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The Impact of Electricity Infrastructure Quality on Firm Productivity: Empirical Evidence from Southeast Asian Countries*

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Abstract

Rapid economic growth in recent years has caused a surge in energy consumption among Southeast Asian countries and laid a considerable burden on the already inadequate power infrastructure. As a result, frequent blackouts and prolonged outages have become common and weakened firm productive performance in those years. The main objective of this study is to examine the impact of power infrastructure quality on the performance of Southeast Asian manufacturing firms. In this study, the World Bank Enterprise Surveys was employed as the training dataset of 4723 manufacturing firms in the period of 2015–2016. The results of this study reveal that industrial firms that suffered from power outages had consistently lower productivity. As measured by the length of such events, more severe outages tend to be more harmful to the firm. Furthermore, the findings also indicated that most firms relied on self-generated electricity to reduce the negative impact of power outages, but this does not bring many benefits when operating at a small scale in some countries. Consequently, this study contributes to a growing literature that examines the economic impact of public infrastructure and how detrimental the poor state of such services is to a firm's downstream operations, productivity, and growth.

Keywords: Electricity Infrastructure, Infrastructure Quality, Firm Productivity, Manufacturing Firms, Southeast Asia

JEL Classification Code: C02, D53, Q14, G15, F37

1. Introduction and Literature Review

Manufacturing enterprises are one of the important actors in today's competitive global economy in practically all developed and developing countries (Nguyen et al., 2020). Policymakers and economic academics have emphasized the need of examining the relationship between energy consumption and economic growth, assuming that energy production and consumption are critical determinants of economic growth. Indeed, energy is a required input for economic activities such as transportation and manufacturing (Long, 2020). Among Southeast Asian countries, recent years have witnessed a marked increase in energy demand relative to other regions due to rapid economic growth (Nar, 2021).

The primary energy consumption of the ASEAN region was projected to grow at an annual growth rate of 6.1% to 7.2% (Erdiwansyah et al., 2019; Nathaniel & Khan, 2020). The incremental rate, on the other hand, would put a strain on the already inadequate and unsatisfactory power infrastructure in terms of both the availability and reliability of power services. For example, access to electricity is inadequate in Myanmar and Cambodia, with the electrification rates remaining low at 43% and 72%, respectively (International Energy Agency (IEA), 2019). Even where connections are available, the quality of power services is deficient. Many firms in developing countries have to rely on self-supply through private generators in response to frequent outages there. The Enterprise Surveys

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by World Bank reflected for this region a significant number of firms that experience power outages and a significant proportion owning or sharing a generator (Geginat & Ramalho, 2018).

As industrial firms heavily rely on electricity for many economic activities, poor power services increase the firm's cost of production, retard productivity and hinder growth in the long term. Abdisa (2018) found that the severity of power shortages in Ethiopia within 2011 and 2015 has raised firm's cost of production by about 15% by inducing firms to reallocate their input utilization that shifts toward a higher share of labor and material inputs. This results in firms operating below their full capacity, thus causing a fall in productivity. Similarly, Fisher-Vanden et al. (2015) observed an eight percent increase in unit production costs for Chinese firms in the energy-intensive sector due to the insecure supply of electricity, as firms are forced in the short run to rely on the most electricity-efficient way of production.

According to Allcott (2012), the poor quality of electricity infrastructure in developing countries contributes to the productivity gap between them and more developed ones. Their study estimated that Indian manufacturers affected by power shortages suffered a 5 to 10% reduction in the average plant's revenue and producer surplus. Unreliable supply of power further affects a firm's investment decision and prospects in the long run. Abeberese (2017) indicated that electricity constraints were responsible for firms' choice of less energy-intensive technology, thus lowering growth rates and unwillingness to operate in productivity-enhancing industries.

This study focuses on investigating the impact of power infrastructure quality on the performance of Southeast Asian manufacturing firms. As studied by Geginat and Ramalho (2018), we look specifically at the economic cost of power outages on a firm's productivity. Given the rapidly increasing energy consumption rate in the region over the last decade, we speculate that the power infrastructure may become overburdened, causing more frequent blackouts and prolonged outages that negatively affect the firm's operations and productivity.

