in the spread of electrification, whereby it tended to be the less well educated households in 1998 who had become electrified—the relatively well-off having already acquired electricity in the base year.[29]

When we turn to our estimates of the effects of electrification on the schooling of boys and girls another reason will emerge to be less concerned about the endogeneity of changes in the maximum years of schooling.

We found no sign of village effects until we use our IV estimator with homogeneity imposed. Then a significant effect emerges for those households without their own electricity. The annualized consumption gain from village electrification for households who are not electrified is 1%. (Note that, given our model specification, β_0 gives the annual growth rate of consumption attributed to village electrification for a household that is not electrified. By contrast, the coefficient on the household becoming electrified gives the total impact over the period.).

We also estimated a specification with extra controls for changes in village characteristics related to village accessibility, infrastructure and institutions.[30] There are concerns about the possible endogeneity of these extra controls, but there are also concerns about omitted variable biases. This specification shows a somewhat stronger village externality of electrification (the coefficient rose to 0.013, t=2.53). The coefficient and standard error for household electrification were almost identical in this augmented model. (Full details are available in the Addendum.)

Table 4 also gives results for components of spending. The simple DD estimates suggest a significant internal effect of electrification on each of the three main categories: food, fuel and other (non-food, non-fuel) expenditures. However, the latter impact is not robust to allowing for the endogeneity of household acquisition of electricity. When we break up spending further, we find significant internal effects on clothing and footwear, entertainment, ceremonies and spending on domestic help, but only the latter is robust to allowing for endogeneity. The positive and strong internal effects on fuel expenditures implies about a 20% increase as a result of the household acquisition of electricity.

[29] This is evident when we regress the change in maximum years of education on the change in household electrification controlling for all other covariates used in the main regression. The regression coefficient is negative and significant (at the 1% level).
[30] The extra variables included the changes in distance to a paved road, market, health clinic and school, and the presence of a public water tap and an agricultural cooperative.

We find significant external effects on non-food, non-fuel, spending. This is suggestive of the social effects on consumption behavior discussed in section 3 whereby households without electricity themselves shift their spending toward consumer goods that display affluence (unlike food, which is typically consumed in the privacy of one's home). We investigated this further using a finer breakdown of non-food consumption. Most suggestive of such a social effect is a significant and positive external effect on spending on ceremonies (a coefficient of 0.180, t=2.57); in contrast, the (just) significant internal effect is negative (-0.705, t=-1.83), suggesting a substitution away from such spending for households who acquire electricity. Additionally, we found significant, but negative, external impacts on travel expenditures (-0.168, t=-3.08), possibly indicating that electrification brings certain attributes to villages which reduce the need to journey elsewhere to find them. There were no significant external effects on clothing and footwear, entertainment, domestic help, housing repairs, health or education spending.[31] We would not expect a village effect on fuel spending and that is confirmed by our results in Table 4.

So the external, village-level, effect for non-electrified households entailed a change in the composition of spending away from food and fuel toward other goods, while the internal (household-level) effects went in the opposite direction.

Electrification also increased the ownership of kerosene stoves (Table 4). Our results are consistent with the claim that subsidized kerosene rations are switched to cooking when electricity becomes available for lighting (as argued by Heltzberg 2004). Here too we would probably not expect a village external effect and this is borne out by the results (Table 4).

It is of interest to compare our consumption impacts with those reported for rural India in Khandker et al. (2012). The latter study obtained much larger impact estimates on consumption than we find; indeed, our effects are at most one quarter of those reported in Khandker et al. (2012). Recall that the latter study used village electrification as the IV for household electrification. Another difference is that Khandker et al. did not include district level fixed effects. Our results lead us to question the exclusion restriction, given that we find significant independent effects of village electrification. To see if this explains the difference between the impact estimates of the two studies we repeated our regressions using the Khandker et al. identification strategy and without including district effects. The impact estimate rose to 0.251

[31] This is with the homogeneity restriction imposed. The restriction was not accepted in the case of durables.

and was statistically significant (t=2.85). However, when we added district effects it became negative (-0.360), but not significantly different from zero (t=-1.64).

Thus the two sources of bias appear to work in opposite directions. First, the excluded village externality leads to an over-estimation of the welfare impact of acquiring electricity; this stems from the fact that the externality is positive. Second, the omission of geographic effects leads to under-estimation. This suggests that districts with lower consumption levels were more likely to acquire electricity over the period. That is consistent with a model in which the early benefits of electrification were captured by better off areas.

Notice also that the upward bias from using OLS is small compared to the bias from using an IV estimator for which the exclusion restriction is not valid. The Khandker et al. impact estimate without district effects is over four times our preferred IV estimate, while the OLS estimate is only about one third higher. With district effects, the direction of bias switches sign, though the estimated impact is still larger than with OLS.

Labor supply and wage rates: Turning to labor supply, a more complex picture emerges, involving the substitution of some activities for others. Table 4 gives the results for the various categories of labor supply that can be identified in the REDS survey data and compared over time. (Again the homogeneity restriction performed well and so was imposed.)

The largest increase in days of labor supplied attributed to household electrification is for the regular wage work of men, which rises by 16.6 days with electrification, representing 33 percent of the mean days of regular work in 1999. (There is also an increase in men's non-farm self-employment, though it is not statistically significant.) This extra work came mainly from reduced casual wage work (10.4 days). Thus our results indicate a significant substitution in male labor supply from casual to regular work attributed to electrification. This is consistent with the argument made in section 2, whereby electricity allows the male to switch leisure time from daylight hours to night time, allowing a more regular supply of labor, as required by regular salaried work.

For women the main effect was to increase their casual wage work, amounting to about 6 days per year. It is plausible that this involved the women taking up the casual work that was displaced by men. There are signs that this came in part from reduced days of regular wage work and of non-farm self-employment, although these displacement effects are not statistically significant. Thus we cannot reject the null that the extra casual work of women came from unpaid domestic work or leisure.

In summary, we find that household electrification increased both male and female labor supply. For men, regular wage work increased, much of it coming from casual wage work, and some from other activities, including leisure. For women, there was an increase in casual work.

Using the wage rates reported in the village-survey we can also test whether there is any sign that village electrification affected wage rates. We used the data on harvest wage rates to compare the changes in mean wage rates for those villages that became electrified between the two survey rounds with those for the villages that already had electricity in 1982. The DD estimate gave a small gain of Rp. 2.43 per day (in 1999 prices) for women and a small loss for men of Rp -1.39; however, neither is significantly different from zero (standard errors of Rp.4.27 and 4.11). We also repeated this analysis using the number of years the village was electrified as the treatment effect; again, there was no significant impact on wages. We find no evidence in these data that village electrification increased real wage rates. This does not, of course, rule out impacts on the demand for labor, given that we also find positive effects on labor supply.

