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The effect of electrification on socioeconomic well-being and environmental outcomes: Evidence for the Lao People's Democratic Republic

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THE EFFECT OF ELECTRIFICATION ON SOCIOECONOMIC WELL-BEING AND ENVIRONMENTAL OUTCOMES

EVIDENCE FOR THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

Ricardo M. Sousa, Phouphet Kyophilavong, Chowdhury Abdullah-Al-Baki, Gazi Salah Uddin, and Donghyun Park

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In this publication, "$" refers to United States dollars and "KN" refers to kip.
ADB recognizes "Laos" as the Lao People's Democratic Republic and "Vietnam" as Viet Nam.

ABSTRACT

We investigate the impact of electrification on the economic, educational, and environmental outcomes of the Lao People's Democratic Republic (Lao PDR). We use household-level data and a novel identification scheme, whereby we instrument the electrification status with the proportion of grid-connected households in a community. We find evidence consistent with the so-called "peer pressure for technology adoption," as a higher proportion of electrified households is linked with a boost in the electrification of neighboring households. Additionally, we find that electrification: (i) significantly increases income (in particular, farm income); (ii) improves children's educational completion; and (iii) reduces the use of dirty fuel for lighting and cooking. From a policy perspective, public investments and financial incentives for electricity generation and distribution can play a key role in alleviating the existing economic, educational, and environmental bottlenecks of developing countries like the Lao PDR.

Keywords: electrification, household, fuel, income, education, Lao People's Democratic Republic

JEL codes: Q40, Q49

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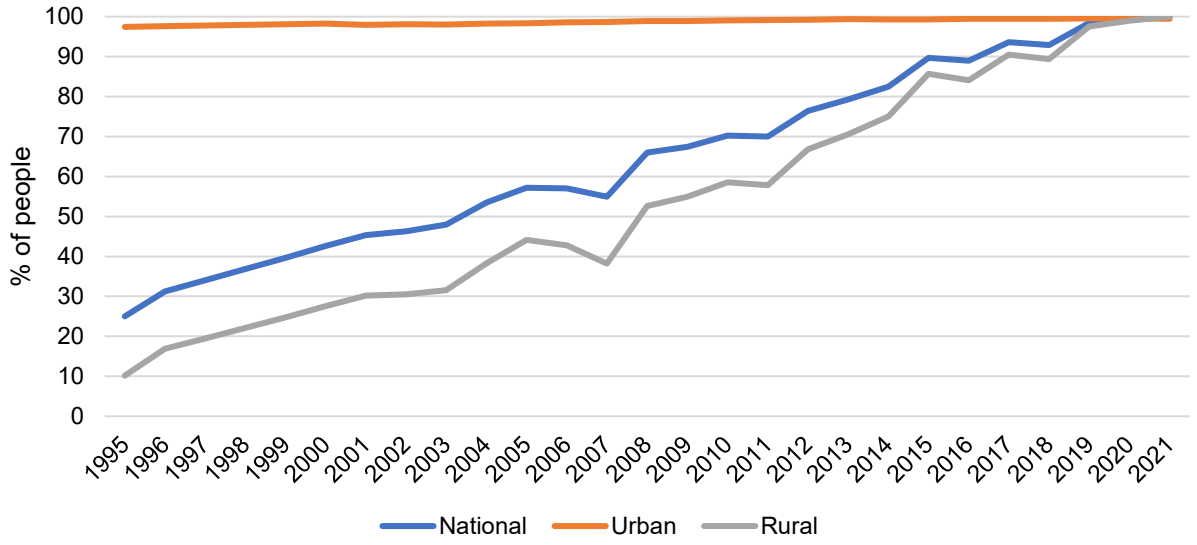
1. Introduction

Electrification leads to major improvements in people's sociocultural lives. For instance, the introduction of television or radio to villages, the ability to communicate via mobile phones and the growth of the internet are all facilitated by electricity. Electrification also induces advances in economic standards. For example, such sociocultural changes include not just entertainment but also comfort and economic enhancements, such as air conditioning, education, health care, and safety (e.g., electric light, hazards). The availability of electric power in particular areas might even be a driving force for migration (Luukkanen et al. 2012).

