A Firm Level Analysis of Outage Loss Differentials and Self-Generation: Evidence from African Business Enterprises

Musiliu O. Oseni[1] and Michael G. Pollitt

Judge Business School,

University of Cambridge, UK, CB2 1AG

Abstract

This study examines the outage loss differential between firms that engage in backup generation and those that do not. Unmitigated outage losses were estimated to be US$2.01–US$23.92 per kWh for firms engaging in self-generation, and range from US$1.54–US$32.46 per kWh for firms without self-generation. We also find that firms engaging in self-generation would have suffered additional 1–183% outage losses had they not invested in self-generation. On the other hand, firms without self-generation would have reduced their outage losses by around 6–46% if they had engaged in self-generation. Further analyses however reveal that, although engagement in self-generation reduced outage losses, a firm engaging in self-generation may still suffer a greater unmitigated outage loss relative to a firm without a backup generator. The relative outage losses depend on the relative vulnerability of the operations of the two sets of firms to power interruption, and the relative generating capacity of a self-generating firm to its own required electricity loads. Policy reforms that allow firms, whose operations are highly vulnerable to outages, to make a binding contract with utilities in order to get preferential supply are recommended.

Keywords: Self-generation; outage loss; firms; value of lost load; Sub-Saharan Africa; South Asia

JEL Codes: L94, Q41, L6, L8

[1] Corresponding author: musloseni@yahoo.com, moo23@cam.ac.uk (M.O. Oseni); m.pollitt@jbs.cam.ac.uk (M. G. Pollitt).

1. Introduction

Despite the significance of electricity for economic development, poor electricity infrastructure is one of the major challenges that firms in developing countries face on a daily basis. The poor state of electricity infrastructure has undermined the productivity and competitiveness of the business sectors in the Sub-Saharan African and South-Asian regions. The lack of quality electricity infrastructure has been found to have significantly reduced firms' total factor productivity in Sub-Saharan Africa (Arnold, Mattoo and Narciso, 2008; Escribano, Guasch and Pena, 2009), while the possession of a generator has a significantly positive effect (Arnold et al., 2008). Indirect costs, of which energy costs account for the largest share, contribute 13–15% of the total costs for firms in South Asia and 20–30% of the total costs for firms in most Sub-Saharan Africa countries (Eifert, Gelb and Ramachandran, 2008). It is estimated that the use of electricity can raise productivity per worker by 50–200% for microenterprises in Kenya, depending on the item being produced (Kirubi et al., 2009).

In a survey of manufacturing firms by the Asian Development Bank (2002), almost 30% of Indian firms, 40% of Pakistani firms, 41% of Sri Lankan firms and over 70% of firms in Bangladesh reported that the poor state of the electricity network was a major constraint to their operations. Surveys of business enterprises between 2006 and 2014 by the World Bank Enterprise Survey (WBES) showed that around 43% of firms in South Asia identified electricity as a major constraint.[2] A similar pattern was observed in Sub-Saharan Africa. Between 2006 and 2010, more than 50% of Sub-Saharan African firms identified electricity as the major constraint to their businesses, compared to just 27.8% that named transportation as the most critical problem (WBES, 2012). In 2007, the average Sub-Saharan African firm suffered a loss of economic activities for around 77 hours per month due to power outages. The situation is even more serious in some countries and particularly when compared with other developing regions of the world. For instance, the average firm in Nigeria experiences an outage of 8.2 hours 26.3 times in a typical month. This translates as a loss of economic activity for 216 hours (nine days) on average every month, assuming that there are no palliative measures. Meanwhile, the average firm in East Asia or the Pacific experiences power outages of

[2] World Bank Enterprise Survey: http://www.enterprisesurveys.org/data/exploretopics/infrastructure#south-asia--7. Accessed on 18/09/2014.

less than 15 hours per month. Similarly, a typical firm in Latin America or the Caribbean only suffers electricity outages of around six hours per month (World Bank, 2012).

Given the prevalence of power outages, one of the strategies most commonly adopted by African firms is to invest in self-generation (i.e. complementary capital). Many end users of electricity, from small to large enterprises, now operate small- to medium-sized plants with capacities ranging between 1 MW and 700 MW for their own use (Karekezi and Kimani, 2002). Self-generation has increased and now accounts for more than 20% of generation capacity in some countries in Africa (Foster and Steinbuks, 2009).

Although the use of backup generators is common among African firms because of the poor public provision of power, a number of studies have argued that a firm's size and export participation significantly influence the decision to own a generator (Steinbuks and Foster, 2010). However, investing in a backup generator does not always guarantee the complete mitigation of outages (Beenstock et al., 1997): a firm may have a backup and still suffer outage losses. These may take the form of restart costs or losses due to the inability of the backup method to generate and supply the total power load required by the firm. Unmitigated outage losses refer to the losses incurred by a firm as a result of power interruptions; for a firm that self-generates electricity during power outages, unmitigated costs or losses can arise due to inadequate self-generation capacity.

This study examines the unmitigated outage loss differential between firms that engage in self-generation and those that do not. We investigate these issues by using data on the backup generation used by over 4,400 firms operated in eight African and two South-Asian countries in 2007. We find that firms engaging in self-generation would have suffered additional 1–183% outage losses had they not engaged in self-generation. However, we also find that though engagement in self-generation reduced firms' vulnerability to power outages and consequently reduced their outage losses, it did not (in some countries) automatically make them more immune to power outages than firms without self-generation. The relative unmitigated outage loss differential depends on the relative vulnerability of firms' operations to power outages and the self-generation capacity of a firm relative to its required loads. Nevertheless, we find that firms engaging in self-generation would have suffered additional outage losses had they not invested in self-generation. On the other hand, firms without self-generation would have reduced their outage losses by around 6–46% if they had engaged in self-generation.

The remainder of this paper is structured as follows. The next section reviews the literature. Section 3 presents the theoretical and empirical frameworks. Section 4 discusses the data. This is followed by a discussion of the empirical results in Section 5. The last section describes the conclusions.

2. Literature Review

A number of studies have examined the impacts of poor quality electric infrastructure on firm productivity and output growth in developing countries. They all suggested that low quality electricity provision significantly affect firms operation and productivity. Andersen and Dalgaard (2013) demonstrated that poor power infrastructure in Sub-Saharan Africa leads to a substantial growth drag. Diboma and Tatietse (2013) estimated the costs of power interruptions to Cameroonian industries and concluded that advance interruption notices could help reduce outage costs by approximately 20 – 33%. Fisher-Vanden, Mansur, and Wang (2015) demonstrated that increasing electricity scarcity raised the unit production cost for Chinese firms by 8%. Allcott, Collard-Wexler, and Connell (2014) showed that power shortages reduced average output of Indian manufacturing firms by about 5%, but had much smaller effects on productivity because most inputs can be stored during outages.