When the estimated impacts on days of labor supply are valued at the sample mean wage rates the implied impact on total labor earnings in 1999 is Rp 2277 per household.[32] Recall that the implied mean impact on household consumption is Rp 1450. This gap has two possible explanations. The first is the existence of foregone income from market labor supply due to displaced activities within the household. In terms of the model in Section 3, this would entail that the extra market labor supply comes from domestic work in producing marketable commodities. The second explanation is not something we modeled in Section 3, namely savings; by this interpretation, about one third of the income gain was saved or invested directly.

We cannot say which of these explanations is the right one. However, some support for the first explanation can be found in past estimates of the household income foregone in taking up new employment opportunities provided by public works projects in India. Datt and Ravallion (1994) estimate a foregone income of about one quarter of the gross wage rate in Maharashtra. Dutta et al (2012) estimate a mean forgone income of about one third of the gross wage rate in

[32] The Addendum provides details on the wage rates used for imputation. A potentially contentious assumption we make is in using the casual wage rate for agricultural work in valuing the income effect of the impacts on days of self-employment in agriculture. As a sensitivity test we also tried using 50% of the casual wage rates; the impact of total earnings rose to Rp 2363.

Bihar. These observations suggest that our gap between the mean earnings gain and the gain in consumption could be explained by foregone income even if there is no impact on savings.

It is of interest to compare our results to the simple "diff-in-diff" impacts. The above estimate of Rp 2277 is very close to the impact on household consumption implied by the simpler estimator, which is Rp 2280. However, the more appropriate comparison is with the simpler estimates for labor supply, as also given in Table 4, which imply a net gain in labor earnings of Rp 1523. This is again well below the implied impact on consumption.

Turning now to the effects of village level electrification, we find a significant increase in women's non-farm self-employment due to village electrification. The effect is only half a day; but recalling that it is annualized, it would add up to an extra week of such work over 10 years. The principle village effect on labor supply is that connecting the village to the electricity grid increased the non-farm self-employment work of women.

Schooling: Table 5 summarizes the impacts on schooling. We find positive effects of household electrification on schooling, measured by both enrollment and the average years of schooling as a share of the maximum possible for a given age. The effects are only statistically significant for girls. The effect of household electrification on enrollment accounts for 14% of the mean in the girls' school enrollment rate in 1999 for households with electricity (Table 3). The positive effect on girls' years of schooling is larger for girls in households with both boys and girls present where household electrification explains 22% of the mean max years of schooling in 1999. We find little sign of significant external effects of village electrification on schooling. These results were quite robust to dropping the potentially endogenous controls for changes in household size and maximum education.

Note that the fact that we find that the impact of electrification was almost solely for girls helps relieve the prior concerns about the possible endogeneity of the maximum years of schooling. The maximum is almost always for a male household member.

The stronger effect for girls may well reflect the "net wage effect" discussed in Section 2, whereby household electrification reduces the opportunity cost to parents of sending their children to school, on the presumption that the home duties of girls will be more easily re-allocated to the evenings when electricity is available.

7. Conclusions

While positive claims are often heard in the literature and policy discussions about the consumption and income gains from household electrification in developing countries, there is surprisingly little rigorous evidence on the long-term impacts, as required for assessing the economic benefits of public investment in expanding access to electricity for the great many people in the world today who do not have such access. Doubts also remain about past identification strategies. Nor has the literature adequately addressed the distinction between internal (household-level) impacts and external, village-level, effects.

The paper has tried to fill this gap in knowledge by studying the household-level impacts on consumption and labor supply of a period of huge expansion in rural electrification in India in the 1980s and 1990s. We have distinguished the long-run village-wide external effect of electrification from the direct, idiosyncratic, household effect on consumption, labor supply and schooling in rural India. It is hoped that this study of the long-run impacts of expanding household access to electricity will have salience not only for India's continuing efforts to expand electrification but for the many other developing countries where this is still ahead.

We find that the external effect of village electrification on consumption has a strong interaction effect with household-level electricity use, such that the external effect is asymmetric, favoring households without electricity. Indeed, we do not find that the external effect is shared by those who already have electricity. However, the effect is sizeable. Village connection to the grid adds one percentage point to the annual consumption growth rate for a household that does not have its own electricity, but the effect is negligible for households already connected. The external effect appears to also come with a shift in consumption spending away from food toward other goods, possibly associated with an attempt to maintain status amongst those still without electricity.

Side-by-side with the village effect, we find a significant "internal" impact of household acquisition of electricity during the period. Consumption increases, and this is mainly food and fuel spending. After about seven years of village electrification, the external effect dominates the internal effect. We find evidence of effects on labor supply, with electrification resulting in extra work by both men and women—regular wage work for men and more casual wage work for women. Our findings on the direct, household-level, impact on labor supply do not support the idea of a rural economy in labor surplus, whereby only the demand side matters to employment. Assuming that the income gains are fully consumed, our imputations of the income gains generated by the labor supply effects using gross wage rates suggest that about one third of the impact of electrification on gross earnings is lost due to foregone incomes stemming from displaced activities within the household. However, we cannot rule out the possibility that a share of the income gain from electrification is saved or directly invested.

We find significant effects on schooling, but only for girls. This is also suggestive of longer-term welfare gains. This gender difference may well reflect differences in the nature of the lighted time constraints on the type of work done within the household, whereby better lighting allows girls to re-allocate their time to permit school attendance, but matters less to boys, given that their work alternatives to schooling are more likely to be outside the home.

Our estimate of the internal household effect on consumption is appreciably lower than the only prior estimate in the same setting and we have explored why. We argue that the difference can be attributed to the omission of the external effect in the prior study. This has an implication for the methodology used to evaluate infrastructure interventions, such as the provision of access to electricity. Standard impact evaluation methods are designed to pick up the internal effects, by comparing outcomes for households who have electricity with those who do not. Depending on how this is done (notably whether variation across villages is factored in) the large external effect we have found may not be picked up by such an evaluation.

Depending on whether one allows for local geographic effects, much larger or much smaller estimates are obtained using an instrumental variables estimator that ignores external effects within villages. By exploiting a second instrumental variable, based on the proximity of the village of residence to power-generating plants, we have tested the exclusion restriction that external effects of village electrification are absent, and found that it fails. We have shown that the induced bias is large. It appears that (in this case) it would be better to ignore the endogeneity of acquisition of electricity rather than use an instrumental variable that imposes an invalid exclusion restriction by ignoring the external effect.

