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Impacts of access to electricity on employment and household income growth in Cambodia

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This study examines the impacts of access to electricity on household welfare in terms of employment and income growth in Cambodia. To correct for the endogeneity of electricity, we introduce two instruments: (1) population density at village level; and (2) distance between the center of the village and the nearest electricity substation point. Results show a strong and positive effect of household access to electricity on the probability of participation in wage employment and self-employment in the nonfarm sector. Access to electricity contributes to total household income growth through the growth of household nonfarm income. Evidence shows that electrification has facilitated the shift of household livelihood away from self-employment on farms and to wage work in the nonfarm sector, which eventually served as the main driver of household income growth.

JEL classification: J21, O13, Q4
Keywords: access to electricity, employment, household income, Cambodia

1. Introduction

For the achievement of 17 Sustainable Development Goals (SDGs), access to modern energy such as electricity is one of the most essential and fundamental inputs to socio-economic development. Access to electricity is crucial for the provision of basic needs such as food, health, water, education, and transportation. Electricity is an important input for income generation and productive activities particularly in industry and services.

However, it is estimated that 1.2 billion people, 16 percent of the global population, still had no access to electricity in 2014 [International Energy Agency 2016]. In particular, some countries in Asia and the Pacific are struggling to ensure affordable, reliable, and sustainable energy resources to meet their increasing

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energy demands. Like other developing countries in Southeast Asia, Cambodia recognizes that one of the key obstacles to its economic development is the inadequate supply of electricity and basic infrastructure, along with roads and water. As stipulated in Cambodia's socio-economic policy agenda, the national development strategy of Cambodia identifies electricity as one of the priority areas for investment to promote economic and social development.

Except for a few studies such as Saing [2017], Han et al. [2020] and Chhay and Yamazaki [2020], previous studies on Cambodia tend to investigate linkages between various infrastructure and household welfare qualitatively without addressing the endogeneity problem [Bliss 2007; World Bank 2006, 2013]. To reduce concerns about the endogeneity of access to electricity, we employ the instrumental variable (IV) approach with fixed effects and introduce a new instrument, the distance between the center of the village and the nearest electricity substation point. This instrument is an improvement upon previous IVs because we use information on the location of substation points, the first attempt in Cambodia because these data are difficult to obtain. In addition, we shed light on how electrification benefits household welfare in both urban and rural areas, while most of the existing studies focus on only rural areas.

Using nationally representative household survey data, the estimation results show a strong and positive effect of household electrification on wage employment and self-employment in the nonfarm sector. With regard to household income, our findings indicate that increased access to electricity contributes to total household income growth through an increase in nonfarm income. Furthermore, the effect of electrification on income growth is much stronger in urban areas. These results suggest that electricity projects, by creating jobs and stimulating the development of the nonfarm sector, could serve as an effective instrument in improving household welfare. The rest of this paper is organized as follows: Section 2 provides the literature review and testable hypotheses. Section 3 describes the datasets and the changes in the sources of income with the expansion of electricity coverage. Section 4 describes the estimation strategy, while Section 5 presents the estimation results and Section 6 checks for robustness. Finally, Section 7 concludes this paper.

2. Literature review and testable hypotheses

Many previous studies have investigated the effects of electrification on household welfare in developing countries, but the results on employment structure have been mixed. For example, some studies observed positive impacts of electrification on female employment, while there is no statistically significant impact on male employment (Dinkelman [2011]; Grogan and Sadanand [2013]; Dasso and Fernandez [2015]). Rathi and Vermaak [2018] found that access to electricity in India increases paid employment for women while it decreases

paid employment for men. They explained that access to modern technology via electricity frees up women's time from household chores, allowing them to engage in income-generating activities. On the contrary, men may drop out of the labor force as a result of extra income from female family members. However, Vande Walle et al. [2015] found a positive impact on both male and female labor supply in India. For men, the results indicate a significant substitution in labor supply from casual to regular work since electricity allows longer working times including night time. For women, the main effect is to increase casual wage work, while no evidence of wage increase was found. Furthermore, Lipscomb et al. [2013] estimated the development effects of electrification across Brazil and found large, positive effects of electrification on employment in both formal and informal sectors. Chhay and Yamazaki [2020] and Fetter and Usmani [2020] assessed the impact of electrification in rural Cambodia and India respectively and found that access to electricity significantly increased non-agricultural employment. To sum up, results from the existing literature are mixed on the impacts of electricity on employment.

Given the aforementioned, we propose the following hypotheses relating electricity to employment:

Hypothesis 1 (H1): Access to electricity increases the probability that household members are engaged in wage employment in nonfarm sectors.

Hypothesis 2 (H2): Access to electricity induces household members to start their own household businesses in the nonfarm sector.

With regard to household income, some studies found significant positive impacts, especially on nonfarm income, but the effects on agricultural income are small or not significant (Kumar and Rauniyar [2018]; Charkravotry et al., [2014]; Khandker et al., [2014], while other studies failed to observe any effects [Peters and Sievert 2016].