Adenikinju (2003) analysed the economic cost of power outages in Nigeria. Using the revealed preference approach on business survey data, he estimated the marginal cost of power outages to be in the range of USUS$0.94–3.13 per kWh of lost electricity. Given the poor state of electricity supply in Nigeria, the study concluded that power outages imposed significant costs on business. Small-scale operators were found to be the most heavily affected by infrastructure failures. Reinikka and Svensson (2002) examined the impact of poor provision of public capital goods on firm performance in Uganda. Using a discrete choice model on business survey data, they found that an unreliable and inadequate electricity supply significantly reduced investment in productive capacity. Firms invest in auto-generation when public provision is unreliable. The direct cost of this action, however, is that less productive capital is installed. In addition, there are diseconomies of scale in self-generation.

Steinbuks and Foster (2010) analysed the determinants of self-generation and its costs using business survey data from 25 African countries. They estimated two binary choice models of generator ownership and the capacity thereof. They found that the size of the firm and export orientation played more important roles than reliability of supply in the decision to invest in a backup generator. The study further attempted to compare the outage losses suffered by firms with and without a generator. It used the cost of self-generation as a measure of outage losses for firms with a backup, while outage losses for non-backup firms were measured as the ratio of the reported outage loss to outage time. The study concluded that firms owning generators suffered smaller outage losses. However, the study did not account for the fact that investing in self-generation might not entirely eliminate the possibility of suffering from power outages. The implication is that the estimates of outage losses for backup firms were underestimated (unless the firms were fully backed-up), because such estimates reflect only the mitigated outage losses.

We evaluate the (unmitigated) outage loss differential for firms with generators compared to those without by accounting for several other characteristics that might simultaneously affect firms' outage losses. In addition, we use counterfactual analyses to estimate what the outage losses by a backup firm would have been had it not invested in backup generation, and vice versa.

3. Methodology

3.1 Theoretical Model

A simple two-period model is presented below to guide the empirical specification. The objective is to show how firms that invest in backup generation (backup firms) may still suffer greater unmitigated outage losses than those without such investments (non-backup firms), even though self-generation helps them reduce their potential sales/output losses. The salient features of the model is the assumption that firms can invest in backup generation to (partly) cope with inadequate public power supply but that this does not mean that they suffer smaller unmitigated losses than non-backup firms, even though they suffer smaller losses than if they did not self-generate. Consider a firm that would have an output/sale of size Q per hour if it avoided a power outage loss (where Q is measured in USUS$). Output/Sale Q is subject to a loss amount $L_q = \lambda Q$ due to an hour interruption in power supply, where λ is a measure of the degree of vulnerability of the firm's operations to power outages. The vulnerability of a firm to power outages is determined by its size and the nature of its operation which can be reflective of the sector in which it operates and the reliance of its operation on electricity service. We assume, for simplicity, $\mathrm{L_q} = 0$ (indicating zero outage loss in the absence of service interruption), and $\mathrm{L_q} = \lambda Q$ (indicating the level of outage loss when there is an hour interruption in supply). $L_q \leq Q$ and $\lambda \leq 1$. $\lambda = 1$ if the firm's total operations are completely vulnerable to power outages.[3]

There is uncertainty about the availability and quality of publicly provided electricity. A risk-neutral firm therefore has to decide whether to invest in self-insurance activity – backup generation – in order to mitigate the size of an outage loss should an outage occur. Let G denote the kW of the installed generator such that the (unmitigated) loss function is:

$$L = L_q - L(G).$$

The effect of self-generation on the outage loss size is determined via the function $L(G)$, which relates the size of the outage loss to the level of self-generation. It is assumed that outage loss is related to backup generation as $L'(G) < 0$, and $L(0) = L_q$ is the loss sustained in the absence of mitigation action. We assume a two-period model. In the first period, there is an investment of kG in a backup generator, where k denotes the unit price (US$) per kW. In the second period, there is a possibility of an unanticipated power interruption of t hours. The discount rate (%) is $0 < r < 1$, δ denotes the depreciation rate (%) of the generator and m represents the maintenance cost (US$/kW). On the basis of the forgoing information, the yearly user cost (US$/kW) per unit installed generating capacity (net of fuel or running costs) can be denoted as:

$$\mu = k(r + \delta) + m(1 + r).$$

[3] Another possible condition is $\lambda = 0$: a situation where the firm's operations are totally immune to power outages.

Thus, μG is the yearly capacity cost (in US$) to the business of having installed G kW of backup generation, when measured in the second period. Assume the generator is used to capacity during an outage and that the annual outage times is T, the yearly running costs (mainly fuel costs) in US$ can be written as vTG, where v denotes fuel costs per kWh and T is the expected yearly total duration of outages measured in hours per year. We assume the constant (periodic) marginal productivity of the backup generator is α such that per hour loss (US$) is:

$L = L_q - \alpha G,$

We assume α is greater than v because it is obvious running a backup generator would not be worthwhile if the (marginal) operating cost per kWh is greater than the (marginal) benefit per kWh.

Suppose there are two identical firms who face the same level of unreliability but only differ by the degree of their vulnerability to power outages. At the end of Period 2, two possible histories need to be considered for each firm given yearly service interruption, T:

Firm 1

1. The firm invests in a generator and in this case the firms' problem is to minimise the unmitigated outage loss per annum: The yearly expected unmitigated outage loss can be written as:

   $$L_{1g} = \lambda TQ + \mu G + vTG - \alpha TG \quad (1)$$

2. The firm does not invest in a backup generator and in this case the firm's unmitigated outage loss becomes:

   $$L_1 = \lambda TQ \quad (2)$$

At the end of Period 1, the firm makes a decision whether or not to install a backup generator. The optimal choice depends on the initial information on the availability (and quality) of publicly provided electricity and the firm's vulnerability to poor supply. The condition for installing a generator at the end of Period 1 is:

$$L_{1g} = \lambda TQ + \mu G + vTG - \alpha TG \ \leq L_1 = \lambda TQ \quad (3)$$

Solving and rearranging equation (2.3) yields:

$[\mu + vT] \leq \alpha T$ or $\alpha T \geq [\mu + vT]$ (4)

Equation (4) suggests that a firm (Firm 1) would decide to invest in backup generation if, given the unreliability of supply, the marginal productivity of a backup generator (i.e. the marginal reduction in the potential outage loss) is greater than or equal to the user cost of self-generation. Similar to this is the extra investment in backup generation, which can be obtained by minimising equation (1) with respect to duration of outage:

$$\partial L_{1g}/\partial T = vG - \alpha G = 0$$

$$v = \alpha$$

At the optimal level of self-generation, the potential marginal benefit of self-generation, α, (given the interruption of supply) must be as great as the marginal (operating) cost of self-generated electricity. In other words, a risk-neutral firm invests in (extra) self-generation only if the potential benefit (reduction in the outage loss) is at least equal to the marginal cost of self-generation.