Electricity generation and electrification in emerging markets are, thus, inextricably linked to sociocultural changes and economic well-being. For a developing country like the Lao People's Democratic Republic (Lao PDR), access to electricity in rural areas has been a strategic priority, as it helps to reduce poverty and to improve living standards (Government of the Lao PDR 2004, 2015). Thus, the fraction of electrified households increased from 58.2% in 2005 to 72.5% in 2010 (Government of the Lao PDR 2015, Ministry of Energy and Mines [MEM] 2010), with an ambitious national electrification target rate of 90% by 2020 (MEM 2010, 2011). Currently, 100% of Lao PDR citizens have access to electricity, compared to just 70% in 2010 (World Bank 2023), as can be seen in Figure 1.

Figure 1: Electrification Status in the Lao PDR



Lao PDR = Lao People's Democratic Republic.
Source*:* World Bank. World Development Indicators 2023.

Due to its strategic location in the center of Southeast Asia, the Lao PDR is a crucial part of the region's economy. Still, it remains one of Asia's poorest countries, with an income per capita of only $2,630.20 (World Bank 2023). Despite gender disparities, ethnic groupings, high poverty, uneven wealth distribution and growing inequality, the country has made substantial progress over the last 2 decades, with poverty rates falling from 46% in 1992 to 23% in 2015.

According to the 2021/2022 Human Development Report of the United Nations Development Programme (UNDP 2022), the Lao PDR is a medium human development country with a rank of 140 out of 191, i.e., one of the lowest among Southeast Asian countries. However, significant improvements have been observed between 1990 and 2015: life expectancy grew by 13 years, school attendance is now nearly 3 years longer than in 1990, and gross national income (GNI) per capita almost tripled.

The Lao PDR's large energy exports also have a significant positive direct effect on gross domestic product (GDP) and the trade balance and various indirect economic impacts (Luukkanen et al. 2012). For instance, a large share of the Government of the Lao PDR's revenue accrues to its natural resource-based exports (Menon and Warr 2013). Not surprisingly, foreign investment in mining and hydropower, mineral exports, and agricultural development have steadily improved over time (ADB 2006).

Against this backdrop, we assess the effects of electrification on a number of economic, educational, and environmental outcomes for Lao PDR households. Specifically, we make use of cross-sectional data from the Lao Expenditure and Consumption Survey 5 (LECS5) 2012–2013 and implement a novel identification by instrumenting the electrification status with the proportion of grid-connected households in a community.

We find that a rise in the proportion of electrified households is linked with a boost in the electrification of neighboring households. Thus, our instrumental variables (IV) approach reveals the role played by the so-called "peer pressure for technology adoption."

Additionally, electrification positively affects income, particularly crop income, which increases by more than 40%. This result is consistent with previous studies for other developing countries (Khandker et al. 2009a, 2012a, 2013), which also uncovered relevant economic impacts from electrification at the household level. Moreover, we show that electrification acts as a catalyst for stronger educational outcomes, as captured by improvements in education completion. This educational enhancement is also observed in India and Viet Nam by Khandker et al. (2012a, 2013).

Finally, electrification is associated with a significant reduction in dirty fuel usage, which is much more pronounced for lighting than cooking. In the same vein, Sedai et al. (2021) and Litzow et al. (2019) report an adverse effect of electrification on firewood and kerosene consumption in India and Bhutan, respectively.

From a policy point of view, our empirical findings suggest that developing countries like the Lao PDR can counteract existing economic, educational, and environmental bottlenecks by prioritizing public investment and financial incentives for electricity generation and distribution.

The remainder of the paper is as follows. Section 2 discusses the related literature. Section 3 presents the econometric methodology. Section 4 analyzes the empirical results. Finally, Section 5 concludes.

2. Literature Review

The economic and social effects of rural electrification at the household level are multifaceted. While the direct effects can be evidenced by increased income and employment, improved consumption patterns, rising savings and asset accumulation, the majority of indirect effects are connected to social and cultural elements of life, such as education, health, modernization, or women's position (Barkat et al. 2002).

Several studies uncover a substantial impact of electrification on household consumption and income (Khandker et al. 2009a, 2009b, 2012a, 2012b). According to Barkat et al. (2002), households with electricity have an average yearly income that is 64.5% greater than families in non-electrified villages and 126.1% higher than households without electricity in electrified villages. Household electrification can increase income by up to 28% and spending by 23% (Khandker et al. 2013). Using data for Bangladesh,

Khandker et al. (2012a) estimate a rise of household's income of about 25%–50%, while Khandker et al. (2009a) find that the increase in overall revenue from electrification might range from 9% to 30%. Furthermore, a 10% rise in power usage results in a 0.6% revenue boost (Khandker et al. 2012b). Household spending and job level are Ghana's two biggest beneficiaries of household electrification (Adusah-Poku and Takeuchi 2019). In Bangladesh, electrification increases total household income by up to 21%, resulting in a yearly 1.5% age point decrease in poverty (Khandker et al. 2012a).