Despite the region has achieved marginal improvements in the average electrification rate, which reached more than 90% in 2018 (Shyu, 2020), and gradually shifted toward an integrated regional power grid for a sustainable source of energy (Ahmed et al., 2017), there are stills some doubts regarding their operation and the reliability of the services provided. In fact, power utilities in many developing countries are provided by state-owned monopolies characterized by a lack of technical and financial management, resulting in rare investments and improper infrastructure maintenance in these countries.

As recently studied by Dina et al. (2021), the effect of infrastructure on firm performance in nine CAREC countries was investigated based on the 2009, 2013, 2019 enterprise survey. Infrastructure was quantified in terms of the duration of power outages, electricity costs as a percentage of total sales, availability of broadband Internet, and customs efficiency. Total sales, the share of utilized capacity, a dummy variable indicating the business exports, and the share of export sales were used to determine firm performance. The findings revealed that the duration of power outages and electricity expenses negatively affected company performance as assessed by sales and capacity utilization.

Moreover, while the cost of power outages has been recursively examined throughout the literature for African countries (Nkosi & Dikgang, 2018), for the North African and Middle Eastern (Gaugl & Bachhiesl, 2020), there is yet a comprehensive empirical study conducted for manufacturing firms in Southeast Asia region.

The World Bank Enterprise Surveys (WBSE) was conducted in thousands of firms in 8 countries of the Southeast Asia region, including Vietnam, Thailand, Lao PDR, Cambodia, Philippines, Myanmar, Malaysia, and Indonesia. The use of this survey is advantageous in several ways. First, it provides firm inputs and outputs to compute different productivity measures such as total factor productivity (TFP) and firms' labor productivity. Both of these measures were analyzed in the models. Second, the Enterprise Surveys contain a unique set of measures of the performance of electrical services, including both subjective and objective indicators. This allows us to investigate the variation in services performed at the establishment level and enables robust evaluation of the impact of power outages using different variable specifications. These measures were directly included in the production function since this would avoid omitted variable bias and inefficiency that affect the estimation results and their significance. Third, based on data available on individual countries, we further estimated the cross-sectional model at the country level to determine the particular impact of power outages for each country in the region.

Therefore, this study aims to estimate the economic cost of power outages, thereby addressing the research gap, and drawing on a unique firm-level survey data set collected by World Bank Enterprise Surveys. To the best of our knowledge, this study is first to evaluate the robust impacts of the reliability of power infrastructure on the performance of manufacturing firms in the ASEAN region. Our results confirmed a significant negative relationship between the performance of manufacturing firms and the reliability of electrical services in the countries of the ASEAN region. The magnitude and significance of impacts may vary depending on the measures of productivity and power quality. These findings are consistent with the view that electrical services matter for the productive performance of firms.

The remainder of this study is organized as follows: Section 2 presents the proposed model. The data is briefly introduced in section 3. In section 4, the results and discussions are presented. Finally, section 5 presents the conclusions along with the limitations.

2. Proposed Model

Traditionally, firm-level productivity refers to total factor productivity, which was defined as the change in output not directly attributable to changes in factor input (Chambers, 1988), and is often estimated using a production function approach. A Cobb–Douglas specification relating a firm's output to its inputs for a given period (Ospina-Holguín, 2017), is defined as:

$$y_i = \alpha_0 + \alpha_1 l_i + \alpha_2 m_i + \alpha_3 k_i + \varepsilon_i \quad (1)$$

In which y_i refers to the logarithm of real gross output of firm_i, l_i, m_i, and k_i refer to the logarithm of average employment, the logarithm of real intermediate inputs, and the logarithm of plant and machinery capital stock of firm *i*, respectively. To investigate the total factor productivity (TFP), the usual approach is first to estimate Eq. (1) to obtain α_1, α_2, and α_3 (which are, economically, the elasticities of output with respect to labor, intermediate inputs, and capital, respectively), and then compute TFP as the sum of remaining components. In doing so, TFP reflects the portion of output not explained by the quantities of inputs used in production:

$$Ln(\text{TFP})_i = y_i - \hat{\alpha}_1 l_i + \hat{\alpha}_2 m_i + \hat{\alpha}_3 k_i = \hat{\alpha}_0 + \varepsilon_i \quad (2)$$

