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Reliable Electricity Access, Micro-Small Enterprises, and Poverty Reduction in Indonesia

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ABSTRACT

The government of Indonesia has launched subsidized electricity tariffs and a massive electrification campaign to improve the quality of life. However, whether these programs have increased access to energy for all and whether it reduces poverty is unclear. We empirically test the causal effects of electricity access on poverty reduction. We also investigate the potential role of micro-small enterprises (MSEs) as the transmission channel for poverty reduction. To isolate the endogeneity concerns, we use the instrumental variable (IV) approach. We exploit the village's proximity to the nearest power plant in 1985 as the exogenous variation of the historical least-cost distance by the state-owned company (PLN) to instrument the endogenous nature of current time electricity access. Our results show that expanding reliable electricity services contribute significantly to poverty reduction.

Nevertheless, we find no evidence that the MSEs' development has an influential mediating role in the poverty reduction effects.

Keywords: Electricity access, Poverty, Instrumental variable, Indonesia

JEL Classification: H54, L94, O15, O18, R23

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1 INTRODUCTION

The notion that electricity infrastructure plays a vital role in development and welfare has been intensively studied in the empirical literature (Dinkelman, 2011; Gibson and Olivia, 2010; Grogan and Sadanand, 2013; Litzow, Pattanayak, and Thinley, 2019; Kassem, 2018a). One aspect that is still understudied is how electricity access impacts poverty and the potential mechanism for this relationship. It is surprising since many developing nations, such as Sri Lanka, India, Mexico, and Ghana, have embedded their redistributive policy into electrification campaigns (Younger, Osei- Assibey, and Oppong, 2017; Bhattacharyya and Ganguly, 2017; Pérez-Denicia et al., 2017; Athukorala et al., 2019). Not exception is Indonesia, with its Public

Service Obligation (PSO) scheme operated by the Indonesian National Electricity Provider/*Perusahaan Listrik Negara* (PLN)—a state-owned company responsible for dominating in transmission, distribution, and selling of electricity service. The PSO scheme involves several fiscal instruments in expanding electricity access, including regressive electricity subsidy by a class tariff (Dartanto et al. 2020), VAT exemption (Marks 2005), and fuel input subsidies (Dartanto 2017; P.J. Burke, Batsuuri, and Yudhistira 2017; Savatic 2016; Burke and Siyaranamual 2019).

Numbers of analytical works have criticised and were sceptical about the PSO's redistributive welfare effectiveness (for example, Burke and Kurniawati 2018). Among those arguments that electricity consumption as a share of total consumption is progressive, the rich benefit more than the poor (TNP2K 2021). In other words, the benefit incidence of the combined fiscal policy is believed to benefit middle and high-income groups. Nevertheless, for those living in poverty, the benefit incidence of PSO can be non-trivial and is likely to alter their status to become the non-poor. Moreover, electricity access should also possess a reliability feature to enable the poor to engage in productive economic activity in fighting against poverty, a trajectory that is an open question for Indonesia. Nonetheless, Sambodo, Novandra, and Farandy (2021) also observe that PLN at the same time also provides compensation that also benefits most of the rich and large industries.

Despite a complex geographical condition, Indonesia has significantly increased the national electrification rate, from 67.2% in 2010 to 99.20% in 2020 (Pribadi, 2021). Nonetheless, even though electrification has increased, consumption per capita remains low compared to other countries with similar income levels (Fukoya Lab, 2017). In addition, the high electrification rate also does not guarantee reliable electricity services across the nation. The high cost and the low incentive in providing electricity access (Burke & Kurniawati, 2018; Kristov, 1995; McCawley, 1970), particularly in remote areas, made some parts of Indonesia not reachable by the decent quality of electricity access. Hence, to what extent electricity access in Indonesia matters to poverty remains an open question. An empirical exercise of the impact of electricity access on poverty, thus, is important. Accordingly, this study intends to examine the effect of electricity services penetration on poverty by exploiting the reliable electricity services that vary across regions in Indonesia. This variation across regions and years permits us to investigate the causal relationship between electricity and poverty. Moreover, the finding from this study is expected to add new empirical evidence in comparing the effectiveness of indirect and direct programs to alleviate poverty.

To further investigate how the poverty effect of electricity access expansion occurs, we focus on income-generating activities, mainly in informal jobs through micro-small enterprises (MSEs). The improvements in access to reliable electricity can arguably substantially benefit people's lives, particularly the poor in developing countries (Pachauri et al., 2012). The investment in new technology and reliable electricity allows MSEs to boost their production capacity and increase the demand for workers. Better reliable electricity may provide firms with flexible and longer operating hours and higher profitability. Higher profit improves both owner and workers' income benefits, which in turn reduces poverty. For further discussion about the case studies on the development of electricity in Indonesia and its impact on people's welfare, please see (Sambodo et al., 2021).

Establishing an empirical causal link between electrification and poverty is challenging, mainly due to the endogeneity concern. Electricity supply expansion is endogenous to demand in which poverty plays a role. The government might target electricity expansion more aggressively in poverty-pocket regions than others. We used an instrumental variable strategy to establish the causal impact of electricity services penetration on poverty to obviate this issue. We followed the approach of Kassem (2018), inspired by the literature on transportation infrastructure (Holl, 2016; Faber, 2014; Banerjee, Duflo, and Qian, 2020). We calculated and used the distance to the nearest power plants in 1985 as the instrumental variable for the recent electricity penetration measure, our key variable of interest. To identify the impact pathway, we adopted the causal mediation analysis in instrumental variable settings, developed by Dippel et al. (2019, 2020).

In this study, we used regional-level data from various resources, i.e., Statistics Indonesia (BPS) digital map, Indonesian National Electricity Provider/*Perusahaan Listrik Negara* (PLN), Ministry of Energy and Natural Resources (ESDM), Geospatial Information Agency (BIG), and Open Street Map (OSM), and Global Modelling and Assimilation Office (GMAO) dataset. The use of BIG and OSM data to extract spatial variables with ArcGIS software in Indonesian context has been widely applied in previous studies, see for example (Bestari, Kurniawan, and Yudhistira 2022; Simanjuntak, Kuffer, and Reckien 2019). We also combine this information with the annual survey of Small and Micro Enterprises (VIMK), Village potential survey (PODES) and other socioeconomic indicators.

Our key findings show that despite Indonesia having a monopoly on electricity transmission and distribution through the state-owned company in the electricity sector (i.e., PLN), electricity access penetration reduces poverty. Our study finds that one percentage point of the district population that lives in villages with reliable electricity access is, on average, associated with a 0.225 percentage points reduction in the poverty rate and 0.046 points reduction in the poverty gap. These effects are somewhat higher and different than, for example, Rwanda's evidence, where access to electricity has a relatively weak effect on several poverty indicators (Lenz et al., 2017). Nevertheless, we find no evidence that MSE development has a potential role in mediating the effect of electrification on poverty reduction in various MSEs' outcomes as indicators.

Our study contributes to the existing empirical evidence on the impact of expanding universal energy access on development (Dinkelman 2011; Grogan and Sadanand 2013;

Litzow, Pattanayak, and Thinley 2019), with the focus on poverty reduction with a microeconomic perspective in the developing country context (Jerome 2011; Pueyo and Maestre 2019). Specifically, this study also offers an ex-post benefit incidence analysis concerning low-income group empowerment of public investment in the energy sector in Indonesia, which is long known to be among Southeast Asian countries implementing a massive subsidy in the electricity sector (McCawley 1970; Burke and Kurniawati 2018).

2 CONTEXT AND FRAMEWORK

2.1 Electricity access penetration in Indonesia

Indonesia is an archipelago country and the fourth largest populated nation globally, with its inhabitant spread across no less than 17,000 islands. Achieving universal access to electricity remain a challenge for the nation (Dartanto et al. 2020) since the distribution and transmission of electricity are facing such unique geographical challenge (Sambodo and Novandra 2019) combined with low incentive and price distortion (Burke and Kurniawati 2018). On one side, at the macro and a national level, the statistics of the electrification ratio provides an optimistic state of the figure. The recently available electrification ratio for the country shows a figure of 99.20% in 2020, indicating that most households in the country have access to clean and affordable energy (BPS-Statistics Indonesia 2020). The electricity conditions in Indonesia have significantly developed from 2014 to 2018, as shown in Figure 1. Indonesia's electrification ratio at the national level increased from 84.35% in 2014 to 98.30% in 2018. Nonetheless, a study by Sambodo (2015) suggests that most of the rapid increase in electrification ratio is used off-grid with low voltage connection, and it is unsustainable. It is confirmed with our exposition in Panel B of Figure 1 using the socio-economic survey (Susenas) data.

On the other hand, this number is believed to mask a substantial sub-national sparse access to electricity. Dartanto et al. (2020) demonstrated that Eastern Indonesia has become the territory with slow progress on electricity access penetration, with most provinces in these areas having less than 60% of the electrification ratio. However, if we examine it using different measures and break down the sub-national variation, namely the proportion of villages with reliable access to electricity instead of the electrification rate at the household level, the story changes. The subnational variation of electricity access appears. There is also a significant variation in rates at the regional level, as shown in Figure 2, where regions in Papua Island generally have a lower electrification ratio than those on other big islands. Figure 3 indicates that reliable access to electricity services can affect people's lives and prosperity. The percentage of the district population that lives in villages with reliable electricity access, our key variable of interest, is inversely correlated with the poverty rate.[1]

Figure 2 shows that the development of electricity access in Indonesia has been a dynamic process since the country's electrification began in the 1980s, when we picked up the instrumental variable period. In the early 1970s, poor service was typical in Indonesia since the only electricity provider was PLN. A good and reliable electricity service comes from the private sector, where hotels and firms use captive generators (McCawley 1970). Nevertheless, until the 1990s, electricity access had remained underdeveloped. Java Island, where two-thirds of national economic activity took place, only had a 40% electrification rate (Kassem, 2018). For further discussion on the historical overview and recent development of the electricity sector, see Sambodo (2017). The major causes of the slow expansion were the geographical and political constraints around the state-owned company, PLN (Jarvis 2012).

[1] The unconditional scatter plot shows a weaker correlation in comparison with the conditional plot when we control for unobservable which indicates the endogeneity problem which we addressed in the empirical section.

The 1980s were notable milestones in Indonesia's power sector development. The period witnessed a rural electrification campaign by PLN that started in the early 1970s (McCawley 1978). Following this policy, the government introduced the structural change in the industry toward gas support to expand capacity. For example, the establishment of the Asahan power plant in 1982 represented the expansion of the access campaign. The resources for the campaign were coming from domestic resources and some from international funding (McCawley 2015). This period also witnessed other major events that affected PLN operation. First is the enactment of Law Number 15, the Year 1985, about electricity that formally provides the opportunity for the private sector to participate in electricity production and distribution in Indonesia and became the key event for power sector liberalization (Sambodo and Oyama 2010; Sriyanto 2017). Second, the period experienced an international commodity price burst and a decline in state revenue (Jarvis 2012). We argue that these situations were ideal exogenous natural experiments forcing PLN to be more efficient. Specifically, the least-cost distance of PLN substations in 1985 reflected the exogenous variation of these two major events. Thus, we use the year 1985 as our time reference for the instrumental variable for these two reasons.

2.2 How does electricity access affect poverty in Indonesia through MSEs?

Electricity can contribute to poverty reduction in several possible ways. We start with a reliable electricity access that makes more productive activities occur for additional income generation changes (Meadows et al. 2003; Kanagawa and Nakata 2007; Torero 2014). Moreover, the poor household's total income is the sum of the incomes of each household member and many different activities, including employment and self-employment. In more detail, an additional income of members by activity comes from the hours they worked and their hourly return (Torero 2014). Thus, the poverty effect of electricity access is expected from the combined effects of freeing up the poor labour supply and the increasing hourly paid rate. The indication of these combined effects in Indonesia is shown in the previous articles of the edition; see, for example, Dartanto and Nurkholis (2013) or Balisacan et al. (2003).

The reliable electricity reduces the cost of doing business, thereby increasing business entry or expanding operational hours; both are arguably absorbing more labour. Firms that previously hardly entered the market in the region lacking reliable electricity access will do so when the access improves. As for the existing firms, now they can prolong their operating hours at night whenever reliable service improves. Hence, these responses allow a greater output and revenue. Moreover, the employment effect from the demand side is arguably reinforced by the labour supply-side effects in the form of freeing up time for paid work as households experience reduced drudgery (Wilcox et al., 2015). As an intermediate input, reliable electricity can increase productivity. Adopting reliable electricity enables firms to use electrical appliances and transition from low-tech production to high-tech, energy-intensive production. Thus, reliable electricity boosts the development and performance of enterprises, including the quality of services (Blimpo and Cosgrove-davies 2019) or goods produced in general. In this study, we see this effect through MSEs' revenue per worker and value-add per worker as the measures of improved productivity.