Based on the above observations, we postulate the following hypotheses on electricity and household income growth:

Hypothesis 3 (H3): Access to electricity contributes to total household income growth through increased household nonfarm income.

Hypothesis 4 (H4): Access to electricity does not significantly affect agricultural income.

3. Data set and household sources of income

3.1. Dataset

This study mainly uses Cambodia Socio-Economic Survey (CSES) data for 2004, 2009, 2014, and 2017. These are nationally representative household survey datasets collected by the National Institute of Statistics under the auspices of the Ministry of Planning of the Royal Government of Cambodia. The main objective

of the survey is to collect statistical information about the living conditions of the Cambodian population and the extent of poverty. CSES contains information related to income and welfare indicators such as health, education, housing conditions, economic activities, and access to infrastructure including electricity, roads and piped water.

We used CSES data for 2004, 2009, 2014, and 2017 for descriptive analyses. For the regression analysis, we selected 2004, 2009 and 2014 because these surveys have a large sample set, which is done every five years since 2004. We limit the individual sample to those of working age (15 to 58 years old). The total sample size is 12,307 households (43,027 individuals) in 2004; 10,209 households (35,319 individuals) in 2009; 15,218 households (53,022 individuals) in 2014; and 3,840 households, (16,909 individuals) in 2017. The CSES has several advantages. First, the datasets are nationally representative, covering all 24 provinces of Cambodia. Second, the data include comprehensive information on household income sources along with descriptions of occupation and industry, employment status (employee, employer, own account worker and unpaid family worker), and wages of paid employees among household members. Furthermore, the data include all sources of household income, such as income from agriculture; income from nonfarm economic activities; and income from other sources such as remittances and pensions. This enables the calculation of total household income from all income sources. Finally, the survey includes questionnaires related to infrastructure including sources of lightning at both household and village levels.

In addition to the CSES data, the Economic Census of Cambodia (ECC), which covers all establishments in Cambodia, is used for descriptive analysis to better capture a comprehensive picture of how electrification has affected employment from the labor demand side. Finally, data from the country's Population Census for 1998 and 2008 were used to construct the population density of the village, which is one of our two instrumental variables, along with the distance between the center of the village and the nearest electricity subpoint.

3.2. Description of sample households

Regarding main sources of lighting, more than half of all households used kerosene lamps, while the percentage of households with access to publicly provided electricity was only 16 percent in 2004. The latter proportion increased significantly from 27 percent in 2009 to 61 percent in 2014 and 82 percent in 2017, thanks to several development assistance projects, which extended coverage of electricity grids. However, these rates are low compared to other CLMV countries (Laos, Myanmar, and Vietnam). This is the result of conflict and civil war under the Pol Pot regime in the 1970s when almost all electricity facilities, including generation, transmission, and distribution facilities, were destroyed throughout the country. Furthermore, there remains a significant urban-rural gap in the percentage of the population with access to electricity.

Regarding the characteristics of households with access to electricity (defined as households using publicly provided electricity/city power as their main source of lighting) and those without electricity, important characteristics for comparison are the educational attainment of household members and their sector of employment and sources of household income. We classify the sector of employment into (1) wage employment, (2) self-employment in the farm sector, (3) self-employment in the nonfarm sector, and (4) unpaid work. Sources of household income are farm, nonfarm, and other income which includes remittances and social benefits among others.

Electrified households have higher levels of schooling attainment and this is particularly noticeable for the proportion of working-age members with tertiary schooling. In contrast, more than 60 percent of members from households without electricity have partially or fully completed primary schooling (1-6 years). A higher proportion of working-age members from households with electricity are engaged in wage work and self-employment in the nonfarm sector, in contrast to members of households with no electricity who are largely engaged in self-employment on farms or work as unpaid workers. Nonetheless, the proportion of unpaid workers in households with no electricity has gone down substantially from 39 percent in 2004 to 23 percent in 2009 to 5 percent in 2014.

Electrified households are better off: they have higher income, especially nonfarm income. The ratio of average monthly income between electrified households and non-electrified households declined from 3.17 in 2004 (USD 476 versus USD 150 in USD PPP in 2010) to 1.87 in 2009 (USD 665 versus USD 354) to 1.46 in 2014 (USD 689 versus USD 469) to 1.49 in 2017 (USD 729 versus USD 490). Non-electrified households have caught up mainly because they have received higher nonfarm income and other income including remittances. Furthermore, electrified households have more assets, such as radio, TV and mobile phones, which may contribute to improving access to information.

At the village level, villages with access to grid electricity have much shorter distances to bus stops, which suggests that transport accessibility is better. The number of functioning large industrial enterprises and infrastructure development projects is higher for villages with access to grid electricity than for those without electricity. However, it is not clear whether these necessarily imply a causal effect of electrification.