After obtaining the estimates of productivity for each firm from Eq. (2), we can then evaluate the impacts of a set of determinants of TFP, drawing on a second regression with regressors being these factors. Specifically, for the purpose of this study, the TFP estimates would be regressed against a set of variables indicating the quality of power infrastructure. This two-stage approach, however, is subject to several problems. First, according to Newey and McFadden (1994), regressing the TFP estimates on the factors of interest in the second equation could potentially result in inefficient estimates of those variables (inconsistent standard errors, inconsistent t-statistics, and hence invalid inference procedure) because this strategy fails to account for either cross-equation restrictions or the correlation of disturbance terms across equations. Second, the omitted variable problem arising out of capturing other known determinants of firm output (which are subsequently shown statistically significant) in the random term ε_i in Eq. (1) leads to substantial biases in estimates of $\hat{\alpha}_i$, and thus those of the determinants of TFP in the second regression (Liao et al., 2012). To address the issues, Harris and Trainor (2005) suggested direct inclusion of the determinants of output and thus TFP into the first-stage equation; such an approach will help avoid serious problems of inefficient and biased estimates and also allow us to evaluate the statistical significance of such determinants directly. This approach was also used by Moyo (2013) in examining the relationship between the quality of power infrastructure and productivity in African manufacturing firms, in which TFP has assumed a linear function of firm characteristics and different proxies for infrastructure quality. Following Harris and Trainor (2005)and Moyo (2013), a baseline production function is, therefore, specified:

$$Y_i = \alpha_0 + \alpha_1 l_i + \alpha_2 m_i + \alpha_3 k_i + \beta_1 \text{INFRA}_i + \beta_1 X_i + \varepsilon_i \quad (3)$$

Where INFRA_i is a set of measures of the quality of power infrastructure, including the number of power outages per month, the average duration of a typical outage in hours, the percentage of output lost due to outages during the last fiscal year, and the perception whether electricity is a significant obstacle to the firm's operations. This measure, which is chosen mainly based on data availability, captures various aspects of the costs of power disruptions and is found to be significantly correlated with a firm's productive performance (Fakih et al., 2020; Takeda et al., 2020). In estimating Eq. (3), each of the power outage variables will be used once to avoid the multicollinearity problem, allowing us to robustly evaluate the relationship and identify which measure would provide the expected result.

Finally, X_i is a vector of control variables presenting all other productivity effects, e.g., firm size, age, foreign ownership, export participation, generator ownership, and country and sectoral heterogeneity. Prior studies have shown that firm productive performance is affected by the size, in the form of full-time labor and total sales or equity, the number of years the firm has been in operation, and foreign ownership, and exporting status (Moyo, 2013).

Following Arnold et al. (2008), we also include generator ownership in our regressions to capture the use of firm-owned generators because producing electricity in-house using a private generator is a means of mitigating the deficiencies of electricity provision from the public grid. Thus, ignoring the significant link between a firm's use of the private generator and power infrastructure can lead to an omitted variable problem resulting in biased estimates. Dummies for countries and sectors are also included in the model to capture the unobserved differences in geographic and institutional characteristics of the countries and sectoral comparative advantages.

For robust analysis, we also provide an alternative estimation strategy, in which firm productivity is instead measured in the form of factor ratios. Specifically, labor productivity, or total sales per worker, will be used as a proxy for productive performances of the manufacturing firms. Compared to TFP, this factor share-based estimate of productivity is much simpler in computing and not affected by the measurement error in capital stock. Further, as shown in the section below, the proxies for capital stock encompass a tremendous amount of missing values that significantly reduce our sample size in the regression stage. As such, using another measure of productivity helps us avoid this problem and robustly evaluate the relationship.

The alternative equation estimated is as follows:

$$y_i = \beta_0 + \beta_1 \text{INFRA}_i + \beta_2 X_i + \varepsilon_i \tag{4}$$

Where y_i now is labor productivity, computed as the total annual sales divided by the average employee, while INFRA_i, X_i is the set of variables defined as above.

3. Data

This study will exploit the World Bank's Enterprise Surveys (WBSE), which provides detailed survey-based data for firms across eight Southeast Asian countries, namely, Vietnam, Thailand, Lao PDR, Cambodia, Philippines, Myanmar, Malaysia, and Indonesia. It should be noted that the selection of countries was based primarily on the availability of comparable data on variables of interest. For each country, the data was collected either in 2015 or 2016 to ensure there is as small as possible discrepancies due to time. Brought together, the surveys from these countries help generate a cross-sectional data set covering 4723 manufacturing firms. These firms were partitioned into six large sectors, formed by grouping together some sub-sectors based on two-digit ISIC codes. The six manufacturing sectors include chemical and pharmacy, food and agriculture, metal and metallic products, nonmetallic products, textile and garment, and wood and furniture.

