Power Outages, Its Economic Cost and Firm Performance: Evidence From Ethiopia

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2 February 2018

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Abstract

Unreliable supply of electricity is the main constraints to doing business in Ethiopia. This paper examined how firms in Ethiopia respond to power outage employing the World Bank Enterprise Survey data. The result shows that, in response to power outages, firms in Ethiopia self-generate electricity. While there is no evidence suggesting outsourcing and improved energy hypothesis, power outages were found to affect the firms' productivity negatively. From 2011 to 2015 firms' cost of production rose by 15% due to power outage. This effect varies positively with output level suggesting that outage is costly particularly for large firms.

Key Words: Power Outages, Firm, Self Generation, Ethiopia

JEL Codes: L6, L81, N77, Q41

1 Introduction

The performance of Africa's power is poor and unsatisfactory. Africa has the lowest electrification rate of all regions. It was estimated that only 42 percent of the population has access to electricity, compared to 75 percent in the developing world (International Energy Agency, 2012). According International Energy Agency (2014) about 585 million people in Sub-Sahara Africa (SSA) lack access to electricity of which 76 million are in Nigeria and 69 million in Ethiopia.

Poor supply of electricity is one of the major challenges that industrial sector in developing countries faces. In SSA countries, power supply is characterized by frequent and prolonged power outage. According to World Bank Enterprise Survey (WBES), in 2007 a typical SSA firm suffered a loss of economic activities for around 77 hours per month due to power outages. The same report pertaining to 2010/2011 shows that 22% of managers cited lack of reliable electricity supply as the most serious constraint to doing business (World Bank, 2015)[2]. SSA countries are poorly ranked on doing business index published annually by World Bank. For instance, Ethiopia is ranked 161th out of 190 countries considered while Eritrea stands 189th (World Bank, 2017).

The poor state of electricity infrastructure retards the productivity and competitiveness of the business sectors in SSA. Allcott et al. (2014) pointed that poor electricity supply is the main contributing factor for productivity gap between developed and developing countries. According to Iacovone et al. (2014), African firms are about 20-24% smaller than firms in other countries of similar age mainly explained by poor business environment including lack of reliable electricity. Unreliable electricity supply affects the competitiveness of a firm by causing a firm to resort to manual methods which reduce product quality, halt production and delay order delivery. It also affects investment decision, cost of production and firm location. A study by Abeberese (2012) shows that in countries with high level of electricity insecurity, firms lack incentive to move to productivity-enhancing industries or to grow larger since doing so comes with the cost of having to rely on electricity. Fisher-Vanden et al. (2015) found that a unit cost of production in Chinese industrial sector has increased by 8% due to insecure supply of electricity.

Given the prevalence of power outages, firms may respond in a number of ways. The most commonly adopted coping mechanism is investment in self-generation. However, investment in self-generation undermines firms' productivity by forcing firms to channel their finance to less productive investment. Empirical evidence shows that self-generation of electricity is costlier than one supplied by the public (Steinbuks and Foster, 2010; Oseni and Pollitt, 2015; Adenikinju, 2003). A high cost of self-generation contributes to a fall in productivity through its impact on capital utilization in the short run: by inducing firms to reallocate and selectively utilizing the most electricity efficient way of production and substitute electricity for material inputs (Fisher-Vanden et al., 2015). This indicates a higher cost of electricity may induce firms to reallocate their input utilization which forces firms not to operate to their full capacity. This could also further induce firms to invest in electricity efficient technology in the long run.

[2] Policy Research Working Paper number 7460, accessed online from http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/10/27/090224b08317215b/2 _0/Rendered/PDF/Electricity0co0nce0in01830countries.pdf

Thus, the way firms respond partly depends on the nature of power outage and the options available to them. Firms may choose to invest in backup energy, invest in electricity saving technology or outsource the production of electricity intensive intermediate inputs. However, it is not clear from previous studies whether power outages leads to electricity efficiency or force firms to substitute away from electricity to material input. The only study is that of Fisher-Vanden et al. (2015) in which they found that Chinese firms re-optimize among inputs by substituting materials for energy and shifts from make to buy of intermediate inputs due to shortage of electricity. Thus, the question of whether firms in SSA optimize among their production inputs or resort to self generation during a period of power outages need to be addressed.

This study focuses on examining how firms respond to power outages and estimate its economic cost in Ethiopia. Ethiopia is an interesting country to consider to study the economic cost of power outages. The country has electricity generating potential of 650 TWh per year, of which 40% is technically feasible. This constitutes 15% of total technically feasible potential of Africa (Federal Democratic Republic of Ethiopia, 2012). The government is putting a huge investment in renewable energy resources and hydropower in particular to improve energy generation capacity of the country. Despite the country has achieved marginal improvements in areas of electricity service, frequent blackouts are common, and become part of everyday life. Thus, the country can be considered as a good representative for the SSA region in terms electricity generating potential, current installed power generating capacity and prevailing power shortages. Moreover, even though power cuts in the country is not only frequent and prolonged, but also erratic, there is no comprehensive empirical study conducted to estimate the impact of power outages on firm productivity and production cost. The purpose of this study is, therefore, to investigate how firms respond to power interruptions and estimate the resulting economic cost using two rounds of firm-level survey conducted on firms currently operating in the country.

The paper is organized as follows. Conceptual framework, review of related literature are presented in section 2 and section 3 respectively. Data source, model specification and estimation strategy are discussed in section 4. Section 5 presents empirical results; while conclusions and policy implications drawn from the study are presented in section 6.

2 Conceptual Framework

Power outage adversely affects output in productive sectors and prompt firm to disinvest as well as discourage new firms from locating in a country. Lack of adequate electricity supply reduces the rate of job creation, accelerates the loss of jobs, reduces household's income and lowers tax receipts at all levels of government. The extent to which power outage affect firms' production depends on a type of electricity user and characteristics of supply interruptions they face (de Nooij et al., 2009).

To cope with such interruptions, firms may adopt different mechanisms. The way firms responds partly depends on the nature of power outage and the options available to it. One common strategy is an investment in self-generation of electricity (Adenikinju, 2003; Steinbuks and Foster, 2010; Oseni and Pollitt, 2015). However, investment in self-generation does not guarantee complete mitigation of outage. Firms that invests in self-generation may still suffer losses possibly because of the inability to completely back up its load (Beenstock et al., 1997) and firms may also incur restart costs.