Firm 2

Following on from the above, the two possible histories for Firm 2 are:

1. It invests in a backup generator and in this case suffers a loss:

$$L_{2g} = \theta TQ + \mu G + vTG - \alpha TG \quad (5)$$

2. It does not invest in a backup generator and in this case suffers a loss:

$$L_2 = \theta TQ \quad (6)$$

Suppose Firm 1 invests in self-generation and suffers the unmitigated outage loss as expressed in equation (1) and that Firm 2 does not invest in self-generation and incurs the unmitigated outage loss represented by equation (6). If the two firms are identical and experience the same level of interruption but differ only in their degree of vulnerability to outages, Firm 2 can still suffer a smaller unmitigated outage loss than Firm 1 if its (Firm 2's) vulnerability to power outages is lower (i.e. if $\theta < \lambda$), even though firm 1 is better off self-generating electricity than if it (firm 1) did not invest in self-generation.

Proof:

.

Suppose that there is an hour power interruption, in which case T= 1. The unmitigated outage loss for Firm 1, having invested in self-generation, will depend on the degree of vulnerability of its operations to outages and the relative efficiency of the backup generator in terms of the generation cost:

$$L_{1g} = \lambda Q + [\mu + v - \alpha]G \qquad (7)$$

Similarly, the unmitigated outage loss for Firm 2, assuming it does not invest in backup generation in the face of an hour power outage (i.e. when $T = 1$), will depend on its vulnerability to outages:

$$L_2 = \theta Q \qquad (8)$$

It follows from equations (7) and (8) that controlling for everything else, a firm that has invested in backup generation may still suffer a higher unmitigated outage loss relative to a non-backup firm if its operations are more vulnerable to power outages and its (investment in) self-generation capacity is not large enough to significantly reduce the potential outage loss.

3.2 Empirical Model Specification

This section provides the empirical specification in line with the theoretical model presented in the previous section. We use an exogenous switching treatment effect regression in a counterfactual framework to estimate the causal of self-generation on outage losses. A pooled regression is not appropriate in assessing the outage loss differential between firms engaging in self-generation and those that do not. This is because a pooled regression model estimation assumes that the set of covariates have the same impact on firms' outage losses regardless of their self-generation status (i.e., a common slope coefficient for both groups). By implication, pooled regression assumes that there is no interaction between the generator ownership variable and other explanatory variables, indicating that self-generation only has an intercept effect or a parallel shift effect, which is always the same irrespective of the values of other covariates that determine unmitigated outage loss. However, numerous variables might have different impacts for firms engaging in self-generation and those that do not.

The exogenous switching treatment effect regression framework can capture such interactions between firms' self-generation status and other characteristics by estimating two separate equations – one for firms engaging in self-generation and one for firms that do not—which are specified as follows:

$$L_s = \boldsymbol{X}_s \beta_s + \varepsilon_s \quad if\ G = 1 \tag{9}$$

$$L_f = \boldsymbol{X}_f \beta_f + \varepsilon_f \quad if\ G = 0 \tag{10}$$

where G is a dummy variable that denotes whether a firm engages in self-generation (i.e., has a backup generator); L_s and L_f are the reported outage losses by a backup (self-generate) and non-backup firm respectively; and $\boldsymbol{X}_i$ is a vector of firm characteristics that are thought to affect a firm's outage loss. β_s and β_f are vectors of parameters while ε_s and ε_f are the disturbance terms.

Although the effects of power outage and other firms' characteristics can be estimated from equations 9 and 10, the equations may not allow us to directly examine the impact of self-generation on outage loss for both groups of firms because their characteristics could be different. We address this issue by estimating the counterfactual unmitigated outage loss level for each group — that is, what the unmitigated outage level of non-backup firms would have been if the coefficients on their characteristics had been the same as those on the backup firms' characteristics, and vice versa. In order to determine the effects of self-generation status on outage losses of self-generating and non-backup firms, we compare the expected unmitigated outage losses under the counterfactual and actual scenarios. The actual and counterfactual expected unmitigated outage losses for backup and non-backup firms are defined as follows

$$E(L_s|G = 1) = \boldsymbol{X}_s \beta_s \tag{11a}$$

$$E(L_s|G = 0) = \boldsymbol{X}_f \beta_f \tag{11b}$$

$$E(L_f|G = 1) = \boldsymbol{X}_s \beta_f \tag{11c}$$

$$E(L_s|G = 0) = \boldsymbol{X}_f \beta_s \tag{11d}$$

where E is the expected operator. Eqns. (11a) and (11b) represent the unmitigated outage losses for self-generating and non-backup firms actually observed in the sample, respectively, while Eqns. (11c) and (11d) are their respective counterfactual expected unmitigated outage losses. The use of these conditional expectations, combined with consideration of the self-generation variable as a treatment variable, allow us to calculate the causal effects of self-generation on outage loss.

For empirical purposes, the outage loss equations (9–10) estimate the natural log of a firm's (unmitigated) annual outage loss obtained from the World Bank Enterprise Survey.[4] Similarly, annual outage time T is converted into days by dividing the reported annual outage times by 24 hours. The exogenous variables in the outage loss regressions (9–10) include the reported (annual) outage time experienced, (converted into days by dividing the reported figures by 24), the natural log of annual electricity consumption, and firm characteristics such as size, age of business, export engagement, sector-specific dummies and regional dummies (i.e. country dummies). However, data on firms' generator capacities, firms' required electricity loads as well as information on how firms run (use) their generators relative to outage times are not available.

4. Data

This study makes use of a dataset compiled from WBES and collected from business enterprises operating in Sub-Saharan Africa in 2007.[5] The WBES capture firms' perceptions of the obstacles to their growth, the relative significance of various constraints to increasing employment opportunities and productivity and the effects of a country's investment climate on the international competitiveness of its firms. The WBES follow a stratified random sampling method,[6] and focus on the weaknesses in an economy's infrastructure, law enforcement, public administration and regulatory framework. The major advantage of the WBES database is the provision of both managers' opinions regarding the (un)reliability of electricity supplies and the economic data relevant for structural microeconomic analysis.

[4]Data on outage losses are first converted to US dollars (US$) from the local currency using the market exchange rates obtained from World Bank Development Indicators. Then, the obtained outage loss in US$ is winsorised at the 90th percentile (upper tail) to avoid measurement errors and extreme values.

[5] Detailed information on the WBES can be found at http://www.enterprisesurveys.org/.

[6] The sample is stratified on the basis of firm location, industry and size. However, because most countries have more small and medium firms than large firms, the surveys may oversample large enterprises.

4.1 Sample Selection

The entire WBES dataset comprises information from surveys of over 130,000 business enterprises in more than 130 economies. The main analysis in this study, however, is restricted to a selection of 2,665 firms from eight Sub-Saharan African countries. These samples were chosen to ensure better compliance with the assumptions of the theoretical model and empirical specification. In particular, the following sample selection criteria were used.

