Let There be Light!

Firms Operating under Electricity Constraints in Developing Countries

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Abstract

Many developing countries are unable to provide their industrial sector with reliable electric power and many enterprises have to contend with insufficient and unreliable electricity supply. Because of these constraints, enterprises often opt for self-generation even though it is widely considered a second best solution. This paper develops a theoretical model of investment behavior in remedial infrastructure when physical constraints are present. It then tests econometrically implications from this model using a large sample of enterprises from 87 countries from the World Bank enterprise survey database. After showing that these constraints have non-linear effects according to the natural degree of reliance on electricity of an industrial sector and on firm size, the paper draws differentiated policy recommendations. Credit constraints appear to be the priority in sectors very reliant on electricity to spur entry and convergence to the technological frontier while, in other sectors, firms would benefit more widely from marginal improvements in electrical supply.

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And God said, 'Let there be light' and there was light, but the Electricity Board said He would have to wait until Thursday to be connected.

Spike Milligan

1. Introduction

There is growing evidence, both micro- and macroeconomic, that better electricity infrastructure significantly boosts economic growth and improves a range of development outcomes.[4] Energy is necessary for the operation of productive capital in the industrial sector. Low levels of infrastructure development and poor quality of services can drive up firms' direct and indirect costs and bias their technological choices away from energy intensive ones, which in turn increases the overall costs relative to competitors in other regions.[5] Enterprises typically face more barriers in developing countries, where firms have difficulties getting connected to the public grid.[6] When firms do get connections, the sanctioned load is often lower than their demand and they face frequent scheduled and unscheduled power cuts. In addition, fluctuations in voltage and frequency of power supplied causes machine damage, material losses, and variations in product quality. As a result, production volumes, manufacturing costs and output quality are all adversely affected; firms invest less or in less efficient technologies and have lower productivity growth.

To offset these negative impacts, industrial firms in developing countries are often opting for self-generation even though it is widely considered a second best solution. Of the 25 Sub-Saharan countries reviewed by Foster and Steinbucks (2009), in-house generation accounts for more than 25% of the installed generating capacity in 3 countries, and for more than 10% in 9 others. This of course has a negative impact on their overall investment capacity. In Nigeria, where 40% of electricity consumed is produced through auto-generation, firms spend up to 20–30% of initial investment on measures to enhance the reliability of electricity supply.[7] It also drives up costs: in Africa, own-generated electricity is on average 313% more expensive than electricity from the grid according to the estimates of Foster and Steinbucks.

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[4] See for example Calderón and Servén (2003), and Calderón (2009) for cross-country estimations, and Dinkelman (2009) and Lipscomb, Mobarak and Barham (2009) for microeconomic evidence.

[5] Eifert, Gelb and Ramachandran (2008).

[6] World Bank (2005); Bartelsman, Haltiwanger and Scarpetta (2004).

[7] Adenikinju (2005).

In environments with important credit constraints, such investments in mitigating technologies are often inaccessible to smaller firms or those more severely exposed to credit restrictions. Infrastructure failures and credit limitations therefore interact in constraining the development of enterprises, both by making existing investments less productive and by discouraging new ones.

In this paper, we use a sample of 46,606 firms from 87 countries covering the period 2002-2006 to analyze the behavior of firms facing infrastructure constraints. In particular, our objective is to understand under which conditions they decide to invest in their own generating capacity, how this decision is affected by the above-mentioned constraints and their interactions with firm- and sector-level characteristics, and ultimately what this implies in terms of firm-size distribution. Finding answers to these questions is important because it conditions industrial development policies and the prioritization by policy-makers of measures to improve the investment climate.

A number of papers have documented the burden imposed on developing country firms by an erratic and low-quality electricity supply. Early contributions include Lee, Anas and Oh (1996) and Lee, Anas, Verma and Murray (1996)—both of which use data from Nigeria, Indonesia and Thailand. Lee, Anas and Oh (1996) document the extent and incidence of public infrastructure deficiencies, the response of private entrepreneurs in terms of investment in private infrastructure and the private cost of generation. They conclude that the private costs of infrastructure deficiencies are substantial and that the burdens fall disproportionately on smaller firms, while pointing out large differences across these three countries, linked in particular to the regulatory environment. In Indonesia and Thailand, the opening up of infrastructure markets to private providers and the possibility of shared production appears to ease constraints on all categories of firms and to improve the reliability of service flows.

Hallward-Driemeier and Stewart (2004) document patterns of access to infrastructure services by enterprises in developing countries and show that access varies by type of service and firm size—with electricity often being the biggest problem, and larger firms expressing more concerns than smaller firms about all services. The authors report that an overwhelming majority of firms in poor countries is affected by electrical outages, leading to losses sometimes exceeding 10% of sales. In Bangladesh, China, Ethiopia, and Pakistan, improvements in the reliability of the power supply is found to increase garment manufacturers' total factor productivity and the growth rates of their output and employment (Dollar, Hallward-Driemeier and Mengistae, 2005). Gulyani (1999) documents the impact of electricity hazards on an Indian car manufacturer and its upstream suppliers, which have devised an innovative generation and power-sharing system to solve their power problems. Gulyani argues that self-generation is economical and, combined with power sharing, can serve as a model that could be replicated to ameliorate the power problems plaguing large manufacturing firms in developing countries.

Closest to our paper are contributions by Reinikka and Svensson (2002) and, more recently, by Steinbucks (2008) and Foster and Steinbucks (2009). Reinikka and Svensson analyze a sample of 171 Ugandan firms, some of which responded to poor electricity supply by investing in generators. They show that this came at the cost of reducing overall investment and installing less productive capital. Foster and Steinbucks (2009), after providing a very rich description of in-house electricity generation in 25 Sub-Saharan African countries, estimate that the weighted average cost of power own-generation for large firms is relatively small and that the main victims are the existing informal firms and the formal ones that were not created as a result of the prevailing constraints. They also allude to the potential benefit of allowing firms with generation capacity to resell power into the national grid. Steinbucks (2008) uses firm-level data from Sub-Saharan African countries and concludes that firms experiencing fewer credit constraints are more likely to own a private generator in the areas where public power supply is unreliable.

Our original contribution is, first, to document systematically the effects of electricity deficiencies on the decision to invest in mitigating technology, i.e., in a generator, and to analyze how the impact varies across firm types and sector technological characteristics and, second, to show how these deficiencies affect the resulting patterns of industrial structure across countries and sectors. A theoretical model of firm responses to power outages allows us to derive precise predictions that are then tested with the data. Using a dataset with a wide coverage — 87 countries and 28 two-digit ISIC industrial classifications — we show that electricity-related constraints have non-linear effects that vary according to the degree of reliance on electricity of the sector and the size of the firm. We also show that, in sectors that are naturally more reliant on electricity, a large number of outages implies a skewed industrial structure with mostly large firms and fewer small ones. Finally, we discuss some policy implications of our results. Addressing credit constraints to allow firms' investments in generators appears to be the priority for sectors that are very reliant on electricity (as a way to spur entry and convergence toward the technological frontier) while, in other sectors, firms would benefit more widely from marginal improvements in electrical supply. We discuss how power-sharing versus pricing policies can be used to address these issues.

The paper is structured as follows. Section 2 presents the dataset and provides descriptive statistics on the extent of electricity deficiencies and credit constraints, as they emerge from the enterprise surveys. Section 3 presents a model of investment by firms when infrastructure and credit constraints are present. Section 4 spells out the econometric specifications used to test the model's predictions. Section 5 presents the results, and Section 6 discusses the policy implications and concludes.

2. Data and Stylized Facts

We use data from the enterprise surveys for 87 countries for which data on number of power outages is available, covering a total of 46,606 firms over the period 2002-2006.[8] Of these, 77 countries also have data on generator and 34 countries have data on cost of electricity.[9]

Many developing countries are unable to provide their industrial sector with reliable electric power and industrial enterprises have to contend with electricity that is insufficient and of poor quality.

Table **1** shows the severity of electricity hazards across regions and country income groups. Column 1 reports a subjective indicator: the percentage of firms' managers quoting electricity as major or severe constraint to their operations and growth. Electricity is perceived as a "major" or "very severe" constraint for 15% of the entrepreneurs overall and for more than 26% of firms located in low-income countries. The highest percentage of firms considering electricity as a serious problem is in South Asia (43% of firms) followed by East Asia, and Africa.

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[8] See https://www.enterprisesurveys.org. The list of countries surveyed can be found in Appendix Table A1. Unfortunately it is not possible to use survey data after 2006 for such an exercise since key questions about power were dropped from the questionnaire.

[9] This yields a sample of 62 countries with data on generator and number of power outages, and 32 countries with data on generator, number of power outages and cost of electricity.