Another option would be for a firm to outsource the production of energy intensive intermediate inputs. A firm may find optimal to purchase intermediate inputs rather than producing them from raw in-house during a period of power outage. In this case, outsourcing could result in less use of electricity and other inputs in the production. This could result in decreased productivity because when a firm is substituting material inputs for electricity, a firm is forced to shift from make to buy these intermediate inputs (Fisher-Vanden et al., 2015).

Firms may also respond to electricity shortages by improving their overall energy consumption efficiency. This could be possible by selectively utilizing the most electricity efficient way of production as well as investing on electricity saving technologies. This would likely cause the share of capital to increases while that of energy inputs to decline.

Thus, based on the above discussions, the following testable hypothesis is set:

H1: Decreased Productivity: Power outages increases a unit cost of production through factor adjustments.

H2: Self-Generation: Firms substitutes electricity supplied from the public grid by self-generated electricity during a period of power outages.

H3: Outsourcing: Firms produces less of energy intensive intermediate inputs in-house during a period of power outages.

H4: Improved Energy Consumption Efficiency: Firm respond to electricity shortages by investing in energy saving technologies to improve their overall energy efficiency.

3 Related Literature

There are considerable empirical studies conducted to test the impact of power outages on firm performance and found that power outages retard firm performance (Scott et al., 2014; Abotsi, 2015; Nyanzu and Adarkwah, 2016; Alam, 2013). In testing the impact of power outages on firm performance, most empirical studies used a proxy measures of power outage. Some studies (Alam, 2013; Andersen and Dalgaard, 2013) used meteorological satellite data lightning density as an instrument for power outages while others Fisher-Vanden et al. (2015) used industry level estimates such as the ratio of thermal electricity generated to thermal electricity capacity. Allcott et al. (2014) have employed supply shifts from hydroelectric power availability as an instrument for electricity shortage. On the other hand, a number of studies (Adenikinju, 2003; Oseni and Pollitt, 2015, 2013; Abotsi, 2015) have used firm level survey data to study the economic cost of power outages and how it affects firm performance.

Numerous studies have attempted to estimate the cost associated with power interruptions using different techniques. For instance, (Bental and Ravid, 1982; Adenikinju, 2003; Steinbuks and Foster, 2010; Oseni and Pollitt, 2013) inferred outage cost from actions taken by firms. However, this method sometimes provides only an upper or lower limit on outage cost estimates (Balducci et al., 2002). Other studies Pasha et al. (1989); Caves et al. (1992) have used survey methods in which firms are asked to report losses suffered from outages. This approach is attractive in that it yields the distribution of outage costs across customers. There are also studies which have adopted production function approach, for instance, Castro et al. (2016), to estimate cost of power interruptions. This study incorporates the strength of survey method into a production function approach in a sense that translog cost function is applied to a firm level survey data.

Power outage affect business activities in a number of ways. However, its impact varies across firms based on the degree of their vulnerability and relative generating capacity of a self-generating firm to its own required electricity (Oseni and Pollitt, 2015). The cost of power outages also varies across firm size and a type economic activities a firm is engaged in. In this regard, (Moyo, 2012; Adenikinju, 2003)] found that power interruption is harmful particularly to small firms because they are unable to finance the cost of backup energy. On the other hand, a study by Oseni and Pollitt (2015) show that larger firms face greater outage loss. They suggested that this is mainly because of larger firms uses machine dependent production process than small firms.

The cost of power outages also depends on the nature of power interruptions that firms face. Power outages can be characterized along a number of dimensions, including duration, frequency, the timing of interruption, and advance notification. Some studies have considered the impact of such characteristics on outage cost. Billinton et al. (1982) and Ontario (1980) reported that firms experience high outage costs initially. However, the cost diminish rapidly as duration increases. With regards to the frequency of interruptions, business enterprises prefer infrequent long duration interruptions to frequent short duration of interruptions (Billinton et al., 1982; Ontario, 1980). Scott et al. (2014) found a similar result which shows frequent power outage is associated with lower firm productivity. Studies on the impact of timing of power interruption and advance notification are limited due to data constraint.

There is also considerable empirical studies devoted to examining mitigation measure taken by firms to reduce the cost of power outages. It was found that the most commonly adopted strategy is an investment in self generation (Adenikinju, 2003; Steinbuks and Foster, 2010; Oseni and Pollitt, 2015). Steinbuks and Foster (2010) found that the probability of owning a generator is about 20% even where the power supply is completely reliable, and incentive to invest in generator and capacity of generator installed are greatly affected by firm characteristics such as size, sector, corporate structure, and export orientation. Similar result was found by Oseni and Pollitt (2015). However, the mitigation strategy taken by a firm partly depends on options available to a firm and the nature of power interruptions. According to Alam (2013), short run power cuts may not induce firms to own generators. A study by Fisher-Vanden et al. (2015) also shows that Chinese firms were not self generating electricity during power shortages rather they re-optimize among production inputs by substituting materials for energy.

Existing empirical studies in outage research focused on estimating the economic cost of power outages. However, it is not clear from these studies whether electricity shortages caused by power interruption leads to electricity efficiency or forces firms to substitute away from electricity to material input. The only study is that of Fisher-Vanden et al.

(2015) in which they found that Chinese firms re-optimize among inputs by substituting materials for energy and shifts from make to buy of intermediate inputs due to a shortage of electricity. This study, therefore, examines economic cost of power outages and the behavioral responses of firms in SSA using translog cost function.

This paper departs from earlier studies in SSA in the following ways. First, a cost function is used to estimate how power outages affect firms' cost, test whether power outages affect input factor shares or overall productivity and how it affects firms input utilization. Secondly, the study uses two round of firm level data which provides a richer data than previous studies in the area.

4 Methodology

4.1 Data Source and Descriptions

The major source of data for this study is the 2011 and 2015 WBES on firms operating in Ethiopia. The survey used stratified random sampling technique and firms were stratified based on their size, sector and region (based on the political administration of the country). From 9 regional states and two self-administrative cities of the country, four regions (Oromia, Amhara, SNNP, and Tigray) and the two self-administrative cities were selected. The size stratification is based on the number of permanent full-time workers reported and defined as: micro (less than 5 employees), small (5 to 19 employees), medium (20 to 99 employees), and large (more than 99 employees). A total of 644 firms were surveyed in 2011. In addition to 644 firms interviewed in 2011, fresh firms were introduced into the survey making a total of 848 firms interviewed in 2015.

