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Abstract

The poor business environment mainly poor infrastructure is found to has paramount importance in explaining Africa's disadvantage relative to other similar countries. To cope with this poor supply of electricity, firms adopt different mechanisms to reduce the resulting effects. The commonly adopted coping strategy is investment in self-generation of electricity. This study examined the role of investing in self-generation in mitigating the outage loss and evaluated the outage loss differential between firms that invested in self-generation and those that did not using World Bank Enterprise Survey data collected from firms operating in 13 Sub-Saharan African countries. The result obtained shows that, though self-generation has reduced the amount of outage loss for firms that invested in self-generation, these firms continue to face higher unmitigated outage loss compared to firms without such investment. In spite of this, firms that invested in self-generation would have incurred 36%-99% more than the current amount of outage loss if they do not engaged in self-generation. Similarly, firms that did not invest in self-generation would have reduced their outage loss by 2% - 24% if they had engaged in self generation. The study thus, recommended a differential supply interruption to be followed by public authorities based on firms' degree of vulnerability to power interruptions.

Key Words: Self-generation, Outages, Sub-Sahara Africa, Firm

JEL Codes: L6, L81, N77, Q41

1 Introduction

The business environment in which a firm operates –encompassing features of legal and regulatory services, infrastructures, financial and institutional systems of the country– has an important impact on firm performance. These business environments also called 'investment climate' varies across regions and countries. For this matter, empirical studies aimed at investigating the impact of business climate on firm outcomes proceed both at a firm and country level.

A poor business environment mainly poor infrastructure is found to has paramount importance in explaining Africa's disadvantage relative to other similar countries.

Cross country empirical works, for instance, (Iacovone et al., 2014; Harrison et al., 2014) shows that African firms lead in productivity levels and growth when controlling for the political and business environments. However, without considering these factors, African firms were found to have a significant disadvantages across all performance measures. This indicates that Africa's disadvantages arise from its weak business environment.

Poor business environment is associated with poor investment, employment and growth. Recent empirical studies on Sub-Saharan (SSA), (Iacovone et al., 2014; Scott et al., 2014; Cissokho and Seck, 2013), show that poor infrastructure mainly poor supply of electricity is negatively related to firm productivity, efficiency and growth[1]. This poor quality of electricity service can drive up firms' cost of production[2] and bias their technological choices.

To cope with this poor supply of electricity, firms adopt different mechanisms to reduce the resulting effects. The commonly adopted coping strategy is investment in self-generation of electricity. The decision to invest in self-generation depends on not only reliability power supply but also other firm characteristics such as industry type, firm's power intensity level, and other firm characteristics (Steinbuks and Foster, 2010; Oseni and Pollitt, 2015; Adenikinju, 2003). Firms facing the same outage time may have different incentive to invest in self-generation due to a difference in their degree of vulnerability to power outages. Referring to the sample of firms used in this study, 76% of firms in Senegal own generator which is greater than the percentage of firms owning generator in Ghana (53%)– where power problem is severe compared to that of Senegal (see Figure 3.1). This is a possible explanation why firm's incentive to invest in self-generation depends not only on the duration of outage but also on the power intensity level of a firm's business activities.

Investment in self-generation, however, does not guarantee a complete mitigation of outages (Beenstock et al., 1997). A firm may investment in self-generation and still continues to face unmitigated outage loss. The data used in this study described in (Figures 3.1) also reveals that in Nigeria, where about 86% of firms own generator, firms still suffer outage loss of 12%. In this regard, this study asks: Does investment in self-generation help firms in mitigating outage loss and what is the outage loss differential between firms that invested in self-generation and those that did not?

[1] see also Steinbuks and Foster (2010); Nyanzu and Adarkwah (2016); Oseni and Pollitt (2015); Adenikinju (2003)

[2] see Fisher-Vanden et al. (2015)

There is a limited literature with a objective of answering the above questions i.e. the role of investment in self-generation in mitigating outage loss. In this regard, Pasha et al. (1989) showed that investment in self-generation reduces the reported cost of power outages in industrial sector of Pakistan but it is impossible to infer outage cost differential between firms that invested in self-generation and those that did not from their result. Steinbuks and Foster (2010) compared the cost and benefits of owning generator for Sub-Saharan African firms, however, they did not consider the role of investing in self-generation in mitigating outage loss. Oseni and Pollitt (2015), a study more close to the current study, examined outage loss differential between firms that engaged in self-generation and those that did not using a switching regression.

However, the switching regression utilized by Oseni and Pollitt (2015) is based on exogeneity assumption of power outages and hence the independence between firm's decision to invest in self-generation and the corresponding outage loss that firms face. However, this assumption may result in selectivity bias. The selectivity bias arises because of the correlation between the outage loss that a firm face and the decision to invest in self-generation. Ignoring this correlation results in a biased estimates (Maddala, 1993). The endogenous switching regression overcomes this problem because the decision to invest in self-generation is treated to be endogenous. Thus, this study uses endogenous switching regression in a counterfactual framework to examine the role of self-generation in mitigating outage loss and examine outage loss differential among SSA firms.

The remaining part of the paper is organized as follows: The following section provides a conceptual framework and research hypothesis. Section 3 presents data source and describes the estimation strategies and the empirical model. Section 4 presents empirical results; while the final section provides conclusions and policy implications drawn from the study.

2 Theoretical Model of Firm's Investment in Self-Generation

Firm's decision to invest in self-generation, like other investment decision, depends on several factors including financial capacity and internal firm decision process. Since the availability and quality of public electricity are uncertain, a risk-neutral firm decides whether to invest in a generator of size, $G_i > 0$. A firm incurs a fixed cost k for installing a generator and a running cost of μG_i per hour, which is mainly a fuel cost. A firm that has installed an electric generator can ensure a return of φG_i, where $\varphi > 0$ is a generator's productivity.