The WBSE cover various aspects of the investment climate at the firm level, allowing us to delve into the exogenous factors of the business environment on firm performance, such as infrastructure, human capital, technology, governance, and financial constraints (Ahmed et al., 2017; Nguyen et al., 2020; Salim et al., 2019; Tran et al., 2020) For power infrastructure specifically, the surveys produce both objective information as well as subjective evaluations of obstacles to firm operations. The set of measures of the quality of power infrastructure used in this study includes the number of power outages per month, the average duration of a typical outage in hours, the percentage of output lost due to power outages in a given year, and also the subjective judgment of firm managers whether electricity is a major constraint. Of the first two measures, the former is a frequency indicator of electricity blackouts while the latter indicates the severity of these power disruptions, and the remaining measures represent an overall cost of power outages to the firm.

Before proceeding to analysis, we inspect these variables to identify unreasonable values and outliers. For the number of outages per month and the average duration of outages, we first check whether the firm experiences power outages during the fiscal year; if yes, then we assume that the number of outages per month and the average duration of outages must be positive. Otherwise, the values for these measures would be dropped. For continuous variables, we conduct outlier identification as these values tend to affect regression results, significantly. First, we transformed variables into the logarithm form as $\ln(x + 1)$, and group observations by economy and sectors. Next, we computed unweighted means and standard deviations of these transformed variables within each group. Observations beyond the range of three standard deviations around the mean were marked as outliers and turned into missing values.

For factor variables like output, labor, raw materials, and intermediate inputs, and capital, the WBSE provides only monetary (as opposed to physical) measures in local currency units valued at the survey time. For estimation purposes, we need to convert the revenues and firm-level line item costs into common-year currency, using the average real effective exchange rates and the deflators corresponding to the years in which the surveys were done in each country World Bank's World Development Indicators. Next, firm size is determined based on the number of permanent, full-time labor and categorized into three groups: small-, medium- and large-sized according to the definition of World Bank. Firm age is computed as the difference between the year of establishment and the year the survey was done, either 2015 or 2016. Foreign ownership is a dummy equal to 1 if the firm has at least 10% foreign ownership and 0 otherwise. Similarly, export participation is a dummy taking the value of 1 if the firm has exported their products in the year of survey and 0 otherwise. The dummy for generator ownership equals 1 if the firm owned or shared a generator over the fiscal year, and 0 otherwise. Lastly, multiple dummies are generated to control for the unobserved country and sector effects. Table 1 presents the profile of firms in our sample.

4. Empirical Results

The above regression equations (3) and (4) were estimated using the Fixed Effect model, and heteroscedasticity-robust standard errors were reported for valid inference. For large samples, this approach is convenient as it allows us to safely ignore whether the constant variance assumption holds and the form of heteroscedasticity present in the population (Jeffrey, 2013).

Table 1: Summary Statistics of the Sampled Firms

	Number of Firms	(% of Firms) Foreign-Owned	(% of Firms) Exporter	Average Firm Age (Years)	Average Annual Sales (in US Dollars)	Average Labor Cost (in US Dollars)	Average Materials Cost (in US Dollars)	Average Capital Cost (in US Dollars)
Countries								
Cambodia (2016)	135	18.52	14.07	13.73	5835023.10	806526.90	1704361.90	654884.80
Indonesia (2015)	1069	11.32	14.69	21.54	71402481.50	1022932.20	25905435.40	801179.90
Lao PDR (2016)	110	20.91	23.64	14.58	699035.30	152106.20	148409.10	489877.70
Malaysia (2015)	585	24.10	46.10	19.47	3302821.60	600414.60	147341.30	861587.80
Myanmar (2016)	367	7.08	10.90	16.25	2873837.00	154116.70	439608.40	608216.10
Philippines (2015)	1037	25.02	24.18	22.60	25980667.00	1631634.90	10140608.80	1615988.20
Thailand (2016)	726	9.54	26.72	19.55	8712858.00	444439.80	2004204.00	952338.70
Vietnam (2015)	694	11.24	24.85	12.95	8981216.60	640986.60	4010790.50	11741660.60
Sectors								
Chemical and Pharmacy	384	19.37	27.44	23.04	20505150.00	951751.50	9774913.00	1345374.40
Food and agriculture	933	8.40	19.46	20.27	26899442.00	1033508.20	6411520.00	1865473.60
Metal and metallic products	1061	24.76	25.45	19.28	27708522.00	1299015.60	12230026.00	6268438.90
Nonmetallic products	876	14.69	23.05	19.56	34811801.00	724326.90	9747624.00	1679212.00
Textile and garment	1061	15.88	27.18	16.97	22940344.00	611588.90	10837807.00	834605.90
Wood and furniture	408	7.60	18.92	17.24	9013311.00	229236.00	5251605.00	781746.00
Firm Sizes								
Small-sized	1455	4.30	6.43	16.56	875161.40	48394.97	228147.80	73029.46
Medium-sized	1732	11.18	18.65	18.75	5185809.10	184473.76	2056133.70	825873.08
Large-sized	1536	31.72	46.07	22.01	71832303.80	2367633.64	26451030.00	6419008.93

