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The Economic Costs of Unsupplied Electricity in Nigeria's Industrial Sector: The Roles of Captive Power Generation and Firm Characteristics

George Abuchi Agwu[1], Iyke Uwazie Uwazie[2], F. Tobechi Agbanike[1], Oguwuike Michael Enyoghasim[1]*, Lasbrey Anochiwa[1], Ikwor Okoroafor Ogbonnaya[1], Chima Nwabugo Durueke[1]

[1]Department of Economics and Development Studies, Alex Ekwueme Federal University, Ndufu-Alike Ikwo (AE-FUNAI), Ebonyi State, Nigeria, [2]Department of Economics, Michael Okpara University of Agriculture Umudike, Nigeria.
*Email: mic_martserve@yahoo.com

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ABSTRACT

Power failure is the most influential business constraint in Nigeria. In this study we pursue answers to two questions concerning policies to mitigate the problem. In the first, we model firms' perception of power failure constraint and found that small and medium enterprises are most constrained. In the second, we examined firms' willingness to pay to avoid power outages and found that on average and ceteris paribus, firms are willing to commit extra 15% of their annual sales to ensure uninterrupted power supply. Furthermore, captive power generating firms are even willing to pay more for uninterrupted power supply. The analysis was based on a sample of 2,676 firms compiled from 2014 World Bank's Enterprise Survey for Nigeria. The empirical estimations were based on ordered probit and censored Tobit models respectively.

Keywords: Power Outages, Industrial Sector, Captive Power Generation, Firm
JEL Classifications: L6, D21, C5

1. INTRODUCTION

Public electric power supply is a huge challenge to firms and households in Africa. Existing infrastructure is insufficient to meet current requirements and the prospect of sustaining future demand has no promise given anticipated future growth in demand. The installed power capacity is expected to rise from 2012's 90GW to 380GW in 2040 in sub Saharan Africa (Kojima et al., 2014). Despite the rise in capacity, an anticipated 530 million people, primarily in rural communities would remain without infrastructure power. While this portends gloomy economic future for those left without access to power, the fact of connection to the grid does not guarantee sufficient supply. About a third of the population of sub-Saharan Africa are without access to electricity but those who are connected suffer frequent supply interruptions (Winkler et al., 2011). There is a clear need for networks and power generation expansion in the region. Multilateral organisations such as the World Bank have shown readiness to support the region improve power infrastructure. In 2011, the World Bank's extended a total of $5 billion as aid to the region in support of power infrastructure expansion (Winkler et al., 2011). However, as African countries seek to expand investment in the power sector, affordability is coming under strain. For a long time, many policymakers have been striving to implement tariff levels that are devoid of subsidies and reflect the costs of electricity generation and distribution. In Nigeria, for example, full efficient cost recovery was provided for in legislation enacted in 2005. Notwithstanding, the pricing of gas has been of great concern in Nigeria's electricity generation challenges, especially in terms of availability and retail prices. About one half of the current generation mix in Nigeria is thermal and this proportion is set to go up with a limitation on utilization of hydro capacity. Events have shown that further exploitation of hydro resources is difficult due to capital barriers, even though the Government has plans that are still at a conceptual stage (Tallapragada, 2009).

Earlier, member states of Southern African Development Community Member States adopted the principle of cost-reflective tariffs as far back as 2004.