The empirical estimation for behavioral response of firms to power outages requires firm level data on production inputs and cost spent by firm on factor inputs. The cost function has five factor inputs which include: capital (K), labor (L), material inputs (M), electricity (E) and non-electricity energy (N). Data for these inputs mainly depends on 2011 and 2015 WBES. In the Survey, firms were asked to report their annual expenditure on wages and salaries for workers, expenditure on intermediate inputs, annual expenditure on electricity and other non-electricity energy. All reported expenditures in local currency are converted to equivalent USD using 2015 market exchange rate.

Thus, using these firm level data, the input prices are computed by firm and year based on expenditure data. Accordingly, the price of labor (Pl) is computed as the annual sum of wages, salaries and bonuses divided by the number of full time permanent workers in the company during the year. Price of capital (Pk) or fixed asset is imputed from firm's value of output minus cost of intermediate inputs (materials, energy and other supplies) and total expenditure on labor; divided by net book value of assets.

The price of material inputs (Pm) for a given specific industry is computed as a composite of annual industry producer price index weighed by input-out shares for that firm's industry. The input-output shares of a firm based on two digits Standard Industrial Classification (SIC) are obtained from the Social Account Matrix (SAM) of Ethiopia. Firms in the same two SIC classification faces the same material inputs over time. Price of electricity (Pe) is obtained from Ethiopian Electric Power (EEP), while the price of nonelectric energy (Pn) is obtained from German Agency for International Cooperation (GIZ). In the WBES data set, there is no information on the quantity of final output. Thus, the deflated total annual sale by general price is used as a proxy for the final output of a firm.

4.2 Power Outages and Firms' Coping Strategies

In this section, empirical model to be estimated for the analysis of the firms' behavioral response to power outage is presented. The study follows Fisher-Vanden et al. (2015) approach in order to test the hypothesis stated in section 2.

The productivity effect of power outages can be estimated either through production or cost function; the choice of which depends on relevant exogeneity assumption and statistical grounds. In production function estimation in which factor inputs determine the level of output, inputs quantities are assumed to be exogenous. Whereas in cost function estimation, input prices are assumed to be exogenous. In this study, since a firm level data is used in which the choice of quantity of factor inputs are endogenous and factor prices more likely to be determined in the market, cost function approach is more appropriate to adopt. The translog cost function handles any neutral and non-neutral efficiency differences among firms (observational units in the data). Thus, because of its flexibility in functional form, the study adopts the translog cost function, which is specified as follows:

$$\begin{aligned} lnC_{it} &= \alpha_0 lnS_{it} + \alpha_1 lnQ_{it} lnS_{it} + \beta_j lnP_{ijt} lnS_{it} + \delta_{jt} lnP_{ijt} + \frac{1}{2}\sum_{l=1}^{J} \varphi_{jl} lnP_{ilt} ln_{ijt} \\ &\quad + \kappa lnQ_{it} + \frac{\Lambda}{2}(lnQ_{it})^2 + \phi lnQ_{it} lnP_{ijt} + \eta_k + \varepsilon_{it} \qquad (1) \end{aligned}$$

where C_{it} is the total production cost of firm i at time t, Q_{it} is the annual output of firm i at time t, $P_{ijt}$is price of input j at time t for firm i (where j includes capital, labor, material, electricity, and nonelectric energy), η_k is industry fixed effect, parameters α_0 and α_1 measures the factor neutral effect of power outages allowing the effect to vary with the level of output while β_j measures the factor biased productivity effect of power outages.

Using Shephard's Lemma, the cost share equation for each of the factor inputs can be derived from equation (1)[3] as:

$$VSH_{ijt} = \beta_j lnS_t + \delta_j + \frac{1}{2}\sum_{i=1}^{J} \varphi lnP_{ilt} + \phi_j lnQ_{it} + \varepsilon_{it} \qquad (2)$$

[3]Even though there are five factors of production in the cost function, the add-up conditions across all factors of production implies the covariance matrix would be non-invertible if all value shares of input are included in the estimation. Thus, the cost function is estimated along with four of the cost share equation; value share for the material is dropped. As shown in Greene (2008), the coefficient estimates and standard errors are insensitive to the value share dropped.

4.2.1 Estimation Strategy

Equations in (1)- (2) represents a system of equations in which shock to factors shares are likely to be correlated across error structure of the model. Since the systems of equations are related to each other through their error term, there is an efficiency gain by estimating the system of equations jointly. Thus, the above system of equations is estimated by three-stage least[4] squares in panel data framework[5].

For the cost function specified in equation (1) is to be well-behaved, i.e. exhibits the usual property of symmetry and homogeneous of degree one in input prices, the following restrictions are imposed.

$$\varphi = \varphi_{lj}, \sum_{i=1}^{J} \delta_j = 1, \sum_{j=1}^{J} \varphi_{jl} = \sum_{j=1}^{J} \varphi_{jl} = \sum_{j=1}^{J} \phi_j = 0 \tag{3}$$

The impact of power outages on firms' cost of production and consequently firms' response can be truly measured only if the power outage is exogenous in the model. However, there are a number of reasons that outage is endogenous. Outages can be correlated with factors which affect firm level output such as location of a firm, firm sector and prevailing economic conditions. For instance, a rapid economic growth could cause an increase in demand for electricity that leads to shortages and affects firm level output. There is also the possibility of measurement error. In order to address the endogeneity and measurement error, the study utilized variation in hydro- electric generation as an instrumental variable.

Electricity from hydropower shares more than 87% in Ethiopia and its electricity generating capacity depend on rainfall. The country has faced major electricity shortages in periods of low recorded rainfall. This shows variation in electricity generation majorly depends on rainfall and it affects firms' production cost only through outages. Thus, variation in hydroelectricity generation is a good candidate to be instrumental variable for power outages.

Variation in a hydro generation is measured as the deviation from the mean annual generation over the period of 2011 -2015 which is given as:

$$Hvar = H_t - mH \tag{4}$$

Where H_t is hydro generation at time t and mH is the mean annual generation over the given period. The choice of the time period is based on the data used in the analysis.

[4]In addition, the description of power rationing scheme in the country and how it varies among firms is estimated using probit and count data modes.

[5]To insure the three stages least square is invariant to the choice of deleted value share equation, the three stage least square is iterated over the estimated disturbance covariance matrix and parameter estimates (see Berndt, 1991: PP 474-475).

