Financial Constraints and Firms' Investment: Results of a Natural Experiment Using Power Interruption*

Jevgenijs Steinbuks†

Department of Agricultural Economics and GTAP, Purdue University.

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†Corresponding Author. Address: 403 West State Street West Lafayette, IN, 47907-2056 United States. Phone: +1 765-494-4321, Fax: +1 765-496-1224, Email: jsteinbu@purdue.edu

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Abstract

A substantial literature has attempted to measure the relation between deepening of the financial services industry and economic development. Some papers have focused on the effects of deepening on firm investment decisions. Such research is confounded by the general difficulty of modeling the demand for capital. This paper uses a natural experiment in which power outages indicate shifts in the derived demand for investment in private generators. A theoretical model demonstrates that firms with better access to credit are more likely to invest in generators. The analysis of firm-level data from Sub-Saharan Africa confirms the theory. Controlling for other factors, firms with better access to credit are more likely to invest in generators when public power supply fails.

JEL Classification: D92, G11, O16, Q40

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1 Introduction

Financing constraints are an important research subject in the economic literature, which attempts to explain why firms do not undertake profit-maximizing investment, i.e. why they do not expand their capital stock if return to capital is above the market interest rate (Hubbard, 1998). Credit constraints now figure prominently in macroeconomic analysis, and there is strong evidence from cross-country regressions that underdeveloped financial systems are associated with poor investment and growth. The microeconomic evidence, especially from the developing country data, remains limited. Establishing evidence of credit constraints from microeconomic data is difficult, because measuring the return to capital is complicated by unobserved factors such as entrepreneurial ability and demand shocks, which are likely to be correlated with capital stock.

Most of the existing literature on financial constraints in developing countries is based on either direct evidence from survey data or series of randomized experiments. This paper is among the first to identify financial constraints in developing countries using a natural experiment. Specifically, it analyzes a firm's decision to invest in a private electric generator. Reinikka and Svensson (2002) demonstrated that firms tend to invest in own electric power generators in countries with unreliable public power supply.[1] Supply shocks to public power supplies are generally uncorrelated with an individual firm's market conditions and entrepreneurial ability. This study exploits these exogenous public power supply shocks to identify the effect of financing constraints on firms' investment.

First, a theoretical model is developed to derive profit maximizing conditions of a risk-neutral firm choosing whether to acquire a private generator to hedge against unreliable public power supply. The model predicts that financing constraints will reduce firm's expected return from the generator. Holding other things constant, firms with better access to credit will be more likely to install the generator if the power outages are frequent.

The predictions of the theoretical model are then tested empirically on firm-level data from 12 Sub-Saharan African countries. Endogenous switching regression and the difference-in-differences methods are used to obtain consistent estimates based on identification restriction that unobserved firm's idiosyncratic shock is uncorrelated with reliability of power supply. The results show that firms with better access to credit are more likely to undertake investment in an electric generator in the areas where public power supply is unreliable. Also, the firms are more likely to respond to the power outage shocks by investing in electric generators if they operate in the countries with more developed financial systems or during the periods of rapid domestic credit growth. Consistent with the predictions of the theoretical model, these findings suggest that financing constraints can significantly restrain firms' ability to invest in a replacement for deficient public services.

[1] The conclusions of Reinikka and Svensson (2002) are based on the microeconomic evidence on the quality of power supply from public grid and private investment in electric power generators in Uganda. Foster and Steinbuks (2009) provide more general evidence from the regression analysis on 24 African countries, which demonstrates that power outages are significant in explaining firms'generator ownership.

The rest of this study is organized as follows. The second section reviews the existing literature. The third section presents a theoretical model, which attempts to explain the effect of financing constraints on firm's choice of electric generator. The fourth and fifth sections discuss data and stochastic specification. The sixth section presents findings based on the analysis of the World Bank enterprise survey data. The last section outlines main conclusions of this study.

2 Literature Review

The effect of credit constraints on manufacturing firms is evident based on economic theory[2] and has been linked in the empirical literature to economic development.[3] Many theoretical models incorporate financing constraints based on information problems (adverse selection and moral hazard).[4] Other theoretical models explore financial constraints in the context of 'enforcement' problems (e.g. ability to seize collateral).[5] More recent theoretical papers[6] also view financing constraints from the perspective of the literature on industry dynamics.

The central challenge in the empirical work on financing constraints is to estimate consistently their effects on firms' performance indicators, such as growth, output, returns to capital, and investment. This task appears to be complicated. First, a firm's financing constraints are difficult to measure, especially in the context of unreliable developing country data. Second, both financing constraints and performance indicators are likely to be correlated with entrepreneurial ability, which is typically unobservable to the econometrician. As a result, omitted variables bias will render ordinary least squares regression estimates biased and inconsistent. The empirical literature provides several approaches to address these challenges.

The first approach, suggested by Fazzari, Hubbard and Petersen (1988) relies on Tobin's q theory of investment and tests for the sensitivity of firm investment to cash flows.[7] The intuition of this approach is as follows. Modigliani and Miller (1958) have shown that, in perfect financial markets, a firm's investment should only respond to its investment growth opportunities (measured by marginal "q"). Indicators of the availability of internal funds, such as cash flow, should not affect the firm's investment. Therefore, a significant coefficient on the measure of the cash flow in an investment equation may indicate the presence of financial market imperfections.

Because cash flow may be correlated with investment for other reasons, for example it may predict future profitability (Schiantarelli 1996), Fazzari, Hubbard, and Petersen (1988) implement cash flow tests separately for firms that are likely to be more constrained and firms that are likely to be less constrained.[8] Their results

[2] For a detailed survey, see Hubbard (1998)

[3] See King and Levine (1993), Rajan and Zingales (1998), Beck, Levine and Loayaza (2000), and Levine (2005).

[4] These models follow Jaffe and Russell (1976), and Stiglitz and Weiss (1981). For a survey of application of these models in the development economics literature, see Banerjee (2001).

[5] See e.g. Aghion and Bolton (1992), and Hart and Moore (1994, 1998).

[6] Gomes (2001), Quadrini (2003), Clementi and Hopenhayn (2006).

[7] A close alternative to this approach suggested by Bond and Meghir (1994) is based on Euler equations.

[8] The economic literature suggests different criteria to sort out firms into "more constrained" and "less constrained" categories.

show large and significant positive coefficients on cash flows coefficients for firms that are likely to be more constrained, and interpret this finding as an evidence of financing constraints. More recent applications of the cash flows test rely on simulation based econometrics. Instead of estimating reduced form investment equations, this method develops and calibrates a dynamic model of firm-level investment and then estimates it using econometric simulation techniques.[9] The recent examples of this approach include Alti (2003), Moyen (2004), Bond and Soderbom (2006), and Schundeln (2007). The major challenge for these cash flow models is measuring either the return to investment or the marginal value of "q" for firms in developing countries where the quality of financial measurement may be a function of the level of financial deepening.[10]

The second approach looks at direct evidence for constraints by analyzing survey data. For example, Bigsten *et al* (2003) estimate the determinants of demand for external formal funds (i.e. bank loans) in Sub-Saharan Africa explicitly using a selection model. Their results suggest that access to finance is greater for larger and more profitable firms. Beck, Demirguc-Kunt, and Maksimovic (2005), Ayyagari, Demirguc-Kunt, and Maksimovic (2008), and Gorodnichenko and Schnitzer (2010) assess the importance of financing obstacles, using survey evidence on each firm's ordinal ratings on how problematic specific financing issues are for the operation and growth of their business.

The limitation of the analysis based on the survey data is that it relies on strong assumptions about the relationship between a firm's perceptions and its true credit demand. For example, a firm that does not apply for a bank loan because "the interest rate is too high" may be constrained or simply unproductive relative to the prevailing market interest rate (Schundeln, 2007). Firms' perceptions are also subject to serious measurement errors. For example, strongly negative assessment of financing constraints can reflect the complaints of overly pessimistic managers, not the true financial position of the firm.[11]

The third approach attempts to identify credit constraints using randomized experiments.[12] A well known example in the economic literature illustrating this approach is a study by Banerjee and Duflo (2004), which investigates credit constraints by looking at the credit allocation rules of a particular (state owned) Indian bank. They exploit a change in government preferential lending rules to investigate whether firms would like to obtain more credit at the going interest rate than they can actually obtain. Banerjee and Duflo (2004) find that directed credit was used to finance more production - not to substitute for other forms of credit, and conclude that many of the firms must have been severely credit constrained. Other examples of this approach include related papers by de Mel, McKenzie, and Woodruff (2008b, 2009), and

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Fazzari, Hubbard and Petersen (1988) group firms according to their deposit retention ratios. Nabi (1989) distinguishes between firms, which borrow in formal and informal markets. Kaplan and Zingales (1997) propose an index of financing constraints based on the predictions from an ordered logit regression.

[9] For a survey of simulation based econometric methods see Gourieroux and Monfort (1996).

[10] See de Mel, McKenzie, and Woodruff (2008a). Rajan and Zingales (1998) attempt to overcome this problem by using U.S. firm information and assuming that the behaviour of the firms in other countries is similar to that of the U.S. firms in the same industry.

[11] Love and Mylenko (2003) attempt to solve this problem, by controlling for each manager's general perceptions of other (non-financial) constraints. They argue that a manager who answers most of questions on any type of constraint negatively will be more likely to report major financing constraints.

[12] For an excellent survey of randomization methods in the development economics, see Duflo, Glennerster, and Kremer (2007).

McKenzie and Woodruff (2008) which use a randomized experiment to measure the return to capital for the average microenterprise in their sample, regardless of whether they apply for credit. They accomplish this by providing cash and equipment grants to small firms in Sri Lanka and Mexico, and measuring the increase in profits arising from this exogenous (positive) shock to capital stock. After controlling for possible spillover effects, the shock is found to generate large increase in the average real return to capital relative to prevailing market interest rate. These studies interpret the increase in returns to capital as an evidence of missing or less developed credit markets. Properly conducted randomized experiments undoubtedly provide consistent estimates of the effects of financial constraints on firms' performance. They can however be rather expensive to conduct and are frequently limited to small set of firms, making it difficult to generalize their findings to other settings (Rosenzweig and Wolpin 2000).

The approach undertaken in this paper is related to studies that use the stock market, financial intermediaries, or enterprise survey data to find natural experiments[13] that directly identify credit constraints. Though it was successfully used in the corporate finance literature (Blanchard, Lopes-de-Silanes, and Shleifer 1994; Lamont 1997; Rauh 2006), its applications to financial constraints in developing countries are uncommon. The idea behind the approach is to exploit an exogenous shock to the demand for capital investment whose source is external to the firm. The advantage of this approach is that the firm's range of investment responses to the exogenous shock are limited, observable, and differ between financially constrained and unconstrained firms. Furthermore this approach is that it makes use of relatively simple information provided by firms, and thus it is less prone to measurement error.

3 Theoretical Model

A simple two-period model is presented below to guide the empirical specification. The objective is to show how financial constraints influence a firm's decisions to invest privately in capital. The salient features of the model are the assumptions that firms can (partly) cope with deficient public capital, but that it is costly to do so, and that the cost of financing of the investment in private capital increases with the degree of financial market imperfections.

3.1 Model Setup

This model adapts the analytical framework developed by Reinikka and Swensson (2002).[14] A risk-neutral firm has to decide whether to make a capital investment $i > 0$. Investment is productive with a one-period lag. The opportunity cost of capital is $c(i)$, with $c(0) = 0$, $c_i > 0$ and $c_{ii} > 0$, where lower subscripts denote

[13] For excellent surveys of natural experiments in economics, see Meyer (1995) and Rosenzweig and Wolpin (2000).