In a NPV approach to investment decision, all capital costs have to be weighed against the expected of future benefits and a firm undertakes an investment with a positive NPV (DeCanio and Watkins, 1998). A firm that invests in a self-generation gets a benefit of a reduced outage loss that the firm would have incurred in the absence of such investment. Given the above information, the firm that invested in a private generator can reduce the outage loss [3] by $\lambda HQ - \varphi HG_i$, where Q is the total annual sales of the firm in USD, λ is a measure of the degree of vulnerability of the firm's operation to power outages, $0 < \lambda \leq 1$ [4] and H is total outage time in a year [5]. Thus, based on the given cost and benefit of investing in self-generation, the NPV can be determined by:

$$NPV = \sum_{t=1}^{T} \frac{1}{(1+r)^t}\{(\lambda HQ - \varphi HG_i) - C_t^G[\mu G_i,\ k, \phi]\} \tag{2.1}$$

Where t is a year, T is the generator's lifetime, r is the discount rate, k is the the fixed cost of generator whereas μG is a running cost, ϕ is financial barriers. Financial barriers indicate among other things whether the firm has easy access to external finance or not.

Based on the above theoretical discussions, the following empirically testable hypothesis is set.

Hypothesis

Firms that invested in self-generation face higher unmitigated outage loss compared to those that did not. Firms that invested in self-generation may continue to suffer higher unmitigated outage loss compared to firms that did not invest in self-generation. This could be possible if electricity from self-generation is not enough to fully back up the electricity load of the firm and the firm is more vulnerable to power outages.

[3] The amount of outage loss depends on the amount mitigated by adopting generator, even if partial, and total duration of a power outage in a year (H).

[4] The value of $\lambda = 0$ indicates a situation where firm's operation is completely immune to power outages and excluded in this study

[5] In the absence of power interruption, the reported outage loss is assumed to be zero

Consider two firms with an information presented above. Assume further that output is subjected to an hourly loss of λQ. The outage loss function when a firm invests in self-generation is given

$$L_s = \lambda Q + C^G(.) - \varphi G \tag{2.2}$$

where $C^G(.)$ is the cost of investing in self-generation defined in equation (2.1)

The outage loss for firms without a generator is given by

$$L_f = \theta Q \tag{2.3}$$

where λ and θ measure the degree to which a firm's operation is vulnerable to power outage for a firm that invested in self-generation and that do not invested in self-generation respectively.

Thus, firms that invested in self-generation can face higher outage loss if $\lambda > \theta$ i.e. more vulnerable to power outages and the mitigating capacity of the generator is small compared the required electricity load of the firm.

3 Methodology

3.1 Data

This study makes use of the World Bank Enterprise Survey (WBES) data collected from firms operating in 13 Sub-Saharan African countries[6].These countries were selected based on sample size and the year of a survey conducted. Comparable information using the same survey instruments across all country is available after 2010. Thus, this study considered only countries for which the survey is available after 2010.

Combining firm level data for these countries, there are about 5,129 observations in data set. However, there are firms that reported zero outage loss either because they are immune to outages due to the nature of their business or they have

[6]The study covers 13 SSA countries namely: Cameron, Ethiopia, Ghana, Kenya, Mali, Namibia, Nigeria, Senegal, Sudan, Tanzania, Uganda, Zambia and Zimbabwe

completely backed up their electricity load. In addition, firms may report unreasonably large outage losses. To control for this, an upper limit of 50% is set on the percentage of annual sales lost due to outage. After excluding these observations, 3,029 firms are left in the sample. . The sampling distribution in the data ranges from 119 firms in Namibia and Uganda, about 4% of total sample, to 505 firms in Nigeria which is about 17% of the sample.

Table 1: Summary Statistics

Variable	Description	Mean	Std.Dev.	Obs.
Outage time(lnH)	Outage time in days/year	2.56	1.27	3029
Outage loss	Percentage of sales lost due to outage	8.65	8.53	2983
lnL_s	Outage loss (in $/year) for adopters	13.03	4.24	1525
lnL_s	Outage loss (in $/year) for non-adopters	11.71	5.23	1063
PID	Power intensity dummy	0.40	0.49	3029
$Constraint$	largest obstacle to firm's doing business	0.16	0.37	3209
lnE	Annual cost of electricity ($/year)	7.16	3.35	2601
G_i	Percentage of firms owning generator	0.59	0.49	3029
G_{sh}	Share of electricity from self-generation	0.26	0.26	1730
lnL	Number of permanent full time workers	3.01	1.20	3029
Age of firm	Age of the firm (years)	2.51	0.70	2984
Experience (ln)	Experience of the top manager (years)	2.63	0.67	2949
Ownership	Percentage of firms owned by foreigners	0.20	0.40	3003
Exporters	Percentage of firms engaged in export	0.14	0.35	3029

Power intensity dummy (PID) is defined on the basis of average sector-level value of electricity expenditures as a percentage of total cost. PID takes a value of one if the average sector-level share of electricity from total annual cost is greater than median value. Obstacle to doing business is factors that firm reported as the main constraint to doing their business. These constraints are collapsed into two categories as electricity (1) and others factors (0) for easy interpretation. Observation counts differ due to non response and due to variable-specific cleaning procedures.

Figure 3.1 (left panel) plots the average share of firms owning generator against the mean outage time across countries. The cross-sectional correlation between outage time and share of firms owning generator is noisy but potentially positive suggesting that firms in a country where there is high power problem tends to invest in self-generation. The right panel of Figure 3.2 shows correlation between outage time and a percentage of sale loss due to power outage. The average outage time and the corresponding percentage of sales loss are positively correlated suggesting that firms in a country where power outage is severe incur higher outage loss compared to firms in a country where the problem is moderate.

Figure 3.2 shows a positive correlation between firm's power intensity, and the share of firms owning generator in each country. This suggest that two firms

Figure 3.1: Outages time, share of firms owning generator and percentage of outage loss by Country