Rural electrification also significantly adds to welfare growth (Dinkelman 2011; Khandker et al. 2012a, 2014) even though it has a skewed impact on wealthier rural household spending (Adusah-Poku and Takeuchi 2019; Khandker et al. 2009a, 2012a, 2012b, 2014). Khandker et al. (2013) show that Viet Nam's rural electrification program considerably influences rural well-being. In Ghana, families with high expenses, male-headed households, and families with employed heads are more likely to have electricity connections in Ghana (Adusah-Poku and Takeuchi 2019). Consequently, higher consumption and a wider diversity of electrical services benefit wealthier families the most.

Household electrification can also improve productivity (Van de Walle et al. 2017) and reduce poverty (Khandker et al. 2012b). For instance, electricity increases annual job earnings for both men and women in India and South Africa, but this is followed by a reduction in the number of hours worked, i.e., electricity increases productivity (Rathi and Vermaak 2018). According to Korkeakoski (2009), micro hydropower-based electrification can alleviate poverty, if not limited to lights. Additionally, electricity can reduce poverty rates in the short and long term (Khandker et al. 2014).

The benefits of electrification also extend to other aspects of life, such as women's participation in the job market. For example, women in electrified households are more active in family income-generating activities and have better time reallocation for remunerated jobs than in non-electrified households (Barkat et al. 2002). Rural electricity allows household members to spend less time collecting fuelwood and more hours on learning (Khandker et al. 2012a, 2014), resulting in a reduction of the physical stress typically placed on rural women (Khandker et al. 2013) and lower indoor air pollution (Barron and Torero 2017). By allowing women to be free from domestic production and hence enabling them to engage in microenterprises, community electrification increases women's employment rates by 9.5% in South Africa (Dinkelman 2011). For India, Rathi and Vermaak (2018) find that access to electricity has a considerably negative impact on men's employment and a positive effect on women's work, but wages and working hours are equally affected for both genders.

Another dimension impacted by rural electricity is children's education, as it contributes to higher future earnings (Khandker et al. 2014). For children in rural homes, electricity leads to a considerable rise in completed schooling years and study time (Khandker et al. 2009a, 2012a, 2013; Litzow et al. 2019) and literacy rates (Barkat et al. 2002). According to Litzow et al. (2019), Bhutan's rural electrification increased education and employment benefits while reducing biomass use.

Our study is highly indebted to the work of Oum (2019), who finds that energy poverty has a detrimental influence on average school years in the Lao PDR, an effect that is magnified by how households live in rural regions with no access to highways, distant from school, and governed by elderly and illiterate household heads. We

contribute to the existing literature in three major directions. First, Oum (2009) mainly focuses on the household's average schooling years, whereas we estimate the educational outcome of the children within the house in terms of completion and education expenses. Second, this paper first provides an empirical indication of how electrification can bring economic well-being such as how a rise in income from both farm and nonfarm income-generating sources and improves life through an increase in food and nonfood expenditure of households in the Lao PDR. Finally, we also demonstrate how electricity improves the indoor environment by replacing dirty lighting and cooking fuel.

The rest of the paper is composed as follows: the econometric methodology and data section illustrate the empirical approach, outcome and control variables and data-related information with descriptive statistics. The empirical result section discusses the results of the study. Finally, the conclusion section summarizes the whole research and provides some policy suggestions.

3. Econometric Methodology and Data

3.1. Empirical Approach

The main research question that we try to address in this paper concerns the impact of electrification on household welfare. As such, a straightforward comparison of households with and without electricity is not advisable, as it can lead to biased results. Instead, a randomized experiment where every factor is similar across households except for the electrification status would be recommended.

Despite this, large infrastructure projects like electrification are typically implemented given the country's needs and financial resources. This means that

electrification reaches the more developed and promising areas first and then sequentially spreads all over the country; that is, electrification is a non-random process, as villages and villagers are not the same. Therefore, it is not possible to observe variation in outcome variables conditional on the electrification status and draw unbiased statistical inferences from it.