However, the empirical findings are mixed. Dinkelman (2011) found in South Africa, the effects are a mixture of the improved female employment but not for males and, at the same time, improved male earnings and a decrease for females. Other literature reported evidence of the positive impact of electricity. They found that access to electricity services will create jobs, generate local industries, and promote mechanization in the production process, making firms have higher productivity and profit, while the poor quality of electricity access will harm the productivity (Arnold et al., 2008; Falentina & Resosudarmo, 2019; Kanagawa & Nakata, 2008; Kassem, 2018b). Peters et al. (2011) investigated the electrification benefit on microenterprises in rural Benin. They found that access to electricity generated the emergence of new firms and proved that electricity-reliant firms located in the access-region have a higher profit than non-reliant firms in both the access and non-access region. However, the non-reliant firms in the access-region did not perform significantly better than firms in the non-access region.

The role of electricity in poverty reduction through small scale enterprises has been undertaken in various studies (van Dijk 2008; van Dijk and Clancy 2010). van Dijk (2008) investigated small-scale enterprises' role in reducing poverty induced by electricity access in the Indian Himalayas. This study observed that reducing poverty depends on the productive use of modern energy appliances to increase or diversify the products. She also pointed out the importance of considering factors that may influence energy uptake and its impacts, such as human assets, financial assets, physical assets, and social assets, in assessing the electrification benefit. However, the study has limited quantitative empirical evidence for a generalized understanding of the causality on which circumstances could contribute to poverty reduction and quantify these impacts over time and at a larger scale since it was conducted based on qualitative research techniques collected from interviews, discussion, literature, and observation of 264 MSEs.

In a study of electrification impact in Bolivia, Tanzania, and Vietnam, using semi-structured and structured interviews, van Dijk & Clancy (2010) found that electricity does have a positive impact on production, but the magnitude differs depending on the location of the enterprise. The increase in income is converted to physical household assets or enterprise assets. The study in all three countries indicated that the employment opportunities did occur, but the number of jobs created remains small and can be considered insignificant. Most transitions following access to electricity in the rural enterprise in Bolivia, Tanzania, and Vietnam is the use of electricity in lighting to replace the traditional lighting that has limited operating hours. Thus, it improves the time flexibility of the enterprises to run the business toward a longer operating hours.

The second transition is mechanization, followed by diversification of industry activities. These transitions do not automatically lead to a decline in production costs (Dijk & Clancy, 2010). Their findings are mixed. In villages in the hills in Vietnam and in Bolivia, where the sampled communities are relatively small and poor and access to market is limited, the energy transitions have not led an increase in production. While in Tanzania and villages near Hanoi in Vietnam, where the sampled communities include some of the most prosperous rural regions and tourism area, the growing economy has enabled energy transitions led an increase in production. These novel mixtures of findings raise interest in whether the electricity impact on MSEs productivity and, subsequently poverty occurs in Indonesia. While this study provided rich information regarding the impact of electricity access in rural enterprises and its contribution to poverty reduction, the generalization is difficult due to limited data. Only 60 rural microenterprises were interviewed in Tanzania and 110 in Vietnam.

Based on 2016 Economic Census data from BPS, the number of MSEs in Indonesia account for 98.3% of the total establishments (around 26.7 million enterprises). Sixty per cent of these MSEs are in Java Island and only ten per cent are in Maluku and Papua. We believe that the distribution is not changed recently. In this study, we focus on examining the potential mechanism in which MSEs' access to reliable electricity matters for poverty reduction as they host a large portion of employment, including workers living in poverty. The MSEs absorb about 53.6 million workers or about 76.3% of the total employment at the time. Based on our calculation using the Susenas (the National Socio-Economic Survey) 2020, about 10 million individuals or about 8% of total employment recorded in this household survey are living in poverty with average monthly per capita consumption of Rp381,952 and it ranges between Rp125,657 and Rp728,956. Combining the two figures, we expect about 7.7 million workers living in poverty are in MSEs. Moreover, forty percent of the poor or about 4 million individuals in Susenas engaged in self-employment activities. According to Tambunan (2008), these enterprises can be characterized as small enterprises (SEs). Therefore, MSEs' owners and employees host non-trivial numbers of people living in poverty (more than a third of the current poverty incidence); thus, changes in MSE's operation and productivity due to electricity access should matter for poverty reduction.

We summarize how electricity services affect poverty through micro-small enterprises (MSEs) as the transmission channel in Figure 4. This analytical framework allows us to better understand one of the mechanisms we expect electricity services to improve household welfare, thus reducing poverty.

3 EMPIRICAL STRATEGY

3.1 Data

The main specification model uses regional-level data sets from various sources: the Indonesia Bureau of Statistics (BPS), the state-owned company in the electricity sector or PLN, the Ministry of Energy and Natural Resources (ESDM), the Geospatial Information Agency (BIG), Open Street Map (OSM), and Global Modelling and Assimilation Office (GMAO) dataset. The annual survey of Small and Micro Enterprises (VIMK), Village Potential Survey or PODES, poverty data, and other demographic and economic data were collected from the Indonesia Bureau of Statistics (BPS). The annual surveys of micro and small industries (VIMK) for two years (2014 and 2018) were used to get information on MSEs' characteristics and performance. PODES 2014 and PODES 2018 were used to get information on road and transportation facilities (mobility access), telecommunication facilities (signal strength), access to financial institution, and geographical data at the village level.[2] We used the historical electricity infrastructure information in 1985 from the Indonesian National Electricity Provider (PLN) and the information about the current electricity infrastructure from the Ministry of Energy and Natural Resources' Electricity Supply Business Plan (RUPTL). Specifically, the PLN historical map contained the planned and actual location of the power plant and substation in 1985. Last, we obtained precipitation data from the GMAO dataset.

We create three digital maps of Indonesia's electricity infrastructure conditions for 1985, 2014 and 2018 using maps and documents from PLN. These digital maps are manually made by marking the coordinate location of all electricity substations and power plants in Indonesia. Further, overlay the maps with the village level administrative map to calculate the Geodetic distance of each village's centroid to the nearest power plants and electricity substations in each year's map. We use these Geodetic distances to calculate two variables: the distance of villages to a substation in 2014 and 2018, and the distance of villages to the nearest power plant in 1985. Maps showing the distribution of these substations each year and their number by provinces and year are available in Appendix A1.

In this study we defined a region, that is a village, has a reliable electricity access if it has accessibility to the steady electric power supply for a productive use, which ensures that the frequency, voltage, and current load level are within the normal operating range. The conceptual definition follows a standard definition of reliability access to a stable electricity, as for example, one that is defined in Blimpo & Cosgrove-davies (2019). They defined it as a circumstance without fluctuations in voltage, always available, and capable of supporting electrical appliances usage for a productive use. The stability of electric power supply, in general, declines with distance. In this study, we use a geographical distance as the element in

[2] The PODES years are available only for 2014 and 2018 but our data set comprises of 2014, 2015, 2017, and 2018. Accordingly, we merge 2014-related covariates from PODES with the years of 2014, 2015, and 2017 of our datasets; and we merge 2018-related covariates from PODES with the year 2018 of our datasets.

determining electricity reliability instead of alternative measures, such as outage or blackout frequencies (see for example Wilcox (2015) or Blimpo & Cosgrove-davies (2019).[3] Moreover, we use a stylized standard based on geographical distance in Indonesian context in determining the distance cut-off of electricity reliability category.

Accordingly, we use the distance of villages to a substation in 2014 and 2018 to code the village status to be with reliable access to electricity or not. The current convention dictates that a reliable electricity service in Indonesia occurs where access to electricity is 20 km or less to the nearest electricity substation measured by Geodetic distance with a capacity of 150/70 kV (Kemdikbud 2016). The relationship between the distribution loss and distance shows that above 20 km, there is an evident increase in distribution loss (see Appendix A2). We refer to this operational definition as reliable access to electricity and ensure that the variation of the key variable of interest reflects productive activities related to poverty reduction. Wilcox (2015) argues that Tier 1[4] access (low reliability) reported few productive use applications beyond lighting. As for the later measure, we use the distance of villages to the nearest planned power plant in 1985 as the instrumental variable. We argue that the nature of the power plant placement in 1985 has no direct association with the current poverty level and it serves as a quasi-random factor determining electricity penetration in the current time, affecting the current poverty. We acknowledge the potential role of the off-grid connection in the economy (see Figure 1). Nevertheless, most off-grid connections have been less reliable (Sambodo 2015). From this status of villages, we create a key variable of interest of the share of villages with reliable electricity access weighted by the rural population at the district level. Effectively,

[3] They used criteria of maximum 4 disruptions per week of total duration less than 2 hours.

[4] It is characterized by maximum amount (capacity) of energy required to support different levels of power loads is 50 W, average time electricity source available divided by the average operating hours is between 25%-50%, number of unscheduled outages per week is more than 4 outages and cumulative length of unscheduled outages per week is more than 2 hours.

it translates into the share of the district population that lives in villages with reliable electricity access.

For comparability, the newly formed villages during 2014-2018 and their origins were excluded from the observation, leaving 78,738 villages. Since some village-level data collected from PODES were missing, the observation now leaves only 77,997 out of 78,738 villages in the dataset.[5] At the district level, unavailable data for some regions from Susenas drop regions sample from 502 to 481 regions. The total observation at the firm level is 290,003 firms.

3.2 Main Estimating Equation

To address the simultaneity nature of electricity access and poverty relationship that may bias our estimate, we utilise the potentially exogenous variation of natural supply-side experiment or the plant construction. Kassem (2018) argued that construction cost is potentially exogenous because it is an element in expanding the electricity infrastructure. The electricity company will build an electricity infrastructure using a cost-effectiveness approach; therefore, it will not correlate with the poverty level at the location where it is being built. We follow this approach and argue for our instrument validity for two reasons. First, the locations of the planned power plants in 1985 were randomly assigned by the geographical difficulty level in which PLN sought for the least cost locations. Therefore, villages nearer to these power plants faced an exogenous probability of receiving electricity access in the future as PLN finds it cheaper to connect closer villages to the existing networsystem. Also, villages' distance to power plants in 1985 affected the present poverty rate through the future expansion of electricity access. Thus, the main specification model to estimate the impact of reliable electricity services on poverty at the regional (district) level will be as follows.

[5] Our inspection of each wave of PODES data yields a nearly even composition of the village with and without electricity access identified from the PODES question among the dropped villages. The composition ranges from 45 to 46% of villages have electricity access. This composition suggests that the missingness can be said to be random and its influence to bias the estimation is arguably minimal.

$$First\ stage: Access_{r,t} = \gamma_0 + \gamma_1 Elec_r + \gamma_2 \mathbf{V}_{r,t} + \gamma_3 \mathbf{Z}_r + \gamma_4 \mathbf{X}_{r,t} + \eta_s + \delta_t + \theta_{st} + \omega_{0rt}. \tag{1}$$

$$Second\ stage: Pov_{rt} = \beta_0 + \beta_1 Access_{r,t} + \beta_2 \mathbf{V}_{r,t} + \beta_3 \mathbf{Z}_r + \beta_4 \mathbf{X}_{r,t} + \eta_s + \delta_t + \theta_{st} + \varepsilon_{0rt} \tag{2}$$

In this model, $r, s,$ and t denote the district, province, and year indices, respectively. Pov is measured by three indicators, such as headcount index (P_0), poverty gap index (P_1), and poverty severity index (P_2). $Access_{r,t}$ is the percentage of district population that lives in villages with reliable electricity access. $Elec_r$ is the instrument corresponding to the average km distance from villages to the nearest power plant in 1985. $\boldsymbol{V_{rt}}$ is a vector of time-varying local economy and demography characteristics consisting of economic growth, density, Gross Domestic Regional Product (GRDP) per capita, number of flood events, the share of the population completed senior high school, share of agriculture in toral GRDP, and share of the rural population. $\boldsymbol{Z_r}$ is a vector of time-invariant geography characteristics consisting of average village elevation, average village distance to the coastline, the share of villages located outside forest area, the share of villages located in a hillside area, coal-producing region dummy, and mining-based region dummy. $\boldsymbol{X_{rt}}$ is a vector of time-varying weather and infrastructure characteristics consisting of yearly average precipitation share of villages with financial institutions, the share of villages with good mobility access, and share of villages with a strong signal. η_s , δ_t, and θ_{st} denote province fixed effects, year fixed effects, and province-year fixed effects, respectively. Province fixed effect controls the time-invariant unobserved heterogeneity characteristics. Year fixed effect controls time-varying unobserved heterogeneity, and province–year fixed effect controls the influence aggregate of time trends by province and the remaining endogeneity issue from time-series element as our instrumental variable is non-time varying. Controlling province fixed effect is expected to absorb all confounding unobserved factors attached to the provincial level. We also estimate equation 2 using Ordinary Least Square (OLS) and panel data fixed effect (FE) for robustness check.