In columns 2 and 3 are objective indicators: the average number of power outages suffered by firms in a given country group, and the share of firms having suffered more than 30 outages in the year before the survey. Overall, firms face cutoffs from the public electricity grid on average 28 times per year, but this number can be as high as 132 in South Asia and 61 in Africa. In these two regions, close to half of all the firms surveyed experienced more than 30 outages a year.

Table 1: Access to electricity by firms across regions and country income groups

Region	Percent of firms mentioning electricity as major or severe constraint	Average number of power outages	Percent of firms having more than 30 power outages	Generator Ownership (Percent of firms)
Europe/Central Asia	8.5%	9.72	5.7%	27.5%
Latin America	9.3%	12.44	7.7%	21.2%
East Asia & Pacific	25.1%	36,49	18.3%	28.7%
Mid. East/North Africa	21.5%	41.32	22.1%	32.4%
Sub Saharan Africa	16.4%	61.12	45.2%	36.6%
South Asia	43.0%	131.74	49.0%	61.7%
Country Income Level				
High	4.9%	1.32	0.2%	-
upper-middle	8.3%	13.02	6.2%	28.0%
lower-middle	14.3%	13.76	9.1%	24.1%
Low	26.4%	64.08	34.1%	42.4%
Average	15.6%	27.57	15.2%	31.1%

The picture provided by these three indicators is consistent across regions and income groups: constraints are more stringent in poorer countries and in South Asian, African, Middle-Eastern/North African, and East Asian countries—in that order. As a result, many firms invest in a back-up power generator: 31% of all firms own one. This number peaks at 62% and 37% in South Asia and Africa, respectively.

Appendix Table A3 presents general firm-level summary statistics. Table 2 shows a breakdown of these numbers according to generator ownership. Firms with installed generator capacity are typically larger and report more days without power from the public grid during the survey year. Moreover, such firms are slightly older. Conversely, firms not owning a generator are smaller, and are found mostly in environments with fewer outages.

Table 2: Summary statistics by ownership of generator

	Owns a generator		Does not own generator	
	Mean	Median	Mean	Median
Number of workers	258.40	55	118.97	21
Age of firm	20.56	15	17.17	12
Number of power outages per year	68.84	12	25.89	5
Percent of Electricity coming from generator	21.35%	10.00%	-	-
Number of firms	13,553		30,093	

Looking now at firm characteristics, Table 3 shows that large firms (in terms of number of employees but with similar conclusions if sales, investment, or capital are considered) as well as foreign-owned, exporting and capital-city based firms report more frequently owning a generator.

Table 3: Generator ownership and frequency of outages by firm characteristics

		% of firms owning a generator	Number of power outage With a Generator	Without a Generator	Whole Sample
By firm size	*Nber of firms*	*37,623*	*11,164*	*26,459*	*37,623*
	Small	30.2%	55.7	24.7	30.2
	Medium	31.6%	55.8	20.0	31.6
	Large	43.6%	67.4	17.7	43.6
By firm ownership	*Nber of firms*	*42,742*	*13,388*	*29,354*	*42,742*
	Domestic	30.2%	73.3	27.4	43.1
	Foreign	39.8%	44.0	17.1	29.0
By firm exporting status	*Nber of firms*	*42,409*	*13,115*	*29,294*	*42,409*
	Exporter	44.1%	62.9	19.4	40.2
	Non-Export	27.1%	69.8	27.9	40.7
By firm location	*Nber of firms*	*31,436*	*10,516*	*20,920*	*31,436*
	Capital City	35.3%	91.5	35.1	55.9
	No Capital City	32.6%	71.9	25.0	40.8

** Small firms have strictly less than 20 employees, medium firms employ between 20 and 99 workers and large firms have more than 100 employees.*

The next section develops a theoretical model of firm-level investment in remedial infrastructure in the presence of electricity and credit constraints.

3. The Model

We consider a continuous moral hazard investment model à la Holmstrom and Tirole (1997). Entrepreneurs are endowed with assets A, which can be, for example, cash or productive assets they can pledge as collateral. To undertake a productive project of variable size I, they intend to borrow an amount $I - A$.

The net return to the project depends on a complementary input, in this case electricity from the grid, the provision of which is of varying quality. We assume that this net return is given by δr, where r is the gross return absent any infrastructure constraint, and $\delta \in [0, 1]$ captures the impact of electricity supply. In practice, the quality of supply as measured by the number of outages affecting the firm interacts with the sector-level "sensitivity to electricity" to determine the actual value of δ. In particular, when operating at the technological frontier, some sectors are naturally more reliant on electricity than others. We assume that for sectors with a higher sensitivity to electricity, a given number of outages has a stronger negative impact on the project return.[10] Formally, in what follows, we will consider a simple version of this differential sensitivity corresponding to our empirical application below, in which there are two types of sectors with either high (indexed by H) or low (indexed by L) sensitivity, with $\delta_H(0) = \delta_L(0) = 1$, and $0 < \delta_H(N) < \delta_L(N) < 1$ for all $N > 0$.

The project yields δrI in case of success and 0 in case of failure, an outcome that is fully verifiable. However, the probability of success depends on the effort exerted by entrepreneurs, which is not observable by the lender. If the entrepreneur works, the probability of success is p_H, while if he shirks, it is only $p_L < p_H$, but he enjoys a private benefit BI or equivalently saves on the cost of effort.

The project is viable only if the project's net present value (NPV) per unit of investment is positive. We assume that it is always negative if effort is not exerted ($p_L\delta r + B < 1$ for all $\delta \in [0, 1]$), but that it may be positive if effort is exerted. In other words, there is a threshold $\delta_0 \equiv 1/p_H r$, such that $p_H\delta r > 1$ for all $\delta > \delta_0$. On the other hand, if $\delta < \delta_0$, the unit NPV is too low and the project is not worth undertaking. Note that it follows from the

[10] As discussed in more details in the empirical section, this may be because the production process relies more on electricity and is therefore more affected by outages, or because deficiencies push firms to adopt less efficient technologies.

model's assumption above that in sectors with a high sensitivity to electricity, the number of power outages N such that $\delta < \delta_0$ is lower.

The credit contract consists of an amount I and shares corresponding to the borrower (R_b) and the lender (R_l), such that $\delta rI = R_b + R_l$. The incentive constraint of the borrower is given by:

$$p_H R_b \geq p_L R_b + BI \quad \Leftrightarrow \quad R_b \geq BI/\Delta p, \tag{1}$$

which defines the maximum income pledgeable to the lender $R_l = \delta rI - BI/\Delta p$. Moreover, the lender must at least break even, which implies that:

$$p_H R_l \geq I - A. \tag{2}$$

The problem is solved by assuming that the credit market is competitive, so profits are null and (2) is binding. After straightforward computations, we can characterize the level of investment:

$$I \leq k^{\delta} A, \tag{3}$$

where $k^{\delta} = 1/[1+(p_H B/\Delta p)-p_H \delta r]$. In a competitive credit market, borrowers get all the surplus, which can be written as $U_b^{\delta}(A) = (p_H \delta r-1)I = (p_H \delta r-1)\ k^{\delta} A$, and they invest the maximum possible amount ($I = k^{\delta} A$).[11]

Alternatively, the firm can invest in a private substitute to ensure reliable electricity input, i.e., an electricity generator. This investment has a cost κ, leaving the firm with an initial capital $A - \kappa$, but the firm then ensures a return R^G, such that $R^G < r$.[12] In that case, the firm proceeds to invest $I^G = k^G(A - \kappa)$, where:

$$k^G = 1 / [1 + p_H B/\Delta p - p_H R^G]. \tag{4}$$

The firm gets utility:

$$U_b^G(A) = (p_H R^G - 1)\ k^G(A - \kappa). \tag{5}$$

[11] The assumptions on the NPV imply that $k^{\delta} > 1$. We also need to assume that $p_H \delta r < 1 + p_H B/\Delta p$ to ensure that the optimal size of the firm is not infinite.
[12] The assumption $R^G < r$ captures the fact that the unit electricity cost from a generator is higher than that from the grid (see Foster and Steinbuks, 2009). It is a shortcut for a characterization with both a fixed and a variable cost of operating the generator.

Optimal Firm Decision

Let us now compare the benefits from investing or not in a generator at different levels of wealth *A*. From the expressions of $U_b^{\delta}(A)$ and $U_b^{G}(A)$, we can draw Figures 1 and 2.

Figure 1 represents the case in which $\delta > \delta_0$, i.e., when the impact of electricity deficiencies is not too severe. In that case, two types of investment behavior coexist. Below the cutoff level A^*, firms do not invest in generators but are still able to obtain credit and enter production, while above the threshold large firms invest in generators and obtain a higher leverage in the credit market.[13] When power from the grid is reasonably reliable, entry to the productive sector is profitable across the range of potential entrepreneurs and sectors. A duality exists in terms of access to remedial investments and therefore productivity, and A^* is increasing in δ, meaning that as long as $\delta > \delta_0$, an increase in power cuts will trigger additional investments in generators.