First, because one of the underlying assumptions of the theoretical framework discussed in the previous section is that a firm embarks on self-generation in order to prevent outage losses, the sample should therefore be restricted to regions with low power supply reliability. One of such regions is Sub-Saharan Africa, where the main reason for backup generator ownership is the poor quality of the public power infrastructure (see Foster and Steinbuks, 2009).

Second, for identification, our empirical models require the exogeneity of power outages. To satisfy the exogeneity requirement, the sample should be restricted to regions where active regional policies that provide considerable public capital and create incentives for businesses to stimulate growth have hardly been implemented. Sub-Saharan African countries satisfy this condition because the implementation of such investment policies has been limited by political instability, corruption, ethnic fragmentation and tribal problems (Easterly and Levine, 1997). In particular, frequent power outages experienced in the region are exogenous to business managerial capability and reflect inefficiency in power sector institutions, which are mainly characterised by unreliability of electricity supply, low capacity utilisation, poor maintenance, high vandalism of transmission and distribution networks and high transmission and distribution losses, among other problems (Karekezi and Kimani, 2002; Oseni, 2011).

Third, because our analysis relies on cross-sectional data it is essential that the state of electricity supply at the time of the survey be correlated with the quality of the power supply at the time of installing a backup generator. Therefore, the sample should also exclude developing countries where economic and structural reforms have led to significant improvements in public power supply and a considerable reduction in power outages. In Sub-Saharan Africa, despite the introduction of some forms of reform in the power sector since the 1990s, only limited progress has been made (Eberhard et al., 2008). Unlike the other countries, South Africa started experiencing serious power outages in 2007 after a long period of high reliability, which suggests that the conditions of stable quality are not met. However, the fact that the majority of South African firms that reported having a backup generator would most likely purchase it during the period of unreliability (i.e., 2007) still satisfies the condition of correlation between the state of electricity supply at the time of the survey (2007) and the quality of the power supply at the time of installing a backup generator.

Lastly, to minimise the impact of measurement errors, our analysis was limited to eight countries: Ghana, Kenya, Mali, Mozambique, Nigeria, Senegal, South Africa (reference case) and Zambia. These countries were selected because the surveys for these countries were conducted in the same year (2007) using the same survey instruments. We excluded firms that reported zero outage losses. This was done to exclude firms that were naturally immune to outages and those that did not experience power service interruptions.

4.2 Data Description

This section discusses the variables used for the empirical analysis. Table 1 presents the variables at the country level for the eight countries.[7] In the WBES dataset, surveyed firms reported their annual electricity expenditure in local currency. This expenditure was converted to US dollar amount using the 2007 market exchange rate. The converted expenditure was then converted into electricity consumption in kWh using data on electricity prices (US$) obtained from UPDEA (UPDEA, 2009). The reliability of the power supply is measured by the number of days per year when firms experienced power outages. To obtain this variable, the reported annual outage times (in hours) were divided by 24 hours. Thus, annual outage times (i.e., the reliability of power supply) indicate 24 hours interruption – an equivalence of a day. The table shows that majority of countries had a very unreliable power supply, with an average number of days with power outages per annum of at least five. The table also demonstrates that there is considerable variation across countries in the average duration of power outages, ranging from more than five days in South Africa to 35 days in Senegal, 61 days in

[7] Further details on the variables are provided in Appendix A.

Ghana and 110 days in Nigeria. It is therefore not surprising that 86% of the surveyed firms in Nigeria and 51% of firms in Senegal owned a backup generator in 2007. Despite the relative level of power reliability in South Africa, around 28% of the firms surveyed still reported having a backup generator. The data reported in Table 1 also indicates that the unreliable electricity supply creates serious challenges for the firms operating in Africa, accounting for around 3% of lost sales in South Africa and around 10% in Nigeria. Even in Zambia, with its relatively stable electricity supply, over 6% of lost sales were attributed to power outages. Export engagement is measured by a dummy variable indicating that a firm reported exporting at least part of its product. Table 1 shows that a sizeable number of firms in our analysis engaged in exports, with proportions ranging from 16% in Nigeria to 50% in Kenya.

Table 1: Descriptive statistics

Country	Share of firms owning a generator		Annual Outage times (converted into days)		Annual outage loss as a % of annual sales		Engaged in export		Annual electricity consumption (ln)	
	mean	sd	mean	sd	mean	sd	Mean	sd	mean	Sd
Ghana	0.25	0.44	60.67	37.08	7.37	6.64	0.25	0.23	8.43	1.90
Kenya	0.63	0.48	14.11	18.12	6.07	7.79	0.43	0.50	10.95	2.25
Mali	0.32	0.47	9.81	18.00	5.68	5.86	0.17	0.38	8.82	1.65
Mozambique	0.18	0.38	18.18	19.62	4.39	6.37	0.05	0.22	9.73	1.86
Nigeria	0.86	0.35	110.30	80.98	9.92	10.33	0.03	0.16	8.71	1.27
Senegal	0.51	0.50	34.67	47.07	8.08	6.83	0.16	0.37	9.44	1.86
South Africa	0.28	0.45	5.44	11.03	2.70	3.53	0.37	0.48	13.60	1.94
Zambia	0.12	0.32	8.14	12.56	6.32	8.47	0.25	0.43	11.48	1.99

sd = standard deviation.

5. Empirical Results

5.1 Coefficients Estimates

Table 2 summarises the results from the exogenous switching regression approach described in section 3.2. The first column reports the factors that might affect firms' decision to invest in self-generation.[8] The coefficients on the electricity consumption variable were positive and significant, indicating that firms using large amounts of

[8] This was estimated using probit model.

electricity were more likely to engage in self-generation. The effect of firm size was positive and significantly increased the probability of self-generation: the larger the number of full-time employees, the greater the probability that a firm would invest in self-generation. This indicates that larger firms are more likely to own a generator when public provision is unreliable. This could reflect these firms' vulnerability to power outages as well as their ability to finance self-generation. All things being equal, larger firms that experienced an outage of a certain duration were more likely to suffer greater losses than smaller firms that experienced an outage of the same duration. Moreover, larger firms were more likely to have access to external funds to finance their operations, including self-generation.

There was also considerable variation in generator ownership across the regions and sectors (Table 2). The results thus show that generator ownership was greatly affected by firm characteristics such as size, sector, electricity consumption, export participation and the business operating environment as measured by country dummy.

