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Does electricity reliability matter? Evidence from rural Viet Nam

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ABSTRACT

Using a three-round panel dataset of more than 3,000 households, the paper estimates the impacts of electricity reliability improvement on the welfare and economic decisions of rural Vietnamese households. The number of days without power outages in communes per annum is used to proxy for electricity reliability. We employ a fixed effect regression with an instrumental variable to deal with the endogeneity issue, led by the simultaneous causal relationship between the reliability of electricity and household outcomes along with the unobservable variables. We use the similar electricity quality variable but measured in other communes within the same province as an instrumental variable. Results from this model show that an improvement in electricity reliability plays an important role in enhancing incomes, durable consumption, access to credit and land investment decisions of rural households.

1. Introduction

A deficiency in electricity access contributes to most problems facing the poor in the developing world, including challenges in obtaining adequate education, information, clean water, sanitation, medical care, food, shelter, and income (Birol, 2007). Given electricity's substantial benefits[1], access to it and other sources of modern energy are considered important objectives to fulfil the United Nations Sustainable Development Goals, which many developing countries have supported through rural electrification projects.

However, most of these analyses have dealt only with electricity access and not its quality, which may more seriously affect household welfare, especially that of the poor. In addition, other aspects of outcome (such as household economic decisions on investment or access to credit) have not been explored[2]. Only recently, Chakravorty et al. (2014) examine the effects of the quality of electricity on household incomes in rural India. They find that a grid connection and a higher power quality (fewer outages and more hours per day of electricity supply) enhanced non-agricultural incomes by about 30 per cent in the same period.

This study aims to make progress in our understanding of whether electricity reliability impacts household welfare including income, durable consumption, education and health. We also investigate how electricity quality affects household economic decisions, such as agricultural investment and access to credit, in rural Viet Nam.

Viet Nam can be an interesting case study to examine this relationship as it is one of the world's most successful stories in rural electrification. In 2014, the World Bank ranked Viet Nam as a developing country with the highest proportion of rural electrification in the world at more than 99 per cent, compared with only less than 5 per cent in the late 1970s when the country was just reconstructing after the war. However, this success is only for electricity access, not for the quality of its supply or the cost of using it.

We use a data set combining household with commune surveys to construct a panel sample of 9,557 observations, which cover the period of 2012–2016 and is representative of Viet Nam's rural population in 12 provinces. We take the number of days without power outage per annum within communes as a proxy for power reliability.

In order to address potential problems of a simultaneous causal relationship between power quality and household outcome or omitted variable problems, we construct a variable that measures the average number of days without outage in other communes of the same

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[1] Many empirical papers show that electrification can improve household incomes (Khandker et al., 2012, 2013; Bridge et al., 2016b; Dinkelman, 2011; Barnes et al., 2009), expenditures (Khandker et al., 2012, 2013; Saing, 2017), education (Khandker et al., 2012, 2013; Bridge et al., 2016a; Saing, 2017), labour productivity (Bridge et al., 2016a). For a more comprehensive review, see Jimenez (2017).

[2] Although there are a few studies that examine the impacts of the quality of electricity on firm performance. They find that unreliable access to electricity reduces firm's output, total factor productivity, or revenues (Fisher-Vanden et al., 2015; Allcott et al., 2016; Arnold et al., 2008).

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province as an instrumental variable. We also control for household fixed effects to capture time-invariant omitted variables. In order to address potential problems of a simultaneous causal relationship between power quality and household outcomes or omitted variable problems, we construct a variable that measures the average number of days without outage in other communes of the same province as an instrumental variable. We also control for household fixed effects to capture time-invariant omitted variables.

The results from the fixed effects regression with instrumental variables show that power reliability positively impacts household incomes. At the same time, an improvement in power reliability makes households better off with higher income from livestock or aquaculture production. Besides, reliable electricity is becoming more critical in affecting household economic decisions such as land investment or borrowing. Better reliability of the power grid increases the probability to invest in farm production and the amount of farm investment as well as the number of labour days used for farm production. It also encourages households to borrow for livestock production and asset purchasing. In addition, the better quality of electricity increases household's applicant ownership such as fridge, air conditioner or washing machines.

Our study has two main contributions to the literature. First, it complements very few studies that examine the impact of electricity reliability on household welfare. Second, to our knowledge, our analysis is one of the first studies that investigate the impact of the reliability of electricity on household economic decisions, including land investment and access to credit.

The paper is organised as follows: Section 2 describes the process of rural electrification in Viet Nam. Section 3 discusses our data, along with descriptive analyses of trends in power reliability and other variables, then presents the empirical model strategy. Section 4 gives estimation results with robustness checks. Section 5 summarises the key findings and presents some policy recommendations.