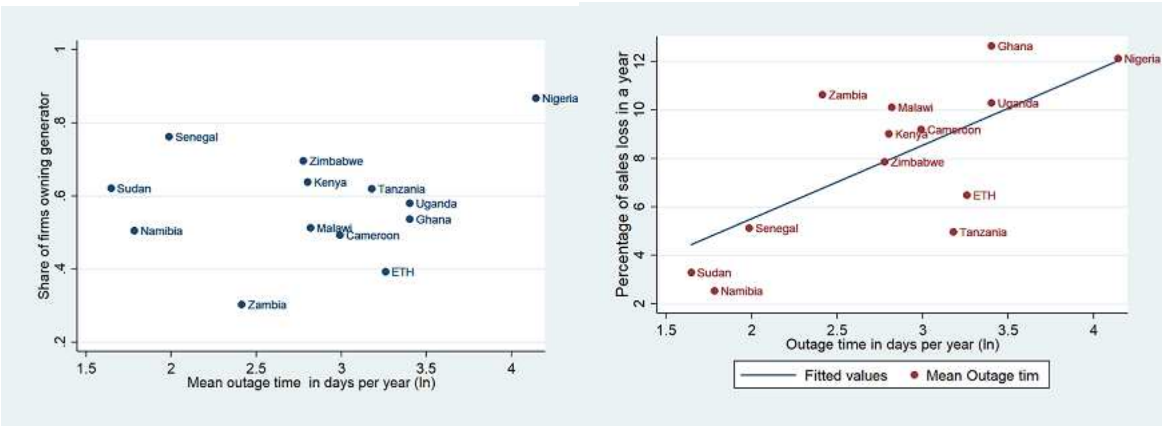
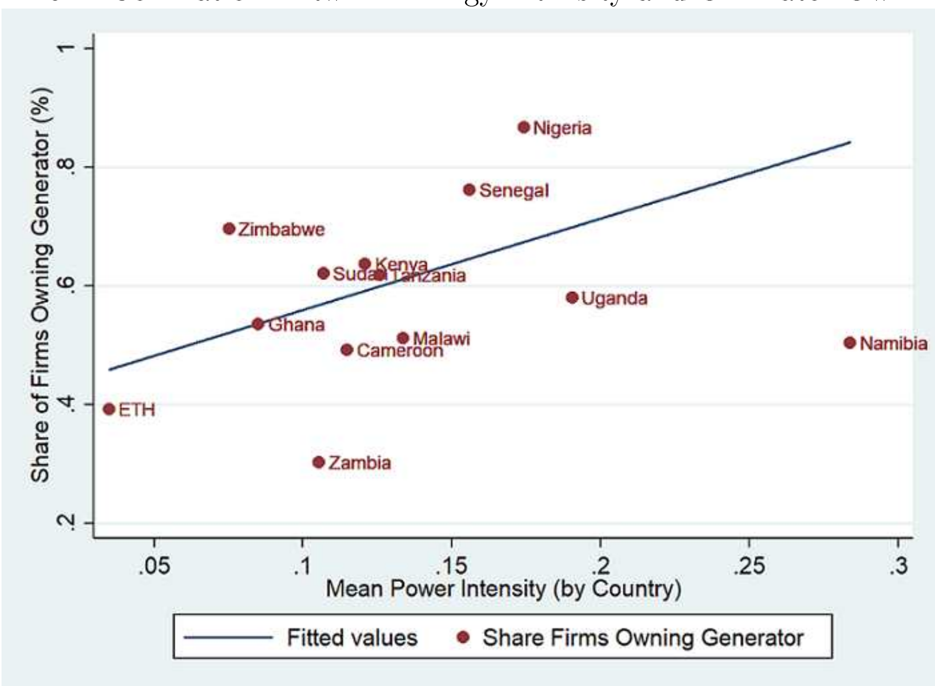


Figure 3.2: Correlation Between Energy Intensity and Generator Ownership



facing the same duration of power outage may have different incentive to invest in generator due to difference in their degree of vulnerability to power outage.

In addition to the above graphical explanations, a simple regression of power related variables on outage time and power intensity is made. The variable "constraints" in Table 2 is a dummy variable which indicates whether a firm reported electricity as a main obstacle to doing its business or not.

Table 2: Correlation of Outages with Power variables

Dependent variable	$Outages(ln)$ [1]	PID[2]	C_{nts}[3]
Self-generation (G_{ow})	0.0341***	0.121***	0.178***
	(0.006)	(0.018)	(0.023)
Share of self-generation (G_{sh})	7.883***	8.03***	12.32***
	(0.444)	(1.254)	(1.524)

The dependent variables are self-generation indicator which is a binary outcome and takes value of one for firms owning generator, zero others, and the share of electricity from self-generation (only for firms that adopted generator). For the purpose of estimating the correlation among the variables, linear probability model is assumed for self-generation indicator and the usual OLS is estimated for the later dependent variable. Figures in brackets are standard errors. *** significant at 1% level; ** significant at 5% level ; * significant at 10% level

The first column of Table (2) shows firms in a country where power supply is highly unreliable are more likely to invest in self-generation and the share of electricity coming from self-generation is higher for these firms. Column 3 indicates firms that report electricity as a main obstacle to doing their business more likely invests in self-generation, and for these firms the share of electricity from self-generation is higher compared to firms that did not report electricity as a main obstacle to doing their business. Power intensity dummy is significant and positively correlated with both self-generation status and share of electricity from self-generation, suggesting that firms operating in a power intensive sectors are more likely to invest in self-generation and for these sectors, the share of electricity coming from self-generation is higher compared to less power intensive sectors.

3.2 Model specification

In this section, the empirical model is presented in line with the theoretical framework discussed in section (2). The main implication of the theoretical model discussed in section (2) is that under certain conditions, firms that expect positive NPV will invest in self-generation and there is a resulting outage loss differential between firms that invest in a self-generation and those that did not.

As discussed in theoretical model, NPV measures the discounted amount of outage loss net of investment cost, as such indicates what a firm would save by investing in a self-generation. Revisiting discussions in section (2), this depends on outage time and whether a firm has invested in self-generation or not, among other things. This differential in outage loss based on investment in self-generation can be captured by estimating the following endogenous switching regression:

$$Pr(G_i = 1) = \beta_0 H_i + Z_i \gamma_i + u_i \tag{3.1}$$

$$L_s = \beta_{0s} H_i + X_s \beta_s + \varepsilon_s \text{ if } G_{owi} = 1 \equiv NPV \geq 0 \tag{3.2}$$

$$L_f = \beta_{0f} H_i + X_f \beta_f + \varepsilon_f \text{ if } G_{owi} = 0 \equiv NPV < 0 \tag{3.3}$$

where equation (3.1) is a criterion (selection equation) that determines which regime occurs, H_i is the outage time, L_s and L_f are the amount outage loss for firms that invested in self-generation and those that do not respectively, X_s, X_f and Z_i are vectors of weakly exogenous variables; β_s, β_f and γ_i are vectors of parameters to be estimated. Assuming u_i, ε_s and ε_f are normally distributed error terms with mean zero vector and the co-variance matrix is given by:

$$Cov(\epsilon_s,\ \epsilon_f,\ u_i) = \begin{bmatrix} \delta_s^2 & \delta_{sf} & \delta_{su} \\ \delta_{fs} & \delta_f^2 & \delta_{fu} \\ \delta_{us} & \delta_{uf} & \delta_u^2 \end{bmatrix} \tag{3.4}$$

where δ_u^2 is a variance of the error term in the selection equation, δ_s^2 and δ_f^2 are variances of the error terms in the continuous equations, δ_{su} is co-variance of ϵ_s and u_i, δ_{fu} is a co-variance of ε_f and u_i[7].