Note: Firm sizes are categorized based on the number of full-time permanent employees, minimal if the firm size is ≤50, medium if firm size ≦100, and large if firm size ≥ 100. Annual sales, labor costs, materials, and capital are first converted to US dollars using the corresponding exchange rate in the World Bank Indicators and then deflated to an ordinary year.

Table 2 below summarizes the cross-sectional model results, which consider the individual country and sector unobserved effects, with Panel A presenting the estimates for Eq. (3) and Panel B for Eq. (4). As mentioned in the earlier section, we used different measures of power infrastructure quality in each model to identify the best proxies for this indicator and check whether the relationship holds in disparate variable specifications. Further, we presented the estimated results of regression for the individual countries for comparison. The use of country-level regressions allows us to compare between countries the extent to which unreliable power infrastructure could undermine firm productivity by relaxing the pooling assumption that imposes the same coefficients on the variables of power quality in all country settings for which the actual effects might, in fact, substantially differ. Panel A and B of Table 3 summarized those results for the two regression equations (3) and (4), respectively.

A priori would expect a negative effect of unreliable power provision on firm productive performances as electrical services are an essential intermediate input to production. Frequent unpredictable blackouts and a high

Table 2: The Regression Results for all of the Countries

Panel A. Estimates of the Equation (3)				
	(1)	**(2)**	**(3)**	**(4)**
Medium-sized	0.22814*** (0.06516)	0.23983*** (0.06540)	0.23339*** (0.06086)	0.23916*** (0.06083)
Large-sized	0.52757*** (0.12361)	0.56096*** (0.12725)	0.57508*** (0.11669)	0.58161*** (0.11666)
Firm age	0.00517** (0.00212)	0.00510** (0.00211)	0.00448** (0.00185)	0.00454** (0.00185)
Foreign ownership	0.44621*** (0.10312)	0.43849*** (0.10360)	0.41792*** (0.09148)	0.41626*** (0.09076)
Exporter	0.29870*** (0.07441)	0.30763*** (0.07708)	0.26687*** (0.06969)	0.27319*** (0.06924)
Number of power outages per month	−0.00364 (0.00477)			
The severity of a typical outage		0.01115 (0.01654)		
Output lost due to outages			−0.00441 (0.00571)	
Electricity as a major constraint				−0.00133*** (0.00051)
Generator ownership	0.00164*** (0.00061)	0.00165*** (0.00063)	0.00195*** (0.00057)	0.00183*** (0.00056)
Log capital input	0.01445 (0.01551)	0.01244 (0.01563)	0.02287 (0.01515)	0.02250 (0.01509)
Log material input	0.45330*** (0.02662)	0.46252*** (0.02504)	0.44427*** (0.02787)	0.44484*** (0.02792)
Log labor input	0.44832*** (0.04184)	0.43398*** (0.04162)	0.44132*** (0.03935)	0.44063*** (0.03923)
Constant	2.40846*** (0.34790)	2.46555*** (0.35406)	2.50860*** (0.32655)	2.51705*** (0.32643)
Country dummies	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes
Observation	2648	2643	2999	3010
Adjusted R^2	0.793	0.791	0.794	0.795