Nigeria is now putting the legislation to work. The country's multi-year tariff order for the period 2012–18 (MYTO II) sets tariffs based on the assumption of full cost recovery and financial viability, allowing licensees to recover efficient costs, including a reasonable return on capital. Nigeria is one of the very few countries in the region that have so far made such move. Cost-reflective tariffs are still some way off for most countries, with governments facing the dilemma of how best to balance strategies that promote investment and energy access while also ensuring that electricity is affordable. The move is often resisted by citizens and welfarist economists who appeal to centrality of public power supply to cost of living of the citizens (Kojima et al., 2014; Winkler et al., 2011). While Nigeria's move may be influential in the region, most countries at the moment are still reliant on government support and still short of the private sector investments that would come if investors could be more confident of tariff regimes that allowed a reasonable return on investment. The Nigerian Electricity Regulatory Commission maintains that outside of cost reflective tariffs, private providers would shun the electricity market and leave the country in near darkness since public provision has failed woefully. The absence of a cost-reflective tariff is a key reason for the failure of the power sector to serve Nigerians for the past three decades but to improve on the situation, households and firms must be prepared to pay more than they are currently paying. To ensure uninterrupted power supply, policy makers are seeking equilibrium price of electricity that will encourage private sector participation in the industry and allow reasonable return on investments to firm users of the electricity supplied.

This is where the current research comes in; how much more are firms willing to pay to secure uninterrupted power supply? We focused on the firms rather than the households given the nature of our dataset which included only firm losses to power outage. In addition to measuring the value of power interruption, we investigated other related policy questions such as; to what extent does investment in backup generation mitigate outage losses? In other words, are firms able to mitigate most of their outage losses by investing in backup generation? How are the measured losses related to other firm characteristics? Are there sectoral differences in the measured losses or are exporting firms also different from the rest of the firms in this respect as in most aspects of business performance? To get a sense of the character of the constraints posed by power supply to the firms and its determinants, an ordered probit regression precedes the outage loss estimation. The firms' perceptions regarding the severity of the power supply constraint is modelled as a function of the firms' characteristics. The results clearly support the outage loss estimation in magnitude and direction.

The remainder of this paper is structured as follows. Section 2 provides some stylized facts on the availability and reliability of electric power infrastructure and the losses due to electrical outages in Nigeria. Section 3 captures the review of related literature whereas section four discusses the data and empirical models of the study. Section 5 presents the estimation results while the robustness check of the study is the focus of section 6. Section 7 concludes and presents the policy implications of the obtained empirical results.

2. STYLIZED FACTS

Poor electricity supply prevails in most African countries and has contributed to the low productivity and poor competitiveness of the manufacturing sector in the continent. Nigeria occupies the topmost position among the African countries surveyed by the World Bank in 2012. Figure 1 shows the standing of eleven African countries with respect to factors constituting obstacles to businesses in the respective countries. As indicated in the figure, Nigeria has the highest number of firms reporting electricity shortage as a severe obstacle to doing business.

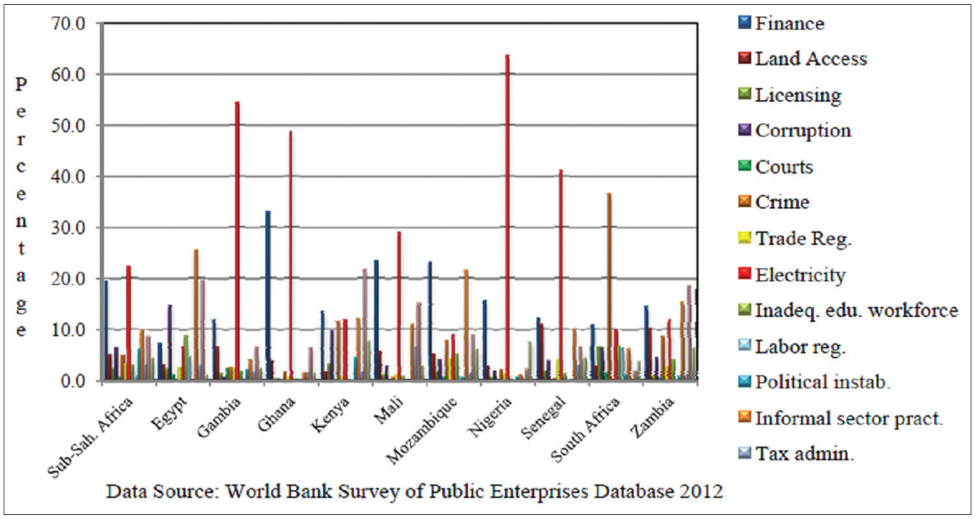
Similar survey also conducted by the World Bank in 2014 in Nigeria indicates that electric outages in Nigeria in a typical month is approximately 33 times whereas the duration of a typical electrical outage is 8 h. A typical electricity outage leads to significant losses of firms output, on average, about 10.8% of annual sales is lost due electricity outage. This average even increases to 15.6% if consider only firms reporting non-zero number of outages. As a result many firms report the ownership of generators for private electricity generation, about 70% of the firms surveyed reported that the own individually or share generator with neighbours.