The empirical specification of the model in equation (3.1)-(3.3) are given as:

$$lnL_s = \beta lnH_i + \beta_{1s} lnE + \beta_{2s} lnL + \beta'_{3s} X_i + \lambda_j + \eta_n + \varepsilon_s \text{ if } G_i = 1 \tag{3.5}$$

$$lnL_f = \beta_{0f} lnH_i + \beta_{1f} lnE + \beta_{2f} lnL + \beta'_{3f} X_i + \lambda_{j+} \eta_n + \varepsilon_f \text{ if } G_i = 0 \tag{3.6}$$

$$Pr(G_i = 1) = \beta_0 lnH_i + \beta_1 lnE + \beta_2 lnL + \beta'_3 Z_i + \lambda_{j+} \eta_n + u_i \tag{3.7}$$

[7]Since the dependent variables L_s and L_f are not observed simultaneously, the co-variance between ε_s and ε_f, i.e. δ_{sf} and δ_{fs} in equation (3.4) are not defined (Maddala, 1993)

where Z_i = [ownership_i, exporter_i , $lnAge_i$, $lnExprience$, PID_j], X_i=[ownership_i, exporter_i]; lnL_s and lnL_f are the amount of outage loss (in USD per year) for firms that have invested in self-generation and those that did not respectively. lnH is log of outage time that firm i face in a year, PID_j is the power intensity dummy for industry j, L is the number of permanent full time workers of firm i, E is the annul expenditure on electricity of firm i, λ_j shows j industry dummies which captures degree of vulnerability to power outages, η_n captures n country dummies and u_i is a normally distributed error term with mean zero and variance of δ_u^2. Because of exclusion restriction imposed, managerial experience, age of firm and power intensity dummy (PID) appear only in the selection equation. The identification strategy and exclusion restriction imposed is discussed more in the next section.

The model in equations (3.5)–(3.6) along with the selection equation (3.7) are estimated by Full Information Maximum Likelihood (FIML) developed by (Lokshin and Sajaia, 2004). The FIML method is more efficient than the two-stage method in estimating the endogenous switching model because it yields a consistent standard error (Fuglie and Bosch, 1995).

3.3 Identification Strategy

For the model described above to be identified, there should be at least one variable in the selection equation which is not included in the outage loss equations[8]. This variable should affects firms' decision to invest in self-generation (the selection equation) but not directly affects the outage loss. To achieve this, managerial experience and average sector-level power intensity are included in the selection equation. The rationale of using managerial experience as an instrumental variable is based on the argument that the decision of whether a firm to adopt a generator or not is mainly managerial decision which mainly depends on managerial experience to predict the nature of power interruptions and managerial capability to exploit firm's available resources. Since good management is aimed at reducing firm's cost of production for a given level of output, managerial experience is expected to be negatively correlated with generator adoption decision.

The inclusion of power intensity in the selection equation is justified in a sense that more power intensive sectors are willing to invest in a self-generation compared

[8] This means there should be at least one variable in Z_i in equation (3.7) which is not included in X_i in equations (3.6)–(3.6)

less power intensive sectors, other things the same. The description of the data in Figure (3.2) and Table (2) supports this argument– firms that are more power intensive are more likely to own generator compared firms that are less power intensive. Taking a cue from this, to further aid the identification, a dummy variable indicating whether a firm is in a power intensive sector or not is computed, and interacted with outage variable. Power intensity dummy is created based on average sector-level electricity cost as a percentage of total cost. A sector is then, classified as power intensive if the computed cost of electricity as a percentage of total cost is above the median (4.8%) and non-power intensive otherwise. This is based on the argument that power intensive sectors are heavily affected by power outages compared to sectors that are not power intensive.

3.4 Conditional Expectations, Treatment and Heterogeneity Effects

The endogenous switching regression model in equations (3.5) and (3.6) can be used to compare the expected outage loss between firms that invested in self-generation and those that do not. The expected outcomes with and without self-generation can be used to calculate the expected treatment effects [9] for each group. This can be addressed by estimating the counterfactual unmitigated outage loss level for each group. For example, the expected outage loss with self-generation for a sample group that actually invested in self-generation can be estimated from data on firms in this group. The expected outage loss without self-generation for this group is a counterfactual outcome. The same logic would describe the actual and counterfactual outcomes for the group of firms without self-generation. The conditional expected outage loss for both group of firms under actual and counterfactual conditions are presented in Table (3). Details on how the conditional expected values under actual and counterfactual conditions, treatment and heterogeneity effects are computed for each group are available in Annex (A.1).

[9] Investment in self-generation is considered as voluntary treatment in which firms choose (self-select) to invest in generator based on the anticipated gains.

Table 3: Definition of Expected and Treatment Effects

	Investment Decision		
Sample	Invest	Don't invest	Treatment
Own generator	$E(L_s/X_s, G_i = 1)$	$E(L_f/X_f,\ G_i = 1)$	TT
No generator	$E(L_s/X_s, G_i = 0)$	$E(L_f/X_f,\ G_i = 0$	TU
Heterogeneity Effects	BH_1	BH_2	

L_s- is the outage loss which firms that invested in self-generation face, L_f- is the outage loss which firms that don't invested in self-generation face, X_s- is the observed control variables and characteristics of firms that own generator, X_f–is the observed control variables and characteristics of firms that don't own generator, $G_i = 1$ if the firm invested in self-generation and 0 otherwise. $BH_1$is the base heterogeneity effect for firms that own generator with the counterfactual that firms that don't invested in self-generation had invested in self-generation. BH_2 is the base heterogeneity effect for firms that don't invested in self-generation with a counterfactual condition firms that don't invested in self-generation had invested in self-generation. TT–measures the effect of generator adoption on firms that invested in generator; this is computed by taking the difference between the actual outage loss that these firms face and the outage loss under the counterfactual condition that if they had not invested in generator. TU–measures the effect of generator adoption on those firms that don't invested in a generator.