Additionally, we highlight that the adoption of electrification at the household level might depend on observable (direct) and unobservable (indirect) factors. For instance, the installation cost, the price of electricity, and the financial ability to pay electricity bills might directly affect the electricity connection. However, some people might have a better perception of the potential benefits of electrification than others, thus, being more prone to be connected. Yet, this motivation is not directly observable. Consequently, one needs to control for direct and indirect issues that might cause endogeneity and generate biased estimates.[1]

In this context, we rely on an instrumental variable (IV) approach. For Bangladesh, Khandker et al. (2009a) use the household's proximity to the electric line as an instrumental variable. In the absence of such information, we follow Khandker et al. (2012b) and control for the proportion of grid-connected households in a community.

This variable satisfies two conditions: (i) it affects the electrification status and does not correlate with the error term, and (ii) it influences the outcome variable solely via the electrification status. Indeed, all neighbors can see if a house is electrified by looking at the connection wires with the closest electricity pole, which allows for direct societal

[1] While propensity score matching (PSM) can produce counterfactuals, it only depends on observable characteristics. Similarly, we cannot use a fixed effect (FE) estimator due to the cross-sectional nature of the data.

comparisons and also acts as a status symbol. Thus, people can perceive the improvements in their neighbors' livelihoods obtained from electrification, propelling them to adopt electric connections too.[2] Consequently, a higher proportion of electrified households is likely to affect the electrification status and, ultimately, the dependent variable under consideration.

The first-stage equation can be formulated as follows

$$E_{ij} = \varphi + \theta \boldsymbol{X_{ij}} + \delta I_j + \mu_i + \varepsilon_{ij} \quad (1)$$

where E_{ij} represents the electrification status of the *i-th* household in the *j-th* community, $\boldsymbol{X_{ij}}$ is a set of household characteristics (e.g., age, education, or assets), I_j is the proportion of electrified households in the *j-th* community (i.e., our instrumental variable), μ_i captures unobserved household characteristics (i.e., fixed effects), and ε_{ij} is the error term.

The second-stage equation can be written as:

$$Y_{ij} = \delta + \beta\, \hat{E}_{ij} + \gamma \boldsymbol{X}_{ij} + \eta_i + \xi_{ij} \quad (2)$$

where Y_{ij} is the outcome variable under analysis that is affected by electrification (e.g., farm income, food expenditure, or primary education completion), $\hat{E}_{ij}$ is the estimated electrification status of the *i-th* household in the *j-th* community (based on the first-stage equation), the unknown β parameter measures the effect of electrification on the outcome variables, $\boldsymbol{X_{ij}}$ is a set of household characteristics, η_i denotes household fixed effects, and ξ_{ij} is the error term.

[2] This is the so-called "peer pressure for technology adoption" (and other decisions, such as schooling), which has been examined, for instance, by Bernard and Torero (2015).

Finally, we consider village-level clustering errors, as the disturbance terms within a village are likely to be associated, whereas those between villages are likely to be independent.

3.2. Outcome and Control Variables

Household welfare (i.e., the outcome/dependent variable of interest, Y_{ij}) can be evaluated along a number of dimensions, including *(i)* economic; *(ii)* educational; and *(iii)* environmental. Among economic outcomes, we consider farm income, nonfarm income, food expenditure and nonfood expenditure. As for educational outcomes, we analyze primary and secondary completion for children aged 6 to 25. We also look at education spending per person by gender. Finally, we measure the environmental impact of electrification by using the amount of dirty fuel for cooking as proxy. All expenditure variables are expressed in logs.

In what concerns the set of control variables, we follow Khandker et al. (2013). The full list of controls can be found in Table 1.