2. Rural electrification in Viet Nam

Viet Nam witnessed remarkable economic changes over the last two decades. Rapid growth was partly the result of the government's commitment to liberalising markets and investing in social sectors and rural development. The construction of rural infrastructure, access to clean water, good healthcare, improvement in primary school services, and the extension of grid electrification improved the quality of life of many families living in the countryside. Roads had helped rural people gain access to markets; grid electricity had enhanced education and the potential for more productive use of time and labour, and improved water supplies contributed to a healthier population. The rural electrification effort in Viet Nam was one of its most remarkable achievements, with the share of rural households with electricity access growing from 2.5 per cent in 1975 to 14 per cent in 1993 and 97.2 per cent by 2012 (World Bank, 2011; ADB, 2015). The most significant increase in electricity access (from 50 per cent to 88 per cent) transpired in 1995–2004 when the newly created Electricity of Viet Nam (EVN), a single-monopoly power company,[3] piloted the electrification of rural communes, and the government set clear electrification targets. The progress continued after 2005, and by 2012 almost 100 per cent of the communes and 97.2 per cent of the households in the country had been connected to the grid (Fig. 1).

The high use of electricity by households mainly came from

[3] Before 1995, the government entirely owned Viet Nam's power sector, with the Ministry of Energy managing three regional power companies, each of them responsible for generation, transmission, and distribution within its region. The Electricity of Vietnam (EVN), now known as Vietnam Electricity, was established from a merger of these three companies when the first stage of energy reforms started in 1995 (ADB, 2015).

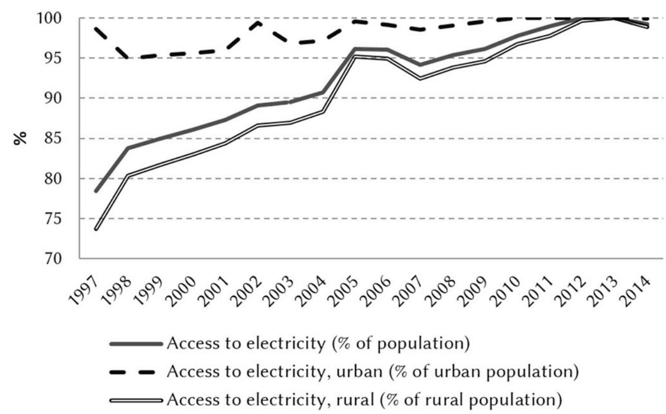

Fig. 1. Population's Access to Electricity, per cent Source: ADB (2015).

preferential pricing favouring residential units. Households paid substantially lower fees than commercial users (about 50 per cent less in 2011) despite the expensive costs of grid distribution. It explained why Viet Nam succeeded in quickly providing electricity to rural areas. However, the below-cost and subsidised tariff rates induced financial difficulties in operational maintenance and capital investment to the EVN, putting considerable tension on central government finances. The grid networks had become obsolete and were unable to meet increasing demand, causing moderately high technical losses. The reliability of electricity supply was, therefore, emerging as an important issue. As a result, since 2005, the government has concentrated on quality and regulation, in addition to a continuing expansion of electrification rates. Regulations were enforced, and focus shifted from network extension to improvement, and the government directly supported minorities and those in remote areas by extending electricity access. The government's focus was consequently not only on increasing electrification rates but also on ensuring efficiency (World Bank, 2011).

3. Data and empirical methodology

3.1. Data description

The paper uses the three waves of rural household panel data set that were collected in the Vietnam Access to Resources Household Survey (VARHS) in 2012–2016. These surveys were conducted through a collaboration between the University of Copenhagen and two Vietnamese partners, the Central Institute for Economic Management of the Ministry of Planning and Investment of Vietnam and the Institute of Labour Science and Social Affairs of the Ministry of Labour, Invalids, and Social Affairs of Vietnam. The VARHS covers rural households in 12 provinces: Dak Lak, Dak Nong, Dien Bien, Ha Tay, Khanh Hoa, Lai Chau, Lam Dong, Lao Cai, Long An, Nghe An, Phu Tho, and Quang Nam (Fig. 2).

Out of the total 9,557 observations in rural areas, there were 3,429 households in 2012; 3,532 in 2014; and 2,596 in 2016. These households were living in 491 communes during the interview period. The VARHS surveys represented households living in the rural areas of the provinces earlier mentioned. The survey consisted of commune modules and household modules. While there had been some modifications over the years, the same information was generally collected across all survey rounds. The commune surveys asked questions on commune characteristics such as infrastructure, income, and poverty.