[14] The model of Reinikka and Swensson (2002) investigates firm's decision to install an electric generator in the absence of financing constraints.

first and second derivatives. The return to i depends (partly) on the power supply, which is either publicly provided or provided by the firm itself. There is uncertainty about the availability and quality of public electricity supply. Firms can (partly) insure against the risk of poor public power supply by investing in electric generator. However, there is a fixed cost $k > 0$ of doing so.[15] A firm that has installed an electric generator can ensure a return $(1 + r)\varphi i$, where $r > 0$ is a fixed return on investment and $\varphi > 0$ is firm's productivity (or entrepreneurial ability). When the power supply is perfectly reliable, the return is also $(1 + r)\varphi i$, while if it is not available (or of poor quality), the return is $\mu(1 + r)\varphi i$, where $0 < \mu < 1$.[16]

Financing constraints are introduced from the model of Kaplan and Zingales (1997). Investment i and the cost of a generator k can be financed either with internal funds (W) or with external funds (E). The cost of internal funds equals the opportunity cost of capital, $c(i)$, which is the rate of return the owners of the firm could get by investing outside the firm. Because of financial market imperfections, it is assumed that the use of external funds generates an additional cost. The reduced form of this cost function is represented by $g(E, \theta)$, where θ is an unobservable measure of a firm's wedge between the internal and the external costs of funds, which reflects the extent of agency or information problems.[17] It is assumed that the total cost of raising external funds is convex in the amount of funds raised and it increases in θ ($g(0, \theta) = g(E, 0) = 0$, $g_E > 0$, $g_{EE} > 0$, $g_\theta > 0$).[18] For the model to be well behaved, it is also assumed that cross-partial derivative of the total cost of raising external funds with respect to the amount of funds raised and the extent of the agency or information problems is positive ($g_{E\theta} > 0$).[19]

At the time of the investment in a generator, the conditions under which production takes place are unknown. Specifically, the timing of events is as follows. Initially, in the start of Period 1, the firms obtain information about the availability (and quality) of public power supply. This information can be used to derive a probability that power supply will be available (and of good quality). To simplify, it is assumed that there are only two possible outcomes: power supply is available with a probability p, and unavailable (or of very poor quality) with a probability $1 - p$. This variation is partly due to large differences in the priority attached to power lines, but also to local geographical (e.g., distance to nearest voltage connection) and

[15] Earlier empirical work, e.g. Bental and Ravid (1982), finds that adding electric generator capacity has two main cost components: a fixed installation cost and an operating cost. These costs are typically higher than that of public supply. The operating cost is captured in k as a present value of running costs in period 2. There is also a second-order effect of the size of investment on k because of increasing returns to scale in electric power generation. Reinikka and Svensson (2002, p. 55) however note that this second-order effect is small, and this assumption "seems like a reasonable first approximation."

[16] The lower return on investment when the power supply is not perfectly reliable could be either because of ouput lost due to power outages or because of higher operational costs of production (if firms choose to build up inventories to protect themselves against power outages). The model's predictions will remain the same irrespective of the cause.

[17] Kaplan and Zingales (1997, p. 174) point out that existing measures of financing constraints discussed in the literature (e.g. cash-flows sensitivities, firms' perceptions, or institutional quality indices) can be thought of as different proxies for unobservable θ.

[18] Kaplan and Zingales (1997) note that this assumption is reasonable but might not be warranted if the average transaction costs decline with loan amount. Also, see Calomiris and Himmelberg (1995).

[19] This assumption implies that the amount of funds raised and the degree of agency problems are complementary in rising the cost of external funds. Thus, the cost of external funds increases faster in the amount of funds rised in presence of agency problems. This is consistent with theory of credit supply under asymmetric information. For example, in Jaffee and Russell's (1976) model, the slope of credit supply function becomes steeper in the degree of default distribution, which, in turn, captures agency problems.

political conditions in Period 1.[20] With this *ex ante* information given, each firm makes a decision whether or not to acquire an electric generator. In Period 2, the outcome is realized and production with or without the newly installed electric generator takes place.

3.2 Equilibrium with no Financial Constraints

First, let us consider the case in which financial constraints are not binding. In this case the firm has either sufficient internal funds to finance investments ($W > i + k$) or has access to perfect capital markets ($g(E, \theta) = 0$). The problem can then be solved by working backwards. At the end of Period 2, two possible histories need to be considered:

1. The firm invests in a generator, and therefore ensures a return $(1 + r)\varphi i$. In this case the investor's problem can formally be stated as

$$\max_i \; (1 + r)\varphi i - c\,(i + k)\,. \tag{1}$$

The optimal investment rate following this history, denoted by i_1 is equal to

$$i_1(r, k, \varphi) = c_i^{-1}\left[(1 + r)\,\varphi\right] - k. \tag{2}$$

2. The firm does not invest in a generator, and has expected return of $\psi(1+r)\varphi i$, where $\psi = p+\mu(1-p)$. In this case the investor's problem becomes

$$\max_i \; = \psi(1 + r)\varphi i - c\,(i)\,. \tag{3}$$

The optimal investment rate following this history, denoted by i_2 is equal to

$$i_2(r, p, \varphi) = c_i^{-1}\left[\psi\,(1 + r)\,\varphi\right]. \tag{4}$$

At the end of period 1, each firm makes a decision whether or not to install private power, taking into account the investment functions (2) and (4). The optimal choice depends on the initial information of the availability (and quality) of public power supply. The condition for installing a generator at the end of period 1 is:

$$(1 + r)\varphi i_1 - c\,(i_1 + k) \geq \psi(1 + r)\varphi i_2 - c\,(i_2)\,. \tag{5}$$

The left-hand side of the equation (5) is the expected return if the firm installs a generator. The right-hand side is the expected return if the firm chooses to rely solely on the public power supply. The main

[20] For more discussion on that subject see Reinikka and Svensson (2002), and Svensson (2000).

result of the preceding analysis is summarized in the following proposition.

Proposition 1 *If a financially unconstrained firm's losses from power outages are high compared to the fixed cost of an electric generator, then (1) there exists a unique p^* defined on a convex compact set $I \subset [0,1]$, such that (5) holds as an equality, and (2) firms will always choose to install a generator if the reliability of public power supply is less than p^*.*

Proof. See Appendix 1. ■

3.3 Equilibrium with Financial Constraints

Now, let us consider the case in which financial constraints are binding. In this case the firm does not have sufficient internal funds to finance investments ($W < i + k$) and incurs extra cost of borrowing externally in capital market ($g(E, \theta) > 0$). The problem can still be solved in a similar way as in the previous section. At the end of period 2, there are the same two possible outcomes:

1. The firm invests in a generator, and therefore can ensure a return $(1 + r)i$. In this case the investor's problem can formally be stated as

$$\underset{i}{max}\ (1 + r)\varphi i - c(i + k) - g(E, \theta), \text{ such that } i + k = W + E \tag{6}$$

which can be rewritten in the unconstrained form as

$$\underset{i}{max}\ (1 + r)\varphi i - c(i + k) - g(i + k - W, \theta). \tag{6a}$$

The first order condition for the problem is

$$(1 + r)\varphi - c_i\,(i + k) - g_i(i + k - W, \theta) = 0. \tag{7}$$

Let $i_1'\,(r, k, \varphi, W, \theta) = \arg\max_i\ (1 + r)\varphi i - c(i + k) - g(i + k - W, \theta)$ be the optimal investment by the financially constrained firm, which solves equation (7). The effects of the rate of return, cost of generator, availability of internal finance, and financial market imperfections on the size of optimal investment can be obtained by implicit differentiation. The optimal investment increases in firm's productivity, the rate of return and the availability of internal finance, and decreases in cost of generator and the external borrowing premium.[21]

[21] The proof of this statement is demonstrated in the Appendix 1.

2. The firm does not invest in a generator, and expected return is $\psi(1+r)\varphi i$, where $\psi = p + \mu(1-p)$. In this case the investor's problem in the unconstrained form becomes

$$\underset{i}{max}\ \psi(1+r)\varphi i - c(i) - g(i - W, \theta). \tag{8}$$

The first order condition for the problem is

$$\psi(1+r)\varphi - c_i(i) - g_i(i - W, \theta) = 0. \tag{9}$$

Let $i_2'(\psi, r, \varphi, W, \theta) = \arg\max\limits_i \psi(1+r)\varphi i - c(i) - g(i - W, \theta)$ be the optimal investment by the financially constrained firm, which solves the equation (9). It is straightforward to show that, as in the case discussed above, optimal investment increases in firm's productivity, the rate of return and the availability of internal finance, and decreases in the external borrowing premium. It is shown in the Appendix 1 that optimal investment also increases in the reliability of power supply. Similar to the analysis in the previous section, the condition for installing an electric generator at the end of period 1 is

$$(1+r)\varphi i_1' - c(i_1' + k) - g(i_1' + k - W, \theta) \geq \psi(1+r)\varphi i_2' - c(i_2') - g(i_2' - W, \theta). \tag{10}$$

The results of the preceding analysis can be summarized by the following proposition.

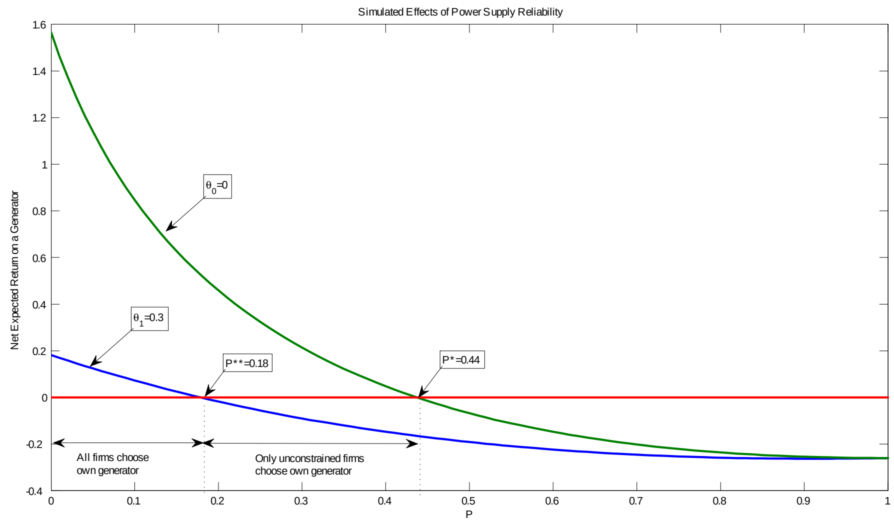
Proposition 2 *If the financially constrained firm's losses from power outages are high compared to the fixed costs of a generator and the financial adjustment costs, (1) there exists a unique p^{**} defined on a convex compact set $I \subset [0,1]$, such that (10) holds as an equality, (2) p^{**} is lower than p^*, holding other things constant, and (3) p^{**} declines with the degree of financial market imperfections θ.*

Proof. See Appendix 1. ■

Proposition 2 summarizes the main result of the model. Financing constraints reduce a firm's net expected return from a generator, and reduce the likelihood of investment in an electric generator. Thus, for a range of power quality levels, firms with better access to credit are more likely to install a generator if the power outages are frequent. Financially constrained firms invest in a generator only if the quality of public power supply is very low. Figure 1 illustrates the aforementioned effects by providing a numerical example.[22]

[22] The numerical example is based on the following assumptions, $c(i) = e^i$, $g(E, \theta) = \frac{1}{2}(E\theta)^2$, $r = 0.3$, $\varphi = 1$, $W = 0.8$, $\theta_0 = 0$, $\theta_1 = 0.3$, $k = 0.2$, and $\mu = 0.1$.