Table 1: Control Variables and Definitions

Variables	Definitions
Electricity	Dummy variable that takes the value of one if the household has the access to electricity, and zero otherwise
Age (and its squared term)	Age of household head in years
Education	Education of household head and his/her spouse: illiterate (=0), primary (=1), lower secondary (=2), upper secondary (=3), vocational (=4), and university (=5)
Household size	Number of members of the household
Dependency ratio	The dependent members of the household are counted as a fraction of the total number of members of the household. Members of the household aged less than 15 years and more than 64 years are counted as dependent.
Poor	Dummy variable that takes the value of one if the household is poor (based on the national poverty line), and zero otherwise
Urban	Dummy variable that takes the value of one if the household lives in an urban area, and zero otherwise
Arable land	Log of total arable land holdings by household
Animals	Log of the monetary value of animals (such as, cattle, pigs…) held by the household
Wall type	Non-brick wall (=0), unbacked brick (=1), and brick (=2)
Roof material	No solid roof (=0), metal sheet/wood (=1), and concrete/tile (=2)
Floor type	No solid floor (=0), wood/bamboo (=1), and concrete (=2)
Latrine	None (=0), normal (=1), and modern (=2)
Kitchen	Dummy variable that takes the value of one if the kitchen is inside the house, and zero otherwise
Loan	Dummy variable that takes the value of one if the household has taken a loan from any source, and zero otherwise
Informal loan	Dummy variable that takes the value of one if the household has taken a loan from informal sources (such as, relatives and local money lenders), and zero otherwise
Sanitary latrine	Dummy variable that takes the value of one if the household owns a sanitary latrine, and zero otherwise
Remittance	Dummy variable that takes the value of one if there is any remittance earner in the household, and zero otherwise
Ethnicity	Ethnicity of the household head: Other (=0), LaoTai (=1), and MonKhmer (=2)
Province	Each of the 17 provinces of the Lao People's Democratic Republic

Sources: Lao Expenditure and Consumption Survey 5 (LECS5) and (LECS6).

3.3. Data

We use cross-sectional data from LECS5 2012–2013 and LECS6 2018–2019[3], which was conducted across the country., including in 16 provinces and the capital in 2013. The survey consists of 8,226 households from 515 villages. It provides data for more than 356 consumption items and 117 production categories (Lao Statistics Bureau 2016). As in Oum (2019), our sample includes 16 randomly chosen households from each village: 8 from LECS4, the previous survey; and the remainder from the village's household list (World Bank 2014).

Table 2 provides information about the electrification status according to several household characteristics. As can be seen, nearly 74% (LECS5) and 91% (LECS6) of households in the Lao PDR live in electrified houses. However, electricity distribution varies with education and residency status. For instance, while electrification reached close to 88% (LECS5) and 98% (LECS6) of household heads with at least a secondary education, it was only available for 55% (LECS5) and 83% (LECS6) of illiterate household heads. Similarly, households with fewer members, non-poor status, LaoTai ethnicity, and urban residence were more connected to the electricity vis-à-vis other households. Compared to other regions, the country's northern region had less access to electricity.

[3] A similar way from LECS5 follows the survey of data collection.

Table 2: Electrification Status by Household Characteristic

Characteristics	Electrified Households (%)	
	LECS5	LECS6
Electrified Houses	73.87	91.49
Household head's education		
No education	55.12	82.58
Primary	69.76	92.84
Lower secondary and more	87.88	98.23
Household size		
1–3 members	82.35	92.77
4–6 members	77.35	92.38
6+ members	58.91	92.38
Poverty		
Poor	53.66	78.97
Non-poor	78.90	93.79
Ethnicity		
LaoTai	89.48	97.40
MonKhmer	50.26	85.10
Others	39.47	79.92
Residence		
Urban	98.16	99.63
Rural	64.98	87.82
Regions		
Vientiane	99.56	100.0
North	57.23	85.74
Central	85.93	95.48
South	74.03	92.59

LECS = Lao Expenditure and Consumption Survey.

Sources*:* Authors' calculations; Lao Expenditure and Consumption Survey 5 (LECS5) and 6 (LECS6).

Table 3 shows the mean differences in outcome variables between households with electricity and households without electricity. In what concerns economic outcome variables, it can be seen that farm and nonfarm income is higher for the former than the latter. Similarly, the expenditure (i.e., food and nonfood expenditure) of electrified households is significantly larger than of households without access to electricity.

As for educational outcomes, Table 3 shows that households with electricity access have higher education completion rates. The mean education expenditure per student is also significantly larger for students who have access to electricity than those

who do not have it. Finally, regarding environmental outcome variables, dirty fuel used for cooking is only slightly lower for households with electricity compared to those without electricity.