Thus, using variation in a hydro generation as an instrument in the main specification of equation (1), the reduced form regression of power outages on variation in the hydro generation and other explanatory variables of the model in equation (1) is given by:

$$\begin{aligned} lnS_{it} &= \theta H_t + \alpha lnQ_{it}H_t + \sum \varphi_{jl} ln_{ilt} lnP_{ilt} + \tau lnP_{ijt}H_t + \frac{1}{2}\sum \varphi_{jl} lnP_{ilt} lnP_{ijt} + \tau lnQ_{it} \\ &+ \kappa lnQ_{it} + \frac{\Delta}{2}(lnQ_{it})^2 + \phi_j lnQ_{it} lnP_{ijt} + \mu_k + \varepsilon_{it} \end{aligned} \tag{5}$$

This is estimated by three-stage least square method along with equations in (1)-(2) imposing restrictions in equation (3). Marginal cost and change in total cost of production due to power outage can be computed from the main equation in (1). Taking the first order derivative of the cost function with respect to power outages,

$$\frac{\partial C_{it}}{\partial S_{it}} = \frac{\alpha_0 C_{it} + \alpha_1 lnQ_{it}}{S_t} + \sum_{j=1}^{J} \beta_j \frac{lnP_{ijt}}{S_t} \tag{6}$$

The first term represents the factor neutral effect while the second term is the factor biased effect. The overall effect depends on the combination of the two effects. The change in total cost of production due to change in power outages is thus, computed using equation (6).

4.2.2 Tests on self-Generation

Evidence for self-generation can be tested from the model specified in equation (1). For the self-generation hypothesis to hold, as stated above, the interaction of power outages and electricity should be negative and that of non-electric energy interacted with power outage should be positive.

A further test on self-generation hypothesis is made by estimating a separate regression of generator ownership on power outages and other firm characteristics. To test for this, the study adopted (Reinikka and Svensson, 2002) approach, which is recently employed by (Steinbuks and Foster, 2010).

Firms adopts a generator if the benefit from adoption is greater than not adopting. Thus, the decision to invest in backup energy can be modeled using a binary choice model.

$$Y_{it}^{*} = X_{it}\beta + \varepsilon_{it}, i = 1, 2..N; t = 1, 2, ...T \tag{7}$$

where $\varepsilon_{it} = \alpha_i + u_{it}, u_{it} \backsim N(0, \delta_u^2); \alpha_i \backsim IN(0, \delta_\alpha^2)$ and Y_{it} is a latent dependent variable which is defined as:

Table 1: Summary of Input Prices and Input Value Shares

Variable	Description	Mean	Std.Dev.
TC	Total Cost (USD)	271665.5	498520.4
Output	Deflated annual sales (USD)	408763.7	1957976
St	Duration of Power Outages (days per year)	49.55	335.08
Vshk	Value share of capital (%)	0.0105	0.035
Vshl	Value share of labor (%)	0.102	0.158
Vshr	Value share of raw material (%)	0.802	0.030
Vshe	Value share of Electricity (%)	0.011	0.206
Vshn	Value share of nonelectric input (%)	0.075	0.11
Pl	Price of labor (per person)	227.0	447.7
Pk	Price of capital	3.91	122.9
Pm	Price of Material	99.16	16.0
Pe	Price of electricity (per KWh)	0.02	0.01
Pn	Price of nonelectric energy	0.911	0.02

Source:Computed based on WBES (2011 and 2015)

$$\begin{cases} 1, \text{ if} & Y^* > 0, \text{ a firm adopt} \\ 0, \text{ otherwise} & Y^* \leq 0, \text{ a firm dont adopt} \end{cases} \tag{8}$$

The dependent variable is a binary outcome which takes a value of one if firm invests on a generator and zero otherwise. The measure of power interruption in this specification is the number of power interruptions that firms face in a year. The decision to invest in a generator is assumed to depend on the frequency of power interruptions in which firm which faces frequent power interruption is expected to invest in a generator.

5 Empirical Results

5.1 Descriptive Statistics

Table (1) reports summary statistics of the total cost of goods (in USD), deflated annual sales in constant (USD), value share of factor inputs and input prices for each of the factors of production. To minimize the effect of outlier in the data, logarithmic transformation of the variables are used in estimation (Wooldridge, 2010).

Table (2) reports the average factor value shares across all sectors. Materials inputs share the highest percentage of average value shares across all sectors. All industries use electricity; thus, power interruptions affect them either directly or indirectly. The average value share of non-electric energy is greater than that of electricity. This is possibly due to fact that non-electric energy is costlier than electricity supplied from the public grid. This may also indicate the degree to which firms are affected by power shortages since firms resort to the use of non-electric energy during power outages.

In addition to production data, the empirical estimation requires firm level measures of

Table 2: Average Input Value Shares by Industry

	Value Share				
Sector	Capital	Labor	Mater.	Elec.	Nonel.
Garments, Leather and Textile	1.56	12.23	79.29	1.11	5.71
Food	0.745	9.64	82.40	1.05	6.15
Metals, Machinery and Equipments	1.568	11.43	80.32	0.71	5.95
Nonmetals, Plastics and Paper	1.234	18.17	71.96	1.17	7.45
Wood and Paper	2.048	17.70	70.87	1.14	8.12
Wholesaler, Retailer and Other Services	1.030	8.56	80.97	1.14	8.29
Electronics, Printing, and Publishing	0.765	10.21	80.75	0.70	7.56
Hotels and Restaurant	0.445	5.05	84.70	0.24	7.56
Transport	0.529	6.34	85.38	0.26	7.46
Construction	0.582	6.54	84.85	0.36	7.65
Chemicals and Others	1.513	11.06	79.08	0.68	7.65

Source:Computed based on WBES (2011 and 2015)

power shortages. A power shortage in this study is measured by the number of days that firm is without power supply from the public grid. The total outage time that firm face is obtained by multiplying the number of outages that firm face with its duration, and the total outage time is converted in days. An aggregate measure of power shortage, however, does not allow one to examine the impact of duration, frequency, and timing of the interruptions, which may affect the cost of production and behavioral response of the firm (Fisher-Vanden et al., 2015). To allow for separate analysis of the impact of duration and frequency of interruption on cost and behavioral response firms, total annual frequency and duration of interruptions are used as the measure of power shortage. Since the WBES do not provide the time of power interruption the study is constrained to analyze the impact of timing of interruptions on production cost and behavioral response of firm.

Table 3 reports summary of power outages both in hours and days per year. In 2011, a firm faces average power outage for 548 hours. The figure has increased to more than 1680 hours during 2015.