The household questionnaire provided information on the general characteristics of the household and household members (e.g. age, gender, education, household size) as well as revenue and cost of income-generating activities including agricultural activities, non-farm self-employment, wage income, transfers, or income from renting out land or house. There were also questions on health, education,

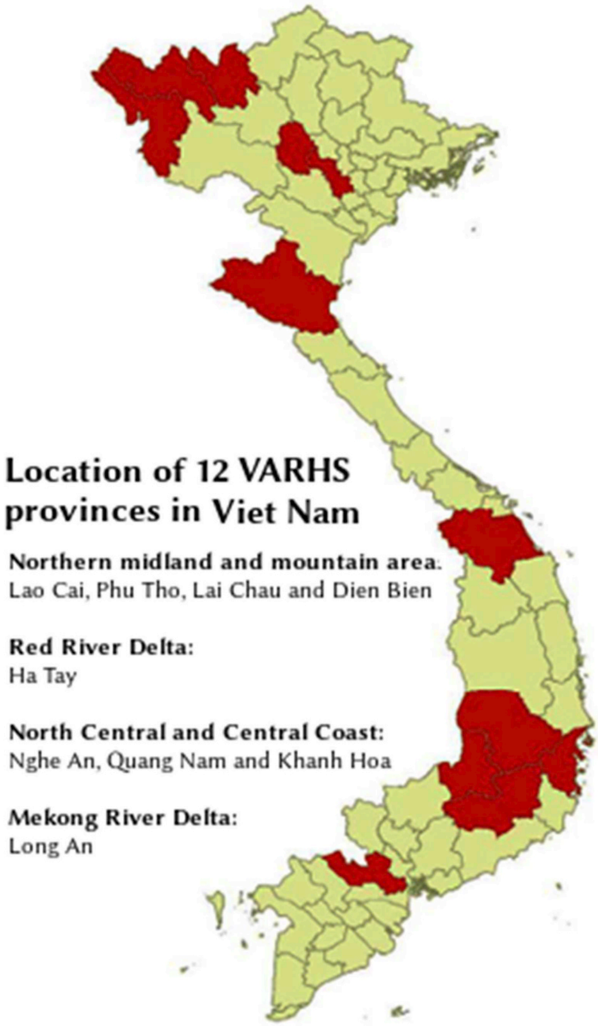

Fig. 2. Map of surveyed provinces Source: Tarp (2017).

investment and access to credit.

Respondents also gave electricity-related information including the percentage of households accessing electricity and number of days with outages during a year. However, to focus our attention to power reliability, we only use the information of a question at the commune level in the survey asking the number of days with power outages in communes. The exact wording of the question is as follows: 'How many days during [year] were there power outages in this commune?". However, to make it easier to interpret the empirical results, we use a number of days without power outages in communes as a proxy for electricity quality instead.

3.2. Empirical model

The following equation summarises our empirical strategy:

$$y_{ijt} = \alpha + \beta e_{jt} + X'_{ijt}\Gamma + C'_{jt}\Phi + \theta_i + \varphi_t + \varepsilon_{ijt}$$

where y is the outcome of household i living in commune j at time t, e describes the electricity reliability in a commune, C is a vector of commune characteristics, X is a vector of household characteristics, θ and φ are household and year fixed effects, and ε is the error term.

In this paper, the outcome y of household i includes the logarithm forms of family income and income component, cash and labour day investment in farm production, loan demand for farm, asset purchasing or consumption purposes, ownership of electrical appliances, having a member with a health problem or having a member dropped out of high school. The main interested variable e uses the Ln (Number of days without power outages in the commune) during a year to proxy for electricity reliability. Controlled variables used in the model include household characteristics X (age, gender, marital status and education of household heads, household size) and commune characteristics C (commune annual income per capita, proportion of poor households in communes, share of commune cropland has been irrigated annually, share of road with central asphalt or concrete in communes). All monetary variables of interest are inflated to 2016 prices.

By using a measure of electricity reliability at commune levels, any biases due to direct reverse causality at the household level should be eliminated. However, the empirical relationship between household outcomes and the electricity variables can be prone to other sources of biases. Omitted variables are one source of biases. Time-invariant household characteristics are, therefore, controlled by including household fixed effects. Time-varying characteristics are, however, more difficult to deal with because we may expect potentially confounding trends in wealth as well as economic and infrastructural development in communes, which could simultaneously affect electricity variables and household outcomes. In addition, measurement errors in the power reliability variable also could induce an attenuation bias.

To overcome these concerns, we rely on the idea of Bai et al. (2017) by taking an average number of days without power outages in the communes other than its own in the province as an instrumental variable. The identification assumption is that electricity reliability is determined independently by each commune. In particular, our first stage specification using the leave-one-out instrumental variable is as follows:

$$e_{jt} = \delta + \eta e_{-jt} + X'_{ijt}\Gamma + C'_{jt}\Phi + \theta_i + \varphi_t + \varepsilon_{ijt}$$

where the variable e_{-jt} is the average number of days without power outages in all other communes other than j in the province.