Table 2: Continued

Panel B: Estimates of the Equation (4)				
	(1)	**(2)**	**(3)**	**(4)**
Medium-sized	0.18854*** (0.06053)	0.18986*** (0.06038)	0.19148*** (0.05612)	0.19650*** (0.05628)
Large-sized	0.29525*** (0.07446)	0.30611*** (0.07408)	0.31951*** (0.06912)	0.30680*** (0.06860)
Firm age	0.01001*** (0.00270)	0.00997*** (0.00266)	0.00795*** (0.00242)	0.00837*** (0.00241)
Foreign ownership	0.13616 (0.10494)	0.13305 (0.10607)	0.19124** (0.09224)	0.19320** (0.09204)
Exporter	0.29190*** (0.08072)	0.29833*** (0.08183)	0.31963*** (0.07321)	0.32904*** (0.07250)
Number of power outages per month	0.00110 (0.00717)			
The severity of a typical outage		−0.03754** (0.01640)		
Output lost due to outages			−0.04246*** (0.00794)	
Electricity as a major constraint				−0.00303*** (0.00063)
Generator ownership	0.00352*** (0.00072)	0.00376*** (0.00072)	0.00381*** (0.00064)	0.00330*** (0.00064)
Constant	8.52841*** (0.19214)	8.56532*** (0.18863)	8.68370*** (0.17813)	8.68430*** (0.17855)
Country dummies	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes
Observation	3757	3745	4356	4381
Adjusted R^2	0.125	0.127	0.136	0.133

Note: Heteroscedasticity-robust standard errors are in parenthesis. The reference group for firm size is small-sized firms. *, **, ***denote significances at 10%, 5%, and 1% level, respectively.

number of hours without power will severely impede manufacturing firms' operations, thus their productivity. Most of these expectations are borne out by the statistical results. As shown in Table 2, most of the estimated coefficients for power quality are negative, half of which are individually statistically significant at the 5% or lower level, although it should be noted that the two regression equations differ at some points. Proxied by the number of power outages per month, power quality did not show any statistically significant effect on productivity, measured by either TFP or labor productivity. In contrast, the severity of power disruptions indicated a significantly negative correlation with labor productivity. The estimated coefficient of -0.038 suggested that an additional hour of electrical blackout would, on average, cause a 3.8% decrease in total sales per worker, holding other factors fixed.

Of the measures of overall costs incurred by power outages, the percentage of output lost entered negatively but significant only in Eq. (4) (Panel B), indicating an approximately 4.2% reduction in the labor productivity caused by one percent increase in the cost of outages per annum while controlling for other variables. Notably, we documented that the coefficients on the subjective measure of power quality were consistently negative and statistically significant at the 1% level in both of the regressions. These results suggested that firms reporting electricity as a significant constraint would have, on average, 0.13% lower real gross output and thus lower TFP than those who did not. In terms of labor productivity, the constrained firms would suffer from a reduction of about 0.3% of total sales per worker. The findings are broadly consistent with some earlier works (Arnold et al., 2008; Harris & Trainor, 2005; Moyo, 2013). Lastly, we also found the coefficients on