3.3. Changing sources of household income

A summary of household income sources in Cambodia is presented in Table 1. We classify income into three major categories: (1) income from wage work, (2) income from self-employment, and (3) other income. Income from wage work comes from agriculture and non-agricultural sectors including manufacturing and services. The manufacturing sector includes garments, food, wood, metal, and others. Income from services includes earnings from construction, retail,

government, transport, business services, and other categories. Self-employment income from agriculture comes from crop farming, animal raising, fishing, forestry, and hunting. Self-employment income from services comes from retail, transport, business services, and other sources. Other income consists of domestic and overseas remittances, and others such as pensions, transfers, bank interest, and dividends.

TABLE 1. Monthly household income sources in Cambodia (USD PPP in 2010)

	2004	2009	2014	2017
Wage work	84 (39%)	109 (26%)	265 (41%)	393 (57%)
Agriculture	20 (9%)	33 (8%)	68 (11%)	27 (4%)
Manufacturing[1]	4 (3%)	7 (1%)	21 (2%)	101 (15%)
Service[2]	60 (27%)	69 (15%)	176 (27%)	264 (37%)
Self-employment	119 (55%)	305 (72%)	301 (47%)	263 (39%)
Agriculture	61 (28%)	143 (34%)	91 (14%)	61 (9%)
Manufacturing	4 (2%)	13 (3%)	18 (3%)	13 (2%)
Retail services	39 (18%)	79 (19%)	134 (21%)	132 (19%)
Other services[3]	15 (8%)	70 (16%)	58 (9%)	57 (8%)
Other income	12 (6%)	9 (2%)	74 (11%)	29 (4%)
Remittances	8 (4%)	6 (2%)	53 (9%)	24 (4%)
Others	4 (2%)	3 (0%)	20 (2%)	5 (0%)
Total income	215 (100%)	423 (100%)	640 (100%)	686 (100%)

Note 1-3: "Manufacturing" includes mining, garments, food, wood, metal and others, "Service" includes construction, retail, government, transport, business services, and others.
Source: Authors' calculations from the Cambodia Socio-economic Survey.

The average total monthly household income in Cambodia increased from USD 215 PPP in 2004 to USD 686 in 2017, a more than threefold increase (Table 1). This was mainly because of the increase in income from wage work in the nonfarm sector, most notably in the garment industry as well as in service sectors such as construction, government, and business. There was a shift in household income structure away from self-employment in agriculture to wage work in manufacturing and services. The share of self-employment income from

agriculture declined from 28 percent in 2004 to nine percent in 2017. The share of wages in manufacturing increased from three percent to 15 percent while the share of services rose from 27 percent to 37 percent in the same year. Government services (administration of the state, provision of services to the community, and compulsory social security activities) are the main sources of wage income across all years. The decline in self-employment income from agriculture indicates the declining importance of crop farming, animal husbandry and fishing and hunting as a source of livelihood. Wage income from agriculture, which made up nine percent of total household income in 2004, has become much less important, as its share of total household income has declined to four percent.

Interestingly, the share of crop income increased from 11 percent in 2004 to 27 percent in 2009, as a result of the higher value of production of rice after the increase in rice prices and rice production during the Asian food crises in 2007 to 2009. According to the World Bank [2013], the price of rice (in constant value) increased by 37.1 percent from 2004 to 2009, boosting farmer income and providing incentives to increase production. In addition, according to FAOSTAT data, the area used for rice production expanded from 2.1 million hectares in 2004 to 2.7 million in 2009 (27 percent increase) and rice yield increased from an average of two tons per hectare in 2004 to an average of 2.8 tons per hectare in 2009 (43 percent increase).

Self-employment in the nonfarm sector such as manufacturing, retail services and other services remains an important source of income accounting for roughly one-third of the total household income in all years. In particular, income from retail services has consistently remained an important source of income, accounting for nearly 20 percent of total income in all years. As a result of Cambodia's real estate boom, fueled by investment from China, income from the construction sector became the second largest income source in Cambodia's service sector in 2009, followed by income from business services (financial intermediation, renting, and business activities) and transport services (transport, storage, and communication).

In summary, there is a clear shift in household income structure away from agricultural self-employment and to nonfarm wage work. Such a shift has been accompanied by income growth. The shift in household income sources has coincided with the expansion of electricity coverage in the country. Households have been increasingly engaged in electricity-intensive sectors such as garments, construction, government, and business services. Here we inquire whether electricity has a significant impact on the choice of employment and household income.

4. Estimation strategy

To examine the impact of access to electricity on employment and household income growth, we obtain household electrification status data from a household

questionnaire within CSES survey data. We define treatment households as those having access to publicly provided electricity or city power (national electricity grid provided by the government) and control households as those which do not have such connection and hence use generator, battery, or kerosene lamp as their main source of lighting.