3.3. Descriptive statistics

This section describes the main variable during 2012–2016. Table 1 shows the reliability of electricity has been improved. The number of days with power outages within a commune was reduced from 25 days in 2012 to 17 days in 2016, which shows an improvement of power quality during this period.

As indicated in Table 1, male headed the majority of the rural households in both 2012 and 2016. There was a slight increase in the number of female household heads in 2016 compared with 2012. Household heads were 49 and 54 years old in 2012 and 2016. Their average year of schooling in 2016 was higher than that in 2012. The household size tends to be smaller.

The trend shows that household revenues have been improved. Agricultural activities, dominated by crop production, played the most critical role for labour incomes. However, the contribution of income from crop production has declined over time. This phenomenon can be partly explained by the cropland area has been reduced substantially in 2012–2016. The share of income from aquaculture and livestock activities also show a decreasing trend. At the same time, the household income from nonfarm activities increases in the same period, which implies switching from agriculture to non-agriculture activities over time in rural Vietnam.

Along with an apparent reduction in income from farming activities, there is a reduction in the share of families deciding to invest in improving their irrigation system, soil and water conservation, ponds, or shrimp farms in 2012–2016. For households who decided to improve their farmland, the total cash spent on that investment seemed to increase. However, the number of labour days spent on farm production has been reduced.

Table 1 also exhibits variations in loan demand for different purposes. The proportion of families applying a loan for farm activities has been diminished, from 7.2 per cent in 2012 to 4.6 per cent in 2016. However, households seem to borrow a higher amount for livestock

Table 1
Descriptive statistics.
Source: Vietnam Access to Resources Household Surveys 2012–2016.

Variables	2012	2014	2016
Electricity variables			
Number of days without power outages	340	346	348
Number of days without power outages in other communes	335	345	348
Household characteristics			
Age of HH head	49.2	51.3	54.2
% HH head is male	81.2	79.8	76.5
% HH head is married	82.0	82.0	78.7
% HH head finished primary school	27.2	24.4	23.5
% HH head finished lower secondary school	28.8	32.1	38.0
% HH head finished at least high school	12.6	15.2	22.0
Household size	4.6	4.5	4.1
Total household income per annum (1000 VND)	82,099	91,018	105,185
Household income from crop production per annum (1000 VND)	20,835	20,723	16,847
Household income from livestock production per annum (1000 VND)	5956	5623	5156
Household income from aquaculture production per annum (1000 VND)	1840	1673	1135
Household income from nonfarm activities per annum (1000 VND)	3565	3440	5101
% HH has a loan for agriculture activities	7.2	6.5	4.6
% HH has a loan for livestock production	6.3	4.6	3.4
% HH has a loan for asset purchasing	6.9	4.6	5.1
% HH has a loan for consumption	2.6	3.1	2.1
Average loan amount for agriculture activities per annum (1000 VND)	582	890	584
Average loan amount for livestock production per annum (1000 VND)	1568	1234	3341
Average loan amount for asset purchasing per annum (1000 VND)	5458	4568	6414
Average loan amount for consumption per annum (1000 VND)	1183	583	1081
% HH invest in farm production	21.2	16.9	15.0
Cash investment in farm production per annum (1000 VND)	1009	1822	1742
Labour days invested in farm production per annum	5.6	3.2	2.8
% HH has a refrigerator	31.7	45.0	56.0
% HH has an air conditioner	2.8	5.3	11.1
% HH has a washing machine	10.3	16.0	22.2
% HH at least one member with a health problem	22.3	18.2	20.4
% HH at least one member dropped out of high school	12.0	11.2	7.5
Commune characteristics			
Ln(Commune annual income per capita)	8.4	9.5	9.8
% Poor households in communes	25.7	18.5	7.8
% Commune cropland has been irrigated annually	50.1	56.1	57.0
% Road with central asphalt or concrete in communes	56.6	66.0	85.9
Province characteristics			
Ln(Provincial gross domestic product)	10.5	10.8	11.4
Provincial growth of industrial production	7.6	7.0	12.1
Ln(number of internet and phone subscribers in provinces)	6.9	6.8	7.2
Observations	3429	3532	2596

Note: Standard errors in brackets. All monetary variables are inflated to 2016 prices.

production. No clear trend was observed for loans applied to buy durable assets or for consumption purposes although the average loan amount for asset purchasing increased in 2012–2016.

Households seem to own more electrical appliances – such as a refrigerator, an air conditioner, a washing machine – when their living standards have been improved. The share of households owning a refrigerator has increased from 31.7 per cent to 56 per cent and air conditioner from 2.8 per cent to 11.1 per cent during the same period. The proportion of households who own washing machines also increases from 10.3 per cent in 2012 to 22.2 per cent in 2016.