The probability[6] that firms face power interruption estimated by random effect probit model shows that firm size, ownership and export orientation does not affect the probability that firms face power outages. Only firm sub-sector is found to be significant. This is mainly because of the majority of firms in the sample, about 88%, found to have experienced power outages during the period considered. Thus, as further step to understand how power interruption varies among firms of a different characteristic, the frequency of interruptions that firms face in a year is estimated using Poisson and Negative Binomial models.

The result shows that a firm in the capital city and foreign-owned companies faces less frequent power interruption while firms in Nonmetals, Plastics, and Paper, Electronics and Publishing, Hotels and Restaurant face more frequent power cuts. The frequency of power interruption has increased in 2015 compared what was in 2011 indicated by the positive coefficient of year dummy.

[6]The results of probit and count data models are not reported here but available upon request

Table 3: Power Outages by Sector and Over Year

Sector		Outages (Hours/year)		Outages (Days/year)	
		Mean	Std. Dev.	Mean	Std.Dev.
Garments,Leather and Textiles		634.99	559.36	26.45	23.30
Food		1550.25	11252.92	64.59	468.87
Metals, Machinery and Equipments		581.57	623.59	24.23	25.98
Nonmetals, Plastics and Paper		725.64	988.04	30.23	41.16
Wood and Furniture		541.88	496.28	22.75	20.67
Wholesaler, Retailer and Other Services		1314.03	7560.28	54.75	315.1
Electronics, Printing, and Publishing		800.84	978.36	33.36	40.76
Hotels and Restaurant		740.20	884.84	30.84	36.86
Transport		2464.74	16924	102.7	705.2
Construction		536.07	711.1	22.33	29.62
Chemicals and Others		2483.5	14816.72	103.5	617.4
	2011	547.94	634.83	22.83	26.45
Year of Survey	2015	1682.81	10659.87	70.11	444.16
	Overall	1189.31	8041.92	49.55	335.08

Source: Computed based on WBES (2011 and 2016)

5.2 Econometric Result

The first column of Table 6 reports results estimated by 3sls based on the systems of equation in (1) -(2) along with the reduced form equation in (5). Because of adding-up restrictions in equation (3), from the five value share equations in (2), only four of them are linearly independent [7]. Thus, a value share of material is dropped from the systems of value share equation to have invertible covariance matrix. In all estimations, power outages and its interactions with input prices and output are instrumented by variations in hydro generations as represented in equation[8] (5).

In all cases, restriction[9] imposed does insignificant changes compared to the result from the main specification in column 1. Coefficients are almost similar to the results in column 1. However, result from the main specification is used for interpretation throughout the paper.

The result shows that power outage leads to substitutions among the factors of production. More specifically, power outages resulted in increased use of labor, material inputs and decreased use of capital and electricity. For instance, 1% increase in power outages leads to an increase the cost share of labor and material input by about 0.08% while cost shares of electricity and capital decreased by 0.40% and 0.045% respectively.

[7] If there are n value share equations, only n-1 of them are linearly independent because value shares always sum to unity (see Berndt, 1991: pp 371-372).

[8] Relevance test of the instrument shows a variation in a hydro generation is significant and positively explains the power outages even though some of the interaction variables found to be insignificant. In addition, the instrument passed Stock and Yogo weak test as the Wald test critical values pertaining to Stock and Yogo weak instrument test ranges from 5.5 to 16.4 which is less than Cragg and Donald (1993) minimum eigenvalue statistic.

[9] The restrictions imposed are tested using Wald test, however, it was found that the test rejects the constraints.

Table 4: Cost of Power Outages: Results from Three Stages Least Square (3SLS)

3SLS			CRS		No interaction	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
lnPklnOutage	-0.45***	0.0151	-0.061***	0.0144	-0.046***	0.013
lnPllnOutage	0.080***	0.0194	0.061**	0.0186	0.074***	0.017
lnPelnOutage	-0.402***	0.0849	-0.329***	00810	-0.357***	0.073
lnPnlnOutage	0.144	0.7728	-0.6904	0.6611	-0.194	0.577
lnPmlnOutage	0.095***	0.0117	0.093**	0.0115	0.093***	0.011
lnOutputlnOutage	0.194***	0.0648				
lnOutput	-0.1288	0.1858	1		0.412***	0.030
lnOutage	-2.203***	0.7793	1.352***	0.3631	-0.60***	0.293
Stock and Yogo Weak Instrument Test						
			10	15	20	25
2SLS size Nominal 5% Wald test			16.38	8.96	6.66	5.53
First Stage F stat			24.68			

Dependent variable of the model is log of cost by firm and year. * Significance at 10%, ** significance at 5% and *** significance at 1%. lnouatges is the log of power outages in days per year. Add up and symmetricity restrictions are imposed, value share for material inputs is dropped to have invertible covariance matrix and the estimation is made for the main specification in equation (1) along with cost shares of the four factors of productions. In the second column, constant returns to scale is imposed and coefficient associated interaction of output with outages is set to zero. The third column does not include interaction of output with outages. The lower panel of the table reports the instrument relevance test; the instrument passed the weak instrument test.

The significant and positive coefficient of material input at first seems to support the outsourcing hypothesis. However, for this hypothesis to hold, the estimated coefficient of electricity and nonelectric energy should be negative. To the contrary, the coefficient of other energy sources is positive and insignificant. Thus, the result does not support outsourcing hypothesis.

The result reported in Table (4) also shows that power outages have resulted in decreased use of capital. This seems supporting the improved energy consumption efficiency hypothesis. However, there is no observed decreased cost share of nonelectric energy in the result obtained. This makes the improved energy efficiency hypothesis fails to hold. The short time span of the data used in the study, however, may not be enough to show the capital adjustment of firms. The result also reveals that the cost share of labor increases in response power outages. This increased use of labor during the outage time possibly explains firms resort to a manual method which needs more human power in certain part of firm's production process during the time of power outages which could have been done with fewer workers when the firm is connected to power.

Referring to the second hypothesis, for the self generation hypothesis to hold, the estimated coefficient of electricity interacted with outages should be negative while that of other energy sources should be positive. Even though the estimated coefficients have their expected sign, the coefficient of other energy sources is insignificant. This shows the result obtained does not support self-generation hypothesis. To confirm this hypothesis, a separate regression of a self-generation indicator on firm characteristics and a measure of power outages is made and discussed in the next section.