Figure 1



4 Stochastic Specification

The theoretical model developed in the previous section leads to the proposition that a rational profit-maximizing firm will choose to have an electric generator if net expected return (36) is positive. In an empirical model the reduced-form of net expected return from a generator can be written as

$$y_{it}^* = X_{it}'\beta + \theta_{it}'\delta + \xi_{it} + \varepsilon_{it} \tag{11}$$

where y_{it}^* is the net expected return from a generator for a firm i in time t, X_{it} is a set of explanatory variables, which, as discussed in the previous section, may include reliability of the public power supply, availability of internal funds, cost of a generator, and return on investment, θ_{it} is a proxy for financing constraints, ξ_{it} is unobserved firm's idiosyncratic shock (e.g. entrepreneurial ability), and ε_{it} is the error term. The net expected return from a generator y_{it}^* is an unobservable variable. Instead, we observe

$$\begin{aligned} d_{it} &= 1 \quad \text{if} \quad y_{it}^* > 0, \text{ and} \\ d_{it} &= 0 \quad \text{if} \quad y_{it}^* \le 0. \end{aligned} \tag{12}$$

where d_{it} is observed firm's investment in a private electric generator.[23]

[23] The observed firm's investment in a private electric generator in the empirical model (12) is a discrete variable, whereas it is a continious variable in the theoretical model. To reconcile this difference note that Propositions 1 and 2 imply that $i_{it} = 0$ if $y_{it}^* \le 0$ and $i_{it} = i_{it}'$ if $y_{it}^* > 0$. Thus one can rewrite the equation (12) as $d_{it} = 0$ if $i_{it} = 0$ and $d_{it} = 1$ if $i_{it} = i_{it}'$.

Based on the theoretical model discussed in the previous section one can formulate the following empirically testable hypothesis to identify the effect of financing constraints on firms' choice of private generator:

Hypothesis 1: The estimated coefficient δ on the proxy for financing constraints θ_{it} in equation (11) will be negative and significant.

The main problem in testing hypothesis 1 is that both the external financing premium θ_{it} and the firm's observed investment in electric generator d_{it} are correlated with the firm's unobserved idiosyncratic shock ξ_{it}. Therefore probit estimates of (11) are biased and inconsistent. The identifying assumption for consistent estimation of equation (11) is based on the theoretical model presented in the previous section. It follows from the model that for a range of power quality levels financially constrained and unconstrained firms will make different decisions about investing in a private generator if reliability of public power supply worsens. While power outages affect firm's choice of electric generator, reliability of public power supply is determined by state infrastructure and should not be correlated with firm's idiosyncratic characteristics.[24] Two econometric approaches that utilize this assumption are discussed below.

4.1 Difference-in-Differences Approach

Difference-in-differences approach uses pre-period differences in outcomes between treatment and control groups to control for pre-existing differences between the groups, when data exists both before and after the treatment.[25] To illustrate this approach, let us sort the firms into two groups. Group T is affected by the power outage shocks ("treated") in period 1 and unaffected by power outage shocks ("untreated") in period 0. Group C is never treated. Denote by y_1^T (y_1^C) the realization of firms' decisions to invest in electric generator in period 1 (after the power outages occur), and y_0^T (y_0^C) the realization of firm's decisions to invest in the electric generator in period 0 (before the power outages).

The difference-in-differences estimator is given by

$$\widehat{DD} = [\widehat{E}[y_1^T\ |T] - \widehat{E}[y_0^T|T]] - [\widehat{E}[y_1^C|C] - \widehat{E}[y_0^C|C]], \tag{13}$$

and provides an unbiased estimate of the treatment effect under the following assumptions:

1. Treatments are exogenous to time and group fixed effects.[26] This assumption is satisfied because power outage shocks are typically caused by random events, such as droughts, natural disasters, or purposeful (e.g. terrorist) attacks.[27]

[24] See section below for a thorough discussion of exogeneity of power outages.
[25] The discussion in this paragraph closely follows Duflo, Glennerster, and Kremer (2007, pp. 12-13).
[26] See Besley and Case (2000).
[27] for a more thorough discussion of this assumption, see section below.

2. $[\widehat{E}[y_1^C\ |T] - \widehat{E}[y_0^C|T]] = [\widehat{E}[y_1^C|C] - \widehat{E}[y_0^C|C]]$, i.e., absent the treatment the outcomes in the two groups would have followed parallel trends.[28] This critical assumption is satisfied because the theoretical model discussed in the previous section predicts that in the absence of power outage shocks neither financially unconstrained nor financially constrained firms would invest in a private generator.

Because there is more than one time period and more than one treatment group in the observed data, this study adopts the fixed-effects estimator, which generalizes the difference-in-differences approach. The fixed-effects models estimated in this study are given by

$$\begin{aligned} y^*_{ijt} &= \alpha + \beta_1 \cdot PO_{jt} + \beta_2 \cdot PO_{jt} \cdot FC_j + \delta'_j\beta_3 + x'_{ij}\beta_4 + \varepsilon_{ijt}, \\ & \begin{cases} d^1_{ijt} = 1 \text{ if } y^*_{ijt} > 0; \\ d^1_{ijt} = 0 \text{ if } y^*_{ijt} \leq 0; \end{cases} \end{aligned} \tag{14}$$

$$\begin{aligned} y^*_{ijt} &= \alpha_i + \gamma'_t\beta_1 + \beta_2 \cdot PO_{jt} \cdot FC_{jt} + \delta'_j\beta_3 + x'_{ij}\beta_4 + \gamma'_t\beta_5 + \varepsilon_{ijt}, \\ & \begin{cases} d^2_{ijt} = 1 \text{ if } y^*_{ijt} > 0; \\ d^2_{ijt} = 0 \text{ if } y^*_{ijt} \leq 0; \end{cases} \end{aligned} \tag{15}$$

and

$$\begin{aligned} y^*_{ijt} &= \alpha + \beta_2 \cdot FC_{jt} + \delta'_j\beta_3 + x'_{ij}\beta_4 + \varepsilon_{ijt}, \\ & \begin{cases} d^3_{ijt} = 3 \text{ if } \mu_2 < y^*_{ijt}; \\ d^3_{ijt} = 2 \text{ if } \mu_1 < y^*_{ijt} \leq \mu_2; \\ d^3_{ijt} = 1 \text{ if } 0 < \ y^*_{ijt} \leq \mu_1; \\ d^3_{ijt} = 0 \text{ if } y^*_{ijt} \leq 0. \end{cases} . \end{aligned} \tag{16}$$

The dependent variable y^*_{ijt} in the specifications (14)-(16) is unobserved net expected return from an electric generator for a firm i in country j and time t. In the models (14)-(15) the observed realization of y^*_{ijt} is the choice of generator. In the model (16) the observed realization of y^*_{ijt} is a categorical variable, which takes values of zero if a firm did not invest in a generator, the value of one if the firm invested in a generator in the absence of serious (at the state level) power outages, the value of two if the firm invested in a generator during power outages, and the value of three if the firm invested in a generator following a series of power outages. The advantage of the latter model is that it takes into account that firm's generator ownership at time t depends on whether it already had one in the previous period, so the timing of investment matters.

[28] See Bertrand, Duflo, and Mullainathan (2004).

The explanatory variables are the pulse dummy variable for observed major disruptions in public power supply PO_{jt}[29], countries' time-invariant characteristics of financial institutions FC_j, time-varying financial system's performance indicators FC_{jt}, vector of firm characteristics x'_{ij}, and country and year dummies δ'_j and γ'_t respectively.[30] The subscripts i, j, and t denote the firm, country, and time effects, respectively, and ε_{ijt} is the error term. In the model (16) μ's are unknown parameters to be estimated with β's.

The models (14)-(15) are estimated by logit for panel data. The model (16) is estimated by ordered logit. The inferences from the theoretical model discussed in the previous section can then be verified by testing if the estimated coefficient β_2 is positive and significant in specifications (14)-(16). This implies that the likelihood of investing in an electric generator during power outages is higher in the countries with better financial systems.

The advantage of the difference-in-differences approach is in its simplicity as well as the potential to circumvent many of the endogeneity problems that typically arise when making comparisons between heterogeneous groups under less restrictive assumptions.[31]

4.2 Endogenous Switching Regression Approach

Endogenous switching regression approach discussed by Maddala (1983), and frequently applied in the literature on financing constraints[32], can be expressed as

$$Y^*_{1i} = \alpha_0 + x'_{1i}\beta_1 + Z'_{1i}\gamma + \varepsilon_{1i} \text{ if } g_1 = 0, \tag{17}$$

$$Y^*_{2i} = \alpha_0 + x'_{2i}\beta_2 + Z'_{2i}\gamma + \varepsilon_{2i} \text{ if } g_1 = 1, \tag{18}$$

$$Y^*_{3i} = W'_i\alpha + \omega_i, \tag{19}$$

$$g_1 = \begin{cases} 1 \text{ if } Y^*_{3i} > 0, \\ 0 \text{ if } Y^*_{3i} \leq 0 \end{cases}. \tag{20}$$

[29] Note that theoretical model is based on firms' *ex ante* expectations (p^* and p^{**}), whereas PO_{jt} is a measure of actual shocks. To reconsile these differences between theoretical and empirical models, it is assumed that firms' expectations are rational. They use available information in period 1 (e.g. weather forecasts) to predict power outage shocks. Observed outage shocks thus reflect firms' *ex ante* expectations.

[30] As specification (14) has time-invariant explantorary variables, we do not include year-specific fixed effects. However, given that formation of institutions (including the financial institutions) is highly persistent (North 2009) the estimated effects are unlikely to be affected by the short-term disturbances.

[31] e.g. endogeneity arising from omitted entry and exit variable bias (see Clementi and Hopenhayn 2006 for discussion of this bias).

[32] See e.g. Nabi (1989), Hu and Schiantarelli (1998), and Lamont, Polk, and Saa-Requejo (2001).

In the endogenous switching regression framework the functional form of the net expected return from a private generator (Y_{ji}^*, $j = 1, 2$) is assumed to vary across two regimes ("financially constrained" and "financially unconstrained") as specified by the equations (17) and (18). Both equations share the same set of explanatory variables, which, as explained above, include reliability of power supply (denoted by x_{ji}, $j = 1, 2$) and other factors, such as return on investment, cost of generator, and the firm's observed idiosyncratic factors (denoted by Z_{ji}, $j = 1, 2$). Equation (19) is a selection equation determining which regime applies. The variable Y_{3i}^* is a latent variable representing the cost of choosing external financing over internal financing, which id our measure of financial constraints. We know from the theoretical model that this choice depends on two factors - availability of internal funds (W) and the degree of informational or agency problems (θ).The matrix W_i captures the set of variables related to these factors, which may include firms' borrowing costs, credit demand, and risk, as well as the financial market's institutional characteristics. The variable g_1 is a dummy variable, which takes value of 1 if firm undertakes internal financing, and zero otherwise. In the presence of financial market imperfections external funding is not a perfect substitute for internal finance, therefore d_1 also indicates whether a firm is more or less likely to be financially constrained.