4 Results

4.1 Outage loss and investment in self-generation

For a comparison, a single-equation outage loss with no switching was estimated with a generator ownership dummy (G) as explanatory variable and reported in the first column of Table (4). The coefficient estimates from this model are biased and inconsistent but are included here to compare with the switching regression model. The coefficient of generator ownership dummy (G) is positive and significant implying that firms that invested in self-generation face greater outage loss relative to firms without such investment. This result provides a preliminary answer to the hypothesis of the study discussed in section (3). This may be a misleading conclusion, however, because additional endogenous effect on outage loss due to investment in self-generation have not been properly accounted for in this simple model.

The endogenous switching regression which overcomes this problem, as specified in 3.5-3.7, is estimated and reported in the columns 2 through 4 of Table (4) . The switching equation, which is estimated by probit model shows the influence of observable firm characteristics and other controls on firm's decision to invest in self-generation. The coefficient of outage time is positive and significant, indicating that outage time induces firms to invest in self-generation. The variable employment is the number of permanent full-time workers and its estimated coefficient is positive and significant. This suggests that a higher number of workers increases the likelihood that a firm invest in self-generation. More specifically, large firms have higher incentive to invest in self-generation compared to small firms during a period of power outages.

The coefficient of power intensity dummy (PID) is positive and significant indicating that power intensive firms have higher incentive to invest in self-generation compared to less power intensive firms. This is mainly due to the fact that power intensive firms need a continues supply of power.

As reported in the second column of Table (4), the estimated coefficient of firm age is positive and significant which indicates that the likelihood that a firm invest in self-generation increases with age of the firm. This might possibly explains the vulnerability and financial capacity of old firms as compared to young firms. Old firms due to their established brand names, are more likely get access to external finance for their operation, including investment in self-generation. On the other hand, old firms which run many establishments suffer a huge outage loss for the same outage time compared to young firms with a single or few establishments. This may induce large firms to invest in self-generation than young firms.

The coefficient of variable experience, which shows the managerial experience of top manager of the firm, is negative and marginally significant. This shows, firms under the management of experienced manager have less incentive to invest in self-generation. This could be due to the fact that motivated and experienced managers take actions which reduces the firm's production cost because alternative source of electricity would add more to cost for a given level of output. Similar literature is that of Cissokho and Seck (2013); in which authors explained positive effect of power outage on firm's cost efficiency as a successful coping strategy. Experienced firms organize their activities in way that could cancel the expected adverse effects of power outages. According to Scott et al. (2014) this strategies could be in the form of shifting workers from tasks that are electricity intensive to tasks that are less electricity demanding, or that do not need electricity or intensify production at times when electricity is running and adapt to the realities of power availability. Thus, the result could explains the role of improved management practices in adapting to the electricity problem.

Next, the study turns to analysis the outage loss differential among firms that invested in self-generation and those that do not, and examine the role self-generation in mitigating the outage loss. The FIML estimates of endogenous switching regression model for outage loss are reported in the third and fourth column of Table (4). The likelihood-ratio test, reported in the last rows of Table (4), rejects the

Table 4: Outage loss by backup-status

	Pooled OLS (1)		Investment decision (2)		Generator(3)		No generator (4)	
Variable	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err
Outages(lnH)	0.049**	0.021	0.046**	0.026	0.367***	0.075	0.452***	0.112
Employment(ln)	0.436***	0.035	0.386***	0.033	0.824***	0.091	2.19***	0.151
Elec. expend.(ln)	0.515***	0.017	0.048***	0.015	0.230***	0.038	0.562***	0.070
Export	0.308***	0.089	0.012	0.092	0.482***	0.215	0.686*	0.417
Ownership	0.191***	0.089	0.190**	0.084	0.082	0.207	0.616*	0.381
Experience (ln)	0.009	0.052	-0.068*	0.037				
G_{ow}	0.298***	0.072						
Age (ln)	0.086**	0.051	0.090**	0.035				
PID	-2.280	0.071	0.192***	0.046				
$Constant$	4.164***	0.476	-0.727**	0.235	6.79***	0.628	5.803***	0.845
ρ_1					-0.053	0.092		
ρ_2							0.951***	0.008
Industry dummies			Yes		Yes		Yes	
Country dummies			Yes		Yes		Yes	
Number obs.						2240		
Log likelihood						-6726		
Wald $\chi^2(17)$				1339			$Prob > \chi^2 = 0.000$	

LR test of independent equations: $\chi^2(1) = 827$ $Prob > \chi^2 = 0.000$

*** P<0.01; ** 0.01<P<0.05; * 0.1<P<0.05. G_{ow} is generator ownership , PID -is the power intensity dummy which is one for industries that have average power intensity above the median value (4.8%). and zero otherwise. Coefficients of $\rho_1$and ρ_2 measures the correlation between selection equation and the outage loss equations. The significance of ρ_1 shows the investment decision and the outage loss equation for those that don't invested in self-generation are positively correlated. Furthermore, the likelihood ratio test rejects the null hypothesis of the two equations are independent in favor of the alternative hypothesis, justifying the estimation of endogenous model.

null hypothesis of the equations are independent in favor of alternative hypothesis that the model is endogenous. The estimated correlation coefficient is positive and significant for firms that do not invested in self-generation. This indicates investment decision and the quantity of outage loss are correlated which shows an evidence of endogenous switching in the model.

As reported in Table (4), the coefficients of determinants of outage loss are similar in sign and significance for both backup and non-backup[10] firms, but differ in magnitude. This observed differences in the magnitude of estimated coefficients could be due to the presence of heterogeneity in the sample or attributed to investment in self-generation. The identification of the heterogeneity effect in the sample and the role investment in self-generation for both group of firms are discussed in the following section.

The coefficient of outage time is positive for both group. This shows outage loss increases with an increase in outage time. However, the impact is stronger on a group of firms that do not invested in self-generation. For instance, a 1% increase in outage time increases annual outage loss for firms that invested in self-generation by 0.37% while the same 1% increase in outage time increases the outage loss for firms without such investment by 0.45%. This shows about 23% more than the corresponding coefficient in the outage loss equation for firms with backup investment. This indicates firms that invested in self generation have managed, even if partial, the effect of power outages.