For the outage loss equations, the coefficients on the electricity consumption variable were positive and significant, indicating that firms using large amounts of electricity were more likely to suffer higher outage losses. Moreover, the estimated coefficient of electricity consumption in the outage loss equation for backup firms was approximately 4% higher (0.32 for backup and 0.28 for non-backup) than the corresponding coefficient in the outage loss equation for non-backup firms. This could reflect the differences in the energy intensiveness of the operations of the two sets of firms to power outages. A comparison of the estimated coefficients for reliability of power supply showed that power outages significantly affected firms' losses. The estimated coefficient of the days of power outages for non-backup firms was 1.5 times higher than the corresponding coefficient in the equation for backup firms. All other things being equal, a 24 hours' (or 1 day's) increase in outage time raised annual outage loss suffered by an average backup firm by 0.2%. On the other hand, an average firm without a backup that experienced an additional one day of outage suffered about 0.3% increase in annual outage loss.

Regarding the other explanatory variables, an increase in the number of employees was associated with an increase in outage losses. This was evidenced in the estimated coefficients for the natural log of the number of employees working in a firm. Regardless of backup ownership, the larger a firm was, the greater its power outage loss. A 10% increase in the number of workers was associated with 4.3% and 7% increases in outage losses suffered by an average backup and non-backup firm respectively. However, a comparison of the estimates suggests that, controlling for other factors, larger backup firms were likely to suffer smaller outage losses than larger non-backup firms. Country dummies were statistically significant for several countries and showed that, when controlling for other factors, backup firms were more likely to suffer greater outage losses than non-backup firms. Although firms operating in non-metals, garment and textiles, as well as chemical and pharmaceutical industries without investing in self-generation were more likely to suffer greater outage losses than backup firms operating in the same industries, firms in food and beverages, metals and machinery, electronics, retails, other manufacturing, and other services industries did not exhibit significant unmitigated outage loss differentials based on their self-generation status.

Table 2: Regression of (unmitigated) outage losses by self-generation status – Africa

Dependent variable	Backup status		Outage loss (ln)			
	marginal effects		Backup Firms		Non-backup Firms	
Electricity consumption (ln)	0.02***	(0.01)	0.32***	(0.03)	0.28***	(0.04)
Days of power outages	0.0001	(0.0001)	0.002***	(0.0006)	0.003***	(0.001)
Employment (ln)	0.07***	(0.01)	0.43***	(0.07)	0.70***	(0.07)
Age	-0.0001	(0.0002)	0.0003	(0.001)	0.0003	(0.001)
Export engagement	0.06**	(0.02)	-0.07	(0.14)	-0.04	(0.13)
Small*ln days of outages			-0.11***	(0.03)	0.02	(0.04)
large*ln days of outages			-0.14***	(0.05)	-0.09	(0.08)
Ghana	0.20***	(0.04)	0.84***	(0.31)	-0.50**	(0.24)
Kenya	0.34***	(0.03)	0.64***	(0.24)	0.66***	(0.20)
Mali	0.24***	(0.05)	0.03	(0.39)	-0.04	(0.27)
Mozambique	0.08*	(0.05)	-0.02	(0.39)	-0.72***	(0.21)
Nigeria	0.68***	(0.03)	0.12	(0.25)	0.08	(0.25)
Senegal	0.37***	(0.04)	0.81***	(0.27)	0.45*	(0.23)
Zambia	-0.09**	(0.04)	0.17	(0.41)	-0.06	(0.18)
Garment and Textiles	0.07**	(0.03)	-0.47***	(0.18)	-0.23	(0.24)
Food and Beverages	0.18***	(0.03)	-0.03	(0.17)	0.25	(0.25)
Metals and Machinery	0.12***	(0.04)	-0.11	(0.20)	0.02	(0.26)
Electronics	0.18**	(0.08)	0.49	(0.42)	0.05	(0.51)
Chemical and Pharmaceuticals	0.16***	(0.05)	0.39*	(0.24)	0.61*	(0.33)
Non-metals	0.13**	(0.05)	0.4	(0.30)	0.82**	(0.33)
Other Manufacturing	0.07**	(0.04)	-0.07	(0.19)	0.15	(0.25)

Retails	0.09**	(0.04)	-0.14	(0.18)	0.33	(0.29)
Other Services	0.24***	(0.06)	-0.22	(0.23)	0.12	(0.66)
Constant			4.27***	(0.48)	3.23***	(0.46)
No of observation	2,665		1,648		1,017	
F-stat.			53.77***		49.10***	
Adj. R-sq			0.42		0.52	
Log likelihood	-1172.24					
Pseudo R-sq	0.34					
Prob. Chi	0.00					

***, **, and * denote significant at 1%, 5% and 10% respectively. Standard errors are in brackets. Base country: South Africa; base sector: Wood & Furniture.

[a] Days of power outages = annual outage times (in hours) reported by firms divided by 24 hours. Outage times refer to periods when public system is not available.

5.2 Estimated Unmitigated Outage Loss Differential

In Table 3 we present the estimated value of lost load per kWh unserved. To obtain the estimates, we assumed that an average firm operated 12 hours daily. To obtain hourly electricity consumption, total annual electricity consumption was divided by the annual operation hours net outage times. We then computed the outage loss per kWh unsupplied assuming that a firm would have consumed the same amount of electricity per hour during outages as it did during uninterrupted hours – that is, we assumed constant hourly electricity consumption during operation times. The estimated value of lost load ranges from US$2.01 – US$23.92 per kWh for firms engaging in self-generation, and from US$1.54 – US$32.46 per kWh for firms without self-generation. This indicates that firms in Africa lost substantial amounts of their potential sales values to power outages. The results further show that the actual unmitigated outage loss per kWh was considerably higher for backup firms than for non-backup firms in countries with frequent power outages (Ghana and Nigeria). These results reflect the degree of vulnerability of backup firms' operations to power outages (relative to non-backup firms) and the inability of their generating capacity to meet the required loads in the event of power interruption.

There are significant variations in the unmitigated outage losses suffered across the countries. For instance, the unmitigated outage loss per kWh suffered by an average backup firm in Kenya is around 10 times the average loss suffered by a backup firm in Nigeria, despite having larger proportions of firms engaging in self-generation in the two countries and a higher reliability in the former. This finding might reflect the variations in the degree of vulnerability of firms sampled in the two countries and the relativeness of self-generation capacity to required loads. Because electricity is more reliable in Kenya, generator capacity owned by firms might be significantly smaller than their required electricity loads. The implication of this low backup capacity is that even if firms invest in self-generation, they might still suffer significantly from power outages because their installed backup capacity is significantly low relative to their energy needs.[9]

Compared to the grid electricity prices, the values of lost load are considerably greater than the grid electricity prices. An average backup firm operating in Ghana and in Nigeria respectively lost around 19 and 29 times more than the prices of the publicly provided electricity in the two countries. Differences between the value of lost load and the grid electricity tariffs were even greater in countries where electricity tariffs were lower including Zambia (269 times) and South Africa (110 times), and in Kenya (127 times), Mali (77 times) and Mozambique (157 times) where firms lost a huge amount per kWh unserved.