Consistent estimation of the endogenous switching model in our case is complicated because the variables Y_{1i}^* and Y_{2i}^* are unobserved. Instead we observe d_{21} and d_{22} defined as

$$d_{21} = \begin{cases} 1 \text{ if } Y_{1i}^* > 0, \\ 0 \ \text{ if } Y_{1i}^* \leq 0 \end{cases} \text{ if } g_1 = 0, \text{ and} \tag{21}$$

$$d_{22} = \begin{cases} 1 \text{ if } Y_{2i}^* > 0, \\ 0 \ \text{ if } Y_{2i}^* \leq 0 \end{cases} \text{ if } g_1 = 1 \tag{22}$$

Kimhi (1999) has shown that in this case the two-stage solution proposed by Maddala (1983) will result in biased estimates. The full information maximum likelihood (FIML) estimator, which corrects the bias, results from maximization of the following likelihood function

$$\ln L = \sum \left\{ \begin{array}{c} g_1 \cdot d_{22} \cdot \ln \Phi\left(\frac{W_i\alpha}{\sigma_1}, \frac{X_{2i}\beta_2}{\sigma_{22}}, \rho_2\right) + \\ +g_1 \cdot (1-d_{22}) \cdot \ln \Phi\left(\frac{W_i\alpha}{\sigma_1}, -\frac{X_{2i}\beta_2}{\sigma_{22}}, -\rho_2\right) + \\ +(1-g_1) \cdot d_{21} \cdot \ln \Phi\left(-\frac{W_i\alpha}{\sigma_1}, \frac{X_{1i}\beta_1}{\sigma_{21}}, -\rho_1\right) + \\ +(1-g_1) \cdot (1-d_{21}) \cdot \ln \Phi\left(-\frac{W_i\alpha}{\sigma_1}, -\frac{X_{1i}\beta_1}{\sigma_{21}}, \rho_1\right) \end{array} \right\}, \tag{23}$$

where $\Phi(\bullet)$ is cumulative distribution function of a standardized bivariate normal random variable, σ_1, σ_{21}, and σ_{22} are components of covariance matrix, and ρ_1 and ρ_2 are the correlation coefficients between the residuals in the selection and switching equations.

If financial constraints have no effect on the firms' decisions to invest in a generator given their expectations of power outages, then the difference between the estimated coefficients β_1 and β_2 ($\beta_1 \geq \beta_2$) on reliability power supply in equations (17) and (18) is not statistically significant:

$$\beta_1 - \beta_2 = 0 \tag{24}$$

This inference can be tested by maximizing the likelihood function (23) both subject to the constraint (24) and without this constraint, and then implementing the likelihood ratio test.

The advantage of the endogenous switching regression approach is that it offers a simple test for financing constraints based on simultaneous estimation of firm's investment and financing decisions. *This test only requires consistent estimates of β_1 and β_2 one can obtain if unobserved firm's idiosyncratic shock is uncorrelated with reliability of power supply (e.g. $Cov(x_{ij}, \omega_i) = 0$) and allows for other regressors in equations (17), (18) and (19) to be endogenous.* It also makes use of more precise cross-sectional data on power outages in local areas, reported at the firm level. The limitation of this approach is that it relies on cross-sectional estimates, and hence stronger assumptions (e.g. positive correlation between current power outages reported by firm and the level of power outages at the time of buying a generator) are needed to identify the model.[33]

5 Data and Empirical Specification

The lack of good quality firm-level data has been a substantial limitation to the research on credit constraints and firm behavior. This study makes use of a new dataset compiled from the *Enterprise Surveys* collected by the World Bank from 2002 to 2006, which at the time of research comprised information from over 60,000 firms in 97 developing countries.[34] The *Enterprise Survey* data capture business perceptions of the biggest obstacles to enterprise growth, the relative importance of various constraints to increasing employment and productivity, and the effects of a country's investment climate on its international competitiveness.

The enterprise survey questions are concerned with factors constraining the effective functioning of the product and financial markets, focusing on the weaknesses in an economy's infrastructure, law enforcement, public administration, and regulatory framework. The enterprise surveys sample from the universe of registered businesses (e.g. firms listed in a country's enterprise register), and follow a stratified random sampling method.[35] The enterprise survey is confidential to protect the respondents.[36]

The analysis in this study is based on the data from Sub-Saharan Africa region. One of the critical assumptions of the theoretical model discussed in the previous section is that a firm purchases a generator to

[33] Another complication from the endogenous switching regression approach arises if some firms are located in the areas without access to public power supply, because the firms' decisions to install private generators in this case will be different. This complication is addressed because all firms used in this study indicated they had an access to public grid.

[34] *Enerprise Surveys* were previously known as *Investment Climate Surveys*. A detailed information on the *Enterprise Surveys* is available on the following website: http://www.enterprisesurveys.org/.

[35] The sample is stratified on the basis of firm's location, industry, and size contribution to a country's GDP. Because the distribution of establishments in most countries is overwhelmingly populated by small and medium enterprises, surveys may over-sample large establishments.

[36] Confidentiality provisions are especially necessary if the firms are underreporting their income or wages to public agencies.

prevent loss on the productive investment from power outages. Therefore, the sample should be restricted to regions where power outages are frequent. One of such regions is Sub-Saharan Africa, where the main reason for electric generator ownership is related to poor quality of electric power infrastructure (Estache 2005; Foster and Steinbuks 2009). Another region, which satisfies this assumption is South Asia (India, Pakistan, Bangladesh). Unfortunately, good quality data were not available for this region at the time of research. In other regions, private generator ownership is frequently not related to the quality of public power supply and therefore this assumption is unlikely to be satisfied.[37]

5.1 Exogeneity of Power Outages

Both empirical approaches require exogeneity of power outages in the generator choice equations. This assumption is generally plausible because reliability of the power supply depends on two factors. The first factor is quality of state power (generation, transmission and distribution) infrastructure, which is affected by government's and utilities' investment decisions. The second factor is exogenous shocks to power infrastructure such as droughts, natural disasters, armed conflicts, or purposeful (e.g. terrorist) attacks (Eberhard et al 2008). Neither of two factors is related to firm's investment decisions affected by idiosyncratic shocks (e.g. entrepreneurial ability). However, one could imagine scenarios under which power outages are endogenous. This scenarios are discussed below.

First, power outages can be endogenous when the governments pursue active regional policies by providing substantial public capital and creating other incentives for productive businesses to stimulate growth in selected areas.[38] Then, the relationship between location-specific power outages and generation ownership may be endogenous because as a result of such policies more productive (and less financially constrained) firms may start up in the locations with more reliable power supply. In Sub-Saharan Africa implementation of such policies is limited by political instability, corruption, ethnical fragmentations and clan struggles (Easterly and Levine, 1997). Power outages are thus exogenous to entrepreneurial ability and reflect underperformance of power sector institutions, that are mainly characterized by unreliability of power supply, low capacity utilization, deficient maintenance, poor procurement of spare parts, and high transmission and distribution losses among other problems (Karekezi and Kimani 2002).

Second, power outages can be endogenous in developing countries where economic and structural reforms rendered them able to improve their infrastructure. For example, rapid improvement in quality of their transport and distribution systems may reduce public power outages (e.g. because coal is delivered on time) and increase investment in private generators (because their price declines due to lower delivery costs). In Sub-Saharan Africa despite some reforms initiated in public infrastructure sector in 1990s, only limited

[37] It happens for other reasons, such as compliance with safety standards, industry-specific requirements, and the adoption of environmentally friendly technologies or economic gains (e.g. from cogeneration).

[38] The impact of these policies has not been yet clearly established. For example, de la Fuente and Vives (1995) find that investment in infrastructure has made only a small contribution to regional convergence in Spain. On the other hand, Demurger (2001) concludes that infrastructure endowment did account significantly for observed differences in growth performance across provinces in China.

progress has been achieved (Estache 2005; Easterly 2009).[39]

Third, firm's choice of location can make power outages endogenous. For example, a highly skilled entrepreneur can better identify parts of a country that are less vulnerable to power outages, thus inducing a correlation between ability and power outages. Reinikka and Svensson (2002, p.54) also noted based on the interviews with firms' managers that "firms connected to "priority" lines (e.g., power lines that connect important army facilities) were more likely to receive reliable power supply." To test for exogeneity of location, the quality of power supply (measured by days of power outages) was regressed on a series of firms' characteristics, and spatial dummy variables. Spatial characteristics were not significant for any of three countries used in endogenous switching regression model.[40] Unfortunately, it is not possible to infer from *Enterprise Survey* data whether the firm is connected to a "priority" line. These connections are, however, quite rare and limited to large firms.[41] The effect of unobserved "priority" lines is therefore captured by size dummy variables.

Fourth, if power outages are pre-announced and their timings are well known to everyone, they may become endogenous, as firms with better entrepreneurial activity can better alter their production schedule. Unfortunately, *Enterprise Survey* data does not differentiate between pre-announced and unannounced power outages. Anecdotal evidence, however, suggests that a large fraction of power outages is unannounced. For example, during 2007-2008 energy crisis, ESCOM, the largest utility company in Sub Saharan Africa, implemented load shedding on a rotational basis[42], and rolling blackouts took place at very short notice, causing major industrial and residential disruptions (IOL 2007, BBC 2008, Mail&Guardian 2008).

Fifth, if financially constrained firms make electric power sharing arrangements with financially unconstrained firms to take advantage of economies of scale in power generation, firm's idiosyncratic shock will be correlated with reliability of power supply, and estimated coefficients will be biased and inconsistent. There is no evidence of such arrangements in the data the hypothesis is tested.

Sixth, the relationship between power outage shocks and the cost of finance could be endogenous if, on the supply side, financial institutions respond to power outage shocks by reducing lending to avoid credit losses due to increased output volatility. On the demand side, an electricity outage may lower the demand for firms' output and thus affect their ability to repay the loan, and ensure future access to finance. To test for these possibilities the growth of domestic credit to private sector was regressed on the dummy variable for power outages, and a series of country and time dummy variables. Contrary the endogeneity hypothesis

[39] This observation is also important because the endogenous switching approach relies on cross-sectional data and the information on power supply reported by the firms in survey year should be correlated with the state of the power infrastructure at the time of installing a generator. For most firms in the sample the gap between survey year and installing own generation was small (about 2 - 3 years), but for some firms it was larger (about 10 years).

[40] Endogenous location criticism is not applicable to difference-in-differences approach, because it considers country-level power shocks independent of firm's location.

[41] Source: author's interview with Dr. Joseph Mutale, formerly a Director of Engineering Development and Transmission Manager at ZESCO, the Zambian National Utility. Dr. Mutale also pointed out that firm's marginal benefit of being connected to a "priority" line is small, because the utility first sheds residential customers if there is excess demand for electric power, and this measure is typically sufficient to balance the grid.

[42] Source: ESCOM Fact Sheet "How does system management work?" available at http://www.eskom.co.za

the estimated coefficient was positive and significant.

Seventh, the estimates from both regression approaches can be biased if the financially constrained firms choose smaller than desired generation capacity in response to the power outage shocks. Unfortunately, the data on generator capacity is not available for most of surveyed countries. Steinbuks and Foster (2010) estimate a tobit regression relating generators' capacity to firms' characteristics for a subset of countries covered in this study. They find that generators' capacity increases with the duration of power outages, but that effect is relatively small. Firms' size and age are the key variables affecting the choice of generators' capacity. Moreover, they find that the generation capacity choice with respect to power outages does not vary across different firm size categories. The only exception are the very small firms (which are most likely to be financially constrained), that choose *larger* generation capacity.