Figure 2 represents the case in which $\delta < \delta_0$, i.e., when the impact is severely adverse. In this parameter space, the outcome is stark: firms above a cutoff level A_L invest in complementary capital, take credit and enter production, while firms below the cutoff are credit constrained, as infrastructure deficiencies are so stringent that the return from production is too low to access the credit market, and they lack the capacity to invest in a generator. Notably, in contrast to the previous case, A_L does not depend on δ as long as $\delta \leq \delta_0$. Although this is not explicitly modeled here, one can imagine that these potential entrepreneurs remain in the informal sector and consume their own endowments.

[13] Note that we represent the case where $k^G > k^{\delta}$. If k^{δ} exceeds k^G, which is likely if electricity supply is completely flawless, firms borrow and produce at any level of wealth without the need to invest in a generator. Our data support the idea that this case is not relevant in our sample.

Figure 1 ($\delta > \delta_0$)

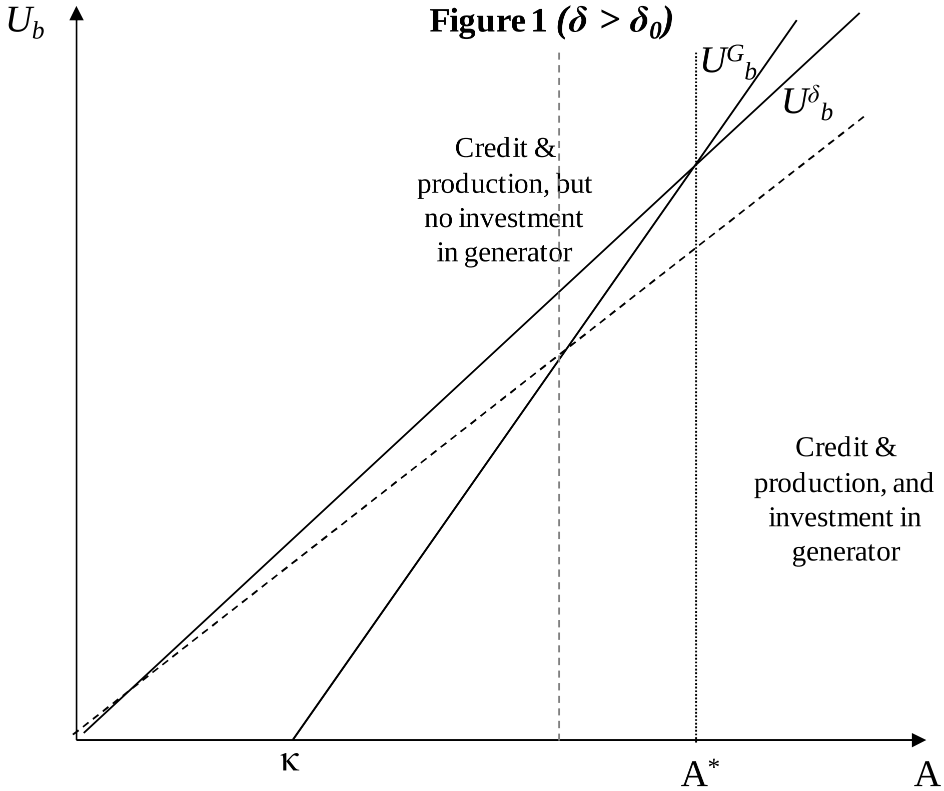
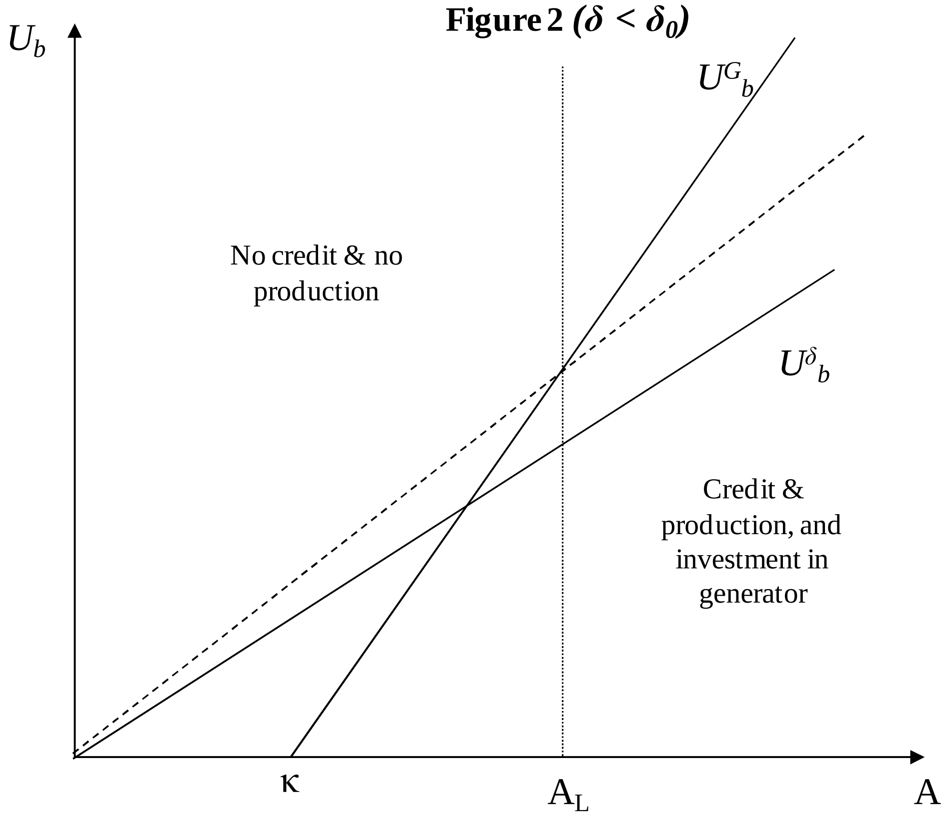


Figure 2 ($\delta < \delta_0$)



Following this discussion on the determinants of δ, one can think of the cases in Figures 1 and 2 as capturing two types of variation in the environment. First, they may capture the difference between countries with reliable electric services and those with relatively worse services, i.e., a higher prevalence of outages. Second, they may relate to the sector-level fundamental characteristics discussed above, i.e., the sensitivity to electricity.

From this basic model, we derive two related results.[14] First, Proposition 1 states that the probability that firms own a generator increases in the number of outages N as long as the efficiency of electricity services is not too low ($\delta > \delta_0$), while this probability does not depend on N when this efficiency is low ($\delta < \delta_0$), as investment is discouraged altogether.

Proposition 1 *There is a threshold δ_0 such that $\partial A^*/\partial\delta > 0$ if and only if $\delta \geq \delta_0$,* while for *$\delta < \delta_0$, $\partial A^*/\partial\delta = 0$.*

Intuitively, as long as the losses related to electricity deficiencies are not too high, it is optimal for firms at all levels of assets to operate, but only those above a given size find it profitable to invest in a generator. In this regime, a decrease in electricity efficiency pushes the marginal firms to invest in remedial equipment, so we expect to find a positive link between the probability to own a generator and the number of outages. On the other hand, when losses due to electricity deficiencies are very high, the returns for firms not owning a generator are so low that they disappear altogether. Then, the industry is populated only by firms that are large enough to invest in a generator, and the probability that they own a generator does not respond to the number of outages.

As a result, in environment with electricity deficiencies, the model also has implications in terms of firm size distribution, as illustrated in Figures 3 and 4. To put it in a nutshell: in sectors that are very sensitive to how efficient electricity supply is, there will be fewer small firms and, among existing (medium and large) firms, a larger proportion of firms owning a generator.

[14] Proofs are straightforward and are therefore omitted. An appendix with the formal derivation of the comparative statics results is available upon request.