Table 3: Mean Differences between Electricity Users and Non-users for the Outcome Variables

Outcome Variables	With Electricity	Without Electricity	*p*-value	With Electricity	Without Electricity	*p*-value
	LECS5			LECS6		
Economic Outcome						
Farm (crop) income per person (KN1,000)	1,817.70	1,281.84	0.000	3,691.06	2,958.58	0.12
	(75.63)	(129.05)		(127.32)	(442.10)	
Nonfarm income per person (KN1,000)	597.89	224.06	0.000	3,013.14	1,403.6	0.04
	(25.62)	(19.41)		(116.03)	(445.08)	
Total food expenditure per person (KN1,000)	206.40	134.19	0.000	381.14	293.01	0.000
	(2.99)	(3.142)		(3.62)	8.63	
Nonfood expenditure per person (KN1,000)	2,367.68	536.86	0.000	329.36	94.06	0.000
	(296.67)	(50.19)		(21.01)	(3.71)	
Educational Outcome						
Primary education completion	0.86	0.72	0.000	0.72	0.66	0.000
	(0.004)	(0.007)		(0.004)	(0.013)	
Lower secondary education completion	0.48	0.18	0.000	0.40	0.35	0.000
	(0.006)	(0.007)		(0.004)	(0.014)	
Higher secondary education completion	0.24	0.06	0.000	0.20	0.25	0.000
	(0.006)	(0.005)		(0.003)	(0.012)	
Education expenditure per student (KN1,000)	559.84	158.23	0.000	693.77	171.85	0.000
(only enrolled students)	(15.98)	(5.98)		(16.21)	(5.98)	
Environmental Outcome						
Dirty fuel used for cooking	0.92	0.99	0.000	0.88	0.99	0.000
	(0.004)	(0.001)		0.004	0.002	

LECS = Lao Expenditure and Consumption Survey.

Sources*:* Authors' calculations; Lao Expenditure and Consumption Survey 5 (LECS5) and 6 (LECS6).

4. Empirical Results

4.1. First-stage Equation

We start by checking if a higher proportion of electrified households influences the electrification of other neighboring households. The empirical results are reported in Table 4. As can be seen, the proportion of electrified households (i.e., our instrument) enters significantly in all models for the electrification status. The high *R*-squared statistics also corroborate the validity of the instrument.

Table 4: First-stage Equation

VARIABLES	(1) Electricity	(2) Electricity	(3) Electricity
The proportion of electrified HH	0.010*** (0.000)	0.010*** (0.000)	0.010*** (0.000)
Male Head (=1)		-0.008*** (0.003)	-0.008** (0.003)
Age		-0.000 (0.001)	-0.000 (0.001)
Head Age Squared		0.000 (0.000)	0.000 (0.000)
Head Education =Primary		0.005 (0.004)	0.006 (0.004)
Head Education =Lower secondary		0.008* (0.004)	0.009** (0.004)
Head Education =Upper secondary		0.006 (0.005)	0.006 (0.005)
Head Education =Vocational training		0.007 (0.005)	0.008 (0.005)
Head Education =University/institute		0.010** (0.004)	0.010** (0.005)
Household Size		0.004*** (0.001)	0.004*** (0.001)
No. of Dependent Member		-0.002 (0.001)	-0.002 (0.001)
Urban (=1)		-0.007*** (0.001)	-0.007*** (0.001)
Poor (=1)		-0.009** (0.004)	-0.009** (0.004)
Log of Total Arable Land		0.002 (0.002)	0.002 (0.002)
Log of Total value of animals		0.000** (0.000)	0.000** (0.000)

Continued on the next page

VARIABLES	(1) Electricity	(2) Electricity	(3) Electricity
Wall Type =Brick/Concrete		-0.003	-0.004
		(0.003)	(0.004)
Roof Material =Metal sheet/wood		0.050***	0.049***
		(0.010)	(0.010)
Roof Material =Concrete/Tile		0.055***	0.056***
		(0.010)	(0.011)
Floor Type =Wood/Bamboo		0.016**	0.015**
		(0.007)	(0.007)
Floor Type =Concrete		0.020**	0.020**
		(0.008)	(0.008)
Latrine =Normal Toilet		0.024***	0.027***
		(0.005)	(0.006)
Latrine =Modern Toilet		0.023***	0.027***
		(0.006)	(0.006)
Kitchen		-0.002	-0.003
		(0.002)	(0.002)
Loan		0.002	0.003
		(0.004)	(0.004)
Informal Loan		-0.004	-0.004
		(0.006)	(0.006)
Remittance Earner in HH		0.005	0.002
		(0.003)	(0.003)
Ethnicity =LaoTai		-0.008**	-0.010**
		(0.004)	(0.004)
Ethnicity =MonKhmer		0.001	-0.002
		(0.004)	(0.005)
Constant	0.000	-0.073***	-0.073***
	(0.000)	(0.019)	(0.019)
Observations	10,888	10,885	10,885
R-squared	0.900	0.903	0.903
Wave (LECS5 & 6) fixed effects	YES	YES	YES
Province FE	NO	NO	YES

FE = fixed effects, HH = household, LECS = Lao Expenditure and Consumption Survey.