Finally, the estimates from the endogenous switching regression can be biased and inconsistent if firms' unobserved entrepreneurial ability follows a specific pattern that affects firms' investment in electric power generator, and is unrelated to power outage shocks. One of such examples is well-known entry and exit bias (Clementi and Hopenhayn 2006).[43] As industry entry and exit rates are not reported in the *Enterprise Survey* data, and generally not available for most (if any) Sub-Saharan African countries, this study attempts to control for this bias using observed firm's characteristics (age, size) based on the predictions from economic theory (Hopenhayn 1992; Ericson and Pakes 1995). Another example is the unobserved heterogeneity bias. This bias can arise if firms with different unobserved productivities respond differently to power outage shocks at the same level of financial constraints. In this case, the model described by the equations (17) - (22) becomes the random coefficient's model.[44] Estimation of random coefficients endogenous switching model is a difficult econometric problem, which (to the author's knowledge) has not been solved yet. Fortunately, the theoretical model helps establishing the direction of this possible bias. It follows from the model that the amount of optimal investment with respect to power outages in the absence of electric generator declines more for productive firms (equation 35, Appendix 1). The more productive firms will therefore choose to invest in electric power generators at higher level of financial constraints (because they lose more from power outages), and vice versa. In presence of large productivity differentials this will result in downward's bias of coefficient β_1 in equation (17), and upward's bias of of coefficient β_2 in equation (18), thus reducing the power of proposed test 24. As demonstrated later, the findings based on the endogenous switching approach show negative and significant effects of financing constraints. These findings imply that either productivity differentials across firms are not high (and the bias is small), or the effect of financing constraint on firm's investment is even more dramatic.

[43] The author thanks T. Beck for making this point.

[44] The author thanks T. Crossley for clarifying this point.

5.2 Empirical Specification

This section describes the variables used in the empirical specification. Based on the theoretical model, a firm's choice of a generator depends on reliability of power supply (positively), cost of a generator (negatively), return on investment (uncertain), availability of internal funds (non-negatively), and the external financing premium (negatively). Tables 1 and 2 summarize the variables representing these factors.[45]

5.2.1 Difference in Differences Approach

For implementation of the difference-in-differences approach one should exploit time dimension of *Enterprise Survey* data. Most of the variables in the dataset were only available at cross-section level. However, most firms reported the year of business start-up, and the owners of electric generator reported the year the generator was acquired. Overall, the firm-level data on time of business start-up and acquisition of electric generator necessary were available for 1309 firms in 12 Sub-Saharan African countries. This information was used to transform the dataset into an unbalanced quasi-panel. One country (Nigeria) was excluded from the sample, because 100 percent of firms owned a generator and nearly all of them acquired it at the time of business start-up. Therefore, country fixed-effect predicted generator ownership perfectly. The dataset includes only firms that started operations after 1990, when reliable data on power outages and cost of external financing were available.[46] It thus excludes firms that could experience power outages (being "treated") in prior periods (outside observation sample) and better anticipate the possibility of a power outage in a later period and prepare accordingly. It also excludes those firms that could have owned a generator before the survey was made.[47] Another problem with the construction of quasi-panel dataset is that we do not observe entry and exit rates. We have discussed this issue in the previous section. Because time-series data on power outages and the cost of external financing were not available at the firm-level, the aggregate indicators were used in panel dataset.[48] Table 1 summarizes the variables used in the difference-in-differences approach.

The information on generator ownership comes from the *Enterprise Survey* dataset, and is measured by the dummy variable, which takes the value of one if a firm owns electric generator at the time the survey was taken, and zero otherwise. Conditional on *ex-post* ownership information, the dummy variable takes value of one starting from the year the generator was purchased. Table 1 shows that there is a considerable variation across countries in the share of firms having a private generator, ranging from 6 percent in South Africa to 68 percent in Kenya.

[45] For more details, also see tables 1 - 9, Appendix 2.

[46] As data for that subsample was collected between 2002 and 2004, the maximum time dimension of the panel is 14 years. For detailed information on age distrubutions, see table 9, Appendix 2.

[47] This is because the average life of electric generator in Sub-Saharan Africa is about 10 years (assuming regular maintenance). The author thanks Rob Mills for making this point.

[48] Gorodnichenko and Schnitzer (2010, p.11) demonstrate using WBES data for Eastern Europe and CIS countries that average firm level indicators for access and cost of finance and macroeconomic indicators of financial development are "clearly positively correlated".

The data on power outages come from the *International Energy Annual (2004)*, published by Energy Information Administration, U.S. Department of Energy. The (average) periods of power outages are measured as a significant (more than 10 percent) increase in country's electricity distribution losses.[49] Starting from 1990 the most frequent power outages were in Benin (57% of surveyed periods), Malawi (35% of surveyed periods), and Eritrea (30% of surveyed periods). The most reliable power supply was in South Africa (0% percent of surveyed periods).[50]

Table 1: Descriptive Statistics (12 Countries Dataset)

Country	Share of Firms Owning a Generator		Periods of Power Outages		Growth in Domestic Credit		Credit Information index	Credit Registry Coverage
	mean	sd	mean	sd	mean	sd		(% of adults)
Benin	0.20	0.40	0.57	0.51	0.06	0.33	1	3.5
Eritrea	0.38	0.50	0.30	0.48	0.19	0.24	0	0
Kenya	0.68	0.47	0.17	0.38	-0.01	0.08	2	0.1
Madagascar	0.18	0.38	0.13	0.34	-0.04	0.12	1	0.3
Malawi	0.35	0.48	0.35	0.48	0.06	0.20	0	0
Mali	0.41	0.50	0.12	0.33	0.03	0.13	1	2.3
Mauritius	0.28	0.45	0.25	0.44	0.06	0.10	0	0
Senegal	0.52	0.50	0.13	0.33	-0.02	0.06	1	4.3
South Africa	0.06	0.25	0.00	0.00	0.04	0.13	5	63.4
Tanzania	0.56	0.50	0.23	0.42	-0.09	0.10	0	0
Uganda	0.26	0.44	0.21	0.41	0.11	0.33	0	0
Zambia	0.20	0.41	0.17	0.39	0.01	0.25	0	0

The data on the cost of external financing come from the World Bank *World Development Indicators* (WDI) and *Doing Business* databases. Costs of external finance are lower in countries with more developed financial markets.[51] Financial market institutional characteristics are measured by the World Bank's *Doing Business* credit information index and credit registry coverage indicator.[52] The credit information index measures rules affecting the scope, accessibility and quality of credit information available through either public or private credit registries. The credit registry coverage indicator reports the number of individuals and firms listed in a public or private credit registry with current information on repayment history, unpaid debts or credit outstanding.[53] Higher values of both indicators are associated with better financial market institutional characteristics. External finance costs are also affected by monetary policy, and are negatively correlated with growth in domestic credit[54] (with domestic credit measured by the ratio of banking sector

[49] For more robustness this measure was checked against the country average days of power outages, reported by the firms from the WBES data in 2002-2005. The Spearman correlation coefficient was 0.5.

[50] According to the WBES data there are rare occasions of power outages in South Africa (about 6 days per year). This may explain why some firms own an electric generator in this country.

[51] See La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1997), and Love (2003).

[52] These indicators can be found on the World Bank's *Doing Business* website http://www.doingbusiness.org

[53] Though these two measures do not vary by time, they reflect an important information about the surveyed countries' financial systems. Different research studies, including La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1997), Love and Mylenko (2003), and Djankov, McLiesh, and Shleifer (2007) found that credit registries are associated with lower financing constraints and higher share of bank financing.

[54] Slow domestic credit growth can occur even at low external finance costs if there is a sufficient credit available. While such scenario is plausible in developed countries, it is extremely unlikely in Sub-Saharan African countries.

credit to private sector to surveyed countries' GDP[55]).

Table 1 presents the summary statistics on the country-level measures of cost of external finance. It follows from table 1, that South Africa differs significantly from other surveyed countries in both the magnitude of power outages and the quality of financial infrastructure. To avoid potential outlier problem, the empirical specification was re-estimated without South Africa, and the results were not sensitive to the exclusion of this country.

5.2.2 Endogenous Switching Approach

For implementation of the endogenous switching regression approach, the data used in this study comprises 860 firms from 3 Sub-Saharan African countries - Kenya, Tanzania, and Uganda. This is because at the time of research, good quality firm-level data on access to credit, generator ownership, and the number of power outages were only available for these countries.[56] All data come from the *Enterprise Survey* dataset. Table 2 presents the variables used in the endogenous switching approach, summarized at country level.

For the estimation of regime-switching equations (17) and (18), reliability of the power supply is measured by the number of days per year when firms experienced power outages, independent how long they were.[57] The theoretical model predicts that higher power outages have positive effects on the probability of investing in a generator. Table 2 shows that all three countries have very unreliable power supply, with average days of power outages per annum ranging from 67 in Tanzania to 82 in Kenya. It is therefore not surprising to observe that sixty eight percent of surveyed firms in Kenya, fifty eight percent of firms in Tanzania, and thirty eight percent of firms in Uganda owned a generator in 2002. The information on the cost of a generator and the return on investment is assumed to be captured by firms' characteristics, measured by size, industry[58] and ownership dummies.[59] Specifically, because electric generation exhibits economies of scale, larger firms are found to have smaller generation costs, and higher probability of owning a generator (Foster and Steinbuks, 2009).

For the estimation of the selection equation (19), the choice of the dependent and explanatory variables is based on the approach of Bigsten *et al* (2003), Fisman and Love (2004), and Ayyagari *et al* (2008). Firms' choice of internal over external financing (the dependent variable) is represented by the share of firms financing more than 90 percent of their working capital from the retained earnings. Table 2 shows that this share was only 30 percent of surveyed firms in Kenya, compared with 62 percent of firms in Tanzania,

[55] This measure has been previously used in the economic literature, see e.g. Beck, Levine, and Loayza (2000), and Barth, Caprio, and Levine (2004).

[56] Enterprise surveys in Sub-Saharan countries were carried in different years, and based on different questionnaires, which varied in purpose of the survey. Detailed questions on access to credit were particularly uncommon. Enterprise surveys in Kenya, Tanzania, and Uganda were done around the same time, and based on the same questionnaire with expanded "access to credit" section.

[57] Ideally, one should also account for the duration of power outages. Unfortunately, reported data on the duration of power outages was sparse and subject to a large measurement error.

[58] Industry dummies also capture important information about energy intensity in firm's production process. Quality of electric power infrastructure is endogenous to observed industrial structure. Sorting out this problem is beyond the scope of this study.

[59] Detailed summary of these variables can be found in tables 1 to 4, appendix 2.

and 68 percent of firms in Uganda. The firms that may have unused borrowing capacity and thus be less financially constrained are separately accounted by the share of firms indicating that they never applied for a loan, because they did not need one.[60] This share was 18 percent in Kenya, 10 percent in Tanzania, and 12 percent in Uganda. According to the model, availability of internal funds increases likelihood of owning a generator. On the other hand, 24 percent of surveyed firms in Kenya never applied for a loan because of other reasons, such as high collateral requirements, large debt burden, or complicated administrative procedures, compared to 50 percent of firms in Tanzania, and 47 percent of firms in Uganda. Even while not being a perfect measure, these reasons may indicate that firm is financially constrained, and is more likely to choose internal over external financing.