3. REVIEW OF RELATED LITERATURE

Empirical debates on the economic cost of public power outages in the industrial sector have produced mix results and as such seem inconclusive. For instance, Steinbuks and Foster (2009) attempted to ascertain the underlying causes and costs of own generation of electric power in Africa. Thorough empirical analysis of 8483 existing firms in 25 African countries showed that the attitude of own generation of power would prevail (at around 20%) even if supply of power is considered perfectly reliable, indicating that other factors such as size of firms, emergency back-up and export regulations play a crucial role in the choice to own a generator. The study discovered that the costs of own-power-generation are about three times as high as the price of purchasing (subsidized) electric power from the national grid. Nevertheless, the study revealed that because these generators operate only a small fraction of the time, they do not seriously impact on the overall mean cost of power to industry. Further, Steinbuks and Foster (2009) found that benefits of generator ownership are also substantial. In specific, firms with their own generators reported a value of lost load of <US$50 per hour, compared with more than US$150 per hour reported by those without. Yet, when costs and benefits were considered side by side, the authors did not find the balance to be significantly positive.

Rud (2011) investigated the effect of electricity provision on industrialization using a panel of Indian states for 1965-1984. To

Figure 1: Nature of obstacles facing businesses in Africa



address the endogeneity of investment in electrification, he used the introduction of a new agricultural technology intensive in irrigation (the Green Revolution) as a natural experiment. As electric pump sets are used to provide farmers with cheap irrigation water, Rud (2011) used the uneven availability of groundwater at the start of the Green Revolution to predict divergence in the expansion of the electricity network and, ultimately, to quantify the effect of electrification on industrial outcomes. The study presented a series of tests to show that the electrification channel remains the most important one among alternative explanations that could link groundwater availability to industrialization directly or indirectly. Results of the study showed that an increase in one standard deviation in the measure of electrification is associated with an increase of around 14% in manufacturing output for a state at the mean of the distribution.

Praktiknjo et al. (2011) contributed to the topic of energy supply security by proposing a Monte Carlo-based and a survey based model. They analyzed the costs of power interruptions in Germany and noted that outage cost estimations are particularly important when deciding on investments to improve supply security (for instance, additional transmission lines) in order to compare costs to benefits. The main focus of their study was on the residential consumers, but the model was as well applied to commercial, industrial and governmental consumers. Taking the high degree of uncertainties into account, a Monte Carlo simulation was conducted in the study for the case of private households in Germany. The study revealed that outage cost for these residential consumers in Germany amounted to an average of 15.7 €/kWh with a median of 11.43 €/kWh.

Moyo (2012) examined the impact of power disruptions on firm productivity in the manufacturing sector of Nigeria using the OLS and the Tobit models. The results indicated that power outage variables (measured using hours per day without power and percentage of output lost due to power disruptions) impacted negatively and significantly on productivity, mainly on small firms. According to him, the significant impact of power outage is suggestive of the need for the Nigeria to develop means of improving energy generation and supply, in addition to proper maintenance of electric power infrastructure. He opined that thoughtful efforts to improve power infrastructure in Nigeria will result into threefold increase in electricity production and thus leading to optimal utilization of installed generating capacity.