Despite the substantial amounts of unmitigated outage losses suffered by the firms, however, our counterfactual estimates show that firms engaging in self-generation were better off than if they did not invest in self-generation. Similarly, firms without self-generation would have been better off if they had engaged in self-generation. Firms self-generating electricity would have suffered between 1–183% more than their current outage loss per kWh if they did not engage in self-generation. On the other hand, non-backup firms would have reduced their outage losses by between 6–46% if they had engaged in self-generation.

Table 3: Value of lost load (US$) per kWh

	Backup Firms			Non-backup Firms			
Country	A Actual	B Counterfactual	C %(B-A)/A	D Actual	E Counterfactual	F % (E-D)/D	G Grid elect. price (US$)
Ghana	2.89	3.32	14.88	1.54	1.45	-5.84	0.15
Kenya	20.29	22.33	10.05	28.89	24.28	-15.96	0.16
Mali	23.92	30.34	26.84	25.23	23.45	-7.06	0.31
Mozambique	23.56	46.63	97.92	32.46	27.42	-15.53	0.15

[9] Moreover, many vulnerable firms might not engage in self-generation given the relative reliability. Thus, they become largely vulnerable in the event of an unexpected outage.

Nigeria	2.01	2.15	6.97	1.78	1.66	-6.74	0.07
Senegal	6.70	18.96	182.99	25.06	13.54	-45.97	0.24
Zambia	10.76	14.51	34.85	15.37	10.05	-34.61	0.04
South Africa	4.40	4.45	1.14	9.30	6.00	-35.48	0.04

5.4 External Validity Check: The Case of South Asia

This study extensively analyses the outage cost differential between firms operating in Sub-Saharan Africa who have invested in self-generation and those that have not made such investments. In this section, we examine whether the main findings are confirmed using a different natural experiment similar to Sub-Saharan Africa. Another region that satisfies the criteria discussed in Section 4.1 regarding our theoretical and empirical specifications' assumption is South Asia (i.e. India, Pakistan, Sri Lanka and Bangladesh). South Asia is an interesting case for this analysis for a number of reasons. First, both regions account for the larger proportion (more than 95%) of the world's population living without access to modern energy infrastructure: electricity.[10] Second, as in Sub-Saharan Africa, the main reason for firms to invest in self-generation in the South-Asian sub-continent is the poor quality of the publicly provided electricity infrastructure (Asian Development Bank, 2002). Third, the reliability of the power supply in both regions is very low and reflects the inefficiency in power sector institutions. Lastly, and similarly to the situation in the Sub-Saharan Africa, the efforts initiated to reform the power sector in South Asia have brought about little progress due to political instability, poor overall acceptance, slow adaptation and poor transition management (Bhattacharyya, 2007).

The analysis of the South-Asian sub-region is restricted to two countries, Bangladesh and Pakistan, due to the lack of a good-quality dataset that meets the criteria highlighted in Section 4.1. Having taken into consideration the above criteria, our sample was limited to 1,736 firms operating in the two countries in 2007. The data was obtained from the WBES.[11] The empirical specifications for the South-Asian case are analogous to those used in the analysis of Sub-Saharan Africa. All variables are as defined above.

[10] For details, see the International Energy Agency: World Energy Outlook – Modern Energy for All, http://www.worldenergyoutlook.org/resources/energydevelopment/.
[11] For further details, see the earlier discussion of the data source in Section 4.

Data on electricity prices used for the conversion of electricity expenditure into electricity consumption (in kWh) were obtained from USAID (2009).

Table 4 reports the descriptive characteristics of the firms surveyed in the two countries.[12] The table shows that electricity supply in the two countries is very poor, with power outages per annum of 36 days in Pakistan and around 51 days in Bangladesh. Investment in self-generation by firms operating in the two countries significantly reflects the relatively poor state of the public electricity infrastructure, with 56% of firms in Bangladesh and 26% in Pakistan reporting having a generator. The information in Table 4 also shows considerable variation in the proportion of sales lost to power outages and firms' export engagement. While an average firm in Bangladesh lost over 12% of their annual sales to power outages in that year, power outages accounted for less than 11% of the annual sales of firms in Pakistan. Firms in Bangladesh were more export-orientated than those operating in Pakistan.

Table 4: Descriptive statistics – South Asia

	Bangladesh		Pakistan	
	mean	sd	mean	sd
Share of firms owning a generator	0.56	0.50	0.26	0.44
Power outages (days per annum)	50.84	28.86	36.49	66.09
Outage loss (% of sales)	12.40	8.34	10.59	11.22
Engaged in exports	0.39	0.49	0.16	0.37
Annual electricity consumption (ln)	11.42	2.16	11.13	2.10

sd = standard deviation.

Table 5 reports the estimated coefficients on the factors affecting outage losses for the two South-Asian countries. The estimates confirm the earlier findings that larger firms and those that use large amount of electricity are more likely to suffer higher unmitigated outage losses regardless of their self-generation status. A 10% change in electricity use was associated with 5.7% and 4.3% changes in outage losses suffered by backup and non-backup firms respectively. Similarly, a 10% increase in the number of employees was respectively associated with 5.4% and 5.5% increases in (unmitigated) outage losses of the two sets of firms. The estimated coefficients for the reliability of electricity supply show that, controlling for everything else, a 100% decrease in the

[12] Further details are provided in Appendix B.

quality of electricity was associated with 0.4% increase in outage loss suffered by an average firm that did not engage in self-generation.

Table 5: Regression of outage loss by self-generation status - South Asia

Dependent variable	Backup status		Outage loss (ln)			
	marginal effects		Backup-Firms		Non-backup Firms	
Electricity consumption (ln)	0.04***	(0.01)	0.57***	(0.04)	0.43***	(0.03)
Days of power outages	0.0002	(0.0002)	0.003	(0.002)	0.004***	(0.001)
Employment (ln)	0.11***	(0.01)	0.54***	(0.07)	0.55***	(0.09)
Age	-0.0002	(0.0002)	0.01	(0.003)	0.0003	(0.0005)
Export engagement	0.07***	(0.02)	0.42***	(0.14)	0.63***	(0.15)
Small*ln days of outages			-0.02	(0.07)	-0.01	(0.03)
large*ln days of outages			-0.07	(0.04)	-0.13**	(0.06)
Bangladesh	0.12***	(0.02)	0.16	(0.18)	0.49***	(0.12)
Garments, Leather & Textiles	-0.24***	(0.06)	-1.23***	(0.43)	0.52**	(0.25)
Food and Beverages	-0.17***	(0.06)	-1.27***	(0.44)	0.44*	(0.26)
Metals and Machinery	-0.21***	(0.06)	-0.99**	(0.46)	0.66**	(0.26)
Electronics	-0.20***	(0.07)	-0.76	(0.52)	0.56	(0.35)
Chemical and Pharmaceuticals	-0.10*	(0.06)	-0.66	(0.45)	0.48*	(0.28)
Non-metals	-0.09	(0.07)	-1.48***	(0.50)	0.36	(0.37)
Auto, Trans, etc	-0.15	(0.13)	-1.24*	(0.68)	1.27*	(0.70)
Other Manufacturing	-0.05	(0.07)	0.76	(0.52)	0.83**	(0.33)
Retails	0.17**	(0.07)	-0.72	(0.48)	1.19**	(0.38)
Hotels & Restaurants	0.08	(0.08)	-2.11***	(0.58)	-0.90**	(0.41)
Constant			2.74***	(0.62)	1.71***	(0.40)
No of observation	1,736		772		950	
F-stat.			48.62***		56.91***	
Adj. R-sq			0.53		0.51	
Log likelihood	-710.21					
Pseudo R-sq	0.41					
Prob. Chi	0.00					