Table 2: Descriptive Statistics (3 Countries Dataset)

Variable	Kenya		Tanzania		Uganda	
	mean	sd	mean	sd	mean	sd
Share of firms owning a generator	0.68	0.47	0.58	0.49	0.38	0.49
Power outages (days per annum)	81.69	103.78	66.85	65.04	70.32	99.21
Share of firms financing more than 90% of working capital from retained earnings	0.30	0.46	0.62	0.49	0.68	0.47
Share of firms that never applied for a loan because it was not needed	0.18	0.39	0.10	0.30	0.12	0.32
Share of firms that never applied for a loan because of other reasons	0.24	0.43	0.50	0.50	0.47	0.50
Share of firms that were rejected a loan	0.03	0.18	0.07	0.25	0.03	0.16
Share of firms that currently have a loan	0.32	0.47	0.16	0.37	0.17	0.38
Share of firms with LTV less than 50%	0.12	0.33	0.02	0.13	0.03	0.18
Share of firms with LTV between 50% and 75%	0.04	0.21	0.02	0.14	0.03	0.16
Share of firms with LTV between 75% and 100%	0.12	0.32	0.08	0.28	0.03	0.18
Share of firms with LTV more than 100%	0.03	0.18	0.04	0.19	0.08	0.26

The external financing premium θ is proxied by several variables. The share of firms that were rejected for a loan may indicate a non-price rationing (redlining) due to asymmetric information, as discussed in Stiglitz and Weiss (1981). According to the data, loans were rejected for 7 percent of surveyed firms in Tanzania and 3 percent of firms in Kenya and Uganda. These firms may be financially constrained, and are more likely to choose internal over external financing. For firms with a loan, the differential cost of external over internal is financing is captured by collateral requirements. The theory of credit supply under asymmetric information predicts that, holding other things constant, loans secured by collateral are less costly.[61] Table 2 shows that, about a half of the firms with a bank loan in Kenya, two-thirds of firms with a bank loan in Uganda and 75 percent of firms with a bank loan in Tanzania had the loan to value ratio above 75 percent. It is expected that firms with high loan-to-value ratio are more likely to choose internal over

[60] A fraction of the firms that indicate they do not need a loan (e.g. because of lack of good investment opportunities) might still be financially constrained in the sense that external capital is more costly than internal capital if they were to look for external capital sources. This creates a measurement error in dependent variable problem, which results in higher standard errors in equation (19). As demonstrated below, almost all estimated coefficients in equation (19) are statistically significant, which indicates that the measurement error is relatively small.

[61] Collateral requirements are measured by firms' response to the Enterprise survey question "What was the approximate value of collateral required as a percentage of the loan value?"

external financing. The institutional financial market characteristics are represented by country dummies. Among three countries, Kenya has the most developed financial system. The World Bank *Doing Business* (2007) report ranks Kenya 33^{rd} among the world countries in the overall ease of getting credit, whereas Tanzania and Uganda are ranked 117^{th} and 159^{th} respectively. Therefore, the anticipated coefficient in the selection equation for the Kenyan country dummy variable is negative. Selection equation (19) also includes firm characteristics, such as size, industry and ownership. Based on earlier findings from the literature on financing constraints (Beck, Demirguc-Kunt, and Maksimovic 2005, Levine 2005) it is expected that larger and foreign owned firms are less likely to face financing constraints, and are more likely to choose external financing over internal financing.

6 Empirical Results

6.1 Difference-in-Differences Approach

This section discusses findings from the difference-in-differences approach. As discussed earlier, the hypothesis is that the estimated coefficient of the product of power outages and financial development (β_2) is positive and significant in stochastic specifications (14)-(16). Tables 3, 4, and 5 contain the test results. Full results, including the estimates of the fixed effects and the control variables are reported in the appendix 2, tables 10, 11, and 12.[62] The predictions from all three models confirm the hypothesis that during the periods of power outages firms from the countries with financially developed markets are more likely to buy generators.

Table 3: Difference-in-Differences: Model 1

Dependent variable: Firm owns a generator (1 = "Yes")

Variable	Coef.	P-value	Coef.	P-value	Coef.	P-value
Power Outages (1 = "Yes")	0.07	0.26	0.09	0.10	0.09	0.09
Registry Coverage > 0 X Power Outages	0.17	0.09				
Registry Coverage > 3% X Power Outages			0.22	0.05		
Credit Information Index > 1 X Power Outages					0.47	0.00
Constant	-0.28	0.48	-0.28	0.47	-0.28	0.48
Wald chi2(27)	263.36	0.00	263.35	0.00	272.62	0.00
Number of obs	8201		8201		8201	

Table 3 shows the findings from the model 1, described by the equation (14) which employs time-invariant indices of financial markets' institutional characteristics for the cost of external financing. The estimated coefficients on the product of power outages and the cost of external financing are all positive and significant. The size and significance levels of the estimated coefficients increase with the degree of countries' financial development. For example, the estimated coefficients on power outages in countries with no registry coverage are positive but not significant. The estimated coefficient is only marginally significant when sole existence

[62] The standard errors used in computation of p-values in Tables 3-5 and 10-12 (Appendix 2) were adjusted for heteroscedaticity and country-level cluster correlations (see Wooldridge 2002, section 13.8.2). The magnitude of the standard errors did not change much when adjusted for country-year cluster correlations.

of public or private registries was used as the measure of financial development. The estimated coefficient increases both in size and the level of significance when only countries with actual registry coverage (at least 3% of all adults) are considered as financially developed.

Table 4 illustrates the results for model 2, described by the equation (15), which uses the growth in domestic credit as a measure for the cost of external financing. The estimated coefficient on the product of power outages and domestic credit growth is positive and significant, suggesting that, consistent with predictions of the theoretical model, the probability of installing an electric generator during power outages is higher in countries experiencing rapid growth of domestic credit.

Table 4: Difference-in-Differences: Model 2

Dependent variable: Firm owns a generator (1 = "Yes")

Variable	Coef.	P-value
Power Outages X Domestic Credit Growth	0.43	0.01
Constant	-0.25	0.56
Wald chi2(39)	441.06	0.00
Number of obs	8166	

Table 5 presents the results from the model 3, described by the equation (16), and estimated by ordered logit.[63] Again the results are consistent with theoretical expectations. The estimated coefficient of the domestic credit growth variable is positive and significant. To understand better the effect of a country's financial development on firm's decision to buy generator, table 5 also presents the computed marginal effects.[64] One percent increase in domestic credit increases the probability of buying a generator by 0.07 at stable power supply. The probability of buying a generator further increases by 0.02 during power outages, and by 0.001 after consecutive power outages. These figures sum to 0.091, which indicates the total marginal effect of a one percent increase in domestic credit growth on the probability of installing an electric generator. All marginal effects are statistically significant.

Table 5: Difference-in-Differences: Model 3

Dependent variable: Firm bought a generator at stable power supply (1 = "Yes"), Firm bought a generator during outages (2 = "Yes"), Firm bought a generator after consecutive outages (3 = "Yes")

Variable	Regression coeff.		Marginal effect (d=1)		Marginal effect (d=2)		Marginal effect (d=3)	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Domestic Credit Growth	0.68	0.00	0.07	0.00	0.02	0.00	0.001	0.00
mu1	1.98							
mu2	4.74							
Wald chi2(26)	313.30	0.00						
Number of obs					8464			

[63] Time-invariant measures of financial deepening could not be used in the ordered logit model because of perfect collinearity problem.

[64] For details on interpreting coefficients and the marginal effects in ordered logit equations, see Greene (2003, chapter 21).

6.2 Endogenous Switching Approach

Tables 6, 7, and 8 summarize the results from the endogenous switching regression approach described by the equations (17)-(22). Table 6 shows the estimates from the selection equation, formulated by (19) and (20). The signs of the estimated coefficients correspond to the predictions of economic theory.[65] Borrowers with low loan-to-value ratios, foreign owned firms, and Kenyan businesses are more likely to choose external financing. Firms that were not able to apply for a loan because of red tape, high collateral requirements or the debt burden are more likely to choose internal financing. The estimated coefficients for firms that did not apply for a loan because it was not needed, and for the size and industry characteristics variables are not statistically significant in the selection equation.

Table 6: Selection Equation

Equation: $g_1 = \Phi(W_i'\alpha) + \omega_i$. Dep. var. ($g_1$): Firm finances more than 90% of working capital from retained earnings (1 = "Yes")

Variable	coeff.	p-value	Exp. Sign
Current loan: LTV less than 50% (1="Yes")	-0.83	0.00	-
Current loan: LTV between 50% and 75% (1= "Yes")	-0.89	0.01	-
Current loan: LTV between 75% and 100% (1="Yes")	-0.45	0.02	
Current loan: LTV more than 100% (1="Yes")	-0.21	0.35	
Never applied for a loan because it was not needed (1 = "Yes")	0.13	0.43	
Never applied for a loan because of other reasons (1 = "Yes")	0.33	0.01	+
Loan application rejected (1 = "Yes")	0.55	0.03	+
Country: Kenya	-0.90	0.00	-
Country: Tanzania	-0.19	0.16	
Industry: Garments and Textiles	0.06	0.73	
Industy: Food and Beverages	-0.14	0.39	
Industry: Metals and Machinery	-0.04	0.81	
Industry: Chemicals and Pharmaceuticals	-0.21	0.25	
Firm's Size: Less than 10 Employees	0.29	0.12	+
Firm's Size: 10 - 49 Employees	-0.02	0.92	
Firm's Size: 50 - 99 Employees	-0.26	0.17	
Foreign Ownership (1 = "Yes")	-0.37	0.01	-
Constant	0.51	0.02	
Number of Observations		659	

Table 7 compares the predicted values for the dependent variable, based on the regression model in the selection equation, with the actual observed values in the data. Table 4 shows that the selection equation correctly predicts 78% of firms that rely solely on internal financing (constrained firms), and 64% of firms that use external funds to finance their working capital (unconstrained firms). Overall, the selection equation correctly classifies 71% of firms, which is an improvement over naive model that blindly estimates the most frequent category (constrained firms) for all cases, and correctly classifies just 54% of firms.

[65] Because some of the explanatory variables are likely to be endogenous no inferences should be made about the direction of the estimated effects. As mentioned above, the test based on the endogenous switching approach allows for endogenous regressors.

Table 7: Selection Equation - Classification Table

	True Classification		
Switching Regression Classification	*Constrained*	*Unconstrained*	**Total**
Constrained	279	109	388
Unconstrained	80	191	271
Total	359	300	659
Correctly classified	78%	64%	71%

Table 8 illustrates the results from the switching regressions (17) and (18). A comparison of the estimated coefficients for reliability of power supply in the switching regressions strongly supports the hypothesis that financial constraints affect the firms' decisions to invest in a generator given their expectations of power outages. The estimated coefficient of the logarithm of days of power outages in the generator choice equation for firms that externally finance their working capital is statistically significant and nearly ten times higher than the corresponding coefficient in the equation for firms that finance their working capital from retained earnings. The likelihood ratio test rejects the hypothesis that the estimated coefficients are equal in the switching equations at the 0.03 level of significance.