Notes*:* Standard errors are clustered at the village-level and are presented in parentheses. Significance level at which the null hypothesis is rejected: * significant at 10%, ** significant at 5%, *** significant at 1%.

Sources: Authors' calculations; Lao Expenditure and Consumption Survey 5 (LECS5) and 6 (LECS6).

4.2. Impact of Electrification on Economic Outcomes

As the proportion of grid-connected households in a village affects the electrification decision, we can now focus on the causal effect of electrification on different outcome variables.

Electrification generally increases economic activity by boosting business opportunities, such as longer operating hours, improved storage facilities, a better business environment, wider product store visibility, and new electric and electricity-based accessories business. While additional storage facilities and new electric Agri-technology might increase farm income, other electricity-related improvements might raise nonfarm income. Operating poultry and farm animals also require a significant amount of electricity.

In this context, we consider a set of economic outcomes in Table 5: (i) farm (crop) income; (ii) nonfarm income; (iii) food expenditure; and (iv) nonfood expenditure. All variables are expressed in log terms, and we report both ordinary least squares (OLS) and IV estimates for comparison in Panels A and B, respectively.

In Columns (1)–(2), we show the impact of electrification on income. As can be seen, electrification has a statistically significant effect on the farm (crop). According to the IV estimates, electrification boosts farm income (crop) by 64.1%. As for OLS estimates, they are lower than the IV estimates but point in the same direction. This finding is in line with prior studies conducted in developing countries. For instance, Khandker et al. (2009a) show that electrification contributes to a 52% rise in annual farm income, a 23% increase in nonfarm income, and a 12% boost in total income in Bangladesh. Khandker et al. (2012b) find that electrification increases per capita income

in India by approximately 40%. Khandker et al. (2013) uncover similar results for Viet Nam.

Columns (3)–(4) summarize the effects of electrification on food and nonfood expenditure, respectively. Our results do not corroborate any relevant impact of electrification on expenditure, as both OLS and IV estimates lack statistical significance at conventional levels.

Table 5: Impact of Electrification on Economic Outcomes

	(1)	(2)	(3)	(4)
Economic Outcome Variables	**Log of farm (crop) income**	**Log of nonfarm income**	**Log of food expenditure**	**Log of nonfood expenditure**
Panel A: OLS				
Electrified household	0.374***	0.222**	0.020	0.103
	(0.122)	(0.107)	(0.018)	(0.101)
Panel B: IV				
Electrified household	0.641***	0.543***	0.247***	0.647***
	(0.133)	(0.135)	(0.034)	(0.122)
Wave (LECS5 & 6) fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Observations	3,792	3,208	10,411	10,411

IV = instrumental variable, LES = Lao Expenditure and Consumption Survey, OLS = ordinary least square.

Notes*:* Robust standard errors in parentheses. Significance level at which the null hypothesis is rejected: * significant at 10%, ** significant at 5%, *** significant at 1%.

Sources: Authors' calculations; Lao Expenditure and Consumption Survey 5 (LECS5) and 6 (LECS6).

4.3. Impact of Electrification on Educational Outcomes

Better lighting through electrification may provide more conducive settings for pupils to concentrate longer, resulting in improved educational outcomes (such as primary education completion). Additionally, electrification might extend mothers' working hours at night, allowing them to release their children from household work and send them to school. For example, Khandker et al. (2013) show that electrification reduces biofuel collection time and increases children's study time.

Thus, we now focus on electrification's effects on educational outcomes (Table 6). In Columns (1)–(3), we look at education completion: (i) primary education completion, (ii) lower secondary education completion, and (iii) higher secondary education completion. In Columns (4)–(5), we assess the impact of electrification on education expenditure, i.e.,: (iv) education expenditure per male student; and (v) education expenditure per female student. As before and for comparison, we report OLS and IV estimates in Panels A and B, respectively.

Our IV estimates show that electrification is associated with an 8.6% increase in lower secondary education completion and 2.7% higher secondary education completion. By contrast, electrification does not seem to impact primary education completion significantly. One reason might be that the net primary enrollment is already around 95% (Sachs et al. 2023). Similar, albeit slightly smaller, point coefficient estimates are obtained via the OLS regressions.