3.3 Mediation Analysis

Next, we aim to assess the relevance of MSEs as the transmission channel. We used several indicators, such as the annual operating hours per firm, annual revenue per worker, annual, annual compensation per paid worker, number of MSEs, and annual value-added per worker to describe the MSEs' performance. We introduce MSEs' performance indicators as a mediator in the main regression to assess the mechanism of electricity's effect on poverty as these variables reflect the cash-income transferred to employee and business owner as in the framework of electrification impact on poverty (see Meadows et al. (2003) or Torero (2014)).

We adopted the Dippel et al. (2019) framework for causal mediation analysis in IV settings with a single instrument to formalize the test. Using this framework, we can quantify the proportion of the total effect explained by the indirect effect by decomposing the total effect of β_1 in equation (2) into the mediated effect of electrification on poverty that operates through MSEs' performance (indirect effect) and the residual effect that does not work through MSEs' performance (direct effect).

The framework's main assumption is that the treatment (*Access*) is endogenous in a regression of mediator (*MSE*) on *Access*. Simultaneously, *Access* endogenous in a regression of the outcome (*Pov*) on *Access* because of the same confounders that affect *Pov* primarily through *MSE*. Thus, the confounders jointly affect *MSE* and *Access*. Using this assumption, the framework estimates i) the effect of *Access* on *MSE*, ii) the effect of *Access* on *Pov*, and iii) the effect of *MSE on Pov* conditional on *Access*. The estimation procedure to identify the causal mediation by Dippel et al. (2020) is first, to find parameter κ_1 of the effect of *Access* on *MSE* (statistically significant, see Table 7) and is identified by standard 2SLS estimation as follows.

$$First\ stage\ \ :\ Access_{r,t} = \gamma_1 Elec_r + \gamma_2 \boldsymbol{V}_{r,t} + \gamma_3 \boldsymbol{Z}_r + \gamma_4 \boldsymbol{X}_{r,t} + \eta_s + \delta_t + \theta_{st} + \zeta_{1rt} \tag{3}$$

$$Second\ stage: MSE_{r,t} = \kappa_1 Access_{r,t} + \kappa_2 \mathbf{V}_{r,t} + \kappa_3 \mathbf{Z}_r + \kappa_4 \mathbf{X}_{r,t} + \eta_s + \delta_t + \theta_{st} + \zeta_{2rt} \quad (4)$$

Next, the parameter mediator and the direct effect of the treatment is identified by the following 2SLS:

$$First\ stage\ : MSE_{r,t} = \lambda_1 Elec_r + \lambda_2 Access_{r,t} + \lambda_3 \mathbf{V}_{r,t} + \lambda_4 \mathbf{Z}_r + \lambda_5 \mathbf{X}_{r,t} + \eta_s + \delta_t + \theta_{st} + \varepsilon_{1rt} \quad (5)$$

$$Second\ stage: Pov_{rt} = \mu_1 MSE_{r,t} + \mu_2 Access_{r,t} + \mu_2 \mathbf{V}_{r,t} + \lambda_4 \mathbf{Z}_r + \lambda_5 \mathbf{X}_{r,t} + \eta_s + \delta_t + \theta_{st} + \omega_{1rt} \quad (6)$$

Dippel et al. (2020) proved that the identifying assumption above yields a new exclusion restriction, allowing for the use *of Elec* as an instrument *for MSE* conditional on *Access*. Thus, this procedure will yield two first stages, equations (3) and (5). Further, equations (4) and (6) will provide the estimates for mediation, where we can decompose the total effect of β_1 in equation (2) so that the total effect (β_1) equals to the sum of direct effect (μ_2) and the indirect effect ($\kappa_1\ x\ \mu_1$). Under the decomposition, the mediator is said to be relevant if the coefficient of MSEs' performance indicator in equation (6) or μ_1 is statistically significant. In an extreme case, the coefficient of electricity access could become insignificant, indicating that the *MSE* completely mediates the effect of electricity access on poverty. In implementing the decomposition, we include the same set of relevant vectors of covariates $\boldsymbol{V}$, $\boldsymbol{Z}$ and $\boldsymbol{X}$ as in equations (1) and (2).

To examine the potential transmission role of the MSEs, we explore the channels by which MSEs' performance could affect the poor's income. In this regard, we utilize a rich set of operational variables measuring these MSEs' performance indicators for consistency checking purposes. As for workers, we focus on their wages (compensation) and employment, and for owners, we focus on various measures of the number of MSEs, their revenue, profitability, and operating hours. We also estimate equations (3) and (4) at the firm-level data as a robustness check. The key independent variable in the estimates is defined as the dummy variable representing whether the location of the MSEs is a village with reliable electricity access or not. In addition to vector covariates of V, Z and X, we add firm level time varying covariates namely firm age.

4 RESULTS AND DISCUSSION

4.1 Key variables variability by treatment status and region

Table 1 reports the summary statistics of some main variables in this study. It is shown that the average poverty rate, poverty gap index, and poverty severity index is about 11.99%, 1.95, and 0.51, respectively. The percentage of district population that lives in villages with reliable electricity access is about 24 which is quite low compared to the national electrification ratio. The access to reliable electricity access, however, has been improving overtime as can be seen in Appendix A5 Panel A, B and C. There has been significant increase in the number of districts having higher shares of villages with reliable electricity access as well as its improvement in distance to the nearest substation from 2014 to 2018.

Table 2 depicts the mean comparison between groups. We divide the region into two groups based on whether the district has more than half of its villages have access to reliable electricity services and in western or eastern Indonesia. The null hypothesis of this mean-comparison test is that the mean between the two groups is statistically equal. When the *p-value* reported is lower than 0.05, the null hypothesis should be rejected, and it concludes that the mean between the two groups is significantly different, except for compensation to worker and value-added per worker.

Table 2–Panel A suggests that a region with more than half of its villages accessing reliable electricity service tend to have more micro-small enterprises (MSEs) and absorb more labour. The overall firm performance in those regions is also better than those without, except for the compensation per paid worker. The three poverty indicators of a region also show that a region

where more than half of its villages have access to reliable electricity service tends to have lower poverty incidence, poverty gap index, and poverty severity index.

Table 2–Panel B shows the comparison of means by location. At the aggregate level, by separating western and eastern regions, we find that MSEs are more dispersed in the western part of Indonesia. However, the annual revenue per worker and compensation paid per worker show no difference between the western and eastern. The mean comparison also reveals that the annual total hours of work and number of MSEs in western is significantly higher than in eastern Indonesia.

4.2 Effect of Reliable Electricity Service on Poverty

This section presents the results of the estimate of the average impact of reliable electricity services on poverty. We start with the first and second stages results. Then we check its robustness by adding sets of control variables and using an alternative measurement for the dependent variable. Lastly, we further estimate the possible differences in the impact, specifically in western and eastern regions.

The First Stage

We instrument regions' reliable electricity access condition by the average distance of each village to the nearest power plant in 1985. Regions' electricity access is the percentage of the district population that lives in villages with reliable access defined by having access to electricity and is 20 km or less to the nearest electricity substation measured by Geodetic distance with a capacity of 150/70 kV as defined above. The first stage regressions for the IV estimates are presented in Table 3. The coefficient of the instrument is significant at a 1 percent level and has the expected negative sign. Controlling for the local economy and demographic characteristics along with geography and infrastructure characteristics lowers the estimate to -0.0375, but it remains significant.

The model predicts 100 kilometers closer in the average of village distance to the power plant in 1985 increases the percentage of the district population that lives in villages with reliable access by 3.75 points. This finding is somewhat consistent with previous research (Kassem 2018b; Dinkelman 2011) that used distance to the nearest electrical substation. Both found that the further away from the grid, the less likely a village will have access to electricity. Similarly, a study by Mainali and Silveira (2013) found that in Nepal, the further the distance of the Medium Voltage transmission lines, the lower the number of households that could access electricity. Moreover, Cook (2011) has also summarized the role of the availability of electricity infrastructure on access to electricity.

The weak identification test by Kleibergen-Paap's rk F- statistics is adequate and above the common threshold of 10 but slightly lower than the statistical critical value[6], and the instrument follows a monotonic assumption (see Figure 5). We infer that the instrument is relevant and relatively not weak. The F-statistics is also above the new threshold proposed by Lee et al. (2022), which suggests that we do not find any weak instrumental variable issue.

The Second Stage

We present the summary of reliable electricity access effect on the poverty rate, gap, and severity index at the regional level in Table 4 from OLS, panel data fixed effects (FE) and IV estimates. The overall results indicate that access to reliable electricity service is associated with poverty reduction. The OLS and FE estimates tend to understate the effect relative to the IV estimate, for a similar bias correction direction case, see for example, Dinkelman (2021) in the case of electrification effects on employment. In our case, we interpret the coefficient movement as the case of the true negative relationship between outcome and key variable of

[6] The relevant critical value for the Kleibergen–Paap Walk rk F statistics reported (i.e., excluded-F) is the Stock–Yogo critical value of 16.38 calculated for one endogenous regressor, one instrument, 10% maximum IV relative bias, and i.i.d errors.

interest being masked by a positive bias from the selection-on-unobservable, including the reverse causality issue. It may come from an unobserved variable that jointly affects poverty level and access to a reliable electricity service in a particular region. For instance, Sambodo et al. (2021) explained that the Indonesian government is expected to prefer grid expansion in the least developed regions and tends to give more incentives (transfer funds) to those poorer people. Thus, our main variable of interest may suffer from an endogeneity issue.

To formally test the direction of the bias correction, we follow the coefficient stability analysis and bounding statement of point estimate reporting prescribed by Oster (2019). Table 4, column 1 and column 3 depict the OLS and panel data unconditional point estimates with a negative sign and, in absolute terms, are lower than the conditional point estimate in columns 2 and 4, suggesting a downward (positive) bias occurs. The significant coefficient adjustment and a major R-squared improvement suggest that bias correction occurred by including the control variables. Moreover, the statement of the bounding values of point estimate with the proportionality assumption equal to one, and the R-squared maximum equals 1.3 of the current R-squared suggested the adjusted coefficient become even more significant in absolute terms presented in the squared bracket.

The above coefficient stability tests showed that controlling for the part of the unobservable factors correct the point estimate upward in absolute terms. The IV-point estimate provides a similar direction of correction with a larger estimate of -0.225. Nevertheless, we cautiously interpret it as the main point of reference of the estimate and consider it as a possible upper-bound effect, given the strength of our instrument. If we refer to this upper-bound effect, panels A and B of Table 4 indicate that one percentage point of the district population that lives in villages with reliable electricity access is, on average, associated with a 0.225 percentage points reduction in the poverty rate and 0.046 points reduction in the poverty gap. We infer these results as the local average treatment effects (LATE) of reliable electricity access on poverty induced by the least-cost distance to the powerplant in 1985.

Our finding that suggests better access to reliable electricity is associated with lower poverty levels is consistent with other similar studies. For example, in Cote d'Ivoire, the impact of better access to electricity is an increase in household consumption per capita by 5.2 to 23.3 per cent (Diallo and Moussa 2020). Moreover, our finding is also in line with a study by Pereira et al. (2011) that evaluates the impact of access to electricity in South Africa, China, India, and Brazil. The study suggests that access to electricity is pivotal in reducing poverty in these four developing countries. Even though it is not closely related to the main outcome indicator, existing literature has agreed that better access to electricity is associated with higher employment (Dinkelman 2011) and productivity (Alam et al. 2018).