Table 8: Switching Regression Equations

Equations: $d_{2j} = \Phi(\alpha_0 + x'_{ji}\beta_j + Z'_{ji}\gamma) + \varepsilon_{ji}$. $j = 1, 2$. Dep. vars. (d_{21}, d_{22}): Firm owns a generator (1 = "Yes")

	Equation d_{21} ($g_1 = 0$)		Equation d_{22} ($g_1 = 1$)	
	coeff.	**p-value**	**coeff.**	**p-value**
Days of Power Outages (log+1)	0.19	0.00	0.02	0.73
Country: Kenya	-0.06	0.82	-0.19	0.43
Country: Tanzania	0.07	0.75	0.31	0.06
Industry: Garments and Textiles	0.04	0.87	0.31	0.17
Industy: Food and Beverages	0.26	0.29	0.16	0.38
Industry: Metals and Machinery	0.51	0.05	0.25	0.24
Industry: Chemicals and Pharmaceuticals	0.21	0.43	0.08	0.76
Firm's Size: Less than 10 Employees	-1.31	0.00	-1.37	0.00
Firm's Size: 10 - 49 Employees	-0.78	0.00	-0.71	0.02
Firm's Size: 50 - 99 Employees	-0.11	0.69	-0.08	0.77
Foreign Ownership (1 = "Yes")	0.10	0.62	0.60	0.03
Constant	0.63	0.18	-0.30	0.38
Rho	0.72	0.01	0.83	0.00
Number of Observations	659		659	

LR Test: chi2(1) = 4.77, Prob > chi2 = 0.0289

The results for other explanatory variables are generally consistent with findings in earlier literature. In both equations larger firms are found more likely to install an electric generator. This may reflect effect of the economies of scale or technical requirements and safety standards with which the larger firms are more likely to comply. The estimated coefficient is positive and significant for the metals and machinery industry in the equation for external financing, which may reflect energy intensity of this industry. The estimated coefficient is also positive and significant for foreign owned firms in the equation for internal financing, which may capture the share of less constrained firms among those financing working capital from retained earnings. Country dummies are not statistically significant in either equation, except for Tanzania in the equation for internal financing, which is positive, but only marginally significant. This coefficient may reflect unobserved financial market institutional characteristics in Tanzania. The correlation coefficients (rho's) between the residuals in the selection and switching equations are large and statistically significant for both switching equations. This confirms simultaneity in choice of electric generator and firm's financing constraints.[66]

The results from the endogenous switching approach, tested on the data from Kenya, Tanzania, and Uganda, thus fully correspond to the predictions of the theoretical model described in the previous section. Holding other things constant, firms that finance their working capital from external funds are more likely to install the generator in the localities where the power outages are more frequent. This happens because these firms are less likely to be financially constrained, and therefore their net expected return from a generator is higher. The theoretical model predicts that financially constrained firms invest in a generator only if the quality of public power supply is very low. Consistent with that prediction of the model, the choice of electric generator is unaffected by small differences in the reliability of power supply for firms that finance their working capital solely from internal funds, and are more likely to be financially constrained.

7 Conclusions

This study uses a natural experiment based on a firm's decision to invest in a private electric generator to identify and measure the effect of access to capital on firms in developing countries. Specifically, this study investigates the effect of financing constraints on the firm's investment response to public power interruptions. The theoretical model focuses on a firm's decision to acquire a private generator to hedge against unreliable public power supply. It shows that holding other things constant, financially unconstrained firms will be more likely to install private generator if the public power supply becomes unreliable.

The effect of financing constraints on a firms' decision to install a private generator is investigated empirically on firm-level datasets from Sub-Saharan African countries where power interruptions are not uncommon and financial systems vary in their development. Both endogenous switching regression and difference-in-differences methods are used to overcome the measurement and identification problems arising from simultaneity of financing constraints and firms' investment.

The results show that, controlling for other factors, firms with a better access to credit are more likely to own a private generator in areas, where public power supply is unreliable. The results also indicate that firms are more likely to respond to the power outage shocks by installing private generators if they operate in the countries with more developed financial systems or during the periods of rapid domestic credit growth.

[66] Tables 13a and 13b (Appendix 2) illustate that exogenous switching regression estimates of the same stochastic specification are seriously biased.

This study thus demonstrates that financial constraints significantly affect firms' investment in developing countries.

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Appendix 1

1. Proof of the Proposition 1.

The equation (5) can be rearranged to define the net expected return from a generator

Proof.

$$f(p) = (1+r)\varphi i_1 - c\,(i_1 + k) - \psi(1+r)\varphi i_2 + c\,(i_2) : \mathbb{R} \longrightarrow \mathbb{R}, \tag{25}$$

which is a continuous function on the $I \subset [0,1]$. A rational profit maximizing firm will always choose to install a generator if $f(p) > 0$. Let $p' = 0$ and $p'' = 1$. Using the results (2) and (4) in (25) and rearranging terms gives

$$\begin{aligned} f(p') = (1+r)\varphi\left[c_i^{-1}\left\{(1+r)\varphi\right\}\right] - \mu(1+r)\varphi[c_i^{-1}\left\{\mu(1+r)\varphi\right\}] \\ -c\left[c_i^{-1}(1+r)\varphi\right] + c\left[c_i^{-1}\left\{\mu(1+r)\varphi\right\}\right] - (1+r)\varphi k, \end{aligned} \tag{26}$$

and

$$f(p'') = -(1+r)\varphi k \tag{27}$$

It can be seen from equation (27) that $f(p'') < 0$. The sign of $f(p')$ depends on parameters μ and k. Differentiating (26) with respect to μ (using the chain rule) and k gives

$$\frac{\partial f(p')}{\partial \mu} = -(1+r)\varphi[c_i^{-1}\left\{\mu(1+r)\varphi\right\}] < 0 \tag{28}$$

and

$$\frac{\partial f(p')}{\partial k} = -(1+r)\varphi < 0 \tag{29}$$

It thus follows from (28) and (29) that $f(p') > 0$ only if the firm's losses from power outages are relatively high compared to the fixed cost of generator (e.g. both μ and k are sufficiently small[67]). If $f(p') > 0$ then, by the intermediate-value theorem there exists at least one point p^* lying between p' and p'', such that $f(p^*) = 0$. Because $f'(p) = -(1-\mu)(1+r)\varphi i_2 < 0$, the function $f(p)$ is monotonically decreasing in p, and hence the solution $f(p^*) = 0$ is unique, which proves first part of the proposition. The firms choose to have electric generator if the net expected return on $f(p)$ is positive, which is true $\forall\ p \in [0, p^*)$ (e.g. where the reliability of public power supply is sufficiently low), which proves second part of the proposition. ■

2. The effects of the rate of return, cost of generator, availability of internal finance, financial market imperfections, and reliability of power supply on the size of optimal investment.

[67] It can be easily verified that if $\mu = 1$ then $f(p') = -(1+r)k < 0$.

By implicit function theorem:

$$\frac{di_1'}{dr} = \frac{\varphi}{c_{ii} + g_{ii}} > 0, \tag{30}$$

$$\frac{di_1'}{d\varphi} = \frac{1+r}{c_{ii} + g_{ii}} > 0, \tag{31}$$

$$\frac{di_1'}{dk} = -\frac{c_{ik} + g_{ik}}{c_{ii} + g_{ii}} < 0, \tag{32}$$

$$\frac{di_1'}{dW} = \frac{g_{iw}}{c_{ii} + g_{ii}} > 0, \tag{33}$$

$$\frac{di_1'}{d\theta} = -\frac{g_{i\theta}}{c_{ii} + g_{ii}} < 0. \tag{34}$$

$$\frac{di_2'}{dp} = \frac{(1-\mu)\,\varphi}{c_{ii} + g_{ii}} > 0. \tag{35}$$

3. Proof of the Proposition 2.

Proof. The equation (10) can be rearranged to define the net expected return from a generator

$$f(p) = (1+r)\varphi i_1' - c\,(i_1' + k) - g(i_1' + k - W, \theta) - \psi(1+r)\varphi i_2' + c\,(i_2') + g(i_2' - W, \theta) \tag{36}$$

If $\theta\ = 0$ then equation (36) becomes the equation (25) analyzed in the previous section. The likelihood of reliable power supply that equalizes expected returns from choosing and not choosing a generator is then given by p^*, and the optimal investments are i_1 and i_2.

Now consider a small increase in θ. We know from the result (34) that both i_1 and i_2 decrease but i_1 decreases by a larger amount.[68] Thus, the net expected return from a generator will become negative at p^*. By the result (29) i_2 increases in p, therefore it should be true that at positive θ, the net expected return from a generator can only increase if p declines, holding other things constant, which proves the second and third parts of the proposition. Because $f(p)$ is monotonic in all arguments, the p^{**} will still be unique. As θ keeps increasing the net expected return from a generator will continue to decline so p^{**} may not exist at very high θ (if the firm is redlined and does not have enough internal resources it may never choose to invest into a private generator), which proves first part of the proposition. ∎

[68] It follows from the results (2) and (4) that $i_1(p^*) + k > i_2(p^*)$. Because $g(\cdot)$ is monotonically increasing in all arguments, $g(i_1(p^*) + k - W, \theta)$ is larger than $g(i_2(p^*) - W, \theta)$. Hence i_1 decreases by more because larger amount will be subtracted.

Appendix 2 (Not for Publication)

Table 1: 3 Countries Dataset - Tabulation by Country

Country	**Frequency**	**Share**
Kenya	205	31.11%
Tanzania	189	28.68%
Uganda	265	40.21%
Total	659	100.00%

Table 2: 3 Countries Dataset - Tabulation by Industry

Industry	**Frequency**	**Share**
Garments and Textiles	117	17.75%
Food and Beverages	173	26.25%
Metals and Machinery	123	18.66%
Chemicals and Pharmaceuticals	89	13.51%
Wood, Pulp and Furniture	157	23.82%
Total	659	100.00%

Table 3: 3 Countries Dataset - Tabulation by Size

Size	**Frequency**	**Share**
Less than 10 Employees	153	23.22%
10 - 50 Employees	296	44.92%
50 - 100 Employees	96	14.57%
More than 100 Employees	114	17.30%
Total	659	100.00%

Table 4: 3 Countries Dataset - Tabulation by Ownership

Ownership	**Frequency**	**Percent**
Domestic	517	78.45%
Foreign	142	21.55%
Total	659	100.00%

Table 5: 12 Countries Dataset - Tabulation by Country

Country	Frequency	Share
Benin	119	9.09%
Eritrea	21	1.60%
Kenya	78	5.96%
Madagascar	160	12.22%
Malawi	94	7.18%
Mali	80	6.11%
Mauritius	67	5.12%
Senegal	122	9.32%
South Africa	154	11.76%
Tanzania	129	9.85%
Uganda	202	15.43%
Zambia	83	6.34%
Total	1309	100.00%

Table 6: 12 Countries Dataset - Tabulation by Industry

Industry	Frequency	Share
Garments and Textiles	172	13.14%
Food and Beverages	349	26.66%
Metals and Machinery	137	10.47%
Chemicals and Pharmaceuticals	107	8.17%
Construction	56	4.28%
Wood, Pulp and Furniture	225	17.19%
Non-metallic and Plastic Materials	73	5.58%
Paper	54	4.13%
Other Manufacturing	63	4.81%
Hotels and Restaurants	73	5.58%
	1309	100.00%

Table 7: 12 Countries Dataset - Tabulation by Size

Size	**Frequency**	**Share**
Less than 10 Employees	244	18.64%
10 - 50 Employees	630	48.13%
50 - 100 Employees	199	15.20%
100-250 Employees	127	9.70%
More than 250 Employees	109	8.33%
Total	1309	100.00%

Table 8: 12 Countries Dataset - Tabulation by Ownership

Ownership	**Frequency**	**Share**
Domestic	989	75.55%
Foreign	320	24.45%
Total	1309	100.00%