In terms of health, due to limited information, we use a proxy of whether a household member suffered from any health problems during the last two weeks. On educational attainment, we use an indicator for whether a household has a member aged 7–22 years who was not attending a school or not graduating from high school. The figures reveal that there is a downward trend in the proportion of households having members with health problems, from 22.3 per cent in 2012 to 20.4 per cent in 2016. Similarly, lower rates of dropout rate among households are also observed. Specifically, the ratio of dropping out of high school, which was 12.0 per cent in 2012, has been reduced to 7.5 per cent in 2016.

Also demonstrated in Table 1, economic variables at the commune level, such as income per capita and share of poor households show some improvement between the two periods. Communes also have better infrastructure. Overall, there is an improvement in indicators of quality of life of households and commune infrastructures in rural Vietnam between 2012 and 2016. Similarly, the figures in Table 1 also indicate that economic and infrastructure conditions at provincial levels are improving with high economic growth and better connection.

4. Empirical results

We estimate equation (1) using the fixed effects regression with an instrumental variable.[4] All models include time dummies to take into account changes over time in the economic environment. In all estimations, we also add household and commune characteristics to control for time-varying effects that may bias the results. The tables provide estimated coefficients with robust standard errors clustered at the household level. The values of dependent variables are inflation-adjusted to reflect changes in prices over time. The F-statistic of excluded instruments is 224, well above the critical values (10) identified by Staiger and Stock (1997), showing that a weak instrument is not our concern.

Previous empirical studies show that electricity shortage can also seriously affect income or labour productivity (Bridge et al., 2016b). Likewise, Barnes et al. (2009) find that electrification improves the income of farm-based households. The possible mechanism to boost this income is the utilisation of electric pumps for irrigation, which in turn leads to higher earnings from agriculture. Better supply of electricity also creates opportunities for many small entrepreneurial activities which can take place within the household, increasing its non-wage income.

The results from Table 2 indicate that the reliability of electricity plays an important role in improving household income. The result in column (1) shows that reducing the number of power outages tends to increase household incomes, which is statistically significant at the level of 11 per cent. Particularly, on average, an increase in electricity reliability by one percentage point (equivalent to 3.6 days without outage in a year) results in one per cent increase in household income, ceteris paribus.

In addition, power quality also has different impacts on household income components. As reported in columns (2)–(5) of Table 2, higher electricity reliability helps improving household income from livestock and aquaculture activities but seems to have no statistically significant impact on income sources from crop production and non-farm activities. One possible explanation for this is an improvement in power

[4] We used the command xtivreg2 in STATA with a cluster option.

Table 2
The impact of electricity reliability on household incomes.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)
	Ln(Income)	Ln (Income from Crop production)	Ln(Income from Livestock production)	Ln(Income from Aquaculture production)	Ln (Nonfarm income)
Ln (Number of days without power outages per annum in communes)	1.03 (0.64)	2.21 (3.26)	7.91* (4.81)	11.60*** (3.40)	1.49 (2.77)
Observations	9,557	9,557	9,557	9,557	9,557
Number of HH	3,563	3,563	3,563	3,563	3,563
Household controls	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 224					

Notes: Standard errors, cluster at household level in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (224), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

reliability makes households better off when switching to other higher-valued activities such as raising livestock or aquaculture rather than relying on only crop production. In details, the results show that, keeping other things equal, one per cent improvement in the number of days without power outages increases household income from livestock production by approximately 8 per cent and from aquaculture activities by 11.6 per cent, respectively. This result is consonant with the findings from Chakravorty et al. (2014) where they show that the quality of power strongly increased the benefit of electrification for non-crop household income. This highlights the importance of providing reliable electricity on changes in household income components.

It is worth noting that this outcome reflects variations within households when the household and time fixed effects are controlled. Therefore, although there is an overall trend of switching from farming to non-farm activities over time (see Table 1), which may be associated with changes in policy or economic environment affecting all rural households, those relying on livestock or aquaculture production still get benefits from more reliable electrification.

In Table 3, we investigate the impact of the power quality on the decision to invest, with cash and labour, in improving the irrigation system, and conserving soil and water, ponds, or shrimp farms. The results show that the reliability of the power grid increases the probability to invest in farm production and the amount of farm investment as well as the number of labour days used for agricultural production. Regular outages could reduce households' expected returns, making them reluctant to invest. In particular, one per cent improvement in electricity grid quality increases the probability to invest in farm production by 3.6 per cent. In terms of the absolute terms, one per cent higher in power quality results in increases by 25.7 per cent and 28 per cent in cash investment and the number of labour days used for farm production, respectively. This outcome is consistent with the one from Table 2 where farming activities such as livestock or aquaculture income are improved as a result of a more reliable power grid.