4.3 Heterogeneous Effects

We divide regions into two groups -western and eastern- and investigate whether these regions have a different impact. The western group consists of Sumatera, Java, Bali, and Kalimantan, while the eastern is Sulawesi, Nusa Tenggara Island, Maluku Island, and Papua. We replicate the IV regression with full control and present it in Table 5. The results show that the impact of reliable electricity access at the region level, reflected in the percentage of the district population living in villages with reliable electricity access, is significantly more prominent in the eastern part of Indonesia. The reliable electricity impact is significant in reducing the poverty rate but not for the poverty gap or the severity. These findings suggest a similar conclusion to Stern & Kander (2012). This study also provides a similar story to our findings on the heterogenous impact of access to electricity on economic growth. When energy services are abundant, an increase in energy availability has less effect on economic growth. However, when energy is relatively scarce, an increase in energy availability has much larger effects on economic growth. It somehow relates to the Indonesian electricity condition, where there is a gap in electricity services level between western and eastern. The availability of reliable electricity services in eastern Indonesia is scarce. Therefore, adding the same number of reliable electricity services gives a larger impact in eastern compared to western. Moreover, the heterogeneous impact estimates by year show that the point estimate tends to be more prominent in recent years (see Appendix A4). It suggests that the dynamic of the poverty reduction effect of reliable electricity access can be attributed to the fast development of substations in poverty concentrated regions.

4.4 The transmission mechanism: MSE's improved outcomes

In the previous section, we have established that access to reliable electricity services significantly reduces poverty. This section presents the decomposition analysis following the Dippel et al. (2019) framework to examine whether the MSE's development plays mediating role. The first column of Table 6 reports the decomposition of the total effect of reliable electricity access on poverty into direct and indirect effects on three indicators: poverty rate, gap, and severity, respectively. Each outcome table shows the limited potential mechanism of the mediating variables as indicated by the statistical insignificance of all the indirect effect coefficients. Nevertheless, the estimates with firm-level data in Table 8 suggest the potential mechanism comes from the improved annual operating hours and revenue per worker. These two variables are also among the highest point estimate of the indirect effect in Table 6 despite their statistical insignificance.

Our findings on the potential role of electricity and poverty are consistent with similar existing literature. For instance, Allcott, Collard-Wexler, and O'Connell (2016) studied the impact of electricity on firms' productivity in India. They observed that lack of access to electricity would reduce revenue and producer surplus by 5 to 10 per cent. In other words, better access to electricity will boost firms' performance. Similarly, a study by Geginat and Ramalho (2018) also suggests that electricity connection affects firms' performance. They find that better access will lead to a simpler and less costly electricity process, thus allowing firms to perform better. They also find that this effect will be substantial, especially in sectors that require a significant amount of energy. In general, our study complements the existing results that have suggested a significant positive relationship between access to electricity and firms' performance, which will also affect lower poverty, especially in Indonesia.

5 CONCLUSION

This study empirically tests the causal impact of reliable electricity access on poverty and examines whether MSEs' performances mediate the impact. We show that access to reliable electricity services positively impacts poverty reduction. In terms of upper-bound magnitude, one percentage point of the district population that lives in villages with reliable electricity access is, on average, associated with a 0.225 percentage points reduction in the poverty rate and 0.046 points reduction in the poverty gap. By dividing the regions into two groups: western and eastern, we show that the bigger impact of electricity on poverty reduction occurs in the eastern part of Indonesia, the lagging region.

These findings imply that even though access to reliable electricity has improved in the past decades, expanding better and more reliable access to electricity will be paramount to reducing the poverty level in Indonesia. The policy implication for these findings is to enhance electricity expansion, particularly in eastern Indonesia or regions with unreliable access to electricity. Accelerating the addition of new power plants will be crucial to fulfilling the government's target of reducing poverty.

Moreover, we find no evidence that MSEs play an important role in mediating the positive impact of electrification in reducing the poverty rate. One possible interpretation is that the concentration of the positive impact of reliable electricity access is more toward the owners and workers of a medium and large segment of the enterprises that are living above the poverty line. It suggests a further challenge in addressing the inequitable welfare effect of electricity expansion. Nevertheless, we leave the investigation of the issue for future research avenues.

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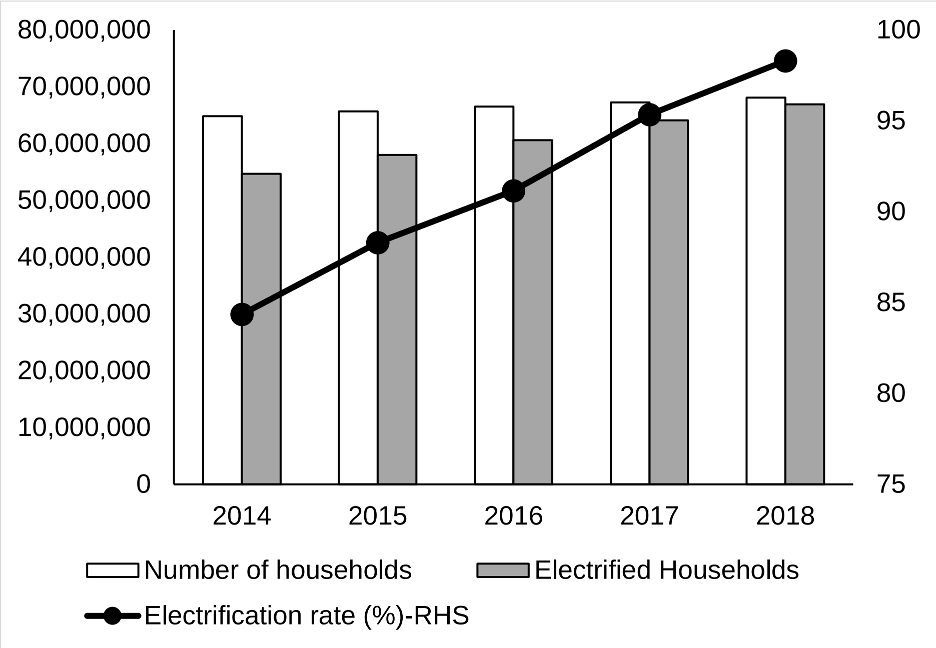
Tables and Figures

Panel A – Electrification rate



Panel B – Electrification by PLN and Non-PLN

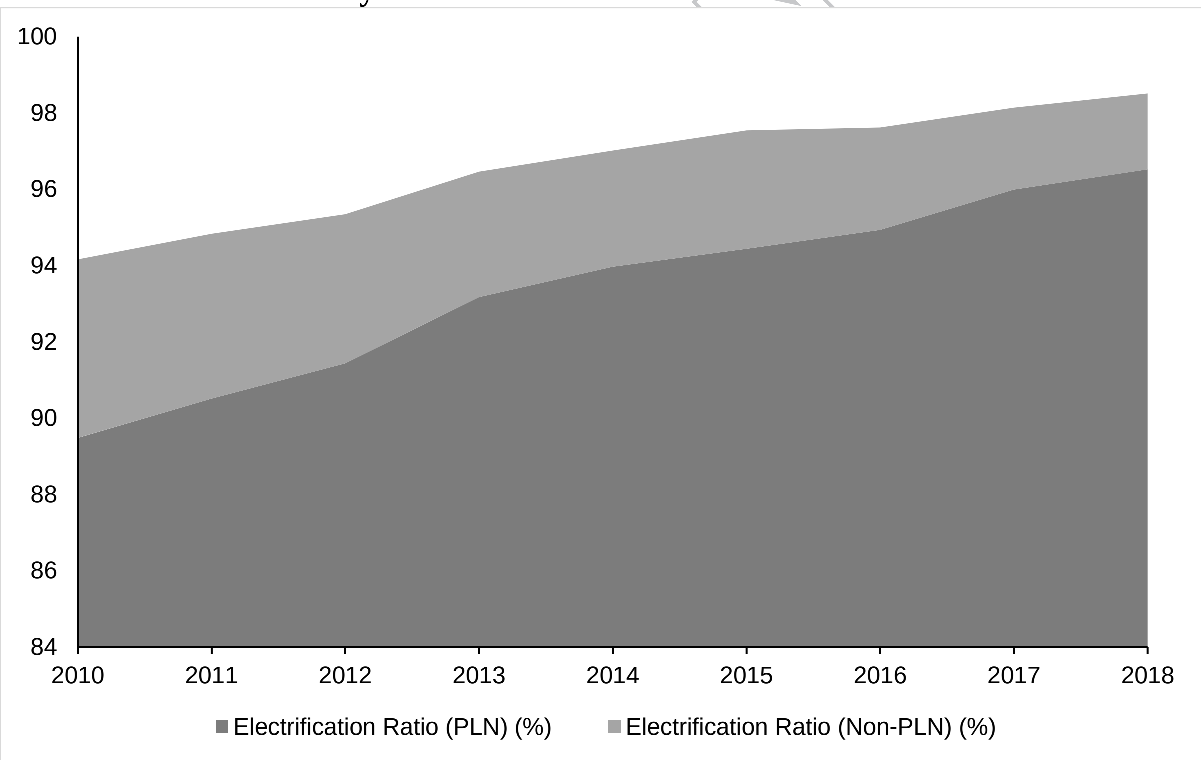


Figure 1. Electrification progress in Indonesia, 2014–2018

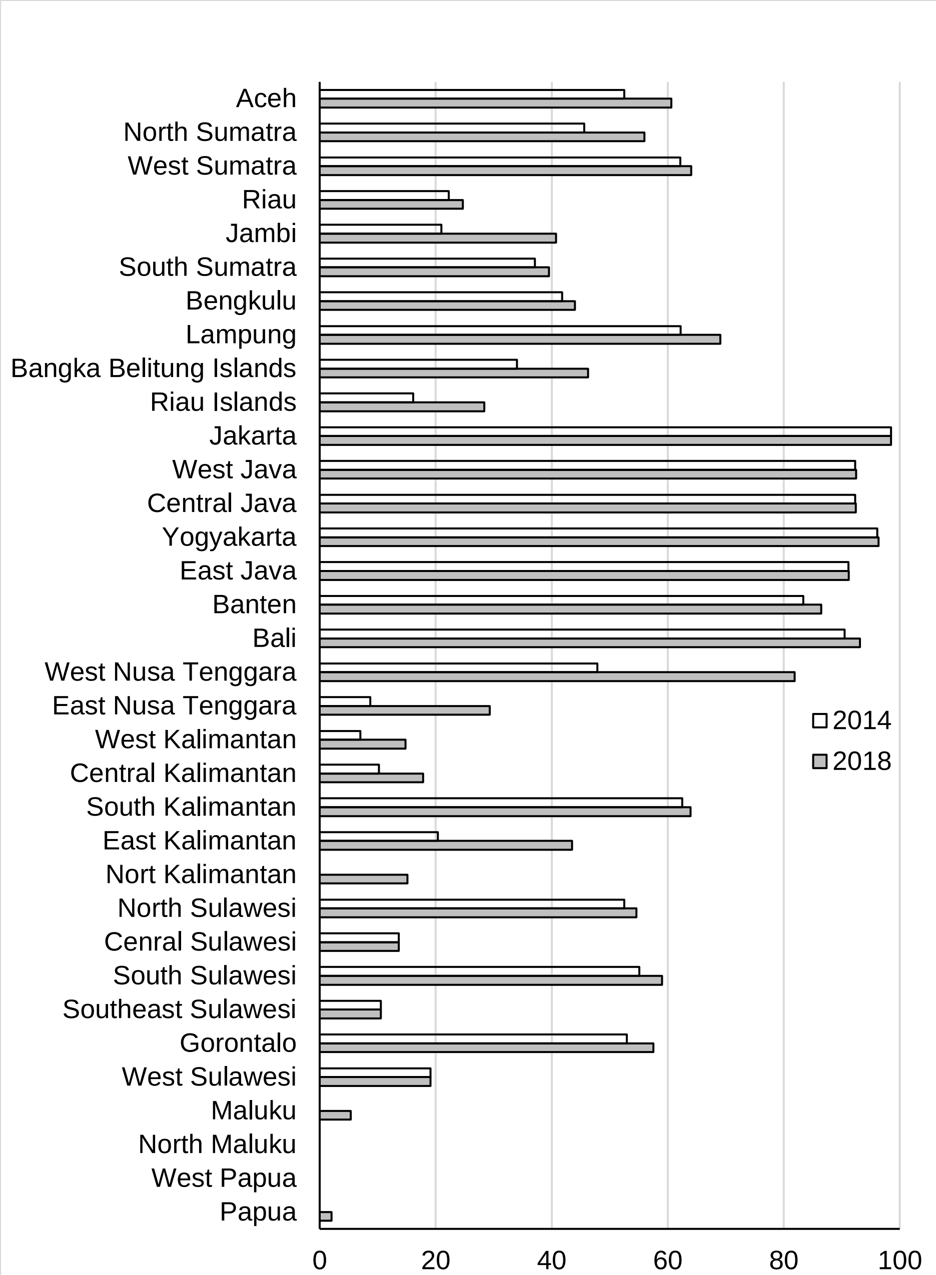
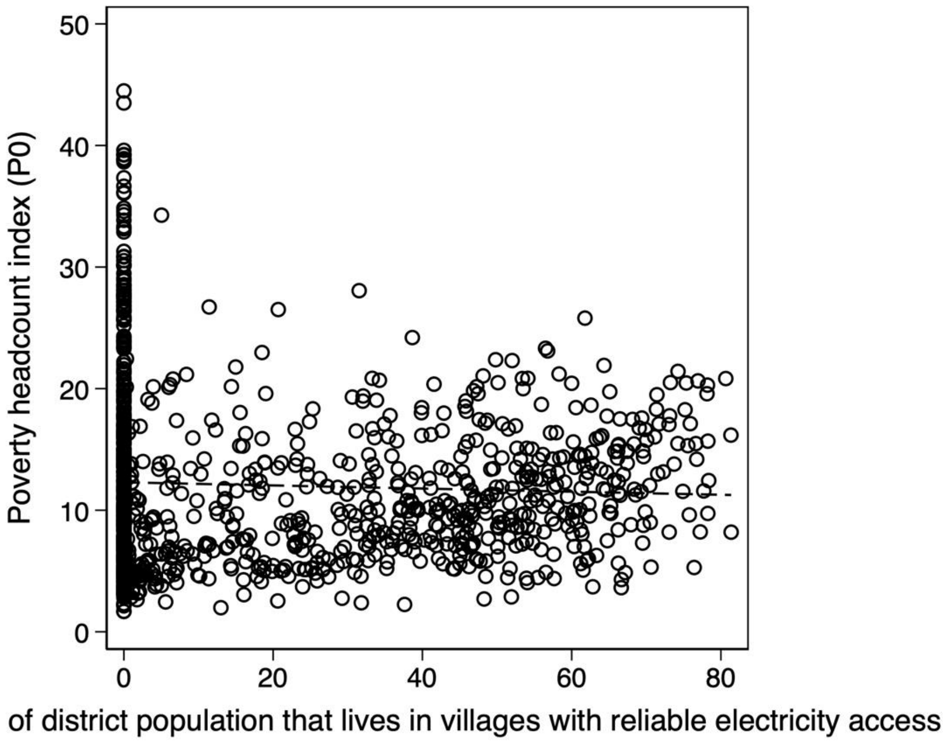