Table 9: 12 Countries Dataset - Tabulation by Age

Age	**Frequency**	**Share**
1990	73	5.58%
1991	70	5.35%
1992	72	5.50%
1993	78	5.96%
1994	94	7.18%
1995	104	7.94%
1996	125	9.55%
1997	129	9.85%
1998	116	8.86%
1999	99	7.56%
2000	124	9.47%
2001	103	7.87%
2002	70	5.35%
2003	52	3.97%
Total	1309	100.00%

Table 10: Difference-in-Differences Approach (Model 1)

Variable	Coef.	P-value	Coef.	P-value	Coef.	P-value
Country: Benin	-1.07	0.00	-1.11	0.00	-0.97	0.00
Country: Eritrea	-0.02	0.97	-0.02	0.96	-0.02	0.97
Country: Kenya	0.26	0.33	0.29	0.28	0.21	0.43
Country: Madagascar	-2.19	0.00	-2.17	0.00	-2.17	0.00
Country: Malawi	-0.96	0.00	-0.97	0.00	-0.97	0.00
Country: Mali	0.23	0.48	0.25	0.43	0.25	0.43
Country: Mauritius	-1.07	0.00	-1.07	0.00	-1.07	0.00
Country: Senegal	0.15	0.58	0.15	0.59	0.17	0.52
Country: South Africa	-2.33	0.00	-2.33	0.00	-2.33	0.00
Country: Uganda	-0.61	0.02	-0.61	0.02	-0.61	0.02
Country: Zambia	-1.66	0.00	-1.66	0.00	-1.66	0.00
Industry: Garments and Textiles	-0.58	0.11	-0.58	0.11	-0.58	0.11
Industry: Food and Beverages	-0.01	0.97	-0.01	0.97	-0.01	0.97
Industry: Metals and Machinery	-0.65	0.08	-0.65	0.08	-0.66	0.08
Industry: Chemicals and Pharmaceuticals	-0.10	0.78	-0.10	0.78	-0.10	0.78
Industry: Construction	-0.54	0.20	-0.54	0.20	-0.54	0.20
Industry: Wood, Pulp and Furniture	-1.08	0.01	-1.08	0.01	-1.08	0.01
Industry: Non-metallic and Plastic Materials	-0.16	0.68	-0.16	0.68	-0.16	0.68
Industry: Paper	-0.11	0.80	-0.11	0.80	-0.11	0.80
Industry: Other Manufacturing	-0.06	0.91	-0.06	0.91	-0.06	0.91
Firm's Size: Less than 10 Employees	-1.32	0.00	-1.32	0.00	-1.32	0.00
Firm's Size: 10 - 50 Employees	-0.34	0.11	-0.34	0.11	-0.34	0.11
Firm's Size: 50 - 100 Employees	0.11	0.66	0.11	0.66	0.11	0.66
Firm's Size: More than 250 Employees	0.28	0.35	0.28	0.35	0.28	0.35
Foreign Ownership (1 = "Yes")	0.76	0.00	0.76	0.00	0.76	0.00
Power Outages (1 = "Yes")	0.07	0.26	0.09	0.10	0.09	0.09
Registry Coverage > 0 X Power Outages	0.17	0.09				
Registry Coverage > 3% X Power Outages			0.22	0.05		
Credit Information Index > 1 X Power Outages					0.47	0.00
Constant	-0.28	0.48	-0.28	0.47	-0.28	0.48
Wald chi2(27)	263.36	0.00	263.35	0.00	272.62	0.00
Number of obs	8201		8201		8201	

Dependent variable: Firm owns a generator (1 = "Yes")

Table 11: Difference-in-Differences Approach (Model 2)

Variable	Coef.	P-value
Country: Benin	-1.21	0.00
Country: Eritrea	0.09	0.88
Country: Kenya	0.43	0.15
Country: Madagascar	-2.52	0.00
Country: Malawi	-1.34	0.00
Country: Mali	0.25	0.48
Country: Mauritius	-1.29	0.00
Country: Senegal	0.21	0.49
Country: South Africa	-2.60	0.00
Country: Uganda	-0.74	0.01
Country: Zambia	-1.71	0.00
Industry: Garments and Textiles	-0.69	0.08
Industry: Food and Beverages	-0.002	1.00
Industry: Metals and Machinery	-0.77	0.06
Industry: Chemicals and Pharmaceuticals	-0.09	0.81
Industry: Construction	-0.41	0.36
Industry: Wood, Pulp and Furniture	-1.18	0.01
Industry: Non-metallic and Plastic Materials	-0.08	0.85
Industry: Paper	-0.06	0.90
Industry: Other Manufacturing	-0.14	0.81
Firm's Size: Less than 10 Employees	-1.52	0.00
Firm's Size: 10 - 50 Employees	-0.48	0.04
Firm's Size: 50 - 100 Employees	0.05	0.86
Firm's Size: More than 250 Employees	0.35	0.28
Foreign Ownership (1 = "Yes")	0.71	0.00
Year: 1991	-2.76	0.00
Year: 1992	-1.87	0.00
Year: 1993	-2.03	0.00
Year: 1994	-1.49	0.00
Year: 1995	-1.46	0.00
Year: 1996	-1.36	0.00
Year: 1997	-0.87	0.00
Year: 1998	-0.37	0.00
Year: 2000	0.36	0.00
Year: 2001	0.63	0.00
Year: 2002	0.79	0.00
Year: 2003	0.91	0.00
Year: 2004	1.29	0.00
Power Outages X Domestic Credit Growth	0.43	0.01
Constant	-0.25	0.56
Wald chi2(39)	441.06	0.00
Number of obs	8166	

Dependent variable: Firm owns a generator (1 = "Yes"). Firm fixed effects are not reported.

Table 12: Difference-in-Differences Approach (Model 3)

Variable	Regression coeff.		Marginal effect (d=1)		Marginal effect (d=2)		Marginal effect (d=3)	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Country: Benin	-0.90	0.01	-0.07	0.00	-0.02	0.00	-0.001	0.00
Country: Eritrea	-0.24	0.62	-0.02	0.59	-0.01	0.58	-0.0004	0.58
Country: Kenya	0.19	0.42	0.02	0.44	0.01	0.45	0.0004	0.46
Country: Madagascar	-1.96	0.00	-0.12	0.00	-0.03	0.00	-0.002	0.00
Country: Malawi	-0.75	0.01	-0.06	0.00	-0.02	0.00	-0.001	0.01
Country: Mali	0.03	0.90	0.003	0.90	0.00	0.90	0.0001	0.90
Country: Mauritius	-1.01	0.00	-0.07	0.00	-0.02	0.00	-0.001	0.00
Country: Senegal	0.06	0.81	0.01	0.81	0.002	0.81	0.0001	0.81
Country: South Africa	-2.41	0.00	-0.13	0.00	-0.03	0.00	-0.002	0.00
Country: Uganda	-0.71	0.00	-0.06	0.00	-0.02	0.00	-0.001	0.00
Country: Zambia	-1.66	0.00	-0.10	0.00	-0.03	0.00	-0.002	0.00
Industry: Garments and Textiles	-0.49	0.11	-0.04	0.08	-0.01	0.07	-0.001	0.08
Industry: Food and Beverages	0.07	0.80	0.01	0.81	0.002	0.81	0.0002	0.81
Industry: Metals and Machinery	-0.56	0.09	-0.05	0.05	-0.01	0.04	-0.001	0.06
Industry: Chemicals and Pharmaceuticals	-0.01	0.97	-0.001	0.99	-0.0003	0.97	-0.00002	0.97
Industry: Construction	-0.40	0.29	-0.03	0.23	-0.01	0.21	-0.001	0.22
Industry: Wood, Pulp and Furniture	-1.03	0.00	-0.08	0.00	-0.02	0.00	-0.002	0.01
Industry: Non-metallic and Plastic Materials	-0.09	0.77	-0.01	0.77	-0.003	0.77	-0.0002	0.77
Industry: Paper	-0.06	0.87	-0.01	0.87	-0.002	0.87	-0.0001	0.87
Industry: Other Manufacturing	0.03	0.96	0.003	0.96	0.001	0.96	0.0001	0.96
Firm's Size: Less than 10 Employees	-1.28	0.00	-0.10	0.00	-0.03	0.00	-0.002	0.00
Firm's Size: 10 - 50 Employees	-0.33	0.10	-0.03	0.09	-0.01	0.09	-0.001	0.12
Firm's Size: 50 - 100 Employees	0.07	0.75	0.01	0.76	0.002	0.76	0.0001	0.76
Firm's Size: More than 250 Employees	0.30	0.26	0.03	0.30	0.01	0.32	0.001	0.33
Foreign Ownership (1 = "Yes")	0.71	0.00	0.08	0.00	0.03	0.00	0.002	0.00
Domestic Credit Growth	0.68	0.00	0.07	0.00	0.02	0.00	0.001	0.00
mu1	1.98							
mu2	4.74							
Wald chi2(26)	313.30	0.00						
Number of obs				8464				

Dependent variable: Firm bought a generator at stable power supply (1 = "Yes"), Firm bought a generator during outages (2 = "Yes"), Firm bought a generator after consecutive outages (3 = "Yes").

Table 13a Switching Regession Models (Firms with External Financing of Working Capital)

Model	Exogenous switching (g_1 = 0)		Endogenous switching (g_1 = 0)	
	coeff.	p-value	coeff.	p-value
Days of Power Outages (log+1)	0.08	0.08	0.19	0.00
Country: Kenya	0.84	0.00	-0.06	0.82
Country: Tanzania	0.13	0.41	0.07	0.75
Industry: Garments and Textiles	-0.02	0.91	0.04	0.87
Industy: Food and Beverages	0.24	0.19	0.26	0.29
Industry: Metals and Machinery	0.29	0.12	0.51	0.05
Industry: Chemicals and Pharmaceuticals	0.36	0.08	0.21	0.43
Firm's Size: Less than 10 Employees	-1.31	0.00	-1.31	0.00
Firm's Size: 10 - 49 Employees	-0.50	0.00	-0.78	0.00
Firm's Size: 50 - 99 Employees	0.13	0.49	-0.11	0.69
Foreign Ownership (1 = "Yes")	0.46	0.00	0.10	0.62
Constant	-1.01	0.00	0.63	0.18
Number of Observations	659		659	

Table 13b Switching Regession Models (Firms with Internal Financing of Working Capital)

Model	Exogenous switching (g_1 = 1)		Endogenous switching (g_1 = 1)	
	coeff.	p-value	coeff.	p-value
Days of Power Outages (log+1)	0.05	0.08	0.02	0.25
Country: Kenya	-0.44	0.00	-0.19	0.01
Country: Tanzania	0.18	0.41	0.31	0.20
Industry: Garments and Textiles	0.25	0.91	0.31	0.19
Industy: Food and Beverages	0.08	0.19	0.16	0.64
Industry: Metals and Machinery	0.14	0.12	0.25	0.44
Industry: Chemicals and Pharmaceuticals	0.02	0.08	0.08	0.93
Firm's Size: Less than 10 Employees	-0.96	0.00	-1.37	0.00
Firm's Size: 10 - 49 Employees	-0.35	0.00	-0.71	0.02
Firm's Size: 50 - 99 Employees	-0.10	0.49	-0.08	0.61
Foreign Ownership (1 = "Yes")	0.13	0.00	0.60	0.34
Constant	-0.62	0.00	-0.30	0.02
Number of Observations	659		659	