Figure 3 $(A < A_L)$

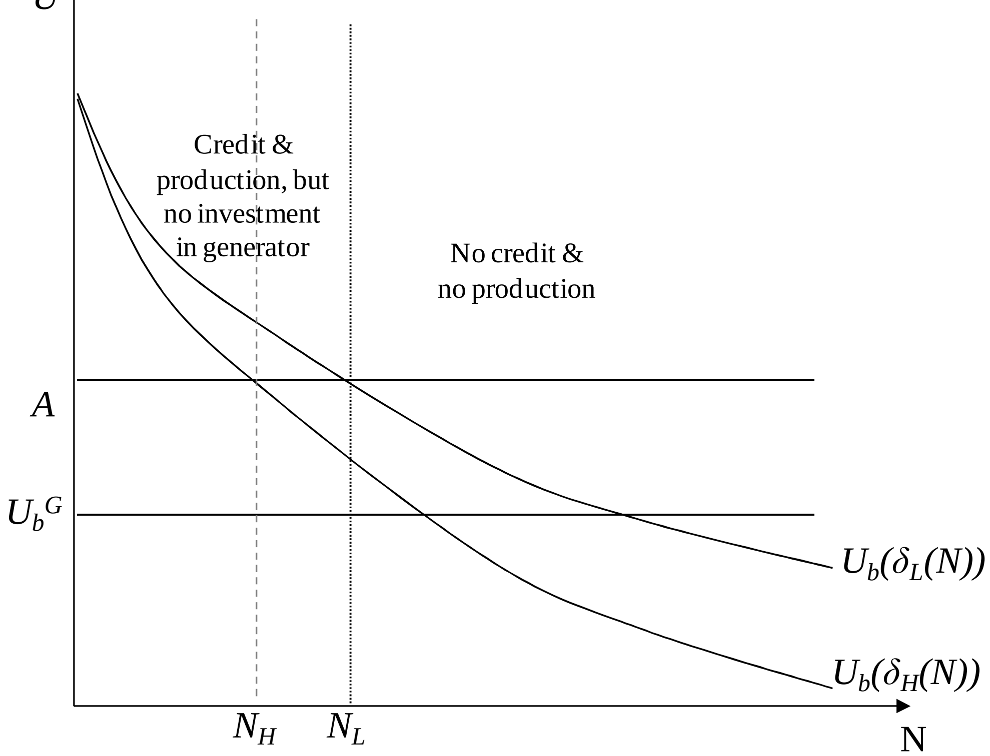


Figure 4 $(A > A_L)$

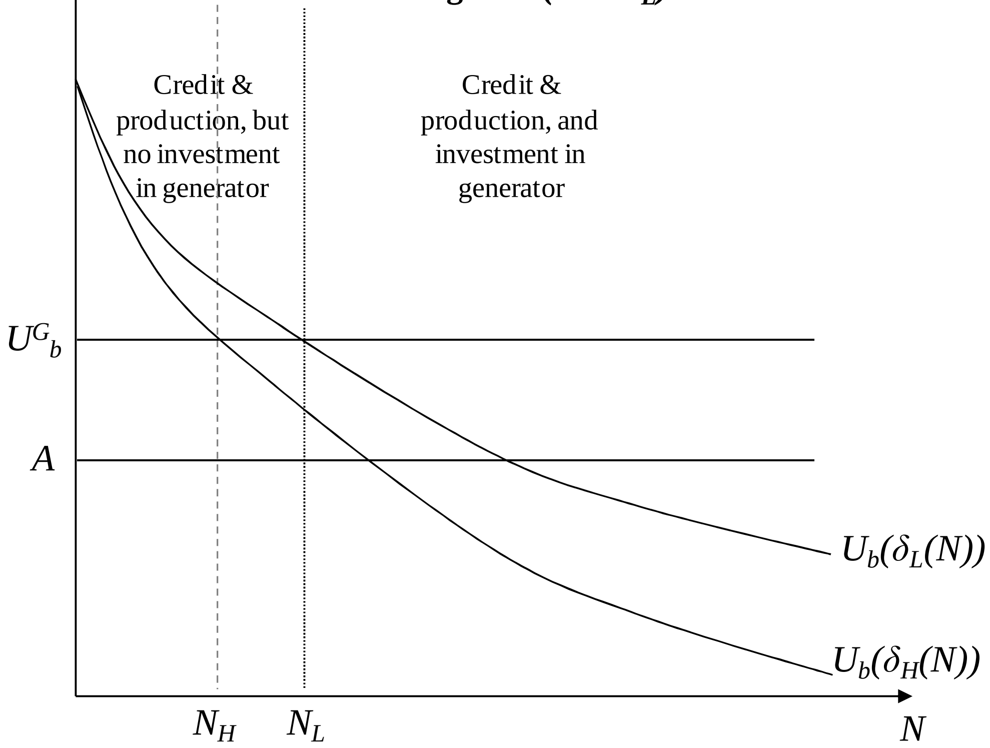


Figure 3, which represents the profit of a firm of fixed size $A < A_L$ (i.e., a relatively small one) as the number of power outages N varies, illustrates the first part of this prediction. The downward slopping curves denoted $U_b(\delta_L(N))$ and $U_b(\delta_H(N))$ represent how the firm's utility evolves with the number of outages in the low-sensitivity and high-sensitivity cases, respectively. The cutoffs N_H and N_L on the horizontal axis show the number of power outages above which small firms are pushed to exit. Outages are too much of a drain on profits to allow them to operate and they cannot afford a generator. Clearly, in the presence of electricity deficiencies, firms in more sensitive sectors are less likely to be profitable and therefore a smaller proportion of small firms are likely to exist.

Figure 4 illustrates the second part of the prediction, concerning generator ownership by existing firms. It represents the profit of a firm of fixed size $A > A_L$ (i.e., a medium or large one) as the number of power outages N varies The cutoffs N_H and N_L are defined as before, and they now show the number of power outages above which the firm finds it profitable to invest in a generator. Again, the proportion of firms not owning a generator is smaller in sectors more sensitive to electricity.

We summarize these insights in Proposition 2.

Proposition 2 *Deficiencies in electricity supply have a different impact on the distribution of firms' size depending on sectors' characteristics. In sectors comparatively more sensitive to the efficiency of electric supply, a large number of outages results in small formal firms being relatively less abundant.*

As explained above, this proposition states that, in the presence of outages, the likelihood that small firms invest and produce while not owning a generator is decreasing in the sector's sensitivity to electricity. As a result, a larger proportion of existing firms, medium and large, own a generator.

The next section lays down the econometric specification to test these implications.

4. Econometric Specifications

The model specified above leads us to test the following empirical specifications regarding the decision to invest in an electric generator, which we can write as a binary decision problem:

$$Gen_{ijc} = 1[Gen^{*}= \theta_j + \theta_c + \theta_t + \alpha log N_{ijc} + X_{ijc}\,\gamma + \varepsilon_{ijc} > 0], \qquad (6)$$

where $1[.]$ is an indicator function equal to 1 if the statement in brackets is true, i indexes firms, *Gen* is a binary variable equal to 1 if the firm owns a generator and 0 otherwise, the θ*'s* are sets of dummy variables for industries (j), countries (c), and years (t), N_{ijc} is a measure of the number of power outages facing the firm, and X_{ijc} is a vector of firm-level controls, also including measures of possible financial constraints facing the firm.

The logarithmic term is meant to capture in a very generic fashion the non-linear effects of power outages outlined in the model, and we expect $\alpha > 0$, meaning that the probability of owning a generator is increasing in the prevalence of outages.

The model also implies that the coefficients should differ according to the intrinsic sensitivity of productive sectors to the quality of electric supply. An important question is how to define this latter aspect. We define S_i as a measure of electricity expenditure as a percentage of total cost. To simplify further the empirical test, we define S_h as a dummy variable equal to 1 for sectors relying importantly on electricity as an input, and 0 otherwise.

To mitigate potential worries linked to the fact that technology choice is to some extent endogenous—so that industries in environments with many outages may substitute towards technologies that use less electricity—, the sector-level benchmark value is defined by reference to countries with relatively low electricity constraints.[15] The underlying logic is to have a reference value of what technological choices would look like in a distortion-free environment, akin to a sectoral technological frontier. We do not need to assume that technological choices are the same in the presence of electricity deficiencies but, rather, that in sectors in which the first-best technology would be very electricity-intensive the impact of deficiencies will be felt stronger and will penalize firms more heavily, as those not owning generators will either suffer critical failures and damages, or they will have to settle for second-best technologies implying in both cases a larger efficiency gap. We discuss the technical details of the variable construction further in the next section.

Equipped with this measure of "benchmark electricity intensity", we can then test (6) on the two subsamples corresponding respectively to $S_h = 0$ and $S_h = 1$. From the model, we expect a marginal increase in the number of outages to have a lesser impact in electricity-intensive sectors, because firms have strong incentives to invest in generators as soon as

[15] This is standard practice in the empirical literature. Examples of industry-level reference values for innovation or barriers to entry can be found for example in Rajan and Zingales (1998) and Fisman and Sarria-Allende (2004).

some deficiencies are felt, while in sectors that rely less on electricity a similar marginal increase should significantly increase the probability to own a generator (see Proposition 1).[16]

The second set of predictions concerns the differential distribution of firm size across sectors. To address this, we start by presenting double differences across sectors (following the classification according to S_h defined above) and countries—distinguishing between countries with a high and small median (or average) number of outages. Formally, we estimate:

$$Z_{jct} = \theta_j + \theta_c + \theta_t + \beta N_{jct} + \delta (N_{jct}*S_h*C_h) + X_{jct} \gamma + \varepsilon_{ijc} > 0], \qquad (7)$$

where Z_{jc} is some industry/country level measure of the relative number of small firms. On the right hand side, N_{ijc} is the number of power outages as above and the triple interaction term $N_{jc}*S_h*C_h$ captures the effect of outages in the group of electricity-intensive industries ($S_h =1$) in countries with a number of outages above the median/average ($C_h =1$). Finally, the full sets of industry, country and time dummies are included, as well as industry-country level controls, including all the related double-interaction terms.