Coll-Mayor et al. (2012) estimated the economic losses in five regions of the Spanish industrial sector as a result of lack of power quality. According to them, the term power quality includes, in general, a set of boundary solutions that allow electrical systems connected to the grid to function optimally. Hence, the operation of the electric power system outside these boundaries directly affects the economic performance of the entire system directly. In the main, the paper sought to offer decision makers and all other authorities in charge of enforcing reimbursements for losses derived of power quality issues with a comparatively easy to apply method for computing the real quantity of these losses. The study found that the value of lost load [€/kWh] variable showed to be a useful tool for analyzing the energy behavior for activities.

Using cross-sectional data from 6854 firms operating in 12 African countries, Oseni and Politt (2013) examined the extent to which firms' characteristics might create incentives for auto-generation and whether these incentives lead to lesser unmitigated outage costs. They employed three different evaluation techniques namely; marginal cost, incomplete backup and subjective. The results of their study indicated that large firms, firms engaging in exports, and those using the internet for their operations suffered higher unmitigated outage costs in spite of having a higher penchant of investing in backup generation. They also found that unmitigated costs accounted for the larger proportion of the total outage costs despite high prevalence of backup ownership among the firms.

Thus reflecting the inefficiency in backup generation due to small backup capacity held by firms. In addition, their estimates indicated that ignoring firms' characteristics such as size and the nature of operation (e.g., export promotion, internet usage, among others) may result in underestimation of outage losses. The analysis further suggested that firms can still benefit significantly even when subsidised tariffs are replaced by cost-reflective rates that ensure stable electricity supply. Oseni and Politt (2013) concluded that the net outage cost (having adjusted for a cost-reflective tariff) incurred by firms are large enough to expand their scope of operation and hire more workers.

4. DATA AND EMPIRICAL MODELS

4.1. Data Description

The main analyses of the study are based on a dataset compiled from World Bank's Enterprise Survey (WBES) which was collected from business enterprises operating in Nigeria as at 2014. The WBES captures firms' perceptions of the obstacles to their growth, the relative significance of various constraints to increasing employment opportunities and productivity and the effects of a country's investment climate on the international competitiveness of its firms. The WBES follow a stratified random sampling method and focus on the weaknesses in an economy's infrastructure, law enforcement, public administration, and regulatory framework. The major advantage of the WBES database is the provision of both managers' opinions regarding the reliability of electricity supplies and the economic data relevant for structural microeconomic analysis. A key variable of the analysis is firms' investment in backup electricity generation, measured as dummy variable the equals 1 if the given firm invested in backup generation and 0 otherwise. The other explanatory variables are selected characteristics of the firm that derive from firms adaptive behaviours against public power supply failure. The dependent variables are; (i) firms' perception of obstacle relating to the supply of electricity and (ii) economic losses of firms due to public power supply cut. The first dependent variable is measured in five ordered categories ranging from zero to five, while the second is measured as firm's lost sales as a percentage of the total sales of the firms in the previous year.

With respect to the lost sales, we observed that the survey question generated a good number of zeros which on its own invalidates the application of the classical ordinary least square estimator. The age of the firm is the number of years since the firm started operation in the country. Number of outages is the count of outages in a given month and energy consumption is the quantity in kilowatts the firm consumes daily. Firms that sell a positive amount of output in foreign markets are described as exporters while firm sizes are as follows: Micro firms employ <5 employees, small firms employ between 5 and 19 employees, medium firms employees between 20 and 99 employees while large firms employ more than 100 employees. The summary statistics for the variables is presented in Tables 1 and 2. In the main, the dataset is cross-sectional but we confirm the robustness of our key findings using similar dataset in panel format. The panel data has some limitations that prevented us from basing the entire analyses on it. Namely, there are significant changes in key questions that affected their interpretation by firms and some questions are missing in some years. Data description for the panel dataset is presented in the Appendix.