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Table 1: Proportion of rural households with electricity access at household level by state

		1982		1999	
	N	Mean	Std. Dev.	Mean	Std. Dev.
Andhra Pradesh	350	0.12	0.33	0.76	0.43
Bihar	277	0.00	0.06	0.08	0.28
Gujarat	463	0.21	0.41	0.94	0.24
Haryana	353	0.23	0.42	0.87	0.34
Himachal Pradesh	94	0.32	0.47	1.00	0.00
Karnataka	500	0.04	0.19	0.86	0.35
Kerala	330	0.38	0.49	0.91	0.29
Madhya Pradesh	627	0.14	0.34	0.68	0.47
Maharashtra	310	0.15	0.35	0.76	0.43
Orissa	337	0.27	0.44	0.57	0.50
Punjab	228	0.68	0.47	1.00	0.00
Rajasthan	639	0.19	0.39	0.64	0.48
Tamil Nadu	458	0.21	0.40	0.88	0.32
Uttar Pradesh	783	0.05	0.23	0.37	0.48
West Bengal	259	0.04	0.20	0.54	0.50
Total panel	6008	0.17	0.38	0.70	0.46

Notes: There were two more households in AP in 1999 and 2 less in TN.
Source: 1982 and 1999 REDS panel.

Table 2: Change in rural household level electricity access status 1982 to 1999

Household has electricity?		1982		
		No	Yes	Total
1999	No	1752	74	1826
	Yes	3217	965	4182
	Total	4970	1039	6008

Source: 1982 and 1999 REDS panel households.

Table 3: Summary statistics for household level outcome variables, by electricity status and year

Panel HHs only	1982				1999			
	No electricity		Electricity		No electricity		Electricity	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Consumption variables								
Total consumption per capita	3494.85	2007.83	6199.84	5035.55	5160.17	2673.01	9222.44	7774.95
Food consumption per capita	2122.84	1255.51	3467.31	2651.19	2772.48	1211.91	3795.35	1786.66
Non-food, no-fuel consumption per capita	1179.40	993.59	2390.50	3221.06	2047.69	1680.59	4891.98	6426.59
Clothing & footwear expenditures per capita	389.62	282.00	664.63	623.46	461.01	295.64	749.99	609.38
Entertainment expenditures per capita	42.05	64.82	94.96	168.35	74.62	125.09	156.54	254.34
Ceremonies expenditures per capita	53.24	288.35	155.11	995.06	197.54	764.29	651.24	2458.66
Travel expenditures per capita	57.15	80.31	111.21	148.90	105.09	137.42	232.76	337.85
Education expenditures per capita	47.13	139.32	137.82	318.94	78.98	194.17	293.04	763.45
Health expenditures per capita	100.57	168.33	151.11	175.29	207.53	250.86	366.27	638.64
Domestic help expenditures per capita	4.35	38.85	62.35	424.88	2.90	84.65	22.42	271.82
Repairs to housing expenditures per capita	0.84	10.31	2.39	24.97	1.03	13.37	22.42	271.82
Fuel expenditure per capita	192.60	176.71	342.03	350.55	340.01	284.85	535.11	419.99
Kerosene stove ownership	0.17	0.37	0.45	0.50	0.28	0.45	0.57	0.50
Days of (non-domestic) work per adult (aged 16 -55)								
Total days of work by women	78.36	78.92	65.78	70.76	73.47	78.06	68.88	77.92
Total days of work by men	146.72	97.31	136.07	102.24	170.24	93.36	166.48	106.73
Days of regular wage work women	0.92	11.97	5.28	34.91	0.83	14.96	5.26	39.55
Days of regular wage work men	20.87	62.79	43.24	87.84	18.97	68.10	49.43	109.67
Days of casual wage work women	27.12	62.84	4.86	27.99	41.44	70.61	23.16	57.15
Days of casual wage work men	58.31	91.72	15.77	50.95	101.89	98.37	50.52	86.90
Days of agricultural self employment by women	46.64	54.32	52.15	55.82	29.72	42.57	39.36	50.74
Days of agricultural self employment by men	58.98	60.73	56.84	63.12	39.83	48.23	52.31	58.99
Days non-agricultural self employment by women	3.93	18.77	3.88	17.70	1.68	16.38	1.41	14.97
Days non-agricultural self employment by men	11.18	44.63	23.19	70.51	10.96	46.40	17.63	60.64
Schooling variables (children aged 5 – 18)								
Enrolment rate	0.38	0.39	0.65	0.37	0.50	0.41	0.71	0.38
Enrolment rate for boys	0.44	0.44	0.71	0.39	0.58	0.44	0.75	0.39
Enrolment rate for girls	0.29	0.41	0.58	0.44	0.43	0.45	0.69	0.42
Mean school years as share of max possible years	0.30	0.26	0.46	0.27	0.39	0.30	0.58	0.29
Min school years as share of max possible years	0.15	0.25	0.28	0.32	0.26	0.32	0.45	0.35
Max school years as share of max possible years	0.46	0.34	0.62	0.30	0.53	0.35	0.70	0.30
Girls mean school years as share of max possible years	0.23	0.28	0.41	0.31	0.35	0.32	0.57	0.32
Girls mean school years as share of max possible (hh w/ boys & girls)	0.23	0.28	0.40	0.31	0.36	0.32	0.58	0.30
Girls min school years as share of max possible years	0.17	0.27	0.33	0.33	0.29	0.33	0.51	0.35
Girls max school years as share of max possible years	0.30	0.33	0.50	0.34	0.40	0.35	0.63	0.32
Boys mean school years as share of max possible years	0.36	0.29	0.50	0.29	0.44	0.32	0.60	0.30
Boys mean school years as share of max possible (hh w/ boys & girls)	0.37	0.29	0.51	0.28	0.44	0.31	0.60	0.29
Boys min school years as share of max possible years	0.26	0.31	0.40	0.33	0.36	0.34	0.53	0.33

Boys max school years as share of max	0.46	0.34	0.58	0.31	0.52	0.35	0.66	0.31
Percent of total panel households with electricity			17.30	37.83			69.60	46.00
Observations	4967		1039		1826		4180	

Notes: Consumption aggregates are expressed in 1998 prices using a deflator obtained from NCAER. A household is involved in an activity if at least one family member aged 16 and over is involved in the activity either as their primary or secondary activity. The number of days worked in each activity is calculated based on the total hours reported in the activity during the last year and dividing by 8. These are expressed as a household mean for male and female members aged 16 to 55. Enrolments are defined as the household mean for all children aged 5 through 18 of a given gender. Years of education are defined as the household average years of schooling as a share of the maximum possible for a given age and gender group. The data are unweighted.