5. Empirical Analysis

In order to estimate the specification above, we first need to construct the parameter S_h. The countries in our sample with the smallest number of power outages are Indonesia, Lithuania, Brazil, Poland and Thailand. Within this subsample, we compute the average cost of electricity as a percentage of total cost by industrial sector, as shown in Table 4. We classify as “very reliant on electricity” ($S_h=1$) industrial sectors that are above the median (7.7 percent) and the rest as sectors not relying too much on electricity ($S_h=0$). As all industrial sectors are not represented in our subsample of five countries with reliable electricity services, we assign a value for S_h in height missing industrial sectors following intuitive criteria.[17] Table 5 presents summary statistics on these two subsamples of firms.

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[16] In a previous version of this paper (Alby, Dethier and Straub, 2010), we approximated the non-linear shape with a quadratic specification of outages instead of the logarithmic one, and showed that the turning point was lower for electricity-intensive sectors.

[17] A “core” set of sectors is systematically included in all enterprise surveys, so that the missing ones represent relatively few firms overall (see Dethier, Hirn and Straub, 2010, for a detailed description). We consider Sports Goods, Other manufacturing, and Mining and quarrying as industrial sectors that do not rely heavily on electricity (their cost share of electricity is less than 3.5 percent in the full sample of countries), and assign these sectors, as well as Accounting and Finance and Advertising and Marketing a value of $S_h=0$. Symmetrically, we assign a value $S_h=1$ for firms operating in IT services, Hotels and Restaurants, and Telecommunications (average cost share of electricity above 8.6 percent in the full sample for the first two).

Table 4: Reliance on electricity in countries with reliable service, by industrial sector

Industrial Sector	Cost of Electricity (% of total cost)	Number of firms having non zero electricity cost
Other services	2.21	1
Metals and machinery	3.50	352
Leather	4.07	161
Garments	4.44	759
Auto and auto components	5.61	280
Agroindustry	5.70	17
Electronics	5.94	266
Non-metallic/plastic materials	6.30	234
Wood and furniture	6.93	495
Construction	7.58	18
Other unclassified	7.72	8
Food	8.59	474
Transport	11.08	11
Chemicals and pharmaceutics	11.47	153
Textiles	11.89	510
Paper	12.40	28
Retail and wholesale trade	13.31	2
Other transport equipment	21.86	18
Real estate and rental services	24.49	1
Beverages	30.49	16
Overall Total	7.07	3,804

Note: Lithuania, Thailand, Poland, Indonesia and Brazil are the countries in our sample with the least number of power outages.

Table 5: Describing firms sub-samples according to S_h

	S_h 0	1	TOTAL
Whole Sample			
Number of firms	20,064	20,651	40,715
% of firms quoting Electricity as a major or severe constraint	18.81%	15.88%	17.33%
Average Number of power outage	22.71	23.18	22.95
% of firms with a generator	28.59%	40.39%	33.33%
Average Cost of Electricity (% of total cost)	6.29%	9.04%	7.43%
By firms size			
Large(100 and over)			
Number of firms	5,173	4,212	9,385
% of firms quoting Electricity as a major or severe constraint	21.95%	21.90%	21.93%
Average Number of power outage	29.96	27.35	28.79
% of firms with a generator	46.69%	61.46%	52.65%
Average Cost of Electricity (% of total cost)	4.99%	7.49%	5.99%
Medium(20-99)			
Number of firms	6,942	6,276	13,218
% of firms quoting Electricity as a major or severe constraint	19.10%	19.47%	19.28%
Average Number of power outage	21.65	25.33	23.40
% of firms with a generator	27.30%	40.05%	32.62%
Average Cost of Electricity (% of total cost)	6.33%	9.38%	7.62%
Small(<20)			
Number of firms	7,949	10,163	18,112
% of firms quoting Electricity as a major or severe constraint	16.51%	11.13%	13.50%
Average Number of power outage	18.92	20.13	19.60
% of firms with a generator	15.31%	22.15%	17.92%
Average Cost of Electricity (% of total cost)	7.91%	10.41%	8.94%

One standard worry with firm surveys is the potential non-response bias, since some firms may not respond to specific questions. Overall, non-response is more frequent among small and service firms, and this is also the case when looking in particular at missing data on generator ownership. This is a standard observation in firm surveys, the main reasons including lack of time and/or information by the person responding to interviewers, which is more likely to occur when dealing with small firms. Because of the way generator ownership is distributed among firm size categories, this may affect our estimates, even if these non-responses are not driven by strategic considerations at firm level. While we have no systematic way to address this problem, results [not shown here to save space] indicate that most of our conclusions corresponding to specification (6) are robust to excluding small firms and all service activities respectively.[18]

The results from estimating equation (6) by maximum likelihood using a probit model on the full sample are shown in Table 6.[19] All specifications include country, industry and year dummies, and standard errors are clustered at the country-industry level. We first introduce the number of power outages alone in columns 1 to 3. Column 1 reports the results with fixed effects only, and column 2 those with firm-level controls (age of firm, location, whether it exports or not, whether it has foreign capital or not, and firm size). To the extent that more power outages are likely to lead to more generator ownership, we expect the coefficient for the number of outages to be positive, and this is indeed what we obtain. In column 2, a 10 percent increase in the number of outages adds 0.3 percent to the probability that firms own a generator. Note that in column 2, the coefficients of the age, capital city, and particularly export and foreign ownership dummies are large, positive and significant, while their inclusion actually reinforces the effects of power outages and credit constraints.

Column 3 introduces several measures of financial constraints: a dummy indicating whether access to financing is a major/severe constraint; a dummy indicating whether the cost of financing is major/severe constraint; and a dummy indicating whether the firm has access to an overdraft facility or line of credit. These variables again have the expected effect

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[18] A more general issue is the fact that surveys cannot provide information on firms that were not born, because of credit constraints or unreliable public power supply. Dethier, Hirn and Straub (2010) address this "camels and hippos" self-selection issue in details, stressing in particular that econometric models like the one in this paper only provide information about the effect of constraints on the sample of existing firms, and that the analysis of entry would require different models. However, since self-selection is hardly ever likely to be complete, some informative variation should remain in the data.

[19] See Appendix Table A2 for a description of the variables.

on the probability to own a generator, i.e., more stringent constraints decrease it, and more importantly their inclusion does not invalidate the results on outages.

Both firm-level controls and financial constraints proxies should be seen as control variables for the sake of robustness and their respective coefficients should not be interpreted as uncovering causal links, as specific endogeneity concerns arise from omitted variable bias and unobserved effects such as entrepreneurial skills.

In column 4 we add the electricity-intensive sector dummy, and in columns 5 to 7 we introduce its interaction term with outages, which turns out to be negative as expected. This means that the marginal impact of outages is lower in electricity-intensive sectors. Note that in columns 4 and 7, the coefficient for S_h is large, positive and significant. Indeed, as stressed in the model, firms in these sectors are much more likely to own a generator at baseline, as even a small number of interruptions can have very disruptive effects. In such a context, a marginal increase in the number of outages only has a limited effect on generator ownership.