The productivity effect of power outages depends on the factor neutral and factor bias effects. This is equivalent to testing the significance of $\alpha_0 = \alpha_1 = 0$ and $\beta_j = 0$ in our main cost specification. From the first column of Table (4), it is clear that the null hypothesis is rejected except for other energy sources. The net effect of power outages on a unit cost of production depends on the combination of this factor neutral and factor biased effects. The negative factor neutral effect of outages indicated by the negative coefficient of power outages alone shows an increase in power outages lowers firms' cost of production. This suggests that holding inputs constant, firms are induced to improve their overall productivity when faced power interruptions. This effect, however, diminishes with the output level of the firm indicated by the positive interaction of output and power outages. This shows that power outage is especially costly for large firms. This may be partly because of large firms use electricity dependent machinery and process than small firms.

5.2.1 Industry Heterogeneity

To account for heterogeneity among sectors in responding to power outages, the system of equations in (1) -(2) is estimated by 3sls separately for each sector[10]. A significant response to power outages in electricity share is observed in Food, Wholesaler and Construction sectors. The negative coefficient associated with the interaction of electricity and power outages in these sectors shows power outages reduces the cost share of electricity. The interaction coefficient of outages with electricity and material inputs is positive and significant for the majority of the sectors. This shows the cost share of material input increases in response to power outages. However, revisiting the earlier hypothesis, the result obtained is noisy.

5.2.2 Further Test on Self Generation of Electricity

As a further test of the self-generation hypothesis, a separate estimation is made using equations(7)-(8). Two measures of a self-generation indicators are used, the share of energy consumption coming from self-generation and indicator variable of self-generation which is a binary outcome which takes a value of one if a firm invests on a generator and zero otherwise. For firms that do not invest on a generator, the share of electricity coming from generator is zero. Thus, our dependent variable is zero for a substantial part of firms in the sample. For this model, Tobit is assumed as it is suited to model a problem of this nature (Verbeek, 2004). For the self-generation indicator, a probit decision adoption is assumed.

The measure of power outage used in both specification is the number of power interruptions that firm faces in a year. A year and industry fixed effects are included in the estimation. Determinants of firm decision to invest in backup energy (adopting of a generator) is estimated using the regression approach stated in equations (7)-(8) and reported in the first column of Table (7). Both pooled probit and Correlated Random Effect Probit (CREP) is estimated. However, the pooled probit estimator underestimates most of the coefficients because it does not control for time-invariant unobserved heterogeneity. The likelihood ratio test on the coefficient of ρ, which captures unobserved heterogeneity among firms, is significant. This indicates the importance of capturing unobserved firm heterogeneity in the model, CREP is more appropriate.

The positive and significant coefficient of a variable ownership shows foreign-owned com-

[10]The result will be available upon request

Table 5: Test for Self-Generation

Dependent Variable: Generator Ownership =1 if Own			Dependent Variable: Share of self-Generation		
Variable	Coef.	Std.Err.	Variable	Coef.	Std.Err.
Exporter (=1 if export)	0.173	0.188	Exporter	0.404	0.350
Ownership (=1 if foreigner)	0.483**	0.201	Ownership	0.867**	0.349
Region (=1 if capital city)	0.530***	0.123	Region	1.097***	0.230
Manufacturing	-0.121	0.210	Manufac.	-0468	0.404
Retail	-0.181	0.174	Retail	-0.298	0.349
Large	0.480***	0.151	Large	0.348	0.296
Medium	0.175*	0.262	Medium	0.673	0.490
lnAge	0.134	0.067	lnAge	0.438***	0.140
lnSize	0.205***	0.077	lnSize	0.289***	0.130
Number of Interruption (ln)	0.162**	0.071	ln(Fre.Inter.)	0.392***	0.133
ρ	0.319	0.111	ρ	0.214	0.090
Waldχ^2(21)=87.86 Prob>χ^2=0.00			Waldχ^2(21) = 200.78 Prob> χ^2= 0.000		
LR test of $\rho = 0$:$\bar{\chi}^2(01) = 7.47$ Prob $\geq \bar{\chi}^2$= 0.003					

*, **, *** shows significance at 10%, 5% and 1% respectively. CREP-Correlated Random Effect Probit. Ln(Freq.Inter) shows log of number of power interruptions. Two indicators of self-generation are used, generator ownership; estimated probit model and the share of electricity from generator; estimated by Tobit model

panies are more likely to own generators compared to domestically owned firms. The variable size in the model shows the number of full-time permanent workers in the company. The estimated coefficient of the variable is positive and significantly explains generator ownership. The effect of firm size on generator ownership is positive and indicates larger firms are more likely to invest in generators compared to small firms. This explains the degree to which these firms are vulnerable to power interruptions and their financial position to invest in the self-generation. Larger firms may suffer a huge loss for the same duration of power outages compared to small firms due to large capital and labor costs they incur. This substantiates previous findings in the literature (Steinbuks and Foster, 2010; Oseni and Pollitt, 2015)

In contrast to earlier findings export orientation does not affect firms' decision to own a generator. This may be due to a small number of exporters in the sample (only 8.5% of firms in the sample participate in export). The positive and significant coefficient of the variable region shows firms located in the capital city are more likely to own a generator compared to firms located in other regional states. There is also considerable variation in a generator ownership across sectors. The variable of interest in this regression, the frequency of power interruptions, is positive and significant under both regressions. More specifically, frequent power interruption increase the likelihood that firms invests in a generator and hence increases the share of electricity coming from the generator. Revisiting the earlier hypothesis, this supports self-generation hypothesis.

5.3 Robustness Check

The earlier analysis is based on the aggregate measure of power outages, the total number of days that a firm is without a power from the public grid. This aggregate measure, however, does not allow inferring the effect of frequency and duration of outages has on firms' cost of production and behavioral responses. To account for this issue, the study has utilized a total number of interruptions that a firm face in a year and the duration of outages separately.

Table 6: Cost of Power Outages: Results from Alternative Measures of Outages

	Frequency of Interruptions		Duration of Interruptions	
lnTC	Coef.	Std.Err.	Coef.	Std.Err.
lnPklnOutages	-0.020*	0.011	-0.021***	0.011
lnPllnOutages	0.027**	0.014	0.044***	0.017
lnPelnOutages	-0.208***	0.060	-0.224	0.084
lnPnlnOutages	-1.480	1.159	-1.008	1.115
lnPmlnOutages	0.052***	0.011	0.058***	0.009
lnOtputlnOutages	0.344**	0.158	-0.087	0.308
lnOutput	-1.208	0.726	0.682	1.178
lnOutages	5.301***	2.020	3.153	3.626

The first column reports the result when the measure of a power outage is the frequency of power interruptions in a year. Similar to the result from the aggregate measure of power outages, the interaction of price of other energy sources with power outages is insignificant. A comparable result is obtained in terms of sign and estimated magnitude for other inputs. The second column of the Table (6) reports the result when a power outage is measured by the duration power interruptions. A similar result is obtained for the factor biased effect of outages. However, the factor neutral effect of power outages and its composite effect are found to be insignificant. This implies other things the same; frequency of power interruptions makes firms to be more productive during outage time. This effect, however, dissipates with output level because of the positive composite effect outages. When the duration of power interruption is used as a proxy for power outages, these effect is found to be insignificant. This implies that frequency of interruptions is more detrimental to firms' productivity, particularly for large firms.