To identify the causal effects of electrification on employment and household income, we have to control for the endogeneity of project placement. The Cambodia Energy Sector Strategy 2004 specified that the electrification strategy in Cambodia tends to give priority to areas with the best potential for economic development and with higher income levels, which suggests that project placement is not random. Therefore, to resolve the endogeneity problem, this study employs an instrumental variable (IV) estimation with fixed effects. The impact of electrification is identified using the following equations:

$$\hat{E}_{hvt} = \alpha_1 + Z_V + \pi_1 H_{hvt} + V_{vt} + \lambda + \theta_t + \varepsilon_{hvt}, \quad (1)$$

$$Y_{ihvt} = \alpha_2 + \beta_2 \hat{E}_{hvt} + \delta_2 X_{ihvt} + \pi_2 H_{hvt} + V_{vt} + \lambda + \theta_t + \varepsilon_{ihvt}, \quad (2)$$

$$Y_{hvt} = \alpha_3 + \beta_3 \hat{E}_{hvt} + \pi_3 H_{hvt} + V_{vt} + \lambda + \theta_t + \varepsilon_{hvt}. \quad (3)$$

Household's access to electricity is predicted by using instrumental variables (IVs): Z in Equation (1); and then our interest variable, the predicted value of the access to electricity ($\hat{E}_{hvt}$), measured by the coefficient (β), is used in the second stage outcome equations. This is effective since IVs break the correlation between the treatment and the error term, eliminating the endogeneity bias [Khandker et al. 2009].

Regarding the outcome variables, Y_{ihvt} in Equation (2) represents the outcome variables of individual i of household h in village v at time t. We examine four outcomes related to employment at an individual level: (1) a binary variable for an individual i of working age who is a paid employee, generally categorized as wage employment; (2) a binary variable for an individual i of working age who is self-employed in the nonfarm sector; (3) a binary variable for an individual i of working age who is self-employed in the agriculture sector; and (4) a binary variable for an individual i of working age who is an unpaid family worker.

The variable, Y_{hvt} in equation (3) represents household income, (1) log of monthly total household income, (2) log of monthly income in the nonfarm sector (including both wage income and income from self-employment), (3) inverse hyperbolic sine transformation of income in the agriculture sector and (4) log of monthly other income. We use the inverse hyperbolic sine transformation because a substantial number of households in urban areas have no income in agriculture. Regarding control variables, X_{ihvt} is a vector of individual-level characteristics, including gender (1 if female and 0 if otherwise), age, age-squared (to detect non-

linear effects of age), a dummy variable for marital status of individual i (1 if married), and years of education. H_{hvt} is a vector of household-level characteristics, including a binary variable indicating whether the household resides in an urban area (1 if urban, 0 otherwise); the number of toddlers aged 0 to 6; the area of irrigated land used for rice and other crop production (in hectares); and household assets (defined as the number of radios, televisions, mobile phones, and personal computers), in the case of equation (2).

In the case of the equation (3), H_{hvt} includes the dummy variable whether a household head is female, the number of household members aged 15 to 20, 21 to 30, 31 to 40, 41 to 50 and 51 to 58 years old, proportion of household members who are female, proportion of household members who completed primary school, secondary school and tertiary school, a binary variable for household living in urban area, and size of irrigated land for production of rice and other crops (hectares). V_{vt} is a vector of village-level characteristics including distance to the nearest bus stop, a binary variable for the presence of large industrial enterprises (e.g., factory, company employing more than 10 persons, hotel or restaurant), a binary variable for the presence of infrastructure development projects (e.g., road development), the proportion of female and male who are employed in the village and mean monthly earnings from wage employment in the village, which may partly reflect the scope of local labor market opportunities. District-level fixed effects are denoted as λ and year-fixed effects are denoted as θ_t. ε_{ihvt} is an error term representing unobserved variables. Finally, standard errors are clustered at the village level.

The IVs we propose are: (1) population density at village level and (2) distance between the center of the village and the nearest electricity substation point. First, in the prediction of household access to electricity, one plausible exogenous factor is population density at the village level before the expansion of electrification projects. If the extension of a given length of grid cable reaches fewer customers in an area where customers are widely dispersed, i.e., areas with low population density, the marginal cost of an additional household connection is relatively high. Thus, population density is a cost-related factor; and is one of the keys to our identification strategy. In this study, we use population census data collected in 1998 and 2008 by the Cambodian Ministry of Planning. The proportion of households with electricity was 13 percent in 1998 and 26 percent in 2008, which is substantially low compared to 82 percent in 2017. Thus, it is reasonable to conclude that the period 1998–2008 is the period before the electrification projects expanded. Population density at the village level during 1998-2008 can be considered exogenous and one of the significant factors influencing the status of village electrification in later periods.

Second, we propose the "distance between the center of the village and the nearest electricity substation" as a second IV to predict electricity availability. In general, there are four steps in the provision of electricity by an electrical network. First, power is produced at the power plant. Second, it is transmitted

along transmission lines to substations. Third, at the substation, the voltage is lowered from 230kv to a level that can be distributed to consumers. Finally, power is distributed along distribution lines from substations to households in a connected village. Thus, it is plausible to suggest that a household located in a village near an electricity substation has a higher probability of being connected to the electricity network than one in a village far from any substation. Furthermore, that distance does not affect our outcome variables related to employment and household income. According to the government's announced electricity expansion strategy, the focus is on areas which are far from the substation points, indicating that distance is one of the important elements for targeting electrification areas in Cambodia. Thus, based on the above arguments, the proposed two IVs (population density and household distance to the nearest electricity substation) could sufficiently address the endogeneity issue associated with household access to an electric grid.