Table 6: Remedial capital ownership

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Full Sample			
Probit	Generator	Generator	Generator	Generator	Generator	Generator	Generator
Number of Power Outage (Log)	0.082	0.097	0.057	0.055	0.098	0.117	0.077
	(7.99)***	(8.61)***	(4.24)***	(3.98)***	(6.82)***	(7.46)***	(4.56)***
Sectors very reliant on electricity S_h				0.379	0.155	0.239	0.459
				(1.76)*	(0.58)	(0.88)	(2.01)**
Number of Power Outage (Log) * S_h					-0.037	-0.046	-0.051
					(1.53)	(2.03)**	(1.86)*
Access to Financing Major/Severe Constraint			-0.12	-0.142			-0.142
			(3.02)***	(3.96)***			(3.98)***
Cost of Financing is Major/Severe Constraint			-0.057	-0.055			-0.053
			(1.74)*	(1.6)			(1.53)
Overdraft Facility or Line of Credit			0.209	0.198			0.198
			(5.47)***	(5.09)***			(5.16)***
Age		0.005	0.003	0.004		0.006	0.004
		(3.89)***	(2.40)**	(3.96)***		(6.03)***	(3.90)***
Capital City dummy		0.11	0.144	0.146		0.109	0.144
		(2.14)**	(2.46)**	(2.38)**		(2.05)**	(2.33)**
Export dummy		0.372	0.303	0.287		0.358	0.282
		(7.90)***	(6.68)***	(6.33)***		(7.57)***	(6.29)***
Foreign dummy		0.218	0.206	0.208		0.227	0.214
		(5.01)***	(4.38)***	(4.32)***		(5.25)***	(4.53)***
Constant	-1.001	-1.068	-0.799	-1.016	-1.411	-1.325	-1.057
	(5.38)***	(4.63)***	(3.58)***	(6.50)***	(10.74)***	(8.34)***	(6.67)***
Firm Size dummies		Yes	Yes	Yes		Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,943	18,786	12,704	12,240	24,451	18,320	12,240

Absolute value of z statistics in parentheses, standard errors are clustered at the country-industry level.
* significant at 10%; ** significant at 5%; *** significant at 1%

Next in **Table 7**, we estimate (3) on the two subsamples corresponding respectively to $S_h=0$ (columns 1 to 3) and $S_h=1$ (columns 4 to 6). This specification is less constraining, as it does not impose equality of the control variables' coefficients across subsamples. Table 7 confirms that the marginal effect is smaller in electricity-intensive sectors. Comparing columns 3 and 6, which include the full set of control variables for the cases $S_h=0$ and $S_h=1$ respectively, the coefficient of the log of outages in electricity-reliant industries is 36% smaller and only significant at the 10% level.

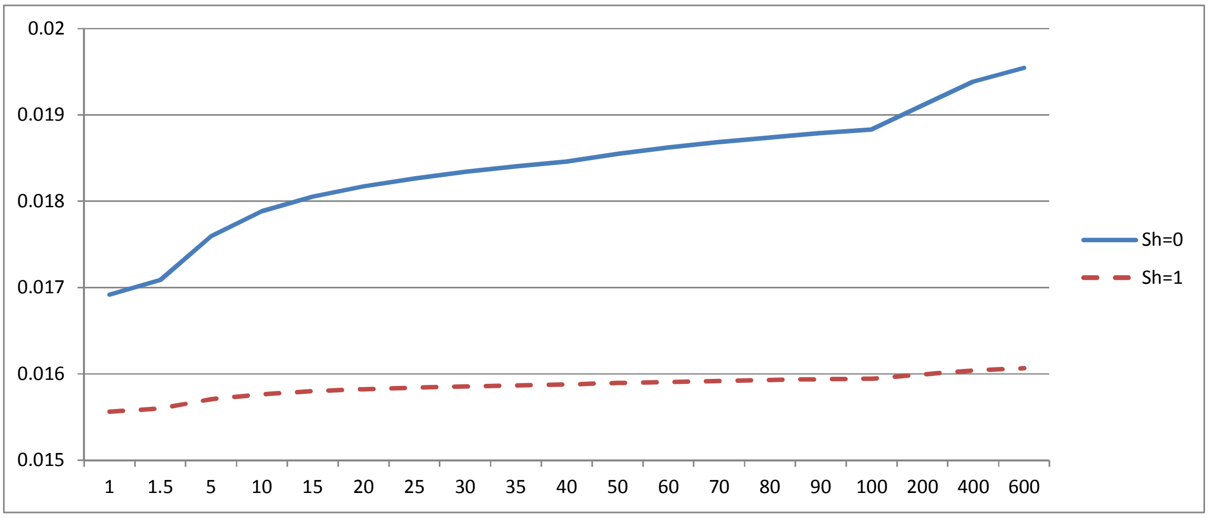
Table 7: Complementary capital decision depending on sectors' reliance on electricity

	(1)	(2)	(3)	(4)	(5)	(6)
	$S_h=0$	$S_h=0$	$S_h=0$	$S_h=1$	$S_h=1$	$S_h=1$
Probit	Generator	Generator	Generator	Generator	Generator	Generator
Number of Power Outage (Log)	0.091	0.109	0.064	0.069	0.08	0.041
	(6.37)***	(6.90)***	(3.56)***	(4.99)***	(4.81)***	(1.92)*
Access to Financing Major/Severe Constraint			-0.096			-0.197
			(2.11)**			(3.67)***
Cost of Financing is Major/Severe Constraint			-0.116			0.022
			(2.72)***			(0.41)
Overdraft Facility or Line of Credit			0.21			0.177
			(4.64)***			(2.59)***
Age		0.005	0.004		0.006	0.004
		(3.97)***	(2.72)***		(4.44)***	(2.76)***
Capital City dummy		0.146	0.168		0.065	0.123
		(2.13)**	(2.13)**		(0.8)	(1.27)
Export dummy		0.438	0.319		0.23	0.208
		(6.83)***	(5.79)***		(3.30)***	(2.92)***
Foreign dummy		0.185	0.184		0.276	0.239
		(3.56)***	(3.13)***		(3.81)***	(2.97)***
Constant	-1.506	-1.57	-1.319	-0.834	-0.522	0.082
	(13.33)***	(9.53)***	(7.78)***	(3.07)***	(1.44)	(0.28)
Firm Size dummies		Yes	Yes		Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,907	10,511	7,595	10,544	7,806	4,645

Absolute value of z statistics in parentheses, standard errors are clustered at the country-industry level.
* significant at 10%; ** significant at 5%; *** significant at 1%

The marginal effects mentioned above, however, are average marginal effects of the variables of interest computed at the sample mean of explanatory variables (28 for outages). The model's prediction can be more accurately confirmed by comparing the evolution of the marginal impact across the range of values of outages, which in our sample goes from zero to several hundred each year. Figure 5 shows the marginal effect computed at different level of outages, ranging from 1 to 600. Clearly, the marginal impact increases for sector not very reliant on electricity while, in electricity intensive sectors ($S_h=1$), it is almost flat across the entire range. In this group, a 10% increase in outages implies approximately a 1.5% increase in the probability to own a generator, while in the $S_h=0$ group, the added probability varies between 1.6% at low level of outages and close to 2% at high levels.

Figure 5: Marginal effect of outages at different level of efficiency



Next we turn to the analysis of firm size distribution. Following the model, we hypothesize that the higher the number of power outage the fewer small firms will manage to operate, especially in sectors relying strongly on electricity. We first present some simple difference-in-differences to highlight this phenomenon.

Table 8 shows the percentage of firms by size categories in different groups of countries (respectively those above or below the median number of outages in the full sample, equal to 7.9)[20] and sectors, for the two first categories of firms (strictly less than 10 employees, and between 10 and 19 employees), while Figure 6 shows corresponding values for all size categories.[21]

Concentrating for example on firms in the second category (less than 10 employees), we find that, as expected, there are relatively less small firms in countries where the average observed number of outage is above the median (31.42 and 22.01% respectively) than in

[20] The median across country-level averages is 7.9 and we split the sample in two equally-sized groups of countries.

[21] Using instead as threshold the average number of outages (11.56) yields very similar results. We have omitted tables and figures for this case in order to save space.

countries where the average number of outages is below this median (36.17 and 22.92% respectively). However, specific sector characteristics imply that the number of small firms is always higher in sectors very reliant on electricity than in others (36.17 and 31.42% vs. 22.92 and 22.01% respectively). Taking the double difference across countries and sectors therefore allows us to control for sectors' unobserved characteristics.

Table 8: Firm size distribution as a function of efficiency of the grid

	Countries With Number of Outages < 7.90 (Median)	Countries With Number of Outages > 7.90 (Median)	Above vs. Below median diff.
Percent of firms employing strictly less than 5 employees			
$S_h=1$	26.37%	18.02%	-8.35%
$S_h=0$	16.01%	9.34%	-6.67%
$S_h=1$ vs. $S_h=0$ diff.	10.36%	8.68%	**-1.68%**
Percent of firms employing strictly less than 10 employees			
$S_h=1$	36,17%	31,42%	-4,75%
$S_h=0$	22,92%	22,01%	-0,90%
$S_h=1$ vs. $S_h=0$ diff.	13,25%	9,41%	**-3,84%**
Percent of firms employing between 10 and 19 employees			
$S_h=1$	15,49%	19,54%	4,05%
$S_h=0$	14,81%	21,86%	7,05%
$S_h=1$ vs. $S_h=0$ diff.	0,68%	-2,32%	**-3,00%**

To put these numbers in perspective, note that looking only at electricity-intensive sectors ($S_h=1$), comparing the group of countries with a number of outages below the median to that of countries with above-median number of outages shows that the absolute number of firms decreases by 2,087 (a 16% decrease). Of these firms' disappearances, 71% (i.e., 1,474 firms) correspond to establishments of less than 5 employees. A similar comparison for non-electricity-intensive sectors ($S_h=0$) shows that the total number of firms is stable between the two groups of countries (only 18 less firms in high-outage countries) and that the reduction in the number of small firms is smaller than in electricity-intensive sectors, as shown by the double differences highlighted in bold in Table 8.