Table 4: Impacts of household and village electrification on consumption and labor supply

Outcomes	Simple DD Change in household electrification	IVE: Allowing for external village effect, endogenous electrification and with controls Change in household electrification	Years of village electrification *times* household not electrified
Consumption			
Total consumption expenditure per capita (log)	0.161*** (6.55)	0.067** (1.99)	0.010** (2.11)
Food expenditure per capita (log)	0.081*** (3.34)	0.096*** (2.89)	0.002 (0.39)
Fuel expenditure per capita (log)	0.172*** (3.00)	0.213*** (3.90)	-0.007 (-0.70)
Non-food, non-fuel expenditure per capita (log)	0.271*** (7.87)	0.054 (1.26)	0.017** (2.49)
Of which: Clothing & footwear	0.209*** (4.95)	0.081 (1.41)	0.007 (0.85)
Entertainment	0.972*** (3.00)	0.553 (1.39)	0.034 (0.49)
Ceremonies	1.138*** (2.71)	-0.705* (-1.83)	0.180** (2.57)
Travel	0.297 (1.51)	0.060 (0.24)	-0.168*** (-3.08)
Education	0.181 (0.67)	-0.057 (-0.15))	0.040 (0.80)
Health	0.192 (1.56)	-0.016 (-0.10)	-0.020 (-0.79)
Domestic help	0.448*** (2.93)	0.684*** (2.65)	0.023 (0.70)
Repairs to housing	0.207 (1.40)	-0.031 (-0.19)	-0.019 (-0.80)
Owns a kerosene stove (1=yes; 0=no)	0.137*** (6.63)	0.194*** (6.06)	0.009 (1.54)
Labor supply (days per year)			
Days of regular wage work women	-0.582 (-0.53)	-4.722 (-1.68)	0.225 (0.82)
Days of regular wage work men	10.881*** (3.45)	16.599** (2.60)	0.883 (1.34)
Days of casual wage work women	-5.184** (-2.00)	6.116* (1.70)	0.008 (0.02)
Days of casual wage work men	-18.443*** (4.64)	-10.424* (1.91)	-1.141 (-1.32)
Days of agricultural self-employment by women	2.441 (1.03)	-0.176 (-0.05)	-1.132* (-1.89)
Days of agricultural self-employment by men	10.363*** (3.27)	-2.134 (0.52)	-1.134 (-1.64)
Days non-agricultural self-employment by women	-1.975** (2.32)	-2.234 (-1.19)	0.463** (2.30)
Days non-agricultural self-employment by men	2.146 (0.87)	3.409 (0.73)	0.641 (1.46)

Notes: DD: "difference-in-difference". IVE: Instrumental variables estimates of a panel data model treating the acquisition of electricity as endogenous and using the 1982 electrification and geographic proximity to power generating plants as IVs. Controls and district effects included. See text for further details. ***: 1%; **: 5%; *:10%.

Table 5: Impacts of household and village electrification on schooling outcomes

Schooling Outcomes	Simple difference in difference	Allowing for external village effect, endogenous electrification and with controls	
	Change in household electrification	Household became electrified	Years of village electrification *times* household not electrified
Share of children 5-18 in school	0.033	0.082**	0.001
	(1.58)	(2.56)	(0.30)
Share of girls 5-18 in school	0.042	0.094**	0.008*
	(1.53)	(2.05)	(1.80)
Share of boys 5-18 in school	0.020	0.073	-0.013*
	(0.70)	(1.52)	(-1.81)
Mean school years as share of max	0.046**	0.026	0.002
possible years	(2.66)	(1.00)	(0.69)
Min school years as share of max	0.066***	0.037	0.004
possible years	(3.21)	(1.15)	(0.13)
Max school years as share of max	0.029	-0.010	0.005
possible years	(1.32)	(-0.30)	(1.02)
Girls mean school years as share of max	0.058**	0.092**	0.005
possible years	(2.42)	(2.29)	(0.94)
Girls mean school years as share of max	0.038	0.127**	0.002
possible years (hh w/ boys & girls)	(1.33)	(2.21)	(0.30)
Girls min school years as share of max	0.061**	0.096**	0.004
possible years	(2.37)	(2.18)	(0.83)
Girls max school years as share of max	0.067**	0.102**	0.004
possible years	(2.47)	(2.28)	(0.73)
Boys mean school years as share of max	0.039	0.002	-0.004
possible years	(1.63)	(0.05)	(-0.80)
Boys mean school years as share of max	0.044	0.028	-0.007
possible years (hh w/ boys & girls)	(1.25)	(0.43)	(-0.107)
Boys min school years as share of max	0.062**	0.041	-0.001
possible years	(2.53)	(0.98)	(-0.27)
Boys max school years as share of max	0.014	-0.034	-0.004
	(0.55)	(-0.85)	(-0.87)

Notes: Instrumental variables estimates of a panel data model treating the acquisition of electricity as endogenous and using past acquisition and geographic proximity to power generating plants as IVs. Controls and district effects included. See text for further details. The restriction passes in all cases.

Statistical addendum (not intended for publication)

Notes on data and summary statistics

Construction of the consumption variables

The components of total consumption expenditure included imputed rent, expenditure on ceremonies and purchase of durables in the year before the survey. We inflated 1982 expenditures to 1998 prices using rural CPI data.

82 households claimed to have both imputed rent and to have paid housing rents. For these households, we set housing rental expenditures to zero. 76 households had neither imputed rent nor rental expenditures reported. These tend to be poorer households on average. We created 10 household consumption per capita quintiles and assigned mean imputed rent of a household's quintile to households with missing housing expenditures.