5. Results

5.1. First stage results

To examine whether there are any obvious violations of the IV approach, we first test whether or not the IVs are good predictors of the endogenous variable, household access to electricity. Table 2 shows the first stage results of prediction of household access to electricity using the two IVs, (1) population density at the village level in 1998; and (2) distance between the village center and the nearest electricity substation point. The fit is very strong: the coefficients of both IVs are statistically significant at the one percent level. Furthermore, they are also jointly significant with a *p*-value equal to zero and high *F*-statistics, indicating that the IVs are strong.

TABLE 2. First stage regression results

Outcome	**Household access to electricity**	
Instruments	**(1)**	**(2)**
1. Population density	0.0185***	0.0187***
	(0.0058)	(0.0051)
2. Distance between village and a nearest electricity substation point	-0.0623***	-0.0533***
	(0.0224)	(0.0181)
Observations	96,760	26,714
Joint significance of all IVs	*F*=9.13	*F*=11.77
Hansen J statistics	3.505	0.088
	Chi-sq(1) *P*-val = 0.0612	(Chi-sq(1) *P*-val = 0.7663)

Note: Column (1) shows the first stage regression results at individual level with all the control variables. Column (2) shows the first stage regression results at household level with all the control variables. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

TABLE 3. Exclusion restriction

	Employment				Income			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	**Wage emp**	**Self-employment in nonfarm sector**	**Self-employment in farm sector**	**Unpaid**	**Total income**	**Nonfarm income**	**Farm income**	**Other income**
ln_population density	0.00169	0.0060657	-0.00655	-0.00510*	-0.0112	0.0330*	-0.0402	0.0178
	(0.00355)	(.0045493)	(0.00660)	(0.00283)	(0.0128)	(0.0182)	(0.0247)	(0.0400)
ln_distance	-0.0502***	0.00593	0.0535**	0.0323***	0.0363	0.0516	0.0884	-0.0334
	(0.0127)	(0.00473)	(0.0214)	(0.0115)	(0.0465)	(0.0580)	(0.0737)	(0.184)
Observations	46,176	46,176	46,176	46,176	13,370	5,622	5,263	3,609
R-squared	0.116	0.098	0.228	0.246	0.309	0.363	0.189	0.356

Note: The dependent variables are (1) whether an individual is employed as a wage earner (paid employee), (2) self-employed in nonfarm sector, (3) self-employed in farm sector, (4) unpaid family worker, (5) log of total monthly household income, (6) log of monthly income in nonfarm sector, (7) log of monthly income in farm sector and (8) log of monthly other income. The sample is limited to observations before the village had electricity. All errors are clustered at village level. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

It is essential to ensure that the IVs are exogenous, namely the IVs should not correlate with the error term of the outcome equations. First, this test can be performed using Hansen's *J* statistic, under the null hypothesis that the over-identification restriction is satisfied; that is, the IVs are not correlated with the error term of the outcome equation. As can be seen in Table 2, the results of Hansen's *J* statistic are insignificant, suggesting that the null hypothesis cannot be rejected, which in turn implies that the over-identification restriction is satisfied. Thus, it is reasonable to say that the proposed IVs do not affect our outcome variables and are not correlated with the error term. The second test is to check the exclusion restriction of the IVs to the outcome variables before the expansion of electricity projects following Squires [2015]. If the IVs satisfy the exclusion restriction, we would expect them to have an impact on the probability that households have access to electricity, but not on the outcome variables before electrification. Table 3 shows that except for a few cases (i.e., the distance between the center of the village and the nearest electricity substation point with respect to employment), the IVs do not significantly impact the outcome variables before electrification.

Overall, these tests suggest that the two IVs (1) population density at the village level; and (2) distance between the center of the village and the nearest electricity substation point have a strong first-stage impact on electrification and that there is no strong evidence that the IVs fail the exclusion restriction.

5.2. Second stage results

5.2.1. Electricity and employment

Since household income sources are affected by the probability of employment of working-age members, we explore the factors affecting individual member employment as related to the impact of electricity. Table 4 shows the results of IV estimations at the individual level with all the control variables at the household and village level, as well as, year and district fixed effects related to employment defined as follows: (1) wage employment, (2) self-employment in the nonfarm sector, (3) self-employment in the farm sector and (4) unpaid family worker. The estimation is performed for women and men separately.

Column (1) of Table 4 shows the two-stage least squares (2SLS) estimation results of the impact of household electrification on the probability of wage employment for all individual samples of working age. As the table shows, our interest variable, the binary variable household access to the electricity grid, is positive and significant, which supports our *H1: Access to electricity increases the probability that household members are engaged in wage employment in nonfarm sectors.* By gender, the value of the coefficient of electricity dummy is greater among men than among women. These results indicate that the effect of household electrification on male time allocation is much larger than that on women because men are usually the main earners of households and spend more time working as employees.

For women, the coefficient of the number of small children aged 0 to 6 years old is negative and significant indicating that household production activities matter a lot for women's decision in wage work.