Table 8 thus shows that the number of small firms, as a percentage of the total number of firms, is smaller in electricity-intensive sectors in countries with a higher than median number of outages. Figure 6 confirms that the effect concentrates on the lowest size categories, while the relative proportions increase for all other categories.

Figure 6: Change in firm size distribution as a function of grid efficiency

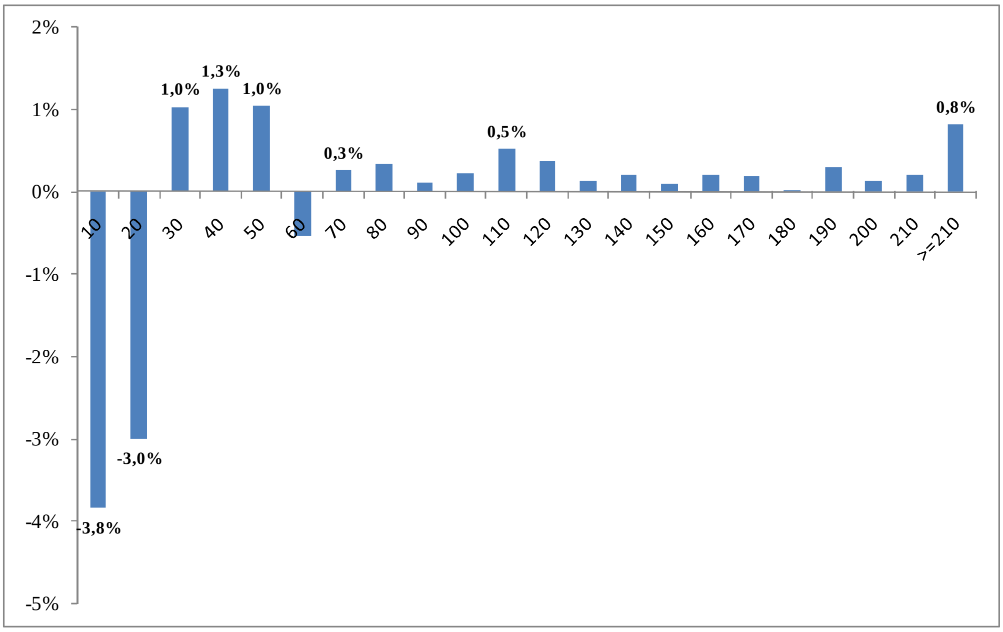


Table 9: Firm size distribution as a function of power outages

	(1)	(2)	(3)
	Number of Small Firms (<5) per Industry and Country / Total Number of Firms per Industry and Country	Number of Small Firms (<10) per Industry and Country / Total Number of Firms per Industry and Country	Gini index (computed on firms' number of employees) per Industry and Country
	Tobit	Tobit	OLS
Average Number of Power Outage (/100) per Industry and Country	-0.499	-0.253	0.178
	(1.96)*	(1.37)	(1.96)*
Average Number of Power Outage (/100) per Industry and Country * Sh (dummy) * High Number of Power Outage Country (dummy)	-0.642	-0.606	0.122
	(2.02)**	(1.69)*	(0.62)
Country dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Observations	1,777	1,777	1,777

Absolute value of z statistics in parentheses, standard errors are clustered at the country level.
* significant at 10%; ** significant at 5%; *** significant at 1%

To confirm these results, in Table 9 we present estimations of specification (7), including a full set of industry, country and time dummies. In columns 1 and 2, consistently with the previous evidence, our dependent variable Z_{jct} is the number of small firms (less than 5 or 10 employees) per industry and country divided by the total number of firms per industry and country. Alternatively, in column 3 we use a different measure of size distribution, namely a Gini index computed on firms' number of employees per industry and country.

In columns 1 and 2, we find as expected, that for a given industry and country a higher number of outages corresponds to a smaller proportion of small firms. Moreover, the triple interaction term (Average Number of Power Outage (/100) per Industry and Country * S_h * C_h (High Number of Power Outage Country dummy)) is negative and significant for both size categories (under 5 and 10 employees).

In column 3, we get similar results using the Gini index, which is a measure of concentration of the whole distribution of firms, although the interaction term is not significant (signs are now reversed as a higher Gini index implies that there are less small firms). The slight loss of significance is not surprising though, as our Gini measure capture a change in the full distribution rather than exclusively focusing on the share of small firms.

6. Conclusions and Policy Implications

The results of our empirical exercise can be summarized in an intuitive way as follows. For sectors that are very reliant on electricity, such as the chemical or textile industries, a high prevalence of outages affect the returns to investment so badly that small firms that lack enough initial assets to invest in an electric generator end up being squeezed out of the financial market and unable to borrow to expand production. In these sectors, the probability that firms invest in a generator only depends mostly on their level of initial assets; it is not (or less) affected by the prevalence of outages. In these sectors, we see a number of large firms with investments in complementary capital (power generator) and few small formal firms.

The policy implication hence seems to be that the priority to improve performance in sectors that naturally rely heavily on electricity is to relax financial constraints before addressing physical ones, because firms active in these sectors will have to invest in own generating capacity in order to avoid costly production interruptions and their ability to do so depends primarily on their access to the credit market. On the other hand, at least as long as (close to) full reliability is not obtained, marginal improvements in the quality of electric supply will have little effect, as they will be insufficient to spur meaningful entry of small firms to the market, while leaving large firms unaffected.

It is in sectors for which the first-best technology is very reliant on electricity that deficient supply will induce the biggest distortions, as firms will face the choice of invest in costly generators or settle for second-best technologies implying large efficiency gaps. Targeting these sectors with policies easing the access to credit, for example through the provision of credit guarantees for firms investing in electric generators, might have large payoffs if it allows for sector-wide technological adjustments towards the efficiency frontier.

By contrast, in sectors that are less reliant on electricity, the probability to invest in a generator is positively affected by the prevalence of power outages, and it is also affected by financial constraints, though less strongly than before. In addition to a number of large firms with investments in complementary capital, a larger range of small firms manage to access the credit market and produce formally, despite not having invested in a generator, and whose technology is closer to the frontier. For these firms, improvements in electric supply are likely to have significant positive payoffs.

Both sets of implications could theoretically be addressed by a policy mix targeting the relaxing of credit constraints to large firms willing to invest in electricity generator (specific public loans or guarantees for example) while allowing for the resale of this electricity to small firms around them.[22] However reselling electricity to the grid is not the general practice for enterprises in developing countries. It requires a legislative and/or regulatory enabling framework and, more importantly, economic incentives for utilities and private firms, which is not automatically the case.[23] While co-generation (for example, from bagasse by sugar producers) is easier to accommodate because it has a zero marginal cost, this usually involves considerable negotiations because of seasonality and uncertainty in terms of volume. Another consideration highlighting the difficulty to succeed with such arrangements relates to the reason for which firms purchase their generators in the first place. They are either large enterprises wanting to be independent from the grid for economic or security reasons (e.g., refineries or mining companies)—and therefore having little incentive to sell small volumes to the grid—or small and medium enterprises which need stand-by generators in case of outages or to ensure high reliability of power supply.

[22] See the discussion in Lee, Anas and Oh 1996 and in Lee, Anas, Verma and Murray 1996.

[23] Most firms' generators run on diesel and their marginal cost is much higher than that of large public utilities using fossil fuel-fired power plants, even when there are large line losses.

If reselling electricity to the grid is not feasible, a policy of charging different electricity prices for large and small firms is a possibility. As mentioned earlier, there are important scale economies in own-power generation so that smaller firms would be willing to pay much more for public power than larger firms. Instead of giving quantity discounts, public monopolies should charge larger firms more and smaller firms less than they presently do. As pointed out by Lee, Anas, Verma and Murray (1996), in countries where large firms have excess capacity like Nigeria, they could make intensive use of their idle power generating capacity while, in countries where firms are expanding like Indonesia, they would enlarge their facilities. In both types of countries, small users would realize savings by having to rely less on expensive power generators. The evidence uncovered in this paper adds to the potential rationale for such an approach.

Appendix.