On the basis of the raw data presented in Table 1, the unconditional mean firm loss due to power outage is about 20% of annual sales. Average number of outages in a given month is about 39 while private back-up generator is owned by 79% of the firms. The unconditional proportion of electricity supplied by self is 58% of total electricity consumed. The average firm has operated in Nigeria for 14 years and 27% are engaged in export activities. The size distribution of firms are as follows; micro firms-12%, small firms - 52%, medium firms - 28 and large firms - 8%. Most firms about 36% consider electricity as a major obstacle to business operation while about 14% perceive it as a very severe obstacle (Table 2).

4.2. Empirical Models

The analysis is based on two empirical model specifications: We specified electricity supply obstacle as a function of firm characteristics and estimated it using ordered probit regression. Thereafter, we specified power outage loss as a function of firm characteristics and estimated it with both linear and non-linear regression procedures. The electricity supply obstacle is based on the firms' perceptions and is a type of ordered outcome since firms ranked their perceptions of electricity supply obstacle from 0 to 4, zero being no obstacle and 4 very severe obstacles. We employed ordered Probit model to capture the ordered nature of the responses and their fairly normally distributed nature. In line with other studies undertaken by economists modelling individual-level survey responses on ordered outcomes (Litchfield et al., 2012; Pietrovito et al., 2016), an ordered probit model is described as follows: Let Y_i denote an observable ordinal variable coded 0, 1, 2, 3 and 4 on the basis of responses to the electricity obstacle question. Let y_i^* represent an unobservable variable that captures

Table 1: Summary of statistics for the estimation variables

Variable	Mean±SD	Min	Max
Outage loss (%)	20.25±68.1	0	2400
Age	14.49±12.22	0	117
No of outages	38.53±134.77	0	2000
Energy consumption (ln)	7.09±3.02	−2.94	17.79
Intensity of generator use (%)	58.26±26.79	0	100
Firm ownership of generator	0.79±0.41	0	1
Ownership of ISO certificate	0.34±0.24	0	1
Use of internet for operation	0.69±0.52	0	1
Exporting firm	0.27±0.45	0	1
Micro firm	0.12±0.32	0	1
Small firm	0.52±0.50	0	1
Medium firm	0.28±0.45	0	1
Large firm	0.08±0.27	0	1
Fabricated metal	0.06±0.24	0	1
Food and beverages	0.07±0.26	0	1
Furniture	0.07±0.25	0	1
Garments	0.05±0.23	0	1
Non metals	0.06±0.24	0	1
Publishing	0.06±0.23	0	1
Other services	0.04±0.19	0	1
Vehicle sales and repairs	0.05±0.22	0	1
Wholesale	0.04±0.20	0	1
Hotel and restaurants	0.05±0.21	0	1
Retailing	0.05±0.21	0	1
Transport	0.04±0.20	0	1
Other retails	0.10±0.30	0	1
Services	0.08±0.27	0	1

Table 2: Summary statistics of the electricity obstacle

How much obstacle is electricity?	Frequency (%)
No obstacle	380 (14.33)
Minor obstacle	445 (16.78)
Moderate obstacle	449 (16.93)
Major obstacle	963 (36.31)
Very severe obstacle	394 (14.86)
Total	2,631

the perception of ith firm regarding the intensity of electricity supply obstacle. The perceptions can be expressed as a function of a vector of explanatory variables (xi) using the following linear relationship:

$$Y_i^* = X_i'\beta + \mu_i \qquad u_i \sim N(0,1) \tag{1}$$

Where β is a vector of unknown parameters. It is assumed that y_i^* is related to the observable ordinal variable Y_i as follows;

$$Y_i = 0\ [no\,obstacle]\ if\ -\infty < y_i^* < \theta_0$$

$$Y_i = 1\ [minor\,obstacle]\ if\ \theta_0 \le y_i^* < \theta_1$$

$$Y_i = 2\ [moderate\,obstacle]\ if\ \theta_1 \le y_i^* < \theta_2$$

$$Y_i = 3\ [major\,obstacle]\ if\ \theta_2 \le y_i^* < \theta_3$$

$$Y_i = 4\ [very\,severe\,obstacle]\ if\ y_i^* \ge \theta_3$$

Generally, under the ordered probit framework, the probability of the ordered response taking on any particular discrete value may be given by: $prob[y_i = j] = \Phi(\theta_j - X_i'\beta) - \Phi(\theta_{j-1} - X_i'\beta)\ for\ j = 0,1,2,3,4$.