***, **, *, denotes significant at 1%, 5% and 10% respectively. Standard errors are in brackets. Base country: Pakistan; base sector: Wood & Furniture

Table 6 presents the estimated value of lost load per kWh unserved. A comparison of the estimates show that an average backup firms operating in Bangladesh suffered smaller outage loss per kWh than a backup firm operating in Pakistan. However, a non-backup firm in Bangladesh suffered a greater amount than an average non-backup firm in Pakistan. The average backup firm in Pakistan lost around 1.6 times more per kWh than the average backup firm in Bangladesh. Meanwhile, an average non-backup firm in Pakistan lost just 0.78 times the outage loss per kWh of a non-backup firm operating in Bangladesh.

The estimated values of lost load further show that while backup firms in Bangladesh suffered smaller outage loss per kWh unserved compared to the non-backup firms, backup firms in Pakistan suffered greater outage loss than non-backup firms. These findings further strengthen our theoretical proposition and indicate that investing in self-generation may not necessarily make a firm suffer smaller outage loss than a firm without such investment, even though the firm is better off than if it did not invest in self-generation.

Table 6: Value of lost load (US$) per kWh – South Asia

	Backup Firms			Non-backup Firms			
	A	B	C	D	E	F	Grid elect.
Country	Actual	Counterfactual	%(B-A)/A	Actual	Counterfactual	% (E-D)/D	prices
Bangladesh	4.73	4.84	2.33	4.83	3.98	-17.60	0.05
Pakistan	7.46	7.94	6.43	3.79	3.52	-7.12	0.07

5.5 The Empirical Findings Puzzle

One question that arises from the above findings is why firms that invested in backup capacity continued to suffer greater unmitigated outage losses. The reason is simply that although firms with certain characteristics have a propensity to invest in backup generation, in most cases they make partial investments that still leave them vulnerable to power outages. As stated in our theoretical prediction (Section 3.1), the optimal choice of the size of generation capacity is determined at the point when the marginal mitigation gain is equal to the marginal cost of adding extra unit of generation capacity – this point is not necessarily at the maximum. So even in the absence of additional imperfections like financial constraints firms may still optimally choose lower capacity than full outage protection.

Reporting on data on self-generation from 12 African countries, Oseni and Pollitt (2013) showed that 76–100% of firms that invested in backup generation made partial investments and complemented their energy needs with the services provided by the national grid. Backup rates (the ratio of installed backup capacity to average electricity demand) were significantly below 10% in most of the countries and below 5% in countries with infrequent power outages (e.g. Mozambique, South Africa and Zambia). The implication of this low backup capacity is that even if firms invest in self-generation based on their firm characteristics, they may still suffer significantly from power outages if their installed backup capacity is low relative to their energy needs. Although larger firms are more likely to invest in backup generation, they can still suffer greater unmitigated outage losses than smaller firms if their investments are partial and do not cover the larger proportion of their potential outage losses.

There are several reasons why firms might decide to make lower investments in self-generation than necessary to back up their energy needs fully. Firstly, firms may decide to invest in low backup capacity (to back up just critical components like freezers, IT, etc) and complement it with energy from the national grid because it is cheaper. The variable cost of self-generating electricity is approximately 3 times as costly as the costs of electricity supplied by the national grid due to diseconomies of scale in self-generation (Steinbuks and Foster, 2010). Another reason for running a lower-capacity backup generator could be financial constraints (Steinbuks, 2012). Firms may opt for less backup capacity if they do not have adequate financial capacity to invest in 100% backup generation.

6. Summary and Conclusion

Several studies have demonstrated that firms possessing certain characteristics are more likely to invest in self-generation when faced with an unreliable electricity supply. This study examined the outage loss differential between firms that invested in self-generation and those firms without such investments. The natural experiments created by the poor quality of publicly provided electricity in Sub-Saharan Africa and South Asia were used to analyse the outage loss differentials between backup and non-backup firms. We first re-examined how firm characteristics may influence decisions regarding self-generation. Our findings confirmed the results from the earlier literature: we found that firms possessing certain characteristics had a greater tendency to invest in self-generation. In particular, electricity use, firm size, export engagement and the operating environment significantly affected investment in self-generation when electricity from the public grid was unreliable.

However, we also found that engaging in self-generation might not necessarily make a firm suffer smaller unmitigated outage losses (costs) than a firm that did not self-generate, although self-generation reduces outage losses. The relative unmitigated outage losses between two firms (one with a backup and the other without a backup) would depend on the relative vulnerability of their operations to power outages and the ability of the former to make sufficiently substantial investments in self-generation relative to its required electricity loads. Nevertheless, we found that firms engaging in self-generation would have suffered 1–183% more outage loss per kWh than their current loss level if they had not engaged in self-generation. Similarly, those firms without backup generation would have, on average, reduced their outage losses by 6 – 46% had they engaged in self-generation.

Regardless of investment in self-generation, we found that firms operating in Sub-Saharan Africa and South Asia suffered significantly from power outages, suggesting that firms can still benefit substantially from a cost-reflective tariff that ensures reliability. Firms engaging in self-generation suffered between US$2.01–US$23.92/kWh of unsupplied electricity, whereas firms that did not engage in self-generation suffered between US$1.54–US$32.46/kWh.

A number of conclusions that inform our thinking regarding energy policy can be drawn from the analyses conducted in this study. First, it would be beneficial if firms whose operations are more vulnerable to power outages could (or are allowed to) partner with electricity suppliers such that they get preferential supply. This arrangement could be in the form of a (binding) contract between vulnerable firms and the utility companies, such that they are offered preferential supply at an agreeable (insurable) optimal tariff but get compensated by the utilities in the events of defaults. This would lessen the effects of unreliability in electricity supply on firms' operations and reduce the constraints posed on their capacity expansion by power outages.