Definition of electricity access

The 1982 survey does not identify whether households are electrified. We construct indicators for whether a household is electrified based on their ownership of electric appliances. However it is not always certain whether an appliance runs on electricity or not. For example, until recently sewing machines, irons and radios were often powered by alternative energy sources in rural India. The various definitions are as follows:
<u>Definition A</u>
1982: a household is electrified if it owns any of the following appliances: a fan or other unambiguously electricity-run appliances; 1999: if households report having electricity
<u>Definition B</u>
1982: households own any of the following appliances: fan, other electric appliances, or radio; 1999: if households report having electricity
<u>Definition C</u>
1982: households own any of the following appliances: fan or unambiguously electricity-run appliances: 1999: if households report having electricity or incur expenditures on electricity
<u>Definition D</u>
1982: households own any of the following appliances: fan, unambiguously electricity-run appliances, or radio; 1999: if households report having electricity or incur expenditures on electricity

Our preferred measure of electricity access is definition C. There were 74 households that had electricity in 1982 but not in 1999 according to definition C. Comparing households that don't have electricity but incur electricity consumption expenditures with households that report having access to electricity, we find that the former (366 HHs) are similar to the latter in terms of variables like ownership of electric appliances. This supports the argument that the 366 HHs should in fact be included among the group of households that are electrified. Thus, we judge definitions C and D to be more appropriate.

Construction of person-day variables

In constructing the total person-days worked, we do not include activities for which information is not available in both survey rounds. For example, construction work in building and additional building work is not found in the 1982 survey; home construction, additional construction work at home and land repair person-days were not itemized in the 1999 round.

Imputed valuations of the impacts on labor earnings

The impacts on regular work were valued at the 1998 sample mean wage rates for salaried regular work of Rp 137 and Rp 122 per day for men and women respectively. The impacts on casual wage work were valued at the 1998 sample mean casual wage for agricultural and non-agricultural work of Rp 57 and Rp 24 for men and women respectively. For agricultural self-employment we used the mean casual wage rates for agriculture of Rp 45 and Rp 30 while non-agricultural self employment we used the corresponding means for casual non-agricultural work of Rp 69 and Rp 17 for men and women respectively. In all cases the means were formed across all wage rate observations in the relevant category.

Table A1: Summary statistics of explanatory variables by electricity status

Panel households (HHs) only	1982				1999			
	No electricity		Electricity		No electricity		Electricity	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Household variables								
HH size	7.65	3.81	8.31	3.92	6.02	3.57	5.99	3.34
Age of head	50.59	13.26	55.04	12.95	47.76	15.52	50.55	14.87
Head is divorced/separated	0.10	0.30	0.08	0.28	0.11	0.32	0.11	0.31
A member 15+ has chronic illness/disability	0.24	0.43	0.40	0.49	0.26	0.44	0.37	0.48
Years of maximum schooling of adult	6.01	5.38	10.21	4.76	5.67	4.90	9.05	4.94
Share of women aged 16-55	0.26	0.13	0.26	0.12	0.25	0.15	0.28	0.14
Share of men aged 16-55	0.29	0.15	0.28	0.15	0.27	0.17	0.29	0.17
Share of girls aged 7-15	0.09	0.12	0.09	0.10	0.09	0.13	0.08	0.12
Share of boys aged 7-15	0.13	0.14	0.10	0.13	0.11	0.14	0.10	0.14
Share of girls aged 0-6	0.07	0.10	0.07	0.09	0.07	0.11	0.05	0.10
Share of boys aged 0-6	0.08	0.11	0.08	0.11	0.08	0.12	0.06	0.11
HH owns land (yes=1, no=0)	0.71	0.45	0.81	0.40	0.56	0.50	0.71	0.45
Inherited land (100s acres)	2.59	3.49	4.80	7.36	1.90	3.90	3.95	6.90
House made of solid construction (yes=1, no=0)	0.06	0.24	0.29	0.46	0.09	0.29	0.44	0.50
Hindu (yes=1, no=0)	0.90	0.30	0.81	0.39	0.89	0.32	0.90	0.30
SC/ST caste (yes=1, no=0)	0.22	0.41	0.06	0.23	0.27	0.45	0.15	0.35
Head moved from outside village (yes=1, no=0)	0.02	0.14	0.04	0.20	0.01	0.12	0.02	0.14
Village Variables								
Years village has been electrified	9.24	9.04	13.51	9.66	21.99	11.16	26.23	10.23
Mean log deviation of household consumption	0.14	0.08	0.15	0.09	0.13	0.09	0.15	0.10
Crop yield below normal last year (yes=1, no=0)	0.23	0.42	0.22	0.41	0.40	0.49	0.29	0.45
Muslim share of population	0.08	0.16	0.06	0.14	0.11	0.21	0.09	0.21
Share of cultivable land sown	0.66	0.24	0.65	0.26	0.65	0.24	0.66	0.23
Large landowners in village (yes=1, no=0)	0.30	0.46	0.32	0.47	0.58	0.49	0.59	0.49
Distance to nearest paved road (km)	42.01	39.31	26.99	37.13	16.62	31.67	10.05	25.07
Distance to block headquarters (km)	153.68	114.72	147.74	104.78	118.83	103.32	116.03	110.71
Market within 2km (yes=1, no=0)	0.11	0.32	0.24	0.43	0.55	0.50	0.54	0.50
Agricultural cooperative (yes=1, no=0)	0.23	0.42	0.24	0.43	0.15	0.35	0.34	0.47
Health care facility 5km (yes=1, no=0)	0.48	0.50	0.62	0.49	0.67	0.47	0.69	0.46
Primary school within 2km (yes=1, no=0)	0.28	0.45	0.15	0.36	0.42	0.49	0.53	0.50
Secondary school within 2km (yes=1, no=0)	0.21	0.41	0.21	0.41	0.15	0.36	0.26	0.44
Public drinking water tap (yes=1, no=0)	0.16	0.37	0.25	0.43	0.27	0.44	0.41	0.49
1982 daily agr. wage rate for men	5.89	2.27	5.78	2.98	--	--	--	--
1982 daily non-agr. wage rate for men	8.63	3.56	9.99	4.27	--	--	--	--

1982 daily agr. wage rate for women	3.83	2.15	4.01	2.28	--	--	--	--
1982 daily non-agr. wage rate for women	2.65	2.09	2.74	2.69	--	--	--	--
Km distance to power plant 1965	181.40	108.82	157.44	114.35	199.83	107.34	167.40	109.94
Km distance to power plant 1975	140.92	95.88	129.24	108.73	153.94	98.79	132.33	97.38
N	4969		1039		1826		4182	

Note: The data are unweighted.