Similarly, outage loss increases with firm size and the amount of expenditure on electricity for both group, however, the impact is more pronounced on firms without self-generation. This also possibly explains the importance of investing in self-generation.

4.2 Analysis of Outage Loss Differential

In this section, the study examines the extent to which investment in self-generation has helped firms in mitigating outage loss. This can be answered by comparing the impact of self-generation on firms that have actually invested; the effect of treatment on treated (TT); and its impact on those that do not invested under the condition that if they had invested in self-generation; the effect of treatment

[10]Backup firms are those firms that have invested in self-generation while non-bank up firms are those that don't.

on untreated (UT). This is reported in Table 5). The result indicates firms that have actually invested in self-generation would have incurred a greater outage loss if they had not invested in self generation. For instance, firms in Zambia would have incurred additional 36% more than the current outage loss if they had not invested in self-generation while the figure for firms in Ethiopia is about 99%. On the other hand, firms that do not invested in self-generation would have reduced their current outage loss by 2% to 24% if they had engaged in self generation. This indicates the impact of self-generation is greater on firms that have actually invested in self-generation.

Considering the observed differences in the predicted outage loss between firms that invested in a self-generation and those that did not, firms that have invested in self-generation have faced higher outage loss on average in all countries except in Sudan compared to firms that did not (See Table 5). This simple comparison is, however, misleading because it does not account for unobserved differences between the two groups that may affects outage loss. In order to account for this, the base heterogeneity for both group is computed as specified in equations (A.7)–(A.8) and the result is reported in Table (6). With the counterfactual condition that firms that do not invested in self-generation had invested (BH1 as indicated in equation (A.7), the expected outage loss for firms that actually invested is higher than the outage loss under the counterfactual condition in each country except in Nigeria and Sudan. Firms in Nigeria and Sudan faces almost the same outage loss under actual and counterfactual conditions indicating there is no systemic sources of variation between the groups that could result in observable differences in outage loss. Similarly, with the counterfactual condition that firms that have invested in self-generation do not invested (BH2 as indicated in equation (A.8), firms that have invested in self-generation still face higher outage loss than firms that did not. This explains the degree to which these firms are vulnerable to power outages and their inability to completely back-up their electricity load.

4.3 Extensions and Robustness Checks

This section asses the sensitivity of the result to the identification assumptions. The identification in the previous section is based on the use of managerial experience and power intensity dummy in the investment decision equation and excluding them from the outage loss equation. To asses the validity of this assumption and examine the sensitivity the estimates to this assumptions, the model is re-estimated by relaxing some of the assumptions. Three alternative specifications

Table 5: Predicted outage loss (in log of USD)

	Backup Firms			Non-Backup Firms		
Country	Actual (1)	Counter-factual (2)	%TT (3)	Actual (4)	Counter-factual (5)	%UT (6)
Cameroon	14.97	21.49	43.57	13.27	14.26	-7.43
Ethiopia	8.74	17.48	99.80	8.58	7.83	8.75
Ghana	10.94	16.76	53.10	8.26	10.03	-21.46
Kenya	15.33	22.66	47.84	13.30	14.20	-6.80
Malawi	15.58	21.36	37.04	13.30	15.09	-13.48
Namibia	11.38	16.71	46.75	8.97	11.10	-23.77
Nigeria	12.14	20.97	64.56	11.43	12.02	-5.17
Senegal	15.41	23.08	49.76	14.40	14.72	-2.23
Sudan	11.08	19.12	72.54	11.91	11.10	7.61
Tanzania	16.88	23.77	40.83	13.75	15.26	-11.04
Uganda	16.73	22.85	36.54	14.67	16.02	-9.20
Zambia	18.18	24.70	35.81	16.58	17.62	-6.27
Zimbabwe	10.72	17.19	60.28	9.00	10.27	-14.18

TT– is the effect of investment in self-generation on firms that have invested and obtained by the taking the difference between column 1 & column 2, then divided by the first column. UT–is the effect of investment in self-generation on firms that didn't actually invested, computed by taking the difference of column four and column five, then divided by column four. Both TT and UT are expressed in percentages and TT shows the outage loss that firms that have invested in self-generation would have incurred had they not invested compared the current unmitigated loss given in column 1. UT shows the amount of outage loss that firms don't invested in self-generation would have reduced had they invested in self-generation. Positive figures in UT for Ethiopia and Sudan shows firms in these countries are better off by not investing in self-generation.

are estimated and reported in Appendix (A.2). Compared to the baseline model reported in Table (4), the first alternative model is estimated with managerial experience and interaction of power intensity dummy with outage time in the investment decision model. In the second alternative specification, in addition to the interaction of power intensity dummy with outage time; managerial experience is treated as categorical variable rather than continuous and industry dummies are excluded from both investment decision and outage loss equation [11] . These categories are then included in selection equation. Finally, in the third alternative specification, industry dummies are excluded from both selection and outage loss equation compared to the baseline model.

[11] Managerial experience is categorized into five age quintiles following (Iacovone et al., 2014). The first quintile 1 contains managers that have between 0 and 6 years experience, quintile 2 is from 7 to 11 years, quintile 3 is from 12 to 16 years, quintile 4 from 17 to 26 years and quintile 5 contains managers that have more than 27 years experience

Table 6: Predicted outage loss and heterogeneity effects (in log of USD)

	Backup firms		Non-backup firms		Heterogeneity effects	
Country	Actual (1)	Counter-factual (2)	Actual (3)	Counter-factual (4)	BH1 (5)	BH2 (6)
Cameroon	14.97	21.49	13.27	14.26	0.71	8.21
Ethiopia	8.74	17.48	8.58	7.83	0.91	8.89
Ghana	10.94	16.76	8.26	10.03	0.91	8.50
Kenya	15.33	22.66	13.30	14.20	1.12	9.36
Malawi	15.58	21.36	13.30	15.09	0.48	8.05
Namibia	11.38	16.71	8.97	11.10	0.28	7.74
Nigeria	12.14	20.97	11.43	12.02	0.11	8.54
Senegal	15.41	23.08	14.40	14.72	0.68	8.68
Sudan	11.08	19.12	11.91	11.10	-0.08	7.21
Tanzania	16.88	23.77	13.75	15.26	1.61	10.02
Uganda	16.73	22.85	14.67	16.02	0.71	8.18
Zambia	18.18	24.70	16.58	17.62	0.56	8.11
Zimbabwe	10.72	17.19	9.00	10.27	0.45	8.19

BH1 is the base heterogeneity effect for backup firms with counterfactual condition that non-backup firms had invested in self-generation, and is computed by taking difference between the first column and 4th column. BH2 is the base heterogeneity for non-backup firms with the counterfactual condition that backup firms did not invested in self-generation; and is computed by taking the difference between the second and third column.