We further explored the impact of electrification on loan demand, which is presented in Table 4. The outcome from this table shows that electricity reliability has positive impacts on loan for livestock production and asset purchasing. One per cent increase in the number of days without power outages increased the probability to apply loan for livestock production by 0.79 per cent and for asset purchasing by 0.56 per cent. One potential explanation is that better power quality

Table 3
The impact of electricity reliability on farm investment.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)
	Invest in farm production	Ln(Cash investment in farm production)	Ln(Labour days used for farm production)
Ln (Number of days without power outages per annum in communes)	3.62*** (0.46)	25.66*** (4.91)	28.02*** (3.45)
Observations	9,557	9,557	9,557
Number of HH	3,563	3,563	3,563
Household controls	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Household FE	Yes	Yes	Yes
F-test for the excluded instrument: 224			

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (224), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

encourages households to purchase more durable applicants, and they can be financed from borrowing. In contrast, households are less likely to apply loan for crop production with an improvement in grid

Table 4
The impact of electricity reliability on the decision to borrow.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)
	Apply loan for crop production	Apply loan for livestock production	Apply loan for aquaculture production	Apply loan for asset purchasing	Apply loan for consumption
Ln (Number of days without power outages per annum in communes)	−0.68***	0.79***	0.02	0.56**	−0.16
	(0.24)	(0.25)	(0.03)	(0.25)	(0.19)
Observations	9,557	9,557	9,557	9,557	9,557
Number of HH	3,563	3,563	3,563	3,563	3,563
Household controls	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 224					

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (224), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

Table 5
The impact of electricity reliability on the borrowing amount.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)
	Ln(Loan for crop production)	Ln(Loan for livestock production)	Ln(Loan for aquaculture production)	Ln(Loan for asset purchasing)	Ln(Loan for consumption)
Ln (Number of days without power outages per annum in communes)	−5.49***	11.64***	0.34	8.70**	−2.03
	(1.76)	(3.64)	(0.52)	(3.80)	(2.69)
Observations	9,557	9,557	9,557	9,557	9,557
Number of HH	3,563	3,563	3,563	3,563	3,563
Household controls	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 224					

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (224), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

reliability.

Table 5 reports the same impact of power reliability on household borrowing except the dependent variables are the amount of borrowing. The results in column (1) to (5) of Table 5 show consistent evidence with Table 4. Again, better power reliability increases the amount of borrowing for livestock production and asset purchasing but reduces the borrowing amount for crop production. This also reflects the above story that rural households have less rested on crop production and benefited more from non-crop activities. Therefore, they have reduced borrowing amount for crop production and increased loan for other non-crop activities.

The first three columns of Table 6 illustrate the impact of power interruption on electrical appliance demand. Better power reliability makes less uncertainty, which may change households' consumption behaviour. Being consistent with the description in Table 1, it is a clear and consistent trend that households connected to the more reliable electricity grid tend to purchase more electrical appliances such as a refrigerator, an air conditioner, or a washing machine that improve family living standards and produce better food preservation and greater comfort. In details, keeping other things equal, one per cent increase in the number of days without power outages increases the probability of a household owning a fridge by 0.87 per cent, an air conditioner by 1.07 per cent and a washing machine by 0.71 per cent, respectively. These results are also consistent with the estimation in Tables 4 and 5 which shows that households tend to borrow more for asset purchasing as the quality of power is improved.

Table 6
The impact of electricity reliability on durable asset purchases, health and education.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)
	Has fridge	Has air-conditioner	Has washing machine	Has a member dropping out of high school	Has a member with health problem
Ln (Number of days without power outages per annum in communes)	0.87**	1.07***	0.71***	−0.02	0.57
	(0.37)	(0.19)	(0.26)	(0.36)	(0.45)
Observations	9,557	9,557	9,557	9,557	9,557
Number of HH	3,563	3,563	3,563	3,563	3,563
Household controls	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 224					

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (224), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

Finally, we check the effect of grid reliability on educational attainment and health (the last two columns of Table 6). Khandker et al. (2013) argue that access to electricity may increase children's study hours due to improved lighting. Therefore, getting to electricity help children increase their completed years of schooling or stay in school longer than those in households not connected. Similarly, the lack of electricity makes it impossible for schools to tap modern technology, severely limiting their capacity to access information (Kanagawa and Nakata, 2008a,b). Results from column (4) in Table 6 show a negative correlation between dropout rates from high school and reliable electricity. However, the coefficient magnitude is small and not statistically significant.

Electricity may also influence health outcomes in several ways. Using electricity for cooking will reduce the indoor burning of biofuels that is one of the greatest health concerns facing developing countries (Sagar, 2005). In addition, better access to high-quality power make household willing to by preservation equipment such as a fridge that can help to keep foodstuffs for a longer time and reduce the risk of food contamination. However, as indicated in column (5) in Table 6, power reliability has no statistically significant effect on health. One possible reason is that electricity is not used primarily for cooking and the habit of using biomass in cooking might be a direct factor causing health issues in rural Vietnam.