Table A2: Detailed results for the panel data regressions for household consumption

Log household consumption per capita	(1) OLS	(2) OLS with restriction imposed	(3) IV	(4) IV with restriction imposed	(5) IV with restriction imposed
Yrs village has been electrified 1999	0.002		0.018		
	[1.00]		[1.28]		
Interaction: years village electrified * HH electrified in ‘99	0.001		-0.023		
	[0.92]		[-1.08]		
Interaction: years village electrified * HH not electrified in ‘99		-0.001		0.010**	0.013**
		[-0.60]		[2.15]	[2.53]
HH has electricity –diff. between ’99 and ‘82	0.099***	0.104***	0.049	0.067**	0.067*
	[3.93]	[4.19]	[1.05]	[2.02]	[1.95]
Log HH size (initial cond)	0.035	0.033	0.032	0.034	0.038
	[1.07]	[1.00]	[0.87]	[1.01]	[1.12]
Age of head (initial cond)	0.003	0.003	0.005	0.004	0.003
	[0.55]	[0.62]	[0.86]	[0.74]	[0.66]
Age of head sq (initial cond)	-0.000	-0.000	-0.000	-0.000	-0.000
	[-0.53]	[-0.58]	[-0.84]	[-0.72]	[-0.61]
Head is divorced/widowed (initial cond)	-0.002	-0.002	-0.010	-0.007	-0.009
	[-0.06]	[-0.05]	[-0.24]	[-0.17]	[-0.23]
A member 15+ has chronic illness/disability (initial cond)	-0.061**	-0.060**	-0.039	-0.051*	-0.051*
	[-2.24]	[-2.21]	[-1.22]	[-1.89]	[-1.85]
Head is Hindu (initial cond)	0.034	0.036	0.072	0.053	0.066
	[0.91]	[0.96]	[1.35]	[1.38]	[1.64]
Head is SC/ST (initial cond)	-0.020	-0.024	-0.079	-0.048	-0.064**
	[-0.68]	[-0.84]	[-1.33]	[-1.60]	[-2.06]
Max yrs of schooling of any adult 15+ (initial cond)	-0.009	-0.008	0.006	-0.002	-0.001
	[-1.40]	[-1.29]	[0.40]	[-0.28]	[-0.12]
Max yrs of schooling sq of any adult 15+ (initial cond)	0.001***	0.001***	0.001**	0.001**	0.001**
	[2.60]	[2.61]	[2.38]	[2.57]	[2.48]
Share of women aged 16-55 (initial cond)	0.032	0.032	0.076	0.054	0.067
	[0.31]	[0.31]	[0.61]	[0.50]	[0.61]
Share of men aged 16-55 (initial cond)	0.045	0.039	-0.005	0.021	0.024
	[0.48]	[0.43]	[-0.05]	[0.23]	[0.25]
Share of girls aged 7-15 (initial cond)	0.002	0.003	0.011	0.007	-0.001
	[0.02]	[0.02]	[0.08]	[0.05]	[-0.01]

Share of boys aged 7-15 (initial cond)	0.008	0.011	0.007	0.007	0.012
	[0.07]	[0.09]	[0.06]	[0.06]	[0.10]
Share of girls aged 0-6 (initial cond)	0.385***	0.389***	0.364**	0.373**	0.358**
	[2.60]	[2.63]	[2.09]	[2.44]	[2.28]
Share of boys aged 0-6 (initial cond)	-0.069	-0.065	-0.098	-0.085	-0.115
	[-0.52]	[-0.49]	[-0.69]	[-0.64]	[-0.86]
Head moved from outside village (initial cond)	0.040	0.040	0.011	0.025	0.024
	[0.67]	[0.67]	[0.16]	[0.43]	[0.39]
HH owns land (initial cond)	-0.087***	-0.088***	-0.044	-0.066**	-0.055*
	[-3.14]	[-3.16]	[-0.89]	[-2.12]	[-1.66]
Inherited landownings (100s acres) (initial cond)	-0.014***	-0.014***	-0.014***	-0.014***	-0.014***
	[-3.57]	[-3.54]	[-3.24]	[-3.50]	[-3.49]
House made from bricks/cement (initial cond)	-0.128***	-0.127***	-0.114***	-0.122***	-0.127***
	[-3.66]	[-3.63]	[-3.09]	[-3.56]	[-3.70]
Mean log deviation of total C (initial cond)	-0.284	-0.262	-0.054	-0.171	-0.088
	[-1.08]	[-0.99]	[-0.17]	[-0.67]	[-0.36]
Crop yield below normal (initial cond)	0.046	0.050	0.011	0.029	-0.006
	[0.96]	[1.06]	[0.19]	[0.60]	[-0.10]
Muslim share of population (initial cond)	-0.051	-0.019	-0.039	-0.048	-0.070
	[-0.54]	[-0.21]	[-0.39]	[-0.52]	[-0.70]
Share of village area cultivated (initial cond)	-0.210***	-0.206***	-0.173**	-0.192***	-0.087
	[-3.20]	[-3.12]	[-2.32]	[-2.93]	[-0.93]
Large landowners lease out land (initial cond)	-0.102**	-0.095**	-0.112**	-0.107**	-0.089
	[-2.20]	[-2.04]	[-2.33]	[-2.39]	[-1.48]
Km to nearest pucca road (initial cond)	-0.000	-0.001	-0.001	-0.001	-0.002*
	[-0.84]	[-1.01]	[-1.08]	[-1.09]	[-1.85]
Km to block HQ (initial cond)	-0.000	-0.000	-0.000	-0.000	-0.000
	[-0.99]	[-0.83]	[-0.81]	[-0.93]	[-0.74]
Market within 2km (initial cond)	-0.012	-0.019	0.013	0.000	0.003
	[-0.22]	[-0.34]	[0.21]	[0.01]	[0.05]
Cooperative in village (initial cond)	-0.049	-0.048	-0.081	-0.064*	-0.061
	[-1.44]	[-1.40]	[-1.55]	[-1.84]	[-1.32]
Health facility within 5 km (initial cond)	0.039	0.036	0.056	0.047	0.021
	[1.30]	[1.23]	[1.52]	[1.55]	[0.47]
Primary school within 2km (initial cond)	0.053	0.052	0.048	0.051	0.084
	[1.07]	[1.04]	[1.04]	[1.09]	[1.57]
Secondary school within 2km (initial cond)	-0.009	-0.010	-0.021	-0.014	0.076
	[-0.23]	[-0.26]	[-0.52]	[-0.41]	[1.45]
Public drinking water tap (initial cond)	-0.040	-0.039	-0.031	-0.035	0.022
	[-0.98]	[-0.96]	[-0.80]	[-0.92]	[0.34]