Table (7) presents the correlation coefficients between errors terms in selection and outage loss equations under alternative specifications. The sign and significance of the correlation coefficients are maintained under all specifications.

Under the first alternative specification, the coefficient of interaction term, power intensity interacted with outage time, is positive and significant. This indicates outages induces power intensive firms to invest more in self-generation compared less power intensive firms. Other variables of the model have maintained their sign and statistical significance in both selection and outage loss equations. In all cases, alternative specifications does insignificant changes compared to the result from baseline specification (see Appendix A.2–A.4).

Table 7: The Impact of Alternative Specifications on Correlation Coefficients

Specifications	ρ_1	Std. Err.	ρ_2	Std. Err.
Baseline specification	-0.053	(0.092)	0.951***	(0.008)
Alternative specification (1)	-0.065	(0.093)	0.950***	(0.008)
Alternative specification (2)	-0.059	(0.091)	0.950***	(0.007)
Alternative specification (3)	-0.052	(0.087)	0.948***	(0.008)

Figures in brackets are standard errors. In alternative specification (1), the interaction of PID with outages time is added to the investment decision equation compared baseline specification. Managerial experience is treated as categorical variable and industry dummies are excluded from both selection and outage loss equations in alternative specification (2); while in specification (3) only industry dummies are excluded from the outage loss equation as compared to the baseline equation.

4.4 Why do firms that invested in self-generation face higher outage losses?

As discussed in section (4.2), firms that invested in self-generation would have suffered from 36% to 99% additional outage loss compared to the current outage loss these firms have incurred. This shows self-generation has helped these firms by reducing the outage loss by 36% to 99% that these firms would have suffered. However, comparing the outage loss between a group of firms that invested in self-generation and those that didn't, a group of firms that invested in self-generation continued to face higher outage loss compared to firms without such investment. Thus, a question that arises from such analysis is that why firms that invested in self-generation still suffers higher outage losses?

This is mainly due to the fact that firms make only partial investments which can't fully backup their electricity load. Table (A.5) shows that the share of electricity coming from self-generation is only 9% in Sudan, and it is 11% in Cameroon. Relatively high percentage of backup electricity is observed in Nigeria,which is about 53%. The implication is firms may backup only critical components of their operation due to high cost of self-generation or lack of access adequate finance. The cost of self-generation is approximately 3 times as costly as the costs of electricity supplied by the national grid Steinbuks and Foster (2010); Adenikinju (2003). Firms may also opt for less than full backup investment in self-generation due to financial constraint. The firm may also choose backup only critical components of their operation if the firm don't have adequate financial capacity to invest in complete backup. Thus, firms that have invested in self-generation remain vulnerable to power outages.

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A Appendix

A.1 Conditional Expectations, Treatment and Heterogeneity Effects

Considering equations in (3.5) and 3.6, the actual and counterfactual outcomes for firms with and without self-generation is given in Table (A.1)

Table A.1: Definition of Expected and Treatment Effects

	Investment decision		
Sample	Invest	Don't invest	Treatment
Own generator	$E(L_s/X_s, G_i = 1)$	$E(L_f/X_f,\ G_i = 1)$	TT
No generator	$E(L_s/X_s, G_i = 0)$	$E(L_f/X_f,\ G_i = 0$	TU
Heterogeneity Effects	BH_1	BH_2	

L_s- is the outage loss firms that invested in self-generation face, L_f- is the outage loss firms that don't invested in self-generation face, X_s- is the observed control variables and characteristics of firms that own generator, X_f–is the observed control variables and characteristics of firms that don't own generator, $G_i = 1$ if the firm invested in self-generation and 0 otherwise. $BH_1$is the base heterogeneity effect for firms that own generator with the counterfactual that firms that don't invested in self-generation had invested in self-generation. BH_2 is the base heterogeneity effect for firms that don't invested in self-generation with a counterfactual condition firms that don't invested in self-generation had invested in self-generation. TT–measures the effect of generator adoption on firms that invested in generator; this is computed by taking the difference between the actual outage loss that these firms face and the outage loss under the counterfactual condition that if they had not invested in generator. TU–measures the effect of generator adoption on those firms that don't invested in a generator .These concepts are discussed below.

The conditional expected outage loss for both group under actual and counterfactual conditions are presented in Table (A.1). These conditional expectations are defined as follows:

$$E(L_s/X_s\ ,\ G_i = 1) = X_s\beta_s + \delta_s\rho_1\frac{f(\gamma Z_i)}{F(\gamma Z_i)} \tag{A.1}$$

$$E(L_f/X_f\ ,\ G_i = 0) = X_f\beta_f + \delta_f\rho_2\frac{f(\gamma Z_i)}{F(\gamma Z_i)} \tag{A.2}$$

$$E(L_s/X_f\ ,G_i = 0) = X_f\beta_s - \delta_f\rho_2\frac{f(\gamma Z_i)}{(1 - F(\gamma Z_i))} \tag{A.3}$$

$$E(L_f/X_s\ ,\ G_i = 1) = X_s\beta_f - \delta_s\rho_1\frac{f(\gamma Z_i)}{(1 - F(\gamma Z_i))} \tag{A.4}$$

where F is a cumulative normal distribution function, f is a normal density distribution, ρ_1 measures correlation between ε_s and u_i, ρ_2 measures correlation ε_f and u_i.

Equations in (A.1) and (A.2) are important to estimate the expected unmitigated outage losses for firms that invested in self-generation and those that don't for firms actually observed in the sample respectively, while Equations (A.3) and (A.4) are their respective counterfactual expected unmitigated outage losses. The use of these conditional expectations, combined with consideration of the self-generation variable as a treatment variable, allows the estimation of the causal effects of self-generation on outage loss.