Figure 2. Progress of villages with reliable electricity access, 2014–2018

Note: The define a reliable electricity access we use 20 km as a threshold distance from the village to the nearest electricity substation with a capacity of 150/70 kV.

Source: Authors' own calculation.

Panel A – The Unconditional Plot



Panel B – The Conditional Plot

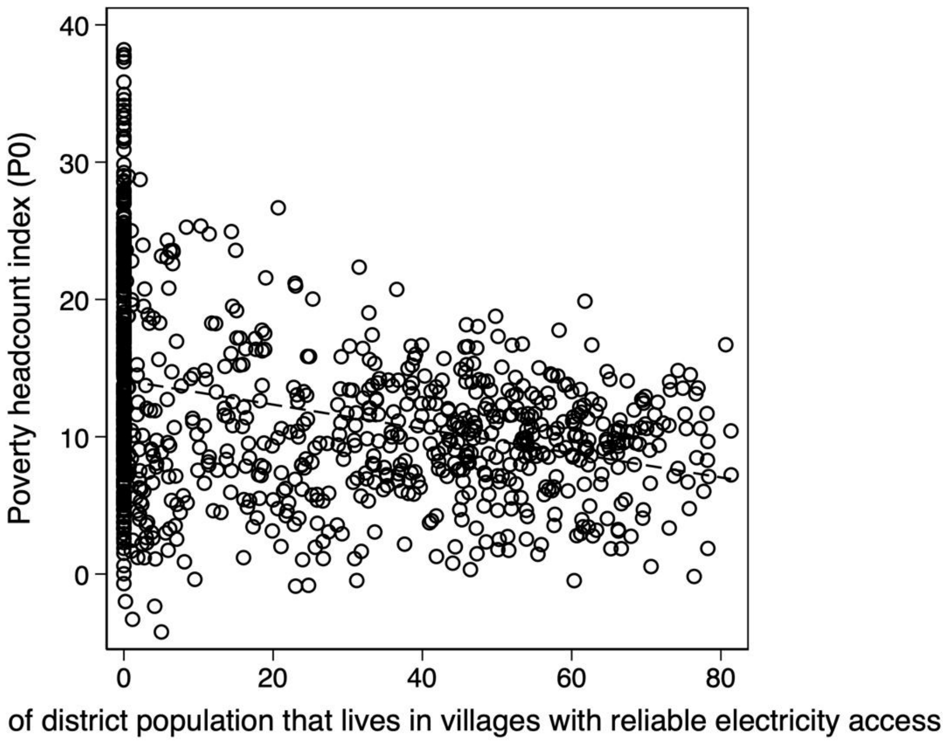


Figure 3. Correlation between the percentage of district population that lives in villages with reliable electricity access and poverty rate at the district level, 2014–2018

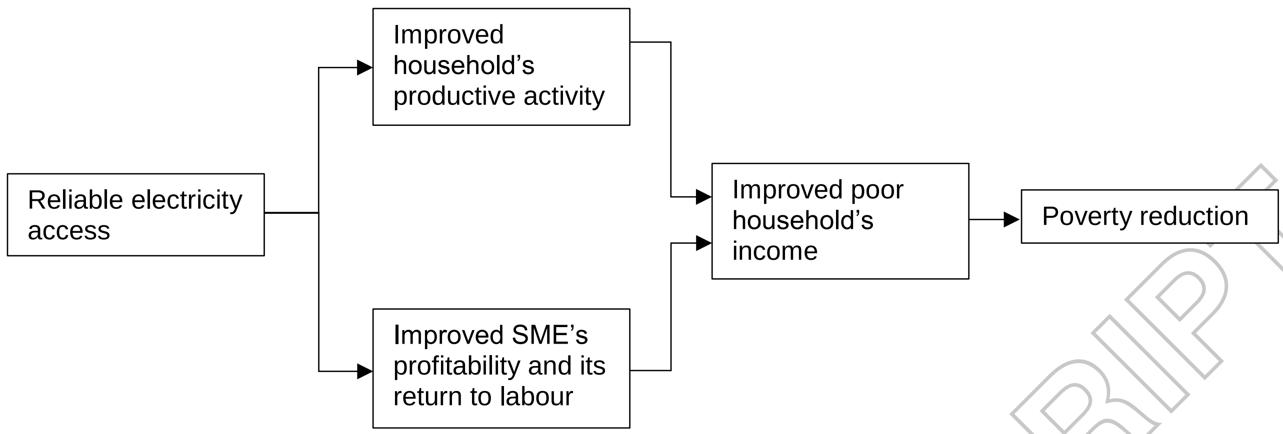


Figure 4. Mediation Framework of the Electricity Infrastructure and Poverty Reduction Relationship through Small and Micro Enterprises as the Transmission Channel

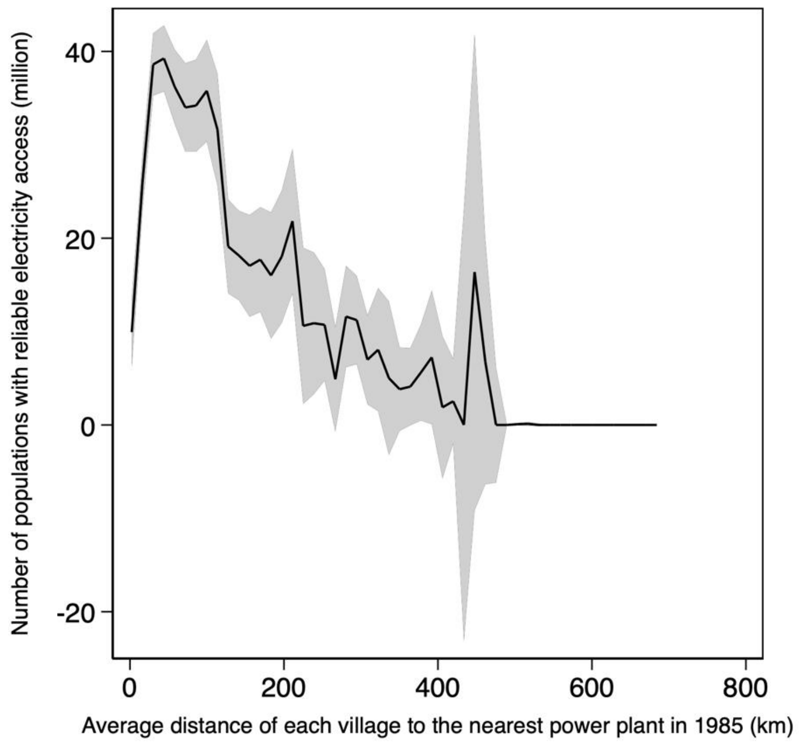


Figure 5. Monotonicity of Instrumental Variable Effect on the Endogenous Variable

Tables

Table 1. Summary Statistics

Variables	Observations	Mean	Std. Dev.	Min.	Max.
Poverty headcount index (% P0)	961	11.99	7.03	2	44
Poverty gap index (P1)	961	1.95	1.67	0	15
Poverty severity index (P2)	961	0.51	0.62	0	7
The % of district population that lives in villages with reliable electricity access	961	23.99	25.28	0	81
Average distance of each village	961	134.26	128.39	2	684

to the nearest power plant in 1985 (km)					
Average of annual operating hours per firm (hours)	961	0.00	0.00	0	0
Annual revenue per worker (million rupiahs)	961	61.19	53.83	1	601
Annual compensation per paid worker (million rupiahs)	940	17.60	10.58	1	159
Number of MSEs	961	7,857.47	1,0321.07	8	62,685
Annual value-added per worker (million rupiahs)	961	26.72	23.19	0	287
Local economy and demography characteristics					
Economic growth (%)	961	5.45	2.38	-34	19
Density (000 person per km-square)	961	1.09	2.59	0	20
GDRP per capita (thousand rupiahs)	961	10.47	0.67	9	13
Number of flood events	961	59.38	65.42	0	625
Share of population completed senior high school (%)	961	33.22	14.03	7	78
Share of agriculture in total GRDP (%)	961	25.71	15.56	0	77
Share of rural population (%)	961	59.99	31.11	0	100
Geography characteristics					
Average of village elevation (m)	961	237.34	303.40	3	2040
Average distance of each village to the nearest coastline (km)	961	33.36	40.65	1	319
Average distance of each village to the nearest main road (km)	961	26.93	55.32	0	483
Share of villages that located outside forest area	961	75.19	23.23	0	100
Share of villages that located in hillside area	961	15.14	19.03	0	100
Coal producing region = 1	961	0.22	0.41	0	1
General mining-based region =1	961	0.93	0.25	0	1
Weather and infrastructure					
Yearly average precipitation (mm)	961	6.31	1.86	2	13
Share of villages with financial institutions (%)	961	37.70	25.15	0	100
Share of villages with good mobility access (%)	961	17.83	21.28	0	100
Share of villages with a strong signal (%)	961	70.25	22.62	1	100

Table 2. Outcome and Mediation Variables Means Differences Panel A–By Treatment Variable Status (Access=1 if majority of its villages has reliable electricity access, 0 otherwise)

Variables	Access=1	Access=0	Difference	P-value
Poverty headcount index (% P0)	10.19	14.82	-4.63	0.00
Poverty gap index (P1)	1.57	2.65	-1.08	0.00
Poverty severity index (P2)	0.39	0.76	-0.38	0.00
Average of annual operating hours per firm (hours)	1732.63	1363,77	368.86	0.00
Annual revenue per worker (million rupiahs)	66.39	55.80	10.58	0.00
Annual compensation per paid worker (million rupiahs)	17.51	18.07	-0.57	0.30
Number of MSEs	12,194.33	2,915.77	9,278.56	0.00
Annual value-added per worker (million rupiahs)	27.59	26.40	1.19	0.29

Panel B–By Region (Western and Eastern Part)

	Eastern	Western	Diff	P-value
Poverty headcount index (% P0)	16.54	10.28	6.26	0.00
Poverty gap index (P1)	3.12	1.56	1.56	0.00
Poverty severity index (P2)	0.93	0.38	0.55	0.00
Average of annual operating hours per firm (hours)	1335.21	1675.56	-340.35	0.00
Annual revenue per worker (million rupiahs)	58.66	63.04	-4.38	0.10
Annual compensation per paid worker (million rupiahs)	17.06	18.06	-1.00	0.09
Number of MSEs	3,931.22	9,951.56	-6,020.34	0.00
Annual value-added per worker (million rupiahs)	27.27	26.96	0.31	0.80

Note: Western refers to Sumatra, Java, and Kalimantan Island; and Eastern refers to Sulawesi, Bali Nusa Tenggara, Maluku, and Papua Island.