Ag wage rate for women (initial cond)	0.013*	0.013**	0.018**	0.016**	0.013*
	[1.94]	[2.01]	[2.19]	[2.39]	[1.73]
Non-ag wage rate for women (initial cond)	0.002	0.004	0.002	0.002	0.007
	[0.32]	[0.57]	[0.35]	[0.33]	[1.00]
Ag wage rate for men (initial cond)	0.004	0.005	0.004	0.004	-0.003
	[0.63]	[0.92]	[0.70]	[0.66]	[-0.41]
Non-ag wage rate for men(initial cond)	0.009**	0.009**	0.005	0.007	0.010**
	[2.09]	[2.08]	[0.81]	[1.63]	[2.35]
Household split in 1999 (yes=1, no=0)	-0.046***	-0.046***	-0.026	-0.036*	-0.032*
	[-2.65]	[-2.68]	[-1.00]	[-1.97]	[-1.73]
Log HH size- diff	-0.428***	-0.429***	-0.404***	-0.416***	-0.409***
	[-20.45]	[-20.45]	[-13.42]	[-19.01]	[-17.68]
Age of head- diff	0.005*	0.005**	0.005*	0.005**	0.005**
	[1.96]	[1.99]	[1.88]	[2.01]	[1.99]
Age of head sq- diff	-0.000*	-0.000*	-0.000*	-0.000*	-0.000*
	[-1.86]	[-1.87]	[-1.77]	[-1.89]	[-1.91]
Head is divorced/widowed- diff	-0.007	-0.007	-0.021	-0.014	-0.013
	[-0.31]	[-0.31]	[-0.74]	[-0.62]	[-0.57]
Member 15+ has chronic illness/disability- diff	0.061***	0.062***	0.078***	0.069***	0.069***
	[3.75]	[3.82]	[3.35]	[4.17]	[4.00]
Max yrs of schooling of any adult- diff	-0.012***	-0.011***	-0.002	-0.007	-0.006
	[-2.72]	[-2.65]	[-0.26]	[-1.58]	[-1.42]
Max yrs of schooling of any adult sq- diff	0.002***	0.002***	0.002***	0.002***	0.002***
	[6.27]	[6.27]	[6.01]	[6.38]	[6.26]
Share of women aged 16-55-diff	0.163***	0.165***	0.188***	0.175***	0.179***
	[2.97]	[2.99]	[2.72]	[3.00]	[2.95]
Share of men aged 16-55- diff	0.225***	0.226***	0.194***	0.210***	0.206***
	[4.39]	[4.40]	[3.14]	[4.19]	[4.01]
Share of girls aged 7-15- diff	-0.049	-0.043	-0.053	-0.052	-0.054
	[-0.69]	[-0.61]	[-0.67]	[-0.72]	[-0.72]
Share of boys aged 7-15- diff	0.083	0.085	0.078	0.080	0.071
	[1.26]	[1.30]	[1.09]	[1.20]	[1.03]
Share of girls aged 0-6- diff	-0.104	-0.101	-0.158	-0.131	-0.146
	[-1.20]	[-1.17]	[-1.52]	[-1.49]	[-1.61]
Share of boys aged 0-6- diff	-0.238***	-0.234***	-0.279***	-0.259***	-0.278***
	[-3.27]	[-3.22]	[-3.12]	[-3.49]	[-3.62]
HH owns land yes=1 no=0- diff	0.088***	0.088***	0.143***	0.115***	0.123***
	[4.35]	[4.36]	[2.65]	[4.70]	[4.80]
Mean log deviation of total C- diff	0.038	0.044	0.100	0.069	0.083
	[0.20]	[0.23]	[0.54]	[0.37]	[0.46]

Crop yield below normal- diff	-0.029	-0.031	-0.066	-0.047	-0.045
	[-0.84]	[-0.91]	[-1.33]	[-1.33]	[-1.20]
Muslims share – diff	0.060	0.060	0.049	0.054	0.105
	[0.61]	[0.62]	[0.47]	[0.56]	[0.93]
Distance to block headquarters- diff	-0.000	-0.000	-0.000	-0.000	0.000
	[-0.33]	[-0.21]	[-0.81]	[-0.60]	[0.17]
Share of cultivable land sown in village- diff					0.103
					[1.28]
Large landowners in village- diff					0.030
					[0.76]
Distance to nearest paved road- diff					-0.001
					[-1.46]
Market within 2km - diff					0.015
					[0.43]
Agr. cooperative operating in village- diff					0.022
					[0.62]
Health care facility within 5km - diff					-0.027
					[-0.71]
Primary school within 2km - diff					0.060**
					[2.06]
Secondary school within 2km - diff					0.070*
					[1.72]
Community has a public drinking water tap- diff					0.052
					[1.15]
Constant	-0.221	-0.137	-0.237	-0.235	-0.417*
	[-1.08]	[-0.70]	[-1.15]	[-1.19]	[-1.95]
F (1, 229)	3.58	--	0.36	--	--
Prob.	0.060		0.548		
N	5,697	5,697	5,697	5,697	5,697
R^2	0.466	0.466	0.344	0.437	0.426

Note: Robust t-statistics in brackets. Clustering is at the village level. *** p<0.01, ** p<0.05, * p<0.1. Five IVs are used: the distances in 1965 and 1975 to the nearest power plant; years since the village was electrified; whether the household was initially electrified and the interaction between the last two. District fixed effects included.