Following Heckman et al. (2001), the effect of generator adoption on firms that have actually adopted, "the effect of treatment on treated (TT)," is computed by taking the difference between equation (A.1) and equation (A.4):

$$TT = E(L_s/X_s,\ G_{owi} = 1) - E(L_f/X_f,\ G_{owi} = 1) \tag{A.5}$$

This represents the effect of investing in self generation on firms' outage loss that have actually invested in self-generation. Similarly, the effect of self-generation on firms that don't invested in self-generation, "the effect of treatment on the untreated (TU)" is computed by taking the difference between (A.2) and (A.3).

$$TU = E(L_f/X_f,\ G_{owi} = 0) - E(L_s/X_s,\ G_{owi} = 0) \tag{A.6}$$

The conditional expectation in equations (A.1)-(A.4) can also be used to compute the heterogeneity effects. For instance, firms that invested in self-generation may have faced higher outage loss than those firms that don't invested regardless of their decision to invest in self-generation but because of the nature their business and other firm characteristics. Adapting Carter and Milon (2005) concept of base heterogeneity, the effect of base heterogeneity for the group of firms that invested in self-generation is computed by taking the difference between equation in (A.1) and (A.3)

$$BH_1 = E(L_s/X_s,\ G_i = 1) - E(L_s/X_s,\ G = 0) \tag{A.7}$$

Similarly, for those firms that don't invested in self-generation, the effect of base heterogeneity is the difference between equation (A.2) and (A.4)

$$BH_2 \quad = \quad E(L_f/X_f, G_i = 0) - E(L_f/X_f, G_i = 1) \tag{A.8}$$

A.2 Alternative specifications for switching regression

Table A.2: Alternativee Specification 1

	Adoption decision		Adopters		Non-adopters	
Variable	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err
Outages(ln)	0.0203	0.027	0.366***	0.075	0.446***	0.112
Employment(ln)	0.386***	0.033	0.818***	0.091	2.17***	0.151
Elec. expend.(ln)	0.047***	0.015	0.229***	0.038	0.569***	0.070
Export	0.009	0.092	0.482**	0.215	0.684*	0.417
Ownership	0.189**	0.084	0.079	0.207	0.618*	0.381
Experience (ln)	-0.068*	0.037				
$A_f(ln)$	0.087***	0.035				
PID*Outages(ln)	0.064***	0.016				
Constant	-0.631**	0.232	6.82***	0.629	5.64***	0.930
ρ_1			-0.065	0.093		
ρ_2					0.950***	0.008
Industry dummies	Yes		Yes		Yes	
Country dummies	Yes		Yes		Yes	
Number Obs.			2237			
Log likelihood			-6796			
Wald $\chi^2(17)$		1335			$Prob > \chi^2 = 0.000$	
LR test of independent equations: $\chi^2(1) = 831$ $Prob > \chi^2 = 0.000$						

PID–is the power intensity dummy, which takes value of one if the average industry -level power intensity is greater than the median value and zero other wise. In this specification, in addition to managerial experience, identification is achieved by the inclusion of the interaction term *PIDlnoutages* which is the interaction of power intensity indicator and the outage time.

Table A.3: Alternative Specification 2

	Adoption decision		Adopters		Non-adopters	
Variable	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err
Outages(ln)	0.025	0.027	0.360***	0.074	0.459***	0.110
Employment(ln)	0.387***	0.032	0.834***	0.090	2.18***	0.148
Elec. expend.(ln)	0.050***	0.015	0.226***	0.037	0.550***	0.068
Export	0.004	0.090	0.493**	0.212	0.811**	0.417
Ownership	0.178**	0.205	0.079	0.207	0.487*	0.371
$Expc2$	-0.157***	0.066				
$Expc3$	-0.151**	0.069				
$Expc4$	-0.166***	0.068				
$Expc5$	-0.178**	0.078				
Age(ln)	0.071**	0.034				
PIDOutagesln	0.058***	0.015				
$Constant$	-0.538**	0.202	6.27***	0.529	5.98***	0.818
ρ_1			-0.059	0.091		
ρ_2					0.950***	0.007
Industry dummies	No		No		No	
Country dummies	Yes		Yes		Yes	
Number Obs.			2291			
Log likelihood			-6867			
Wald $\chi^2(17)$	1356				$Prob > \chi^2 = 0.000$	

LR test of independent equations: $\chi^2(1) = 612$ $Prob > \chi^2 = 0.000$

PID–is the power intensity dummy, which takes value of one if the average industry level power intensity is greater than the median value and zero other wise. In this specification; estimation is made without industry dummies, experience in categories and PID interaction with outages

Table A.4: Alternative Specification 3

	Adoption decision		Adopters		Non-adopters	
Variable	Coef.	Std.err	Coef.	Std.err	Coef.	Std.err
Outages(ln)	0.057**	0.025	0.312***	0.073	0.522***	0.113
Employment (ln)	0.430***	0.027	1.066***	0.083	2.905***	0.133
Export	0.052	0.086	0.373*	0.215	0.712*	0.422
Ownership	0.112	0.084	0.252	0.200	0.691*	0.376
Experience (ln)	-0.049	0.035				
Age(ln)	0.064**	0.031				
PID	0.205***	0.042				
$Constant$	-0.257	0.163	8.032***	0.416	9.986***	0.676
ρ_1			-0.052	0.087		
ρ_2					0.948***	0.008
Industry dummies	No		No		No	
Country dummies	Yes		Yes		Yes	
Number Obs.			2466			
Log likelihood			-7512			
Wald $\chi^2(16)$	1394			$Prob > \chi^2 = 0.000$		
LR test of independent equations: $\chi^2(1) = 1154$ $Prob > \chi^2 = 0.000$						

Compared to the third specification, industry dummies are excluded from both adoption decision equation and the outage loss equations. Identification is achieved through the inclusion of PID and Experience in decision equation.

Table A.5: Percentage of electricity coming from self-generation

Share of electricity from self-generation		
Country	Mean G_{sh} (%)	Sdt.Dev.
Cameroon	11.12	9.62
Ethiopia	21.94	24.78
Ghana	18.04	12.56
Kenya	13.30	13.54
Malawi	20.02	19.61
Namibia	21.09	20.53
Nigeria	53.79	27.40
Senegal	12.71	17.13
Sudan	9.31	14.27
Tanzania	22.45	13.11
Uganda	14.76	18.96
Zimbabwe	19.96	22.70

Share of electricity coming from self-generation is computed as the ration of electricity from self-generation to total electricity load of the firm.