TABLE 4. Impact of electrification on employment (2SLS estimation results)

	All			
	(1)	(2)	(3)	(4)
VARIABLES	Wage employment	Self-employment in nonfarm sector	Self-employment in farm sector	Unpaid family worker
Electricity (1=yes)	0.329**	0.496**	-0.726***	-0.245***
	(0.108)	(0.196)	(0.228)	(0.090)
Observations	96,760	96,760	96,760	97,760
	Women			
Electricity (1=yes)	0.267**	0.375**	-0.649***	-0.231*
	(0.119)	(0.173)	(0.221)	(0.123)
Observations	47,205	47,205	47,205	47,205
	Men			
Electricity (1=yes)	0.453**	0.498**	-0.735**	-0.256***
	(0.148)	(0.200)	(0.243)	(0.084)
Observations	45,788	45,788	45,788	45,788

Note: The dependent variables are (1) whether an individual is engaged in wage employment, (2) self-employment in the nonfarm sector, (3) self-employment in the farm sector, and (4) work as an unpaid family worker. The control variables at individual, household, and village levels are included. District and year fixed effects are included. All errors are clustered at village level. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Next, in the case of self-employment in the nonfarm sector, the coefficient of the dummy variable of household access to electricity is positive and significant for all specifications (Column 2). By gender, the coefficient of the dummy variable of household access to electricity is higher for males than for females (37.5 percent for males and 49.8 percent for females), which partly supports our *H2: Access to electricity induces household members to start their own household businesses in the nonfarm sector*.

Self-employment in the farm sector is largely related to rice production, as rice is a major crop in Cambodia. For all specifications, the effect of electrification on the probability of engagement in self-employment in the farm sector is negative and significant (Col 3). Furthermore, no clear gender difference is observed in the effects of electricity on self-employment in the farm sector. Finally, the results of the estimation for unpaid family workers are reported in column (4). The coefficient of the dummy variable of household access to electricity is negative and significant in all the specifications, suggesting household access to electrification contributes to the reduction of unpaid family workers and the effect is greater among males.

In summary, the estimation results show that household access to electricity increases the probability of work in wage employment and self-employment in the nonfarm sector, and decreases the probability of self-employment in the farm sector and unpaid work; all of which indicates that electricity induces working-age individuals in the households to shift their economic activities to more profitable endeavours in the nonfarm sector such as salaried work and self-employment and away from self-employment on farm and unpaid work.

5.2.2. Electricity and household income

Next, we examine the impact of electrification on the log of monthly household income: (1) total household income; (2) nonfarm income; (3) farm income; and (4) other income. The results of the IV estimations with all the control variables at the household and village levels, as well as year and district fixed effects, are reported in Table 5. All estimations are performed in both urban and rural areas.

Column (1) of Table 5 shows the results of the estimation of the impact of electrification on the log of monthly total household income. Estimation result shows household access to electricity has a positive impact on total household income, though it is not significant. The effect of electrification is much stronger in urban areas than in rural areas, where the impact is insignificant since households in rural areas rely more on farm income.

TABLE 5. Impact of electrification on household income (2SLS estimation results)

	All			
	(1)	(2)	(3)	(4)
VARIABLES	**Total monthly income**	**Nonfarm income**	**Farm income**	**Other income**
Electricity (1=yes)	0.388	1.228**	-1.1916***	-0.815
	(0.369)	(0.484)	(0.586)	(0.869)
Observations	26,714	15,495	21,534	7,583
		Urban		
Electricity (1=yes)	1.159**	1.433*	-5.643***	-1.095
	(0.475)	(0.800)	(1.800)	(1.297)
Observations	6,117	5,324	6,299	1,593
		Rural		
Electricity (1=yes)	0.0551	1.191***	-4.265***	-0.240
	(0.393)	(0.437)	(1.296)	(0.922)
Observations	20,597	10,171	21,324	5,990

Note: The dependent variables are (1) log of total monthly income, (2) log of nonfarm income, (3) Inverse hyperbolic sine of Farm income, and (4) log of other income. The control variables at individual, household, and village levels are included. District and year fixed effects are included. All errors are clustered at village level. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

As for nonfarm income (including both income from wage employment and self-employment) (Col 2), the effect of electrification is positive and significant and much stronger compared to that for total income, which supports *H3: Access to electricity contributes to total household income growth through increased household nonfarm income*. Regarding geographic area, the effect of electricity on nonfarm income is positive and significant in both urban and rural areas and is much stronger in urban areas. As for farm income (Col 3), the results of IV estimations show that the impact of electricity is negative and statistically significant at the one percent level, which partially rejects *H4: Access to electricity does not significantly affect agricultural income.* The negative effect is much stronger in rural areas. This could be explained by the fact that electrification makes nonfarm activities more profitable than farming, inducing people to switch out of farming into nonfarm activities as a result of electrification.

