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A firm-level analysis of outage loss differentials and self-generation: Evidence from African business enterprises

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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$2.01–23.92 per kWh for firms engaging in self-generation, and range from US$1.54 to 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.

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 et al., 2008; Escribano et al., 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 et al., 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 and The World Bank Group (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.[1] 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 (9 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 less than 15 hours per month. Similarly, a typical firm in Latin America or the Caribbean only suffers electricity outages of around 6 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 and 700 MW for their own use (Karekezi and Kimani, 2002). Self-generation has increased and now accounts

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

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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 4400 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 et al. (2015) demonstrated that increasing electricity scarcity raised the unit production cost for Chinese firms by 8%. Allcott et al. (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) analyzed 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 US$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) analyzed 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 US$). 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, $L_q = 0$ (indicating zero outage loss in the absence of service interruption), and $L_q = \lambda Q$ (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.[2]

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

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

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