Where Φ(.) denotes the cumulative distribution function operator for the standard normal. The first and the final intervals are open-ended. If the x vector contains a constant term, the remaining set of threshold parameters ($\theta_0,\theta_1,\theta_2,\theta_3$) is not identified. Identification requires the exclusion of either the constant or one of the fixed threshold parameters. In this application, we estimate the intensity of electricity supply obstacle excluding the constant term. For this particular model, the general expression for the log-likelihood function is given as:

$$L = \sum_{i=0}^{n}\sum_{j=0}^{4} \delta_{ij} log_e \left[\Phi(\theta_j - X_i'\beta) - \Phi(\theta_{j-1} - X_i'\beta)\right] \tag{2}$$

In the power outage loss equation, firm characteristics and the sectors they are located entered the estimation non-linearly. As a result of the censored nature of our dependent variable, we adopt the Tobit model as our study analytical framework. The Tobit model also known as the limited dependent variable regression model is popular in modelling of censored, limited or constrained dependent variables (Reilly et al., 2012; Kim and Cho, 2017; Amemiya, 1984; McDonald and Moffitt, 1980). Theoretically, the censorship in the variable is due to non-observability (Maddala and Lahiri, 1992) but the variable could as well assume negative values which in this application would mean that certain firms derive positive sales from power outages (Carlsson and Martinsson, 2007). However, in line with previous studies (Kim and Cho, 2017; Lawton et al., 2003; Morrison and Nalder, 2009; Reinikka and Svensson, 2002), we take all non-positive outage losses as truncated at zero. Many modifications of the Tobit model have been applied in literature, but the standard type 1 Tobit model is expressed as follows;

$$Y_i = y_i^* \quad if \quad y_i^* > 0 \quad and$$

$$Y_i = 0 \quad if \quad y_i^* \le 0 \tag{3}$$

Where; Y_i is the ith observation on the dependent variable and y_i^* is latent variable. The latent dependent variable is expressed as follows:

$$y_i^* = x_i'\beta + e_i \quad e_i \sim N(0,\sigma_e^2) \tag{4}$$

Where; x_i is the covariate vector, β is the parameter vector to be estimated, and e_i is an independently distributed error term assumed to have a zero mean and constant variance. The error term of the Type I Tobit model is assumed to be homoscedastic and follow normal distribution. When the assumption of homoscedasticity in Type I Tobit model is violated, estimates are inconsistent and no longer dependable (Arabmazar and Schmidt, 1982).

In many Tobit model applications there is often reason to believe that certain regressors may be endogenous. In our case, the assumption of exogeneity of the generator ownership may be questionable and requires empirical testing. This is because, the installation of generators and how intensively they are used by the firms may be determined by the size of the potential loss the firm faces should power outage happen without backup in place (Oseni and Politt, 2015). Smith and Blundell (1986) suggested a simple t-test that may be useful for this purpose. Under the test, the underlying latent dependent variable equation (equation 2), could be re-written to include an additional regressor (z) suspected to be endogenous:

$$y_i^* = x_i'\beta + \gamma z_i + \mu_i \tag{5}$$

The relationship determining the endogenous variable (z) may be written as:

$$z_i = w_i'K + \varepsilon_i \tag{6}$$

Equation 5 is a reduced form model where vector wi contains the full set of exogenous variables in vector x and an additional set of identifying instruments. The additional set of identifying instruments adopted in this case includes; international standard organisation certification (ISO certificate) and firm's use of internet (internet). In order to implement a test for exogeneity, we follow the conventional practice adopted in the linear regression model (see for instance; Barry et al., 2012). However, the reduced form equation was estimated using a linear probability model (LPM) for the generator ownership dummy. Since the LPM provides estimates consistent with OLS, it provides a safer option for estimation of the first-stage reduced-form equation with less concern for model mis-specification (Reilly et al., 2012). The Wald-transformed F-test for the joint significance of the two identifying instruments in the reduced form equation is 13.56, which is above the cut-off of 10.0 generally acknowledged in the literature as providing an acceptable critical value. Further, the proposition of under-identification is also rejected by the data in this case. In addition, the maximal IV size is <10%, which is usually adjudged satisfactory with respect to inference in the second stage. More so, in determining an appropriate set of instruments we need a narrative as to why these two instruments could be considered legitimate.

The chosen instruments are international standard certificate ownership (ISO certificate) and use of internet to communicate customers (internet). International standards are commonly applied to improve market access and competitiveness. Some studies found that ISO certification is often associated with greater export participation (Wilson and Otsuki, 2004; Henson and Jaffee, 2006). It therefore follows that certified firms have obligation to sustain accessed markets, they are therefore wary of production interruptions which makes them more likely to invest in back-up generators. Oseni and Politt (2015) argued that ISO certification signifies quality assurance for the firm's products and having received the certificate, firms will do what is necessary to maintain the assurance including investing in complementary capital. Similar argument can be made with respect to the use of internet. Being a form of innovation, the internet enhances business operation normally but the use of internet is conditional on electric power availability. Thus, firms using internet to transact businesses will have higher propensity to install back-up generator. However, we argue that there is no direct link between these two variables on one side and outage losses on the other except through private power generation. Hence, their choice as identifying instruments. Using these identifying instruments, we tested for the exogeneity of 'generators' within the tobit model. The residuals from the reduced form "generator" equation are retrieved and inserted into the tobit model. The Wald test for the statistical significance of these residuals yields a P = 0.043. The null hypothesis of exogeneity is rejected in this case. Thus, the installation of generators across this sample of firm is not random in nature. Therefore we adopt the instrumental variable Tobit model in order to correct the endogeneity of the generator variable.

5. ESTIMATION RESULTS

5.1. Estimates from Ordered Probit Model of Electricity Constraint

Table 3 contains the maximum likelihood estimates of the ordered probit regression for the electricity supply obstacle. We could not reject the null hypothesis of homoscedasticity using the Machin and Stewart (1990) efficient score test. The reported marginal effects provide the average ceteris paribus effect of a characteristic on the probability of perceiving electricity supply as a very severe obstacle (category 5). Similarly, the signs on the marginal effects provide the directional impact of the characteristics on a firm's perception of electricity obstacle. As the Table 3 shows, firm owners of generators are 24% more likely to perceive electricity supply as a very severe obstacle to business than non-owners. This might appear counter-intuitive at the moment given that private generator are meant as insurance against losses in the event of power outage. However, as data description (Table 1) shows, firms are not merely reporting value of lost loads but they seem to report all the inconveniences associated with power outage.

When the additional costs and the associated inconveniences are added to losses as a result of incomplete insurance, it seems able to outweigh the cost of no insurance at all. The effects of other characteristics support the a priori expectations: Number of power outages is associated with increased perception of power supply as very severe obstacle to business. Micro, small and medium scale enterprises are at least 5% more likely than large firms to report power supply as very severe obstacle to business. The effects of firm age and export status are not distinguishable. Sectoral differences exist in the firms' perceptions: Manufacturing being the sector with the highest frequency in the data is adopted as the reference sector. Benchmarking against the reference sector, firms in publishing and garments making sectors are more likely to perceive power supply as very severe obstacle while firms in non-metal works, wholesales, transport and retailing are less likely to perceive power supply as very severe obstacle. Other sectors have effects that are not distinguishable from the reference category.