Table 3. The First Stage Regression: Effect of Least Cost Distance on Reliable Electricity Access

	Dependent variable: The % of district population that lives in villages with reliable electricity access		
	No control		All controls included
Average distance of each village to the nearest power plant in 1985 (km)	-0.0724***		-0.0375***
	(0.0061)		(0.0103)
Observations	961		961
Province fixed effects	No		Yes
Year fixed effects	No		Yes
Province x Year fixed effects	No		Yes
Kleibergen-Paap Wald *rk* F-statistics	141.762		13.246

Notes: All controls include economy and demography, geography, and infrastructure covariates. Clustered standard errors at district level are in parentheses. Stars *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The relevant critical value for the Kleibergen–Paap Walk rk F statistics reported (i.e., excluded-F) is the Stock–Yogo critical value of 16.38 calculated for one endogenous regressor, one instrument, 10% maximum IV relative bias, and i.i.d errors.

Table 4. Main Estimates Panel A – Poverty headcount index (P0)

	OLS			Panel data fixed effects			IV	
	No control	All controls included		No control	All controls included		No control	All controls included
	(1)	(2)		(3)	(4)		(5)	(6)
The % of district population that lives in villages with reliable electricity access	-0.013	-0.030*** [-0.056]		0.003	-0.008 [-0.014]		-0.333***	-0.225***
	(0.012)	(0.010)		(0.010)	(0.009)		(0.050)	(0.088)
Adjusted R-squared	0.001	0.729						
Within R-squared				0.001	0.599			
Uncentered R-squared							0.405	0.888
Kleibergen-Paap Wald *rk* F-statistics							141.762	13.246

Panel B – Poverty gap index (P1)

The % of district population that lives in villages with reliable electricity access	-0.007***	-0.007*** [-0.007]		0.001	-0.004 [-0.006]		-0.073***	-0.046***
	(0.003)	(0.003)		(0.003)	(0.003)		(0.012)	(0.023)
Adjusted R-squared	0.010	0.631						
Within R-squared				0.000	0.162			
Uncentered R-squared							0.156	0.800
Kleibergen-Paap Wald *rk* F-statistics							141.762	13.246

Panel C – Poverty severity index (P2)

The % of district population that lives in villages with reliable electricity access	-0.003***	-0.002 [-0.002]		0.001	-0.001 [-0.002]		-0.024***	-0.015*
	(0.001)	(0.001)		(0.001)	(0.001)		(0.004)	(0.009)
Adjusted R-squared	0.016	0.522						
Within R-squared				0.000	0.123			
Uncentered R-squared							-0.007	0.684
Kleibergen-Paap Wald *rk* F-statistics							141.762	13.246
Observations	961	961		961	961		961	961
Province fixed effects	No	Yes		No	Yes		No	Yes
Year fixed effects	No	Yes		No	Yes		No	Yes
Province x year fixed effects	No	Yes		No	Yes		No	Yes

Notes: The numbers in the squared bracket are the bias adjusted coefficients with the assumption of R_{max} = 1.3 times R-squared and the proportionality assumption or $\delta = 1$. All controls include economy and demography, geography, and infrastructure covariates. Clustered standard errors at the district level are in parentheses. Stars *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The relevant critical value for the Kleibergen–Paap Walk rk F statistics reported (i.e., excluded-F) is the Stock–Yogo critical value of 16.38 calculated for one endogenous regressor, one instrument, 10% maximum IV relative bias, and i.i.d errors.

Table 5. Heterogeneous Effect of Reliable Electricity Access on the Poverty

	Poverty headcount index (P0)			Poverty gap index (P1)			Poverty severity index (P2)	
	Western	Eastern		Western	Eastern		Western	Eastern
	(1)	(2)		(3)	(4)		(5)	(6)
The % of district population that lives in villages with reliable	-0.115***	-0.358*		-0.016	-0.084		-0.003	-0.030

electricity access								
	(0.055)	(0.186)		(0.010)	(0.051)		(0.003)	(0.020)
Province fixed effects	No	Yes		No	Yes		No	Yes
Year fixed effects	No	Yes		No	Yes		No	Yes
Province x year fixed effects	No	Yes		No	Yes		No	Yes
Observations	657	304		657	304		657	304
Uncentered R-squared	0.915	0.885		0.867	0.789		0.810	0.673
Kleibergen-Paap Wald *rk* F-statistics	15.816	6.087		15.816	6.087		15.816	6.087

Notes: All estimates use control variables that include economy and demography, geography, and infrastructure covariates. Clustered standard errors at district level are in parentheses. Stars *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The relevant critical value for the Kleibergen–Paap Walk rk F statistics reported (i.e., excluded-F) is the Stock–Yogo critical value of 16.38 calculated for one endogenous regressor, one instrument, 10% maximum IV relative bias, and i.i.d errors.

Table 6. Mediation Analysis Panel A – Poverty headcount index (P0)

	Operating hours	Revenue per worker	Compensation per paid worker	Number of MSEs	Value-added per worker
	(1)	(2)	(3)	(4)	(5)
total effect	-0.225**	-0.225**	-0.192**	-0.225**	-0.225**
	(0.088)	(0.088)	(0.076)	(0.088)	(0.088)
direct effect	0.084	-0.026**	-0.015	0.118	-0.028**
	(0.195)	(0.012)	(0.020)	(0.120)	(0.012)
indirect effect	-0.308	-0.199	-0.177	-0.342	-0.196
	(0.602)	(0.124)	(0.180)	(0.311)	(0.134)

Panel B – Poverty gap index (P1)

	Operating hours	Revenue per worker	Compensation per paid worker	Number of MSEs	Value-added per worker
	(1)	(2)	(3)	(4)	(5)
total effect	-0.046**	-0.046**	-0.036*	-0.046**	-0.046**
	(0.023)	(0.023)	(0.020)	(0.023)	(0.023)
direct effect	0.016	-0.006**	-0.004	0.023	-0.007**
	(0.040)	(0.003)	(0.004)	(0.027)	(0.003)
indirect effect	-0.062	-0.040	-0.032	-0.069	-0.040
	(0.122)	(0.028)	(0.036)	(0.068)	(0.030)

Panel C – Poverty severity index (P2)

	Operating hours	Revenue per worker	Compensation per paid worker	Number of MSEs	Value-added per worker
	(1)	(2)	(3)	(4)	(5)
total effect	-0.015*	-0.015*	-0.010	-0.015*	-0.015*
	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)
direct effect	0.005	-0.002*	-0.002	0.007	-0.002**
	(0.013)	(0.001)	(0.001)	(0.009)	(0.001)
indirect	-0.019	-0.012	-0.009	-0.021	-0.012

effect					
	(0.038)	(0.010)	(0.011)	(0.023)	(0.010)

Note**:** Clustered standard errors at district level are in parentheses. Stars *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 7. Details of Mediation Regressions

Panel A–Operating Hours

	Ln (total annual operating hours per firm)	P0 (%)	P0 (%)	P1	P1	P2	P2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
The % of district population that lives in villages with reliable electricity access	0.004	-0.225**	0.084	-0.046**	0.016	-0.015*	0.005
	(0.004)	(0.088)	(0.195)	(0.023)	(0.039)	(0.008)	(0.013)
Ln (annual operating hours per firm)			-66.569		-13.414		-4.162
			(109.192)		(22.170)		(6.999)
Observations	961	961	961	961	961	961	961
Kleibergen-Paap Wald *rk* F-statistics							
1st First Stage	13.246	13.246	13.246	13.246	13.246	13.246	13.246
2nd First Stage			0.329		0.329		0.329

Panel B–Revenue per Worker

	Ln (total an revenue p worker	P0 (%)	P0 (%)	P1	P1	P2	P2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
The % of district population that lives in villages with reliable electricity access	0.029**	-0.225**	-0.026**	-0.046**	-0.006**	-0.015*	-0.002*
	(0.012)	(0.088)	(0.012)	(0.023)	(0.002)	(0.008)	(0.001)
Ln (annual revenue per worker)			-6.635**		-1.337		-0.415
			(3.039)		(0.759)		(0.288)
Observations	961	961	961	961	961	961	961
Kleibergen-Paap Wald *rk* F-statistics							
1st First Stage	13.246	13.246	13.246	13.246	13.246	13.246	13.246
2nd First Stage			9.539		9.539		9.539

Panel C–Compensation per Paid Worker

	Ln (total annual compensation per paid worker)	P0 (%)	P0 (%)	P1	P1	P2	P2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
The % of		-0.192**	-0.015	-0.046**	-0.004	-0.015*	-0.002

district population that lives in villages with reliable electricity access							
		(0.076)	(0.019)	(0.023)	(0.004)	(0.008)	(0.002)
Ln (annual compensation per paid worker)			-12.852		-2.331		-0.063
			(10.014)		(2.135)		(0.720)
Observations	940	940	940	940	940	940	940
Kleibergen-Paap Wald *rk* F-statistics							
1st First Stage	13.217	13.217	13.217	13.217	13.217	13.217	13.217
2nd First Stage			2.345		2.345		2.345

Panel D–Number of SMEs

	Ln (number of SMEs)	P0 (%)	P0 (%)	P1	P1	P2	P2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
The % of district population that lives in villages with reliable electricity access	0.036**	-0.225**	0.117	-0.046**	0.023	-0.015*	0.007
	(0.016)	(0.088)	(0.119)	(0.023)	(0.027)	(0.008)	(0.009)
Ln (number of SMEs)			-9.524		-1.919		-0.595
			(7.467)		(1.671)		(0.584)
Observations	961	961	961	961	961	961	961
Kleibergen-Paap Wald *rk* F-statistics							
1st First Stage	13.246	13.246	13.246	13.246	13.246	13.246	13.246
2nd First Stage			1.552		1.552		1.552

Panel E–Value-Added per Worker

	Ln (total value-added per worker)	P0 (%)	P0 (%)	P1	P1	P2	P2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
The % of district population that lives in villages with reliable electricity access	0.024**	-0.225**	-0.028**	-0.046**	-0.006**	-0.015*	-0.002**
	(0.011)	(0.088)	(0.011)	(0.023)	(0.002)	(0.008)	(0.001)
Ln (value-added per worker)			-8.064**		-1.624		-0.504
			(3.958)		(0.950)		(0.357)
Observations	961	961	961	961	961	961	961
Kleibergen-Paap Wald *rk* F-statistics							

1st First Stage	13.246	13.246	13.246	13.246	13.246	13.246	13.246
2nd First Stage			6.259		6.259		6.259

Notes: All estimates use control variables that include economy and demography, geography, and infrastructure covariates. Clustered standard errors at district level are in parentheses. Stars *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The relevant critical value for the Kleibergen–Paap Walk rk F statistics reported (i.e., excluded-F) is the Stock–Yogo critical value of 16.38 calculated for one endogenous regressor, one instrument, 10% maximum IV relative bias, and i.i.d errors.