The estimated outage loss (value of lost load) shows that power outages impose a substantial cost on the economy regardless of investment in self-generation. An average backup firm operating in Ghana and in Nigeria respectively lost around 19 and 29 times more than the prices of the publicly provided electricity in the two countries. These differences between the estimated value of lost load and the grid electricity tariffs were even greater in Zambia (269 times), South Africa (110 times), Kenya (127 times), Mali (77 times) and Mozambique (157 times). The value of lost load per annum net of grid electricity costs would be sufficiently substantial for some firms to expand their operations and increase employment opportunities. This suggests that a stable electricity supply may have a strong and positive impact on poverty reduction and economic activity. One policy measure is to withdraw subsidies and introduce optimal tariffs that are cost recovering for new grid investment and incentive regulation for reliability in order to encourage private sector participation in the provision of power.

This study is not without its limitations, however. The use of self-reported outage losses by firms could be subjective as firms may have reasons to overstate their outage losses. Although such bias was controlled for by using the winsorised values of the reported outage losses, it is not clear whether such errors were eliminated completely. Another limitation is the lack of data on firms' generator capacities, their required electricity loads as well as information on how firms run (use) their generators relative to outage times. Such information would be relevant to further and more clearly unravel why firms with installed backup capacity still suffer significant unmitigated outage losses.

Acknowledgments

We appreciate the comments from David Newbery and Paul Kattuman of the University of Cambridge. We also appreciate the comments received from the participants at various Energy Economic Conferences where the earlier version of this paper was presented. The comments from two anonymous referees are gratefully acknowledged. The usual disclaimer applies.

References

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.

Allcott, H., Collard-Wexler, A., & Connell, S. D. O. (2014). *How Do Electricity Shortages Affect Productivity? Evidence from India.* NBER working paper 19977.

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

Arnold, J. M., Mattoo, A., & Narciso, G. (2008). Services Inputs and Firm Productivity in Sub-Saharan Africa: Evidence from Firm-Level Data. *Journal of African Economies*, *17*(4), 578–599.

Asian Development Bank and The World Bank Group. (2002). ICS – Investment Climate Surveys, Mimeo.

Beenstock, M., Goldin, E., & 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.

Bhattacharyya, S. C. (2007). Power sector reform in South Asia: Why slow and limited so far? *Energy Policy*, *35*(1), 317–332.

Diboma, B. S., & Tatietse, T. T. (2013). Power interruption costs to industries in Cameroon. *Energy Policy*, *62*, 582–592.

Easterly, W., & Levine, R. (1997). Africa's Growth Tragedy: Policies and Ethnic Divisions. *The Quarterly Journal of Economics*, *112*(4), 1203–1250.

Eberhard, A., Foster, V., Briceño-Germendia, C., Ouedraogo, F., & Shkaratan, M. (2008). *Underpowered: The State of the Power Sector in Sub-Saharan Africa.* Africa Infrastructure Country Diagnostic Background Paper No. 6. The World Bank, Washington D.C.

Eifert, B., Gelb, A., & Ramachandran, V. (2008). The Cost of Doing Business in Africa: Evidence from Enterprise Survey Data. *World Development*, *36*(9), 1531–1546.

Escribano, A., Guasch, J. L., & Pena, J. (2009). *Assessing the Impact of Infrastructure Quality on Firm Productivity in Africa*. Africa Infrastructure Country Diagnostic Working Paper 9, The World Bank, Washington DC.

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

Foster, V., & Steinbuks, J. (2009). *Paying the Price for Unreliable Power Supplies: In-*

House Generation of Electricity by Firms in Africa. World Bank Policy Research Paper 4913. The World Bank, Washington D.C.

Karekezi, S., & Kimani, J. (2002). Status of power sector reform in Africa: impact on the poor. *Energy Policy*, *30*, 923–945.

Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009). Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. *World Development*, *37*(7), 1208–1221.

Oseni, M. O. (2011). An analysis of the power sector performance in Nigeria. *Renewable and Sustainable Energy Reviews*, *15*(9), 4765–4774.

Oseni, M. O., & Pollitt, M. G. (2013). *The Economic Costs of Unsupplied Electricity: Evidence from Backup Generation among African Firms*. University of Cambridge, Cambridge UK: EPRG Working Paper 1326.

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

Steinbuks, J. (2012). Firms' Investment under Financial and Infrastructure Constraints: Evidence from In-House Generation in Sub-Saharan Africa. *The B.E. Journal of Economic Analysis & Policy*, *12*(1), 1–32.

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

UPDEA. (2009). *Comparative Study of Electricity Tariffs used in Africa*. Union of Producers, Transporters and Distributors of Electric Power in Africa.

USAID. (2009). *Cost Competitiveness of Pakistan's Textiles and Apparel Industry*. United States Agency for International Development.

World Bank. (2012). World Bank Surveys of Business Enterprises. Retrieved from http://www.enterprisesurveys.org/

Appendices

Appendix A –The case of Sub-Saharan Africa

Table A.1: Number of firms – Tabulation by country – Sub-Saharan Africa

Country	Frequency	Share
Ghana	206	7.73%
Kenya	345	12.95%
Mali	75	2.81%
Mozambique	123	4.62%
Nigeria	1,331	49.94%
Senegal	209	7.84%
South Africa	220	8.26%
Zambia	156	5.85%
Total	2,665	100.00%

Table A.2: Number of firms – Tabulation by industry – Sub-Saharan Africa

Industry	Frequency	Share
Garment and textiles	573	21.50%
Food and beverages	670	25.14%
Metals and machinery	274	10.28%
Electronics	26	0.98%
Chemical and pharmaceuticals	116	4.35%
Wood and furniture	150	5.63%
Non-metallic and plastic materials	76	2.85%
Other manufacturing	371	13.92%
Retail	328	12.30%
Other services	81	3.04%
Total	2,665	100.00%

Table A.3: Number of firms – Tabulation by size – Sub-Saharan Africa

Size	Frequency	Share
Small: 1–19 employees	1,612	60.48%
Medium: 20–99 employees	752	28.22%
Large: 100+ employees	301	11.29%
Total	2,665	100.00%

Appendix B – The Case of South Asia

Table B.1: Number of firms – Tabulation by country – South Asia

Country	Frequency	Share
Bangladesh	1,086	62.56%
Pakistan	650	37.44%
Total	1,736	100.00%

Table B.2: Number of firms – Tabulation by industry – South Asia

Industry	Frequency	Share
Garments, leather and textiles	826	47.58%
Food and beverages	288	16.59%
Metals and machinery	173	9.97%
Electronics	53	3.05%
Chemical and pharmaceuticals	173	9.97%
Wood and furniture	47	2.71%
Non-metals	44	2.53%
Auto, transport, etc.	11	0.63%
Other manufacturing	46	2.65%
Retail	48	2.76%
Hotels and restaurants	27	1.56%
Total	1,736	100.00%

Table B.3: Number of firms – Tabulation by size – South Asia

Size	Frequency	Share
Small: 1–19 employees	662	38.13%
Medium: 20–99 employees	490	28.23%
Large: 100+ employees	584	33.64%
Total	1,736	100.00%