4.1. Sensitivity tests

One of our assumptions in our IV estimation is that electricity reliability is determined independently by each commune. This assumption could be violated. Electricity outages may depend on commune economic development, which may correlate with income growth in neighbouring communes and what is happening at the province level as well. Therefore, economic and infrastructural development in provinces, which could simultaneously affect power reliability variables and household outcomes and biases our estimates.

To check the potential of these biases, we conduct a sensitivity analysis by adding province's economic and infrastructure development variables, including Ln(provincial gross domestic product), provincial growth of industrial production, Ln(number of provincial internets and phone subscribers). If the results are biased because of confounding economic and infrastructural development, we would expect the estimates to be sensitive to adding these variables. The results in Tables 7 and 8 indicate that the coefficients are almost similar to those in Tables 2–6 in all estimation and statistically significant, confirming the role of power reliability on household welfare and decisions.

We also examine the effects of power reliability on households with a different rate of electrification. In particular, we divided the samples into communes who have has 100 per cent electrified rate since 2012 and the remaining communes. We expect that rural households in fully electrified communes will have different patterns of consumption and borrowing activities compared to the remaining ones. In addition, the composition of household incomes may change differently between the two groups of communes when they are facing the same improvement in electricity quality. The estimations are reported from Tables 9–12. As expected, the results in column (7) to (9) in Table 11 indicate power reliability had more profound effects on household investment in communes that have not been fully electrified. In fact, the magnitude of those coefficients is about three times higher than those in Table 9. Similarly, the results in columns (3) and (4) in Table 11 shows that an improvement in power quality also has higher impacts on household aquaculture income and probability to own fridge compared to those in Table 9. Table 12 documents the effects of power reliability on household borrowing in communes that have not been fully electrified. The results in columns (2) and (5) indicate that better power quality results in higher household borrowings for livestock production, whereas the same effects have not happened in the fully electrified communes. On the contrary, more reliable power had a higher impact on borrowing for asset purchasing or air conditioner ownership in fully electrified communes as reported in Table 10. In general, those results highlight that the impact of electrification on households cannot be considered independently of power reliability.

5. Conclusions and policy implications

Viet Nam has been prosperous to promote rural electrification. With its rapidly growing economy, it had the necessary financing available to quickly expand electricity access and improve the quality of electricity for millions of rural people. This paper sought to examine the effects of electricity reliability on household welfare and economic decisions by

Table 7
The impact of electricity reliability. Adding provincial characteristics.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)	(6)
	Apply loan for crop production	Apply loan for livestock production	Apply loan for asset purchasing	Ln(Loan for crop production)	Ln(Loan for livestock production)	Ln(Loan for asset purchasing)
Ln (Number of days without power outages per annum in communes)	−0.67*** (0.24)	0.77*** (0.24)	0.55** (0.25)	−5.23*** (1.79)	11.31*** (3.58)	8.51** (3.84)
Observations	9,557	9,557	9,557	9,557	9,557	9,557
Number of HH	3,563	3,563	3,563	3,563	3,563	3,563
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes
Province controls	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 221						

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. Province control variables include Ln(Provincial gross domestic product), Provincial growth of industrial production, Ln(number of internet and phone subscribers in provinces). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (221), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

using the data set of households and communes in rural Viet Nam in 2012–2016. To tease out the causal effects, we used the fixed effect regression with an instrumental variable. We found that the quality of power positively affects household incomes. In addition, better power reliability makes households benefit more from livestock or aquaculture production. Besides, reliable electricity also plays an important role in affecting household economic decisions such as land investment or borrowing. Higher reliability of power increases the investment in farm production and encourages households to borrow for livestock production and asset purchasing. In addition, the better quality of electricity increases household's durable asset ownership such as fridge, air conditioner or washing machines.

Table 8
The impact of electricity reliability. Adding provincial characteristics.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Ln(Income)	Ln(Income from Livestock)	Ln(Income from Aquaculture)	Has fridge	Has air-conditioner	Has washing machine	Invest in farm production	Ln(Cash investment in farm production)	Ln(Labour days used for farm production)
Ln (Number of days without power outages per annum in communes)	1.34** (0.65)	8.46* (4.82)	12.46*** (3.42)	0.87** (0.37)	1.02*** (0.20)	0.67** (0.26)	3.79*** (0.47)	26.84*** (4.89)	29.01*** (3.44)
Observations	9,557	9,557	9,557	9,557	9,557	9,557	9,557	9,557	9,557
Number of HH	3,563	3,563	3,563	3,563	3,563	3,563	3,563	3,563	3,563
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 221									

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. Province control variables include Ln(Provincial gross domestic product), Provincial growth of industrial production, Ln(number of internet and phone subscribers in provinces). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (221), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