Finally, the results of the estimation of other income, which are all non-labor income, are reported in Column (4). Other income includes income from sources such as remittance, pensions, and interest on loans. In particular, remittance (both domestic and abroad) accounts for about 70 percent of other income sources. The result shows that the effect of household access to electricity on other income is negative but insignificant. By region, there is a negative association between access to electricity and other incomes in both urban and rural areas—though none of those associations are significant. Overall, there is no clear evidence that electrification affects non-labor income.

6. Robustness check

Here we examine the sensitivity of our results using two strategies: (1) employing the OLS with village fixed effects using village-level panel data, and (2) investigating the spillover benefits of village electrification on non-electrified households.

6.1. Panel data at village level

To test for sensitivity and to control for time-invariant confounding factors at the village level, we restrict the samples to panel data at the village level. We use the same estimation strategies in Equations (1) and (2) as explained in Section 4 and employ village-fixed effects rather than district-fixed effects. The results of the OLS estimations, which include all control variables at the individual, household, and village levels, as well as year and village fixed effects, related to individual employment, are reported in Table 6.

TABLE 6. Impact of electrification on employment using village-panel data

	All			
	(1)	(2)	(3)	(4)
VARIABLES	Wage employment	Self-employment in nonfarm sector	Self-employment in farm sector	Unpaid family worker
Electricity (1=yes)	0.104***	0.172***	-0.105**	-0.00611
	(0.0380)	(0.0475)	(0.0448)	(0.0239)
Observations	10,567	10,567	10,567	10,567
	Women			
Electricity (1=yes)	0.0470	0.171***	-0.154***	-0.00278
	(0.0358)	(0.0512)	(0.0523)	(0.0284)
Observations	5,492	5,492	5,492	5,492
	Men			
Electricity (1=yes)	0.140***	0.162***	-0.0553	-0.00499
	(0.0450)	(0.0496)	(0.0543)	(0.0243)
Observations	5,075	5,075	5,075	5,075

Note: The dependent variables are (1) whether an individual is employed as a wage employment, (2) self-employed in nonfarm sector, (3) self-employed in farm sector, and (4) unpaid family worker. The control variables at individual, household, and village levels are included. District and year fixed effects are included. All errors are clustered at village level. Standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1

Overall, the effect of household access to electricity on employment is similar to our main results using data for all villages. There is an increased probability of wage employment with access to electricity, with the effect much stronger for males. Electricity has a positive impact on the probability of self-employment in the nonfarm sector for both women and men, with the effect slightly higher for women reflecting the fact that self-employment activities in the nonfarm sector are performed within the confines of homes, so women can easily combine them with household chores and domestic activities. There is a negative association between access to electricity and self-employment in the farm sector, although the effect is small and insignificant for males. Finally, the effect of electrification is negative but insignificant on the probability of unpaid work, reflecting a weak association between the presence of electricity and unpaid work.

The results for household income shown in Table 7 using village-level panel data are fairly similar to our main results where all villages are included. The impacts of access to electricity on total household income and nonfarm income are positive and significant and this effect is stronger for urban areas. In contrast, there is a weak negative association between farm income and household access to electricity; the coefficient of electricity is negative and not significant. Overall, our results are robust regardless of the sample composition.

TABLE 7. Impact of electrification on household income using village-panel data

	All		
	(1)	(2)	(3)
VARIABLES	Total monthly income	Nonfarm income	Farm income
Electricity (1=yes)	0.352***	0.345	-0.142
	(0.120)	(0.253)	(0.169)
Observations	10,205	7,159	4,466
	Urban		
Electricity (1=yes)	0.413**	0.280**	-0.0588
	(0.158)	(0.131)	(0.234)
Observations	7,086	5,716	1,771
	Rural		
Electricity (1=yes)	0.179	0.389*	-0.154
	(0.159)	(0.199)	(0.166)
Observations	3,119	1,443	2,695

Note: The dependent variables are (1) log of total monthly income, (2) log of nonfarm income, (3) log of farm income, and (4) log of other income. The control variables at individual, household, and village levels are included. District and year fixed effects are included. All errors are clustered at village level. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

6.2. Spillover benefits to non-electrified households

One question in any village electrification project is whether non-electrified households derive benefits from such a project. Non-electrified households living in electrified villages are marginalized members of the community because they live in remote areas far from the connection grid or are too poor to pay for the fixed cost of connection. We argue that non-electrified households within electrified villages may experience a change in their outcomes related to employment and household income as a result of village electrification, "the spillover benefits". In this analysis, our treated group corresponds to non-electrified households in electrified villages; control households are households in non-electrified villages. That is, we excluded electrified households in electrified villages in our estimations. Estimation strategies are the same as Equations (2) and (3) in Section 4 and our interest variable is the binary variable village connected to grid electricity, rather than access to electricity at the household level.

Table 8 shows the results of IV estimations for spillover effects of village electrification on outcomes related to employment. Individuals in non-electrified households located in an electrified village have a higher probability of engaging in wage employment and self-employment in the nonfarm sector. By contrast, it shows that village electrification decreases self-employment in the farm sector and unpaid family work. The findings suggest that there were changes in local labor market conditions that generated new employment opportunities, which in turn prompted more people to enter either the wage labor market or

self-employment in the nonfarm sector. These labor market improvements benefit all households including the non-electrified households in a village that is hooked to a grid. Village electrification creates jobs which we consider the "spillover benefits" of village electrification to non-electrified households.