Table 3: Individual Regression Results for each Country

Panel A. Estimates of the Equation (3)								
	Cambodia	**Indonesia**	**Lao PDR**	**Malaysia**	**Myanmar**	**Philippines**	**Thailand**	**Vietnam**
Medium-sized	0.58083** (0.22585)	0.33423** (0.13939)	0.16181 (0.22705)	0.30160 (0.19686)	−0.13516 (0.10050)	0.36168*** (0.09344)	0.24954** (0.10835)	0.36367*** (0.13027)
Large-sized	0.36708 (0.32511)	1.06872*** (0.24023)	0.66521** (0.31631)	0.35308 (0.31318)	−0.33386 (0.29890)	0.87137*** (0.17774)	0.25060 (0.18063)	0.48136*** (0.17860)
Firm age	−0.02288* (0.01264)	0.00363 (0.00406)	0.01609** (0.00772)	−0.00680 (0.00783)	−0.00099 (0.00176)	0.00537* (0.00284)	−0.00122 (0.00460)	−0.00175 (0.00389)
Foreign ownership	0.22950 (0.25074)	1.20676*** (0.25286)	0.21497 (0.16476)	−0.05643 (0.16819)	−0.13352 (0.30883)	0.20106 (0.12242)	−0.02358 (0.19831)	−0.07033 (0.14591)
Exporter	0.19858 (0.27645)	0.92987*** (0.20317)	−0.29779** (0.14304)	0.09382 (0.14027)	0.64862 (0.41786)	−0.01087 (0.11686)	0.21933* (0.12923)	0.13142 (0.10088)
Output lost due to outages	−0.03514 (0.03918)	0.01558 (0.03144)	−0.01019 (0.01262)	−0.01353 (0.01125)	−0.00168 (0.00402)	−0.01880 (0.01589)	0.00155 (0.03581)	−0.01419 (0.02471)
Generator ownership	0.00160 (0.00196)	−0.00009 (0.00123)	0.00184 (0.00197)	0.00117 (0.00158)	0.00122** (0.00054)	0.00175** (0.00077)	−0.00142 (0.00183)	−0.00011 (0.00103)
Log capital input	0.16027*** (0.04498)	−0.02910 (0.02150)	0.00221 (0.06316)	0.07899* (0.04521)	0.06694*** (0.02306)	0.03308 (0.02095)	0.09976*** (0.02479)	0.26808*** (0.04326)
Log material input	0.20930*** (0.06611)	0.50191*** (0.03428)	0.33967*** (0.06201)	0.29392*** (0.09064)	0.46366*** (0.04030)	0.47531*** (0.03182)	0.48743*** (0.03095)	0.28660*** (0.06749)
Log labor input	0.64941*** (0.07712)	0.36325*** (0.06731)	0.43149*** (0.08405)	0.61574*** (0.05889)	0.54555*** (0.08434)	0.33480*** (0.03965)	0.29508*** (0.06353)	0.34174*** (0.06382)
Constant	2.18732*** (0.61844)	2.73644*** (0.55270)	3.88412*** (0.84339)	1.72341 (1.24267)	0.57445 (0.62650)	2.89238*** (0.42433)	2.93049*** (0.71131)	2.75457*** (0.64153)
Sectors dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	123	932	105	327	319	265	528	400
Adjusted R^2	0.841	0.827	0.812	0.604	0.879	0.930	0.812	0.785

Table 3: Continued

Panel B: Estimates of the Equation (4)								
	Cambodia	**Indonesia**	**Lao PDR**	**Malaysia**	**Myanmar**	**Philippines**	**Thailand**	**Vietnam**
Medium−sized	0.66274* (0.35722)	0.17040 (0.13106)	0.05653 (0.24515)	−0.31624** (0.15241)	0.05386 (0.12297)	0.42517*** (0.12758)	0.31476** (0.12915)	0.24872* (0.14013)
Large−sized	0.15589 (0.41597)	0.58673*** (0.18325)	−0.16162 (0.23382)	−0.81592*** (0.18402)	−0.03546 (0.17213)	0.80733*** (0.15148)	0.33318** (0.15318)	0.20449 (0.15298)
Firm age	−0.01919 (0.01973)	0.00322 (0.00610)	0.03952*** (0.01058)	−0.00067 (0.00884)	−0.00332 (0.00425)	0.00442 (0.00412)	0.01800*** (0.00660)	−0.00453 (0.00484)
Foreign ownership	0.68699* (0.35697)	1.55810*** (0.31606)	0.11794 (0.20549)	−0.86795*** (0.19508)	−0.06914 (0.30045)	0.26006** (0.12763)	−0.71993*** (0.25814)	0.23071 (0.15912)
Exporter	0.12618 (0.37472)	0.90698*** (0.27462)	−0.36846** (0.16919)	0.02786 (0.15296)	0.10085 (0.37968)	0.41160*** (0.12689)	0.44044*** (0.14691)	−0.02026 (0.12816)
Output lost due to outages	−0.04893 (0.05492)	−0.02512 (0.02674)	0.01701 (0.02298)	−0.04752*** (0.01584)	−0.00320 (0.00647)	−0.06266 (0.03871)	−0.03136 (0.02296)	−0.05439** (0.02159)
Generator ownership	0.00529* (0.00309)	0.00686*** (0.00175)	0.00010 (0.00197)	0.00227 (0.00189)	0.00160 (0.00099)	0.00361*** (0.00113)	−0.00326 (0.00237)	−0.00271** (0.00110)
Constant	7.86695*** (0.41997)	8.20639*** (0.21241)	8.47099*** (0.33491)	9.28732*** (0.26375)	9.12096*** (0.31525)	9.62133*** (0.18452)	7.60207*** (0.44215)	10.28380*** (0.30557)
Sectors dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observation	129	1040	106	508	350	907	650	666
Adjusted R^2	0.097	0.235	0.079	0.161	0.132	0.202	0.085	0.050

Note: Heteroscedasticity-robust standard errors are in parenthesis. The reference group for firm size is small-sized firms. *, **, *** denote significances at 10%, 5%, and 1% level, respectively.