Table 9
The impact of electricity reliability. Communes with full electrification.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Ln(Income)	Ln(Income from Livestock)	Ln(Income from Aquaculture)	Has fridge	Has air-conditioner	Has washing machine	Invest in farm production	Ln(Cash investment in farm production)	Ln(Labour days used for farm production)
Ln (Number of days without power outages per annum in communes)	0.78 (1.04)	5.59 (8.03)	0.87 (4.50)	−0.89 (0.62)	1.34*** (0.33)	0.70 (0.49)	1.58** (0.62)	18.10** (7.35)	11.10** (4.58)
Observations	4,469	4,469	4,469	4,469	4,469	4,469	4,469	4,469	4,469
Number of HH	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 131									

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. Province control variables include Ln(Provincial gross domestic product), Provincial growth of industrial production, Ln(number of internet and phone subscribers in provinces). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (131), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

Table 10
The impact of electricity reliability. Communes with full electrification.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)	(6)
	Apply loan for crop production	Apply loan for livestock production	Apply loan for asset purchasing	Ln(Loan for crop production)	Ln(Loan for livestock production)	Ln(Loan for asset purchasing)
Ln (Number of days without power outages per annum in communes)	−0.39 (0.36)	0.37 (0.31)	0.94** (0.45)	−2.21 (2.00)	5.96 (4.62)	15.25** (7.00)
Observations	4,469	4,469	4,469	4,469	4,469	4,469
Number of HH	1,527	1,527	1,527	1,527	1,527	1,527
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes
Province controls	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 131						

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. Province control variables include Ln(Provincial gross domestic product), Provincial growth of industrial production, Ln(number of internet and phone subscribers in provinces). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (131), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

The findings highlight the importance of improving electricity reliability when most people can access electricity nowadays. Our results provided evidence on how policies that aim to provide reliable electricity to households may bring about significant economic development through promoting household incomes, consumption, investment and access to credit.

The results also bring important implications for economic regulation. Because electricity supply is typically a natural monopoly, so customers dissatisfy with the quality or price of the service often have no alternatives to choose. This makes it important for regulators to monitor utilities' performance on matters relating to outages.

Table 11
The impact of electricity reliability. Communes without full electrification.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Ln(Income)	Ln(Income from Livestock)	Ln(Income from Aquaculture)	Has fridge	Has air-conditioner	Has washing machine	Invest in farm production	Ln(Cash investment in farm production)	Ln(Labour days used for farm production)
Ln (Number of days without power outages per annum in communes)	0.53 (0.79)	6.65 (6.18)	8.47* (4.53)	1.04** (0.47)	0.56*** (0.20)	0.07 (0.30)	4.69*** (0.67)	36.94*** (7.07)	37.18*** (5.07)
Observations	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088	5,088
Number of HH	2,036	2,036	2,036	2,036	2,036	2,036	2,036	2,036	2,036
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 125									

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. Province control variables include Ln(Provincial gross domestic product), Provincial growth of industrial production, Ln(number of internet and phone subscribers in provinces). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (125), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

Table 12
The impact of electricity reliability. Communes without full electrification.
Source: Our calculations from Vietnam Access to Resources Household Surveys 2012–2016.

	(1)	(2)	(3)	(4)	(5)	(6)
	Apply loan for crop production	Apply loan for livestock production	Apply loan for asset purchasing	Ln(Loan for crop production)	Ln(Loan for livestock production)	Ln(Loan for asset purchasing)
Ln (Number of days without power outages per annum in communes)	−1.29*** (0.37)	0.72** (0.33)	0.16 (0.29)	−10.18*** (2.78)	10.53** (4.89)	2.25 (4.57)
Observations	5,088	5,088	5,088	5,088	5,088	5,088
Number of HH	2,036	2,036	2,036	2,036	2,036	2,036
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Commune controls	Yes	Yes	Yes	Yes	Yes	Yes
Province controls	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
F-test for the excluded instrument: 125						

Notes: Standard errors, cluster at the household level, in parentheses. Household control variables are age, gender, schooling of household head, household size. Commune control variables are Ln(Commune average annual income per capita), percentage of poor households in communes, percentage of commune cropland has been irrigated annually, percentage of the road with central asphalt or concrete in communes. Province control variables include Ln(Provincial gross domestic product), Provincial growth of industrial production, Ln(number of internet and phone subscribers in provinces). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level. In all columns, the ratio of days without outage in other communes of the same province is used as the instrument for the electricity reliability (the ratio of days without outage within the commune). In the 1st stage of the FE IV regression of electricity reliability: (a) Ln(Average number of days without power outages per annum in other communes in the same province) is used as an instrument for Ln(Number of days without power outages per annum in communes); (b) The F-test for excluded instrument is larger than 10 (125), implying the instrument is strong (see Staiger and Stock, 1997). ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level.

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Appendix A. Supplementary data

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