Table A1: List of surveyed countries

Country	Year of survey	Number of firms	Country	Year of survey	Number of firms
Albania	2002 / 2005	364	Lebanon	2006	331
Algeria	2002	552	Lesotho	2003	56
Angola	2006	356	Lithuania	2002 / 2004 / 2005	643
Armenia	2005	522	Madagascar	2005	240
Azerbaijan	2002 / 2005	520	Malawi	2005	144
Bangladesh	2002	964	Malaysia	2002	759
Belarus	2002 / 2005	542	Mali	2003	127
Benin	2004	170	Mauritania	2006	212
Bosnia and Herzegovina	2002 / 2005	370	Mauritius	2005	199
Botswana	2006	133	Moldova	2002 / 2003 / 2005	625
Brazil	2003	1,634	Mongolia	2004	195
Bulgaria	2002 / 2005	548	Montenegro	2003	32
Burkina	2006	118	Morocco	2004	276
Burundi	2006	234	Namibia	2006	85
Cambodia	2003	360	Nicaragua	2003	449
Cameroon	2006	108	Niger	2005	115
Cape Verde	2006	43	Oman	2003	78
Chile	2004	930	Pakistan	2002	964
Costa Rica	2005	337	Peru	2002	347
Croatia	2002 / 2005	413	Philippines	2003	668
Czech Republic	2002 / 2005	609	Poland	2002 / 2003 / 2005	1,580
Democratic Republic of Congo	2006	300	Portugal	2005	503
Ecuador	2003	451	Romania	2002 / 2005	855
Egypt	2004	938	Russia	2002 / 2005	1,096
El Salvador	2003	457	Senegal	2003	210
Eritrea	2002	74	Serbia	2003	408
Estonia	2002 / 2005	388	Serbia & Montenegro	2002 / 2005	546
Macedonia (FYROM)	2002 / 2005	342	Slovakia	2002 / 2005	380
Georgia	2002 / 2005	374	Slovenia	2002 / 2005	411
Germany	2005	1,196	South Africa	2003	384
Greece	2005	538	South Korea	2005	598
Guatemala	2003	455	Spain	2005	604
Guyana	2004	148	Swaziland	2006	212
Honduras	2003	443	Syria	2003	421
Hungary	2002 / 2005	796	Tajikistan	2002 / 2003 / 2005	473
India	2006	3,788	Tanzania	2003	211
Indonesia	2003	713	Thailand	2004	1,163
Ireland	2005	498	Turkey	2002 / 2004 / 2005	2,321
Jamaica	2005	71	Uganda	2003	268
Kazakhstan	2002 / 2005	835	Ukraine	2002 / 2005	973
Kenya	2002 / 2003	247	Uzbekistan	2002 / 2003 / 2005	659
Kyrgyzstan	2002 / 2003 / 2005	474	Vietnam	2005	1,610
Laos	2006	236	Zambia	2002	206
Latvia	2002 / 2005	380	**Total Number of Firms**		**46,606**

Table A2: Description of the variables used in the analysis

Variable Name	Related Survey Question	Codification
Number of workers	Average number of permanent workers.	-
Age of firm	In what year did your firm begin operations in this country?	Age of the firm is computed as the difference between the year the survey was made the year in which the firm began operations.
Firm size	-	Small firms have strictly less than 20 employees, medium firms have between 20 and 99 employees, large firms have more than 100 employees.
Industrial sector	In which economic sector does your establishment mainly operate?	A dummy is created for each of the 28 sectors.
Capital City	Where are this establishment and your headquarters located in this country?	If the answer is the capital city of the surveyed country then dummy = 1 and 0 otherwise.
Firm exporting status	What percent of your establishment's sales are: 1) sold domestically; 2) exported directly; 3) exported indirectly (through a distributor).	If more than 20 percent of sales are exported directly or indirectly then dummy = 1 and 0 otherwise.
Firm ownership	What percentage of your firm is owned by: 1) domestic private sector; 2) foreign privates sector; 3) government or state; 4) other?	If more than 20 percent of the firm is owned by the foreign private sector then dummy = 1 and 0 otherwise.
Number of power outage	During how many days last year did your establishment experience power outages or surges from the public grid?	-
Generator ownership	Does your establishment own or share a generator?	Yes, Dummy=1 ; No, Dummy=0
Electricity is a severe or major constraint	Tell us if electricity (e.g. interest rates) is a problem for the operation and growth of your business. If this issue poses a problem, judge its severity as an obstacle on a four-point scale where: 0 = No obstacle; 1 = Minor obstacle; 2 = Moderate obstacle; 3 = Major obstacle; 4 = Very Severe Obstacle.	If this obstacle is a major one (3) or a very severe one (4) then dummy = 1 and 0 otherwise.
100 percent of working capital financed through internal funds	Identify the contribution over the last year of each of the following sources of financing for your establishment's working capital.	If 100 percent of the contribution comes from internal funds or retained earnings then the dummy = 1 and 0 otherwise.
100 percent of new investment financed through internal funds	Identify the contribution over the last year of each of the following sources of financing for your establishment's new investments.	If 100 percent of the contribution comes from internal funds or retained earnings then the dummy = 1 and 0 otherwise.
Access to financing is a severe or major constraint	Tell us if access to financing (e.g. collateral) is a problem for the operation and growth of your business. If this issue poses a problem, judge its severity as an obstacle on a four-point scale where: 0 = No obstacle 1 = Minor obstacle 2 = Moderate obstacle 3 = Major obstacle 4 = Very Severe Obstacle.	If this obstacle is a major one (3) or a very severe one (4) then dummy = 1 and 0 otherwise.
Cost of financing is a severe or major constraint	Tell us if cost of financing (e.g. interest rates) is a problem for the operation and growth of your business. If this issue poses a problem, judge its severity as an obstacle on a four-point scale where: 0 = No obstacle 1 = Minor obstacle 2 = Moderate obstacle 3 = Major obstacle 4 = Very Severe Obstacle.	If this obstacle is a major one (3) or a very severe one (4) then dummy = 1 and 0 otherwise.
Overdraft facility or line of credit	Do you have an overdraft facility or line of credit?	Yes, Dummy=1 ; No, Dummy=0
Total Cost	Sum of purchases of raw materials, cost of energy, cost of labor, interest costs, rental costs (machinery, equipment, land, buildings, vehicles), royalty or license fees) and other costs.	-
Cost of electricity	Value of electricity consumption for a year.	Expressed in Dollar of the year in which the survey was made.
Cost of labor	Manpower costs including wages, salaries, allowances, bonuses and other benefits.	Expressed in Dollar of the year in which the survey was made.
Cost of energy	Consumption of energy including electricity, fuels and others.	Expressed in Dollar of the year in which the survey was made.
Cost of generator (% energy cost)	Percentage of energy costs to run generator.	-
Interest costs	Interest charges and financial fees.	Expressed in Dollar of the year in which the survey was made.
Other costs	Overhead expenses, selling and general administration expenses or design dept.	Expressed in Dollar of the year in which the survey was made.

NB: All questions are related to the year preceding the survey

Table A3: Summary statistics for all firms

	Mean	Median	Minimum	Maximum	S.D	Observations
Number of workers	132.63	22	0	31,664	484.63	45,860
Age of firm	16.60	11	0	261	19.06	45,348
Number of power outage per year	27.57	3	0	7,355	91.08	46,606
Generator Ownership (% of firms with a generator)	34.92	0	0	100	47.67	25,043
Cost of electricity (% total costs)	7.41	3	0	100	15.03	10,327
% of firms' working capital financed through internal funds	62.12	77	0	100	39.73	45,326
% of firms fully financed through internal funds	40.31	0	0	100	49.05	45,326
% of firms quoting access to finance as severe or major constraint	25.80	0	0	100	43.75	44,711
% of firms quoting electricity as severe or major constraint	18.60	0	0	100	38.92	46,332

Table A4 provides information on access by firms to the credit market. Interestingly, most "objective" measures of credit constraints indicate that small firms are suffering more than their larger counterparts, while perceived constraints are more stringent for medium firms. When disaggregating by generator ownership and perception of electricity constraints respectively, firms without generator and firms suffering from electricity constraints appear to be more concerned by access and cost of finance.

Table A4: Credit constraints by firm characteristics

	% of firms quoting Access to finance as severe or major constraint	% of firms quoting Cost of finance as severe or major constraint	% of firms' working capital financed through internal funds	% of firms' new investment financed through internal funds	% of firms with 100% of working capital financed through internal funds	% of firms with 100% of new investment financed through internal funds
By firm size						
Small	19,3%	31,4%	68,4%	54,2%	47,4%	44,6%
Medium	22,7%	36,3%	58,2%	50,8%	35,2%	38,1%
Large	19,9%	31,2%	53,4%	49,8%	30,3%	35,2%
By generator ownership						
With generator	23.3%	35.1%	53.5%	50.7%	30.0%	37.0%
Without generator	26.2%	40.4%	56.1%	44.2%	35.4%	34.0%
By perceived severity of electricity constraint						
Major or severe	40.1%	47.4%	59.1%	57.5%	37.5%	42.3%
Mild	17.1%	28.5%	62.6%	52.1%	39.8%	40.3%
TOTAL	20,7%	32,3%	60,7%	51,7%	38,7%	39,7%

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