Table 4: Electricity Infrastructure Problems in Southeast Asian Countries

Economy	Percent of Firms Experiencing Electrical Outages	Number of Electrical Outages in A Typical Month	If there were Outages, the Average Duration of A Typical Electrical Outage (Hours)	If there were Outages, Average Losses Due to Electrical Outages (% of Annual Sales)	Percent of Firms Owning or Sharing a Generator	If a Generator is used, the Average Proportion of Electricity from a Generator (%)
All Countries	57.4	5.6	4.6	4.3	34.9	18.3
Cambodia 2016	35.3	1.4	1.3	3.6	40	9
Indonesia 2015	22.5	0.5	5.7	1.9	11.7	16.5
Thailand 2016	8.6	0.2	1.7	4.1	0.4	20
Lao PDR 2018	78.5	0.2	2.2	0.9	8.5	3.6
Malaysia 2015	18.9	0.1	3.8	1.8	10.8	20.7
Myanmar 2016	94.9	11	1.3	2.5	52.3	15.4
Philippines 2015	39.9	0.1	3	0.8	42.7	38.9
Vietnam 2015	26.3	0.2	7.5	2.2	25.2	1.6

Source: World Bank Enterprise Surveys (WBSE).

generator ownership to be significant and positive in all models. This corroborates the argument that firms that can generate their own electricity benefit from the fact that the continuity of their production is not dependent on the continuity of public provision. Our data display a strong and positive relationship between the decision to acquire a generator and the experience of power outages by firms. The statistically significant results of generator ownership also validated the inclusion of this variable in our model specifications.

For the country-level regressions, we found that the coefficients on the percentage of output lost due to outages, though negative in most of the models, were significant only in the regression results of Eq. (4). In particular, the estimates were statistically significant at the 5% level or lower in Malaysia and Vietnam, which are among the leading countries having firms that reported the highest average duration of electrical outages. According to the World Bank's World Development Indicators, Vietnamese and Malaysian firms would, on average, suffer from 7.5 and 3.8 hours of a continuing power blackout, respectively if this event happened, while the indicator for the East Asia & Pacific was about 3.4 hours (Table 4). In terms of generator ownership, all of the coefficients were positive and statistically significant, except in Vietnam. As can be seen in the descriptive statistics summarized in Table 4, the proportion of electricity produced by the generator in Vietnam contributed only 1.6%, which suggested that though the ownership of generator is prevalent, their power capacity suited to the only small operation scale, not a cost-effect method of production, highlighting the importance of public grid in this country.

5. Conclusion

The primary objective of this study was to examine the role played by the quality of power infrastructure on firm productivity in the manufacturing sector in Southeast Asia. While the results were mixed, they consistently justified the subjective measure of power outages in a negative association with business productivity, as judged by firm management if electricity is a significant constraint. Besides, using hours of a typical outage, instead of the frequent indicator of disruptions, provides us with expected results. This finding is consistent with the argument of Iimi (2011) that when comparing two types of quality deterioration in electricity services, shorter but more frequent outages seem less harmful for enterprises than longer but less frequent ones. Overall, the impact of power outages on productivity seems not qualitatively different when different dependent measures of productivity are used, but labor productivity resulted in more significant results. At the country level, the regression results also differ according to the severity of the country's power difficulties, as measured by the proportion of output lost to outages.

Specifically, we noted the significant impact of outages on Malaysian and Vietnamese firms that have also suffered from more severe power outages annually. Therefore, it is suggested that power utilities or government ensure robust power supply with minimum disruptions to manufacturing firms. This could be done by the early spot of such events and quickly implement fixing measures to minimize the cost.

Our study settings are, however, limited in some ways that need consideration. First, the available cross-sectional data does not enable us to derive a deep and thorough understanding of the dynamic relationship between power outages and productivity. Second, this survey data noted a number of missing values in some specific variables of interest, which may cause the estimated results to be biased despite our efforts to rule out irrational and anomalous values. It could be suggested that these obstacles be overcome in further research by leveraging longitudinal data provided by World Bank in the future.

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