Table 8. Robustness Check: The Estimates of Reliable Electricity Access on MSEs' Outcome at the Firm Level Data

Dependent variable:	OLS					IV				
	No control	+local control	+firm control	+geography control	+infrastructure control	No control	+local control	+firm control	+geography control	+infrastructure control
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A										
Annual operating hours	287.803***	130.367***	117.481***	105.380***	103.796***	660.455***	401.979***	445.154***	423.241***	417.783***
	(31.2318)	(25.2322)	(20.8822)	(20.5141)	(20.3302)	(87.0329)	(152.9705)	(134.7191)	(161.6200)	(160.0196)
Adj. R-squared	0.080	0.113	0.228	0.230	0.232					
Ln (annual revenue per worker)	0.317***	0.017	0.044	0.030	0.028	0.878***	0.335	0.360**	0.428**	0.418**
	(0.0475)	(0.0443)	(0.0307)	(0.0299)	(0.0297)	(0.1355)	(0.2063)	(0.1745)	(0.2039)	(0.2016)
Adj. R-squared	0.082	0.149	0.331	0.333	0.337					
Ln (annual profit per worker)	0.020***	0.002	0.003	0.002	0.002	0.059***	0.026	0.028	0.028	0.028
	(0.0031)	(0.0027)	(0.0021)	(0.0021)	(0.0021)	(0.0118)	(0.0200)	(0.0178)	(0.0202)	(0.0200)
Adj. R-squared	0.032	0.051	0.108	0.108	0.110					
Ln (annual value-added per worker)	0.027***	0.002	0.002	0.001	0.001	0.078***	0.026	0.029	0.030	0.029
	(0.0039)	(0.0033)	(0.0024)	(0.0023)	(0.0023)	(0.0134)	(0.0223)	(0.0189)	(0.0215)	(0.0212)
Adj. R-squared	0.046	0.075	0.175	0.175	0.177					
Observations	290,003	290,003	290,003	290,003	290,003	290,003	290,003	290,003	290,003	290,003
KPW F-statistics						118.282	47.681	50.377	40.948	40.819
Province fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

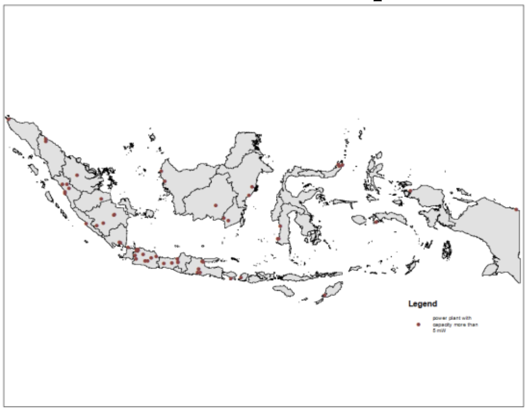
effects											
Year fixed effects	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes
Province x Year fixed effects	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors are in parentheses. Stars *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The relevant critical value for the Kleibergen–Paap Walk rk F statistics reported (i.e., excluded-F) is the Stock–Yogo critical value of 16.38 calculated for one endogenous regressor, one instrument, 10% maximum IV relative bias, and i.i.d errors.

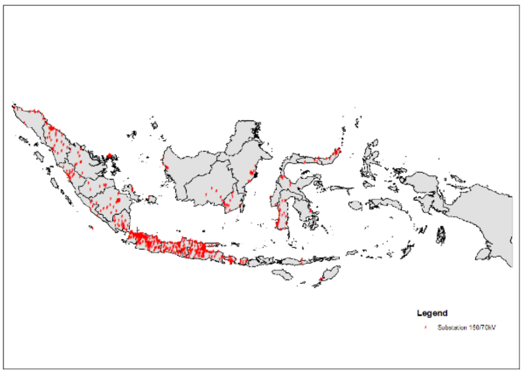
Appendices

Appendix A1. The Distribution of Powerplants in 1985 and Substations in 2014 and 2018

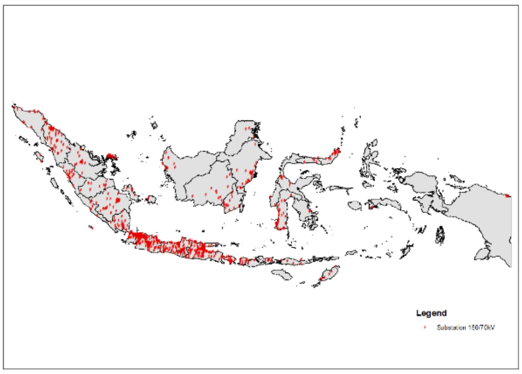
Panel A – The Maps



1985



B. 2014



C. 2018

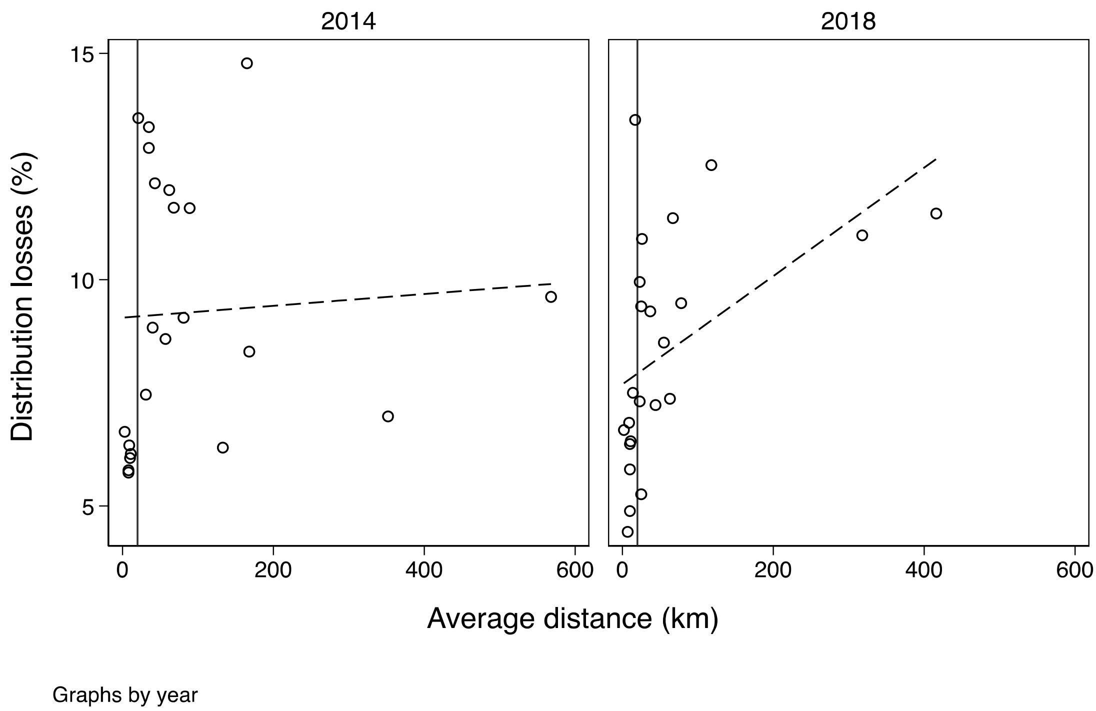
Source: Author’s calculation based on Open Street Map (OSM) combined with PLN data and Ministry of Energy and Mineral Resource data.

Panel B – The Distribution of Substations by Province in 2014 and 2018

Province	2014	2018
Aceh	11	14
North Sumatera	43	56
West Sumatera	19	22
Riau	9	13
Jambi	6	11
South Sumatera	29	39

Bengkulu	6	7
Lampung	21	25
Bangka Belitung Islands	4	8
Riau Islands	9	16
DKI Jakarta	62	68
West Java	152	169
Central Java	81	89
Yogyakarta	8	8
East Java	141	148
Banten	57	71
Bali	15	17
West Nusa Tenggara	6	17
East Nusa Tenggara	4	11
West Kalimantan	5	11
Central Kalimantan	5	11
South Kalimantan	16	18
East Kalimantan	10	24
North Kalimantan	0	3
North Sulawesi	15	18
Central Sulawesi	6	8
South Sulawesi	34	44
Southeast Sulawesi	2	3
Gorontalo	3	4
West Sulawesi	3	3
Maluku	0	2
Papua	0	5

Appendix A2. The Relationship between Distribution Loss and Average Distance to Substations at the PLN Working Area Level, 2014 – 2018



Source: Author's calculation based on PLN Energy Balance Sheet.

Appendix A3. The Steps in Calculating the Distance between Powerplants and Village Centroid and between Substations and Village Centroid

The following steps illustrate the way we calculate the distance variables in our data with the illustration of the village map of Badung Regency and Denpasar City:

Step 1: We convert the polygon feature of the Indonesia village administrative boundary to a point feature using the *feature to point* ArcToolbox in ArcGIS Software. Then, we identify the village centroid from BPS digital maps using *calculate geometry* command in ArcGIS Software.

(a) BPS digital map of Indonesia village administrative boundary

(b) Village centroids

Step 2: We overlay the digital map of Indonesia village administrative boundary with a converted map containing latitude and longitude information from PLN for locations of Powerplants in 1985 and from the Ministry of Energy and Mineral Resource for locations of substations in 2014, 2015, 2017, and 2018 (c). In this step, we manually check the precision of each substations' location by overlaying the resulted map in (d) with the Google Earth base map, which has the substations' image (e). Nevertheless, we cannot replicate such a procedure for powerplants.

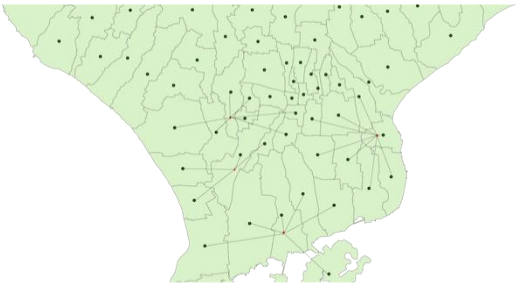
(c) A converted digital map containing locations of powerplant (PLN data) and substation (Ministry of Energy and Mineral Resource) by latitude and longitude

(d) Substation/powerplant's location overlaid with BPS digital map of Indonesia village administrative boundary containing village's centroid

(e) Map in (d) overlaid with Google Earth base map

(f) Manual checking the precision of substations/powerplant's location

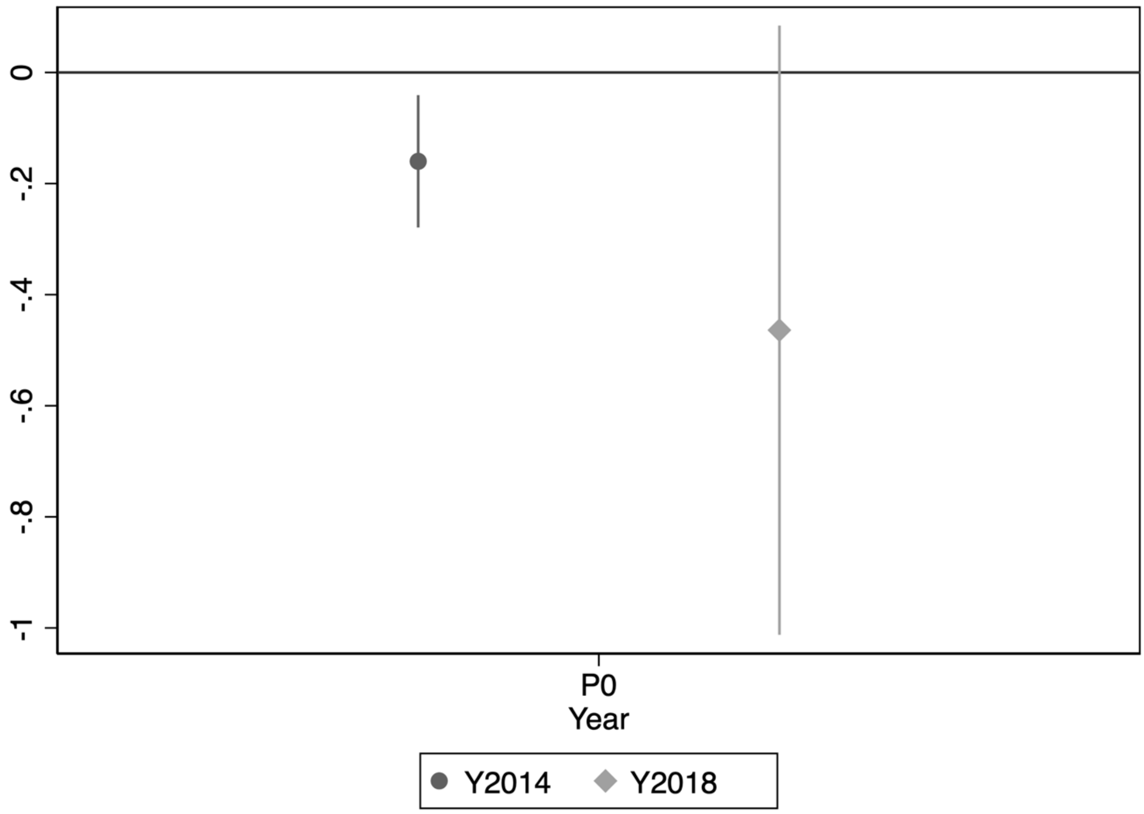
Step 3: We calculate the *Geodetic* distance of the two points using the *geonear* command in Stata.