5.4 Regularity Conditions

For the estimated cost function consistent with economic theory, it is important to test if the estimated translog cost function satisfies certain regularity conditions mainly monotonicity and concavity. Monotonicity is tested by the sign of the predicted cost shares for each input at each observation. The result shows (Table 7) that there are observations with negative predicted cost shares implying cost is decreasing in the price of that input at that observation. However, this occurs at relatively few points compared to the size of observation in the data.

For the cost function to be concave in input prices, the own price elasticity for each input has to be negative. This implies the demand for factor input decreases as the input price increases. This is confirmed by the estimated the own-price elasticities of inputs given along the main diagonal of the lower panel of Table 8. This is consistent with microeconomic theory and the estimated own price elasticities have the correct negative sign.

Table 7: Predicted Cost Shares and price elasticity of inputs

Predicted cost Shares				
Model	Capital	Labor	Electricity	Nonelectric
Main	55	0	0	0
CRS	46	1	0	2
No interaction	59	0	3	0
Cross and own Elasticity of Inputs				
	Capital	Labor	Electricity	Nonelectric
Capital	-0.720	-0.204	0.042	0.055
Labor	-0.290	-0.629	0.277	0.091
Electricity	0.217	0.586	-0.447	-0.350
Nonelectric	0.282	0.379	-0.772	-0.588

The predicted cost shares of each factor inputs at each observation is given in the upper panel of the table; cross and own elasticity of factor inputs is reported in the lower panel of the table

Each pair of cross-price elasticity of input have the same sign, however; their magnitude is not same because they depend on input value share. This satisfies the symmetricity condition imposed.

5.5 Costs of Power Outages

Apart from analyzing how firms responds to power outages, it is important to examine how power outage affects firms' production cost. In particular, it is interesting to consider, how both marginal and total cost have changed between 2011 and 2015 due to the actual change of power outages.

The marginal cost of a power outage is computed using equation (6) and estimated factor neutral and biased coefficients reported in Table (8). The mean value of all explanatory variables including power outage used for the marginal cost calculation is reported in the first column of the Table 2 The overall marginal cost effect is the combination of both factor neutral and factor biased effects.

The overall marginal cost is \$ 1664 of which the factor biased effect is \$2670 and factor neutral effect -\$1006. This show that in substituting one factor of production for the other in response to power outages, the overall productivity losses from the marginal increase in power outages offsets the marginal gains from a marginal increase in power outages. The factor bias effect is decomposed into each of the factor inputs with a shift to other energy sources in response power outages increases the cost by \$73 only, while labor and material increases cost by \$2093 and \$1867 respectively. The decreased use of electricity and capital partially offset the increased firm's cost of production due to shift to labor, material, and other energy sources.

The second column of Table (8) reports the total cost due to the actual change in the power outages. To calculate this, the marginal cost of outages reported under the first column is multiplied by the actual change in the average duration of power outages from 2011 to 2015. The overall total cost has increased by \$78681 which is about 15% of firm's

Table 8: Marginal and Total Cost due to Outages (in USD)

Marginal Cost of Outages		Cost of Outages	% of Aggregate Cost
		(2011-2015)	(2011-2015)
Factor neutral	-1006.3	-47581	-9.0%
Factor biased	2670.5	126262	23.9%
Pk	-117.6	-5562	-1.0%
Pl	2093.3	98970	18.7%
Pe	-1245.9	-58906	11.1%
Pn	73.37	3468	0.6%
Pm	1867.4	88292	16.7%
Net effect	1664.16	78681	14.9%

The first column calculates marginal cost of power outages based on estimated coefficients and mean values of explanatory variables using equation (10). In the second, total cost of power outages due to the actual change in power outages between 2011 and 2015 is computed. The last column divides the total cost due to power outages in the second column by firm's aggregate cost.

aggregate[11] cost. Of this total, shift to labor and material inputs take the leading share which is about 19% and 17% of the aggregate cost respectively.

The result obtained shares similarities with findings of Fisher-Vanden et al. (2015) on the effect of power shortages on firm productivity. The increased in firms' cost of production due to power outage is about 15%, higher than that of Fisher-Vanden et al. (2015). This could possibly due to the differences in the nature of power shortage in China and Ethiopia; and severity of power shortages. However, unlike their findings, there is no evidence supporting outsourcing hypothesis. To the contrary, firms in the country were found to self generate electricity during power outages. This also a further evidence for the difference in the nature of power shortages in the two countries. Firms are willing invest in self generation if the power shortages sustains into the futureAlam (2013), while short term power shortages induces firms to outsource part of their production.

6 Conclusion and Policy Implications

The study has examined the characteristics of power outages and how firms in Ethiopia respond to power outages employing the WBES data of 2011 and 2015. A detailed description of the current power outage condition in the country and how it varies between firms of different size and its characteristics is made. The economic cost of power outages and firms' behavioral response to power interruption is examined using the translog cost function.

It was found that there is observed factor substitution in response power outages. The factor share of electricity and capital has decreased while that of labor and materials has increased in response to power outages. There is no evidence supporting outsourcing and improved energy hypothesis from the result obtained. Even though the result from cost

[11] Aggregate cost is obtained by taking average total cost of production for each year and aggregating over a year

estimation does not show evidence for self-generation, the results from both indicators of self-generation estimated by Tobit and probit models support self-generation hypothesis. Power outages were found to affect the firms' productivity negatively and the overall total cost due to outage has increased by about 15% of firm's aggregate cost from 2011 to 2015. This effect varies positively with output level suggesting that outage is costly particularly for large firms.

The following policy implications may emerge from the result obtained. The marginal cost of a power outage is found to be significant and firms self-generate electricity to cope-up with the power shortages. This shows there is a market for expensive and reliable power supply which suggests building more power plants as means to supply reliable electricity. This can be achieved in a number of ways. One could be removing subsidies and introducing optimal tariffs that are cost recovering for new grid investment. This could also attract international and private investors to the sectors[12] . The government should also introduce incentive regulations that encourage participation of private sector in the generation of electricity.