TABLE 8. Village-level effect of electrification on employment

	All			
	(1)	(2)	(3)	(4)
VARIABLES	**Wage employment**	**Self-employment in nonfarm sector**	**Self-employment in farm sector**	**Unpaid family worker**
Village_Electricity (1=yes)	0.285*** (0.103)	0.228* (0.126)	-0.373** (0.161)	-0.312*** (0.0920)
Individual level				
Female (1=yes)	-0.0685*** (0.00545)	0.0104*** (0.00347)	-0.106*** (0.00756)	0.0924*** (0.00590)
Age	0.0236*** (0.00163)	0.00179 (0.00137)	0.0336*** (0.00189)	-0.0217*** (0.00134)
Age_squared	-0.000359*** (2.23e-05)	-1.74e-05 (1.90e-05)	-0.000324*** (2.66e-05)	0.000218*** (1.76e-05)
Married (1=yes)	-0.115*** (0.00800)	0.0216*** (0.00744)	0.132*** (0.0101)	-0.0384*** (0.00643)
Years of education	0.00193*** (0.000727)	0.00951*** (0.000815)	-0.0144*** (0.00103)	-0.000199 (0.000569)
Household level				
Urban (1=yes)	0.0207 (0.0545)	0.00917 (0.0580)	-0.0908 (0.0741)	0.0532 (0.0375)
Number of toddlers	0.00374 (0.00391)	0.0116** (0.00488)	-0.00944 (0.00595)	-0.0209*** (0.00280)
Size of irrigated land	-0.000763** (0.000326)	-0.000440 (0.000536)	0.000963 (0.000598)	0.000171 (0.000333)
Village level				
Distance_bus_ stop	-8.62e-05 (0.000238)	-0.000676** (0.000272)	4.45e-05 (0.000350)	0.000464** (0.000236)
Village_factory (1=yes)	-0.0204 (0.0152)	0.00497 (0.0181)	-0.00173 (0.0238)	0.0261* (0.0133)
Village_ Infrastructure (1=yes)	-0.0392** (0.0177)	0.0116 (0.0219)	0.0155 (0.0285)	0.0395** (0.0153)
Observations	60,217	60,217	60,217	60,217
R-squared	0.005	-0.010	0.099	0.026
District fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes

***p<0.01, **p<0.05, *p<0.1

In order to check the consistency of the results with the data from the labor demand side, we extracted the CSES survey villages from the ECC 2011 and 2014 and matched them with the village electrification status from CSES in 2009 and 2014. We find that firm size and the percentage of formal firms in electrified villages are larger than those in non-electrified villages. These findings are consistent with household income sources using the CSES data (Table 1) that the proportion of income from wage employment especially in service sectors increased to 41 percent in 2014, suggesting that the number of labor-intensive jobs that employ a large number of workers in wage employment has increased in electrified villages. Clearly, electrification induces positive changes in the labor market through job creation.

Overall, our analysis confirms the presence of spillover benefits from village electrification to non-electrified households, especially in terms of employment. Furthermore, we confirm a demand effect working through changes in local labor market conditions: electrification induced the creation of wage employment especially in the service sector in electrified villages.

7. Conclusion

Cambodia, one of the fastest-growing economies in Southeast Asia, recognizes an inadequate supply of electricity as one of the key obstacles to its economic development. Given the numerous recent enhancements of electrical grid infrastructure in developing countries, it is important to understand how access to electricity has impacted household welfare. This study examines the impacts of access to electricity on employment of the working-age population and various sources of household income. Using the IV approach, we obtained estimation results that suggest a strong and positive effect of household electrification, for both women and men, on wage employment and self-employment in the nonfarm sector. With regard to household income, our findings indicate that increased access to electricity contributes to total household income growth through an increase in nonfarm income. Furthermore, the effect of electrification on income growth is much stronger in urban areas. These results are consistent with estimation results using village panel data; and the analysis of the spillover effect of village electrification. In addition, the descriptive analysis using the data from the labor demand side shows that labor-intensive jobs that employ a larger number of workers in wage employment are expanding in electrified villages. It appears that the development of the nonfarm sector has been positively affected by the expansion of electricity. Such development has created jobs in the wage sector, which appears to be the main pathway through which electricity has impacted household welfare.

In brief, our findings show that electrification has facilitated a shift of household economic activities away from self-employment in the farm sector

and unpaid work to wage work and self-employment in the nonfarm sector, and such a shift appears to have been the main driver of household income growth. These results suggest that electricity projects, by creating jobs and stimulating the development of the nonfarm sector, could serve as an effective instrument in improving household welfare. Inasmuch as labor is the main asset of the poor, expanding access to the national electric grid has a clear positive impact on poverty reduction. In light of all of these, it is essential to give top priority to the energy sector in policy discussions related to development in other areas of the developing world.

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