Table A3: First Stage estimates

	(1) First Stage Years of vill. elec. times HH not electrified	(2) First Stage Change in household electricity	(3) IV restriction imposed
Log household size (initial cond)	0.097	-0.017	0.034
	[0.18]	[-0.72]	[1.01]
Age of head (initial cond)	-0.068	0.004	0.004
	[-0.81]	[1.13]	[0.74]
Age of head sq (initial cond)	0.001	-0.000	-0.000
	[0.83]	[-1.02]	[-0.72]
Head is divorced/widowed (initial cond)	0.333	-0.035	-0.007
	[0.47]	[-1.22]	[-0.17]
Member 15+ has chronic illness (initial cond)	-0.845*	0.031	-0.051*
	[-1.84]	[1.61]	[-1.89]
Head is Hindu (initial cond)	-1.551*	0.066**	0.053
	[-1.96]	[2.33]	[1.38]
Head is SC/ST (initial cond)	2.417***	-0.082***	-0.048
	[4.79]	[-4.04]	[-1.60]
Max yrs of school any adult 15+ (initial cond)	-0.561***	0.027***	-0.002
	[-4.54]	[5.55]	[-0.28]
Max yrs of school sq any adult 15+ (initial cond)	0.001	-0.000	0.001**
	[0.16]	[-0.27]	[2.57]
Share of women aged 16-55 (initial cond)	-1.833	0.066	0.054
	[-0.95]	[0.94]	[0.50]
Share of men aged 16-55 (initial cond)	1.838	-0.078	0.021
	[1.00]	[-1.23]	[0.23]
Share of girls aged 7-15 (initial cond)	-0.327	0.086	0.007
	[-0.14]	[0.96]	[0.05]
Share of boys aged 7-15 (initial cond)	-0.062	-0.044	0.007
	[-0.03]	[-0.51]	[0.06]
Share of girls aged 0-6 (initial cond)	0.701	-0.037	0.373**
	[0.22]	[-0.30]	[2.44]
Share of boys aged 0-6 (initial cond)	1.164	-0.054	-0.085
	[0.50]	[-0.58]	[-0.64]
Head moved from outside village (initial cond)	0.920	-0.070	0.025
	[1.07]	[-1.58]	[0.43]
HH owns land (initial cond)	-1.583***	0.075***	-0.066**
	[-2.88]	[3.34]	[-2.12]
Inherited land (100s acres) (initial cond)	-0.023	0.001	-0.014***
	[-0.80]	[0.52]	[-3.50]
House structure in bricks/cement (initial cond)	-0.636	0.028	-0.122***
	[-1.58]	[1.57]	[-3.56]
Mean log deviation of total C (initial cond)	-10.254**	0.336**	-0.171
	[-2.51]	[2.04]	[-0.67]
crop yield below normal (initial cond)	1.376	-0.014	0.029
	[1.32]	[-0.31]	[0.60]
Muslim share (initial cond)	0.083	0.030	-0.048
	[0.04]	[0.49]	[-0.52]
share of cultivated village area (initial cond)	-1.747*	0.098**	-0.192***
	[-1.67]	[2.18]	[-2.93]
large landowners lease out land (initial cond)	0.625	0.020	-0.107**
	[0.90]	[0.70]	[-2.39]
distance in km to nearest pucca road (initial cond)	0.013*	-0.001***	-0.001

	[1.70]	[-3.13]	[-1.09]
distance in km to block HQ (initial cond)	-0.001	0.000	-0.000
	[-0.30]	[1.02]	[-0.93]
nearest market within 2km (initial cond)	-0.895	0.041	0.000
	[-1.10]	[1.33]	[0.01]
cooperative in village (initial cond)	1.502**	-0.006	-0.064*
	[2.27]	[-0.26]	[-1.84]
health facility within 5 km (initial cond)	-0.724	-0.012	0.047
	[-1.43]	[-0.68]	[1.55]
primary school within 2km (initial cond)	0.307	0.005	0.051
	[0.49]	[0.20]	[1.09]
secondary school within 2km (initial cond)	0.629	-0.003	-0.014
	[0.90]	[-0.11]	[-0.41]
public drinking water tap (initial cond)	-0.317	0.014	-0.035
	[-0.47]	[0.54]	[-0.92]
Female agr wage (initial cond)	-0.281*	0.004	0.016**
	[-1.84]	[0.76]	[2.39]
Female non-agr wage (initial cond)	-0.021	-0.000	0.002
	[-0.20]	[-0.05]	[0.33]
Male agr wage (initial cond)	-0.029	0.006*	0.004
	[-0.28]	[1.69]	[0.66]
Male non-agr wage (initial cond)	0.159***	-0.004*	0.007
	[2.77]	[-1.71]	[1.63]
Household split in 1998 (yes=1, no=0)	-0.706**	0.032**	-0.036**
	[-2.29]	[2.48]	[-1.97]
Log household size- diff	-0.924**	0.027*	-0.416***
	[-2.56]	[1.72]	[-19.01]
age of head- diff	-0.005	0.002	0.005**
	[-0.10]	[1.08]	[2.01]
age of head sq- diff	0.000	-0.000	-0.000*
	[0.12]	[-0.97]	[-1.89]
Head is divorced/widowed- diff	0.564	-0.030*	-0.014
	[1.36]	[-1.84]	[-0.62]
Member 15+ has chronic illness- diff	-0.658*	0.019	0.069***
	[-1.87]	[1.55]	[4.17]
Max yrs of school any adult- diff	-0.343***	0.018***	-0.007
	[-3.83]	[4.84]	[-1.58]
Max yrs of school any adult sq- diff	-0.001	-0.000	0.002***
	[-0.30]	[-0.24]	[6.38]
Share of women aged 16-55-diff	-0.910	0.054	0.175***
	[-0.80]	[1.26]	[3.00]
Share of men aged 16-55- diff	1.204	-0.051	0.210***
	[1.13]	[-1.41]	[4.19]
Share of girls aged 7-15- diff	0.307	0.027	-0.052
	[0.23]	[0.48]	[-0.72]
Share of boys aged 7-15- diff	0.079	-0.027	0.080
	[0.07]	[-0.58]	[1.20]
Share of girls aged 0-6- diff	2.112	-0.071	-0.131
	[1.40]	[-1.15]	[-1.49]
Share of boys aged 0-6- diff	1.729	-0.065	-0.259***
	[1.21]	[-1.20]	[-3.49]
HH owns land yes=1 no=0- diff	-2.123***	0.087***	0.115***
	[-5.13]	[5.15]	[4.70]
Mean log deviation of total C- diff	-3.718	0.141	0.069
	[-1.49]	[1.33]	[0.37]
Crop yield below normal- diff	1.674**	-0.060**	-0.047

	[2.44]	[-2.01]	[-1.33]
Muslim share- diff	0.502	0.098**	0.054
	[0.31]	[2.01]	[0.56]
Distance to block headquarters- diff	0.004	-0.000	-0.000
	[1.21]	[-0.18]	[-0.60]
Distance to power plant in 1965	-2.157***	0.117***	
	[-2.70]	[3.80]	
Distance to power plant in 1975	1.799***	-0.061**	
	[2.70]	[-2.59]	
Yrs village has been electrified 1999	0.318***	0.002*	
	[8.61]	[1.66]	
Yrs of village electrification*HH electrified in 1999	-0.041	-0.004***	
	[-1.09]	[-3.27]	
Years of village electrification times household not electrified in 1999			0.010**
			[2.15]
HH has electricity –diff 99-82	-0.336	-0.845***	0.067**
	[-0.31]	[-18.36]	[2.02]
Constant	4.807	0.082	-0.235
	[1.25]	[0.56]	[-1.19]
N	5,697	5,697	5,697
R-squared	0.434	0.570	0.437
F-test of excluded instruments F(5,229)	17.88	642.18	
Prob.	0.0000	0.0000	

Note: Robust t-statistics in brackets; *** p<0.01, ** p<0.05, * p<0.1. Uses electricity definition C