Generator ownership and the share of electricity coming from self-generation was found to positively correlated with firm size (generator ownership increases in moving from small to large firm). This is mainly because small and micro enterprises lack resources to invest in self-generation of electricity. Under this circumstance, shared generators could help a small and micro enterprise to access and use backup power during power outages. Thus, in the short run, the government should facilitate formalization of shared generators, particularly for industrial parks to avoid coordination problems among firms. The government should also make blackout schedule reliable as it may help firms to shift their productions from machinery dependent to manual methods and makes the necessary preparation.

[12]Currently, the government subsidies about 33% which shows buyers pays only 67% cost of electricity produced

Acknowledgment

I would like to thank Professor Massimo Florio and Andrea Bastianin of University of Milan for their helpful comments and suggestion. I also appreciate the comments received from the participants of seminar at Department of Economics Management and Quantitative Methods (DEMM) of University of Milan. All the remaining errors are mine.

References

Abeberese, A. B. (2012). Electricity cost and firm performance: Evidence from india . University, New York : Department of Economics, Columbia.

Abotsi, A. K. (2015). Foreign ownership of firms and corruption in Africa. *International Journal of Energy Economics and Financial Issues*, pages 647–655.

Adenikinju, A. F. (2003). Electric infrastructure failures in Nigeria: a survey-based analysis of the costs and adjustment responses. *Energy Policy*, 31(14):1519 – 1530.

Alam, M. (2013). Coping with blackouts: Power outages and firm choices.

Allcott, H., Collard-Wexler, A., and D.O'Connel, S. (2014). How do electricity shortages affect industry? evidence from India. Technical Report Working Paper 19977, National Bureau of Economic Research .

Andersen, T. B. and Dalgaard, C.-J. (2013). Power outages and economic growth in Africa. *Energy Economics*, 38(Supplement C):19 – 23.

Balducci, P. J., Roop, J. M., Schienbein, L. A., DeSteese, J. G., and Weimar, M. R. (2002). Electrical power interruption cost estimates for individual industries, sectors, and u.s. economy. Technical Report PNNL-13797, U.S. Department of Energy.

Beenstock, M., Goldin, E., and Haitovsky, Y. (1997). The cost of power outages in the business and public sectors in Israel: Revealed preference vs. subjective valuation. *Energy Journal*, 18(2):39–61.

Bental, B. and Ravid, S. A. (1982). A Simple Method for Evaluating the Marginal Cost of Unsupplied Electricity. *The Bell Journal of Economics*, 13(1):249–253.

Billinton, R., Wacker, G., and Wojczynski., E. (1982). Customer damage resulting from electric service interruptions. Technical Report R&D Project 907 U 131, Prepared for the Canadian Electrical Association.

Castro, R., Faias, S., and Esteves, J. (2016). The cost of electricity interruptions in portugal: Valuing lost load by applying the production-function approach. *Utilities Policy*, 40(Supplement C):48 – 57.

Caves, D., Herriges, J., and Windle, R. (1992). The cost of electric power interruptions in the industrial sector: Estimates derived from interruptible service programs. *Land Economics*, 68(1):49–61.

de Nooij, M., Lieshout, R., and Koopmans, C. (2009). Optimal blackouts: Empirical results on reducing the social cost of electricity outages through efficient regional rationing. *Energy Economics*, 31(3):342 – 347.

Federal Democratic Republic of Ethiopia (2012). Scaling - up renewable energy program: Ethiopia investment plan. Technical report, Federal Democratic Republic of Ethiopia (FDRE), Minstry of Water and Energy., Addis Ababa, Ethiopia.

Fisher-Vanden, K., Mansur, E. T., and Wang, Q. (2015). Electricity shortages and firm productivity: Evidence from China's industrial firms. *Journal of Development Economics*, 114:172–188.

Iacovone, L., Ramachandran, V., and Schmidt, M. (2014). Stunted Growth : Why Don ' t African Firms. Technical report.

International Energy Agency (2012). World energy outlook. Technical report, International Energy Agency (IEA), Accessed onlineDeceomber, 2016 from: www.worldenergyoutlook.org.

International Energy Agency (2014). Africa energy outlook:a focus on energy propects in sub saharan africa. world energy outlook. Technical report, International Energy Agency (IEA).

Moyo, B. (2012). Do power cuts affect productivity? a case study of nigerian manufacturing firms. *International Business & Economics Research Journal*, 11(10):1163–1174.

Nyanzu, F. and Adarkwah, J. (2016). Effect of power supply on the performance of small and medium size enterprises: A comparative analysis between smes in tema and the northern part of Ghana. Technical Report 74196, Munich Personal RePEc Archive, p. MPRA Paper.

Ontario, H. (1980). Ontario hydro survey on power system reliability: Viewpoint of farm operators. Technical Report Final Report No. R&U 78-5.

Oseni, M. O. and Pollitt, M. G. (2013). The economic costs of unsupplied electricity:evidence from backup generation among African firms. Technical Report 1351, Cambridge Working paper in Economics.

Oseni, M. O. and Pollitt, M. G. (2015). A firm-level analysis of outage loss differentials and self-generation: Evidence from African business enterprises. *Energy Economics*, 52(Part B):277 – 286.

Pasha, H. A., Ghaus, A., and Malik, S. (1989). The economic cost of power outages in the industrial sector of Pakistan. *Energy Economics*, 11(4):301 – 318.

Reinikka, R. and Svensson, J. (2002). Coping with poor public capital. *Journal of Development Economics*, 69(1):51 – 69.

Scott, A., Darko, E. Lemma, A., and Rud, J. (2014). How does electricity insecurity affect businesses in low and middle income countries. Technical report, London.

Steinbuks, J. and Foster, V. (2010). When do firms generate? Evidence on in-house electricity supply in Africa. *Energy Economics*, 32(3):505–514.

Verbeek, M. (2004). *A Giude to Modern Econometrics*. John Wiley and Sons, Ldt, Erasmus University Rotterdam, second edition.

Wooldridge, J. (2010). *The Econometrics of cross-sectional and panel data*. The MIT Press, Cambridge, Massachusetts., London, England, second edition.

World Bank (2015). Electricity connections and firm performance in 183 countries. Technical report, World Bank.

World Bank (2017). Doing business 2018: Reforming to create jobs. Technical Report 15, World Bank.