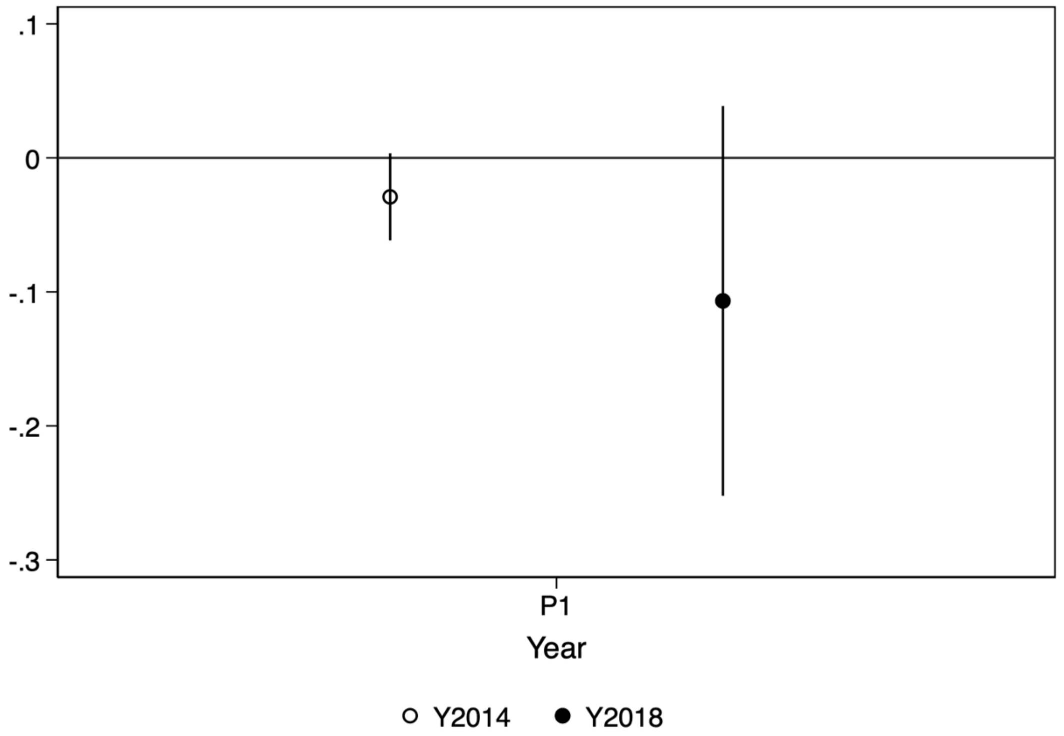
(g) The *Geodetic* distance

Appendix A4. Heterogenous Point Estimates by Year

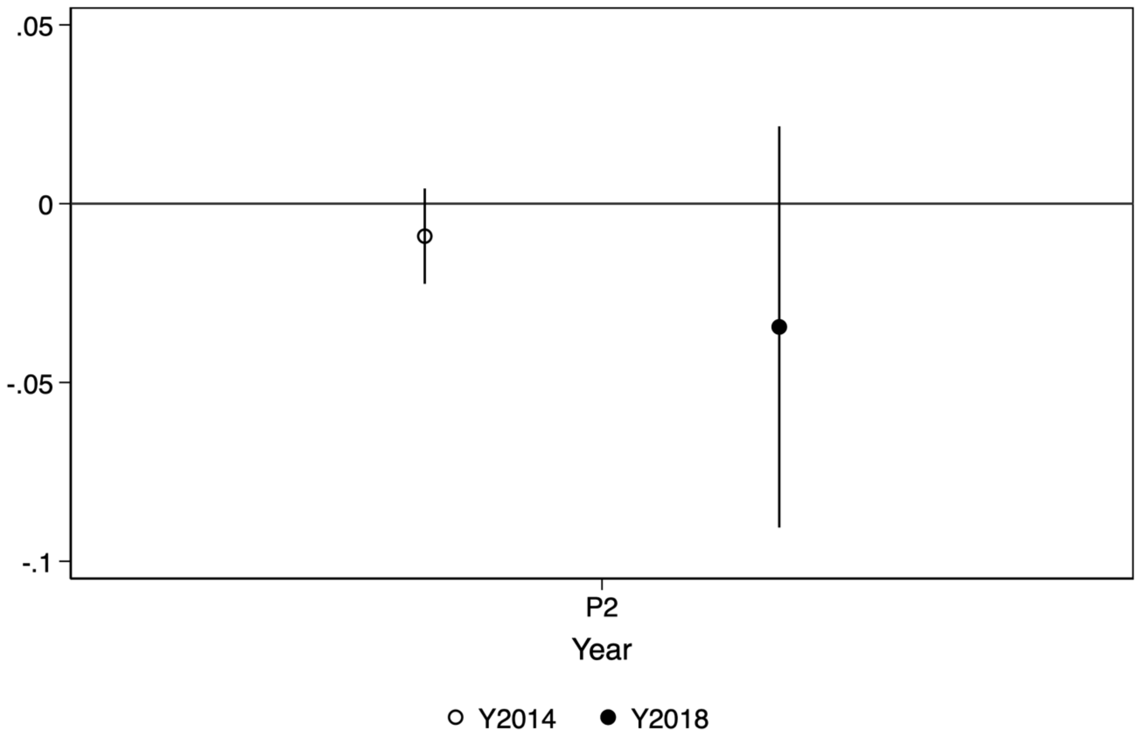
Panel A – P0



Panel B – P1



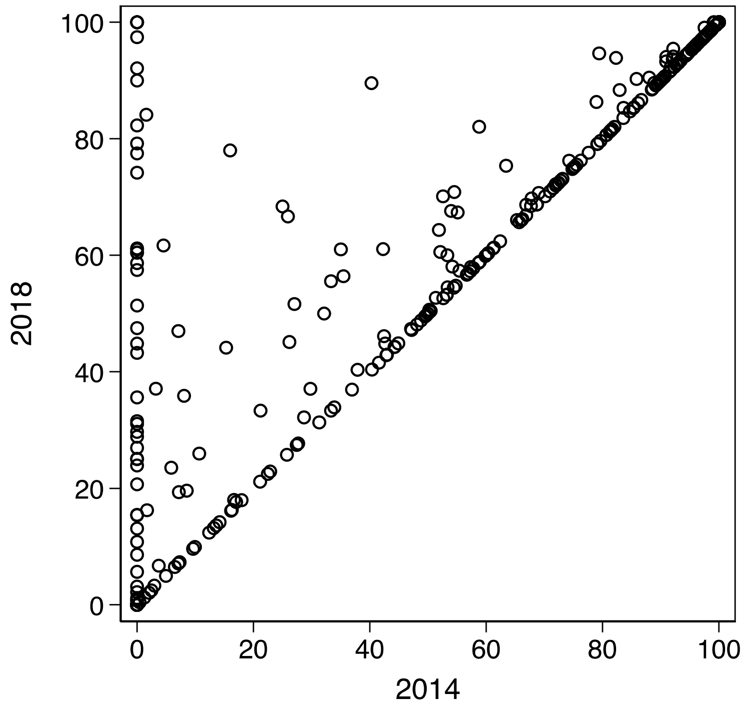
Panel C – P2



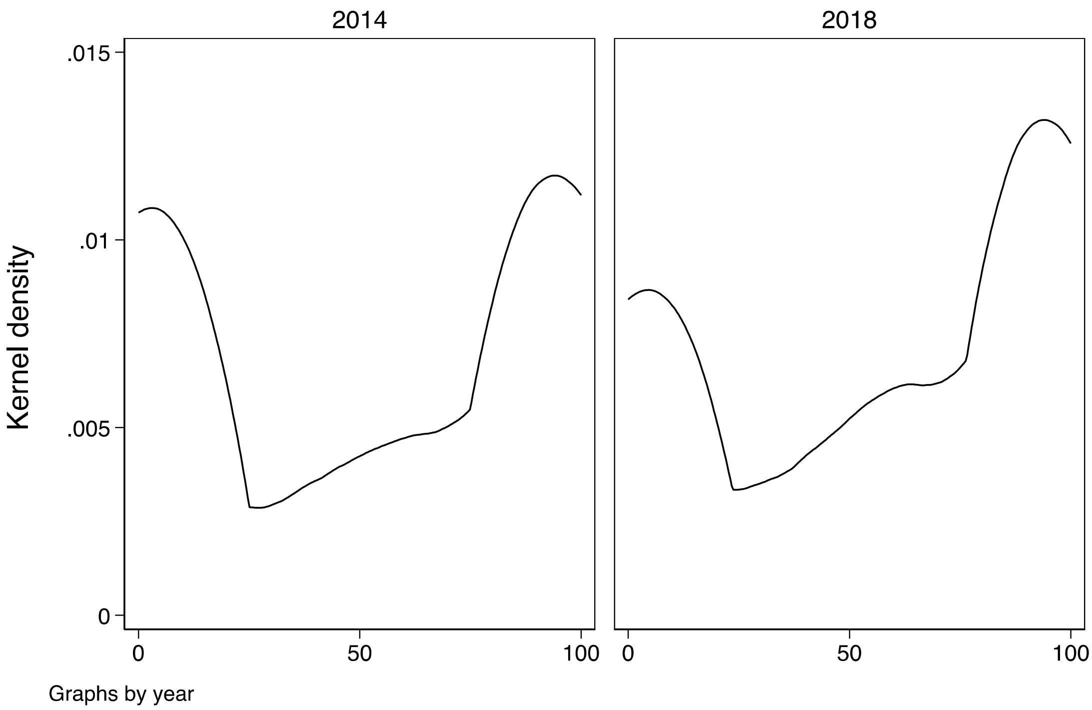
Note: The estimates use IV specifications that include economy and demography, geography, and infrastructure covariates and all fixed effects as used in the main results.

Appendix A5. Changes in reliable electricity access

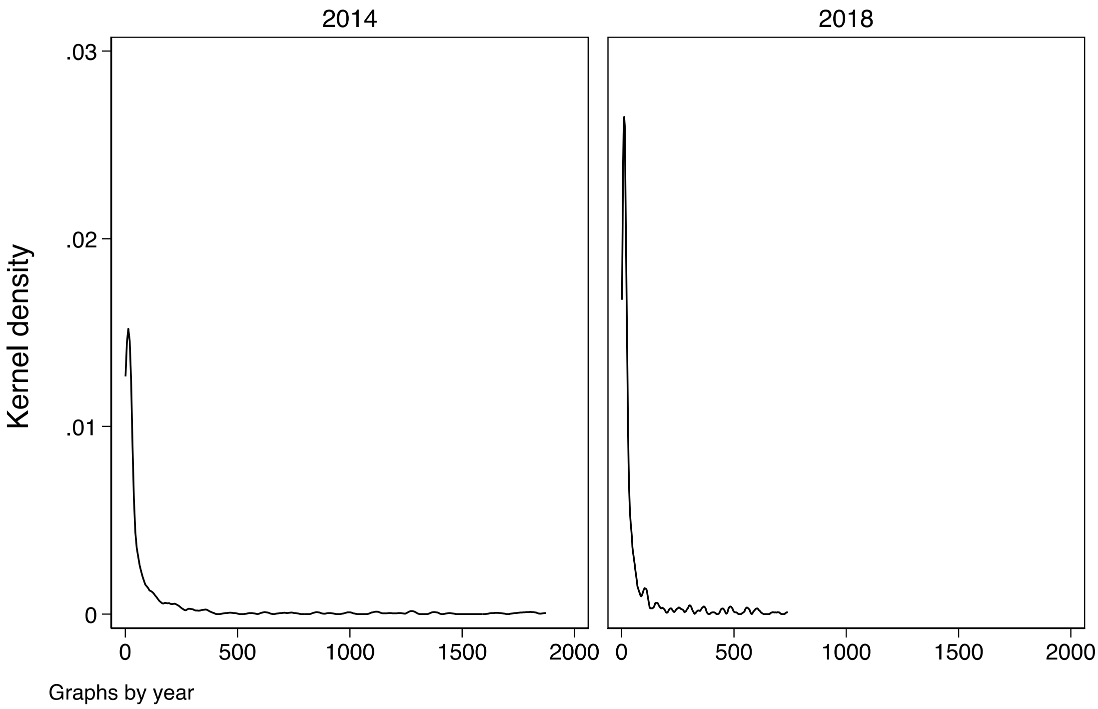
Panel A – Scatter Plot of Shares village with reliable electricity access in 2014 and 2018



Panel B – Distribution of Shares village with reliable electricity access in 2014 and 2018



Panel C – Distribution of villages' distance to the closest substation in 2014 and 2018


2014
2018
Kernel density
.03
.02
.01
0
0
500
1000
1500
2000
Graphs by year