Regarding the impact of electrification on education spending, we find that education expenditure per female student increases by around 12.2% among grid-connected households; however, there is no significant increase for male students. Our results align with the works by Khandker et al. (2012b, 2013), at least for girls, who also report a significant rise in school enrollment in India and Viet Nam due to electrification.

Table 6: Impact of Electrification on Educational Outcomes

Educational Outcome Variables	(1) Primary Education Completion	(2) Lower Secondary Education Completion	(3) Higher Secondary Education Completion	(4) Education Expenditure per Male Student	(5) Education Expenditure per Female Student
			Panel A: OLS		
Electrified household	-0.016	0.064***	0.011	0.092*	0.123**
	(0.015)	(0.016)	(0.014)	(0.055)	(0.061)
			Panel B: IV		
Electrified household	-0.006	0.086***	0.027*	0.110*	0.122*
	(0.017)	(0.018)	(0.015)	(0.060)	(0.065)
Province fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	21,462	21,462	19,691	6,468	5,823

IV = instrumental variable, OLS = ordinary least square.

Notes: Robust standard errors in parentheses. Significance level at which the null hypothesis is rejected: * significant at 10%, ** significant at 5%, *** significant at 1%.

Sources: Authors' calculations; Lao Expenditure and Consumption Survey 5 (LECS5) and 6 (LECS6).

4.4. Impact of Electrification on Environmental Outcomes

Finally, in Table 7, we evaluate the impact of electrification on environmental outcome variable, namely: dirty fuel use for cooking. We adjusted the female educational status to estimate cooking fuel use as they cook more frequently. Panels A and B report OLS and IV estimates, respectively.

We find that both types of dirty fuel usage are significantly reduced in electrified households. This result is consistent with Sedai et al. (2021) and Litzow et al. (2019), who report that electrification reduces firewood and kerosene consumption. In fact, given that the electricity cost is lower than the cost of dirty fuels (such as kerosene) and electricity provides better quality lighting, the reduction in dirty fuel use for lighting is not surprising. Similarly, electrification might encourage indoor cooking, which is more pollutive with dirty fuel than electricity.

Table 7: Impact of Electrification on Environmental Outcomes

Environmental outcome variables	(1) Dirty fuel use for cooking
	Panel A: OLS
Electrified household	-0.043***
	(0.009)
	Panel B: IV
Electrified household	-0.041***
	0.010)
Province fixed effects	YES
Observations	10,428

IV = instrumental variable, OLS = ordinary least square.

Notes*:* Robust standard errors in parentheses. Significance level at which the null hypothesis is rejected: * significant at 10%, ** significant at 5%, *** significant at 1%.

Sources: Authors' calculations; Lao Expenditure and Consumption Survey 5 (LECS5) and 6 (LECS6).

5. Conclusion

Even though the Government of the Lao PDR has assured that all of its citizens should have access to electricity, the country remains one of the poorest in the region. Thus, in this paper, we investigate the impact of electrification on three essential dimensions of the well-being of Lao PDR households: (i) economic; (ii) educational; and (iii) environmental.

We rely on the LECS5 2012–2013 and use a novel identification scheme based on the so-called "peer pressure for technology adoption." Specifically, we implement an IV approach to instrument the electrification status by the proportion of grid-connected households in a community.

Our main findings are fourfold. First, we find that a higher proportion of electrified households is associated with an increase in the electrification of neighboring households. Second, among economic outcomes, electrification boosts income (in particular, farm income) but does not seem to significantly impact household spending.

Third, concerning educational outcomes, we show that electrification is linked with a significant improvement in lower secondary education completion. Fourth, as for the environmental outcomes, electrification significantly reduces dirty fuel usage for lighting and less so for cooking.

From a policy perspective, our results support government policies aimed at prioritizing investment projects and financial incentives for electricity generation and distribution to fill critical economic, educational, and environmental bottlenecks for households in the Lao PDR.

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The Effect of Electrification on Socioeconomic Well-Being and Environmental Outcomes

Evidence for the Lao People's Democratic Republic

This paper investigates the impact of electrification of households in the Lao People's Democratic Republic using data from the Lao Expenditure and Consumption Survey. It finds that a higher proportion of households with electricity is associated with an increase in the electrification of neighboring households. The analysis also finds that electrification increases income, improves children's educational completion, and reduces the use of dirty fuel for lighting and cooking, thus contributing to improved socioeconomic and environmental outcomes.

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