Table 3: Ordered probit marginal effects

Variable	Marginal effects	z-stats	P-value
Firm characteristics			
Age of firm	0.0005	1.09	0.275
Number of outages	0.0001***	3.78	0.000
Generator owned	0.2412***	16.71	0.000
Exporter	0.0143	1.33	0.184
Micro firm	0.1070***	4.56	0.000
Small firm	0.0519***	2.78	0.006
Medium firm	0.0556***	2.89	0.004
Production sector			
Fabricated metal	−0.0022	−0.1	0.921
Food and beverages	−0.0068	−0.33	0.740
Furniture making	−0.0140	−0.63	0.527
Garments making	0.0384*	1.67	0.095
Non metal works	−0.1106***	−4.8	0.000
Publishing	0.0615***	2.66	0.008
Vehicle sales and repairs	−0.0323	−1.33	0.184
Wholesales	−0.0654***	−2.55	0.011
Hotels and restaurants	0.0182	0.73	0.465
Transport	−0.1194***	−4.45	0.000
Retailing	−0.0446**	−2.34	0.019
Other services	−0.0103	−0.51	0.612
No of observations=2,286			
Pseudo R^2=0.0686			

***, **, *Denotes statistical significance at the 0.01, 0.05 and 0.10 level, respectively using two-tailed tests

Table 4: Regression estimates of power outage losses (firm characteristics)

Variables	OLS	Tobit	IVTobit
	Coefficient	Marginal effect	Marginal effect
Generator	9.09*	11.30*	3.26***
	(1.68)	(1.90)	(5.10)
Age of firm	−0.29**	0.00	0.04
	(−1.95)	(−0.05)	(1.44)
No of outages	0.02*	0.01***	0.01***
	(1.74)	(3.18)	(4.64)
Energy consumption	0.05	0.00	0.00
	(0.11)	(1.42)	(0.10)
Export	−1.73	2.67**	1.50**
	(−0.42)	(2.09)	(1.96)
Micro firm	−16.41***	5.57*	2.37
	(−3.02)	(1.90)	(1.45)
Small firm	−21.69***	3.19**	3.07**
	(−3.05)	(1.95)	(2.31)
Medium firm	−24.24***	2.52	2.41*
	(−3.34)	(1.62)	(1.78)

***, **, *Denotes statistical significance at the 0.01, 0.05 and 0.10 level, respectively using two-tailed tests, standard error in parenthesis

5.2. Regression Estimates of Power Outage Loss Function

Our benchmark results are delivered by the power outage loss model i.e., equation 3. The results are summarised in Tables 4 and 5. Table 4 summarizes the results of the outage loss estimations with respect to firms' characteristics other than their sectors and derived from the 3 alternative models of OLS, type 1 tobit and instrumental variable tobit, respectively. Column 4 reports estimates of our preferred model where instruments were used to correct for the endogeneity of the generator variable. Table 5 reports estimates of sectoral variations in power outage losses. In each of Tables 4 and 5, columns 2, 3 and 4 report estimates of OLS, type 1 tobit and IvTobit estimations, respectively.

From Table 4, factors affecting outage losses suffered by the firms include; generator ownership, number of outages per month, export participation and firm size. For reasons bordering on selection bias discussed above, there are marked differences in the estimated coefficients and marginal effects presented in Table 4. The OLS and type 1 tobit models are less efficient due to the censored dependent variable and endogeneity of the generator ownership indicator. Their presentation is only for comparison and confirmation of the adopted methodology. As the marginal effects reported in column 4 shows, generator owners suffer larger outage losses than non-generator owners.

Based on the result of the IVTobit regression, the conditional mean power outage loss in the Nigeria industrial sector is 15% of annual sales but this varies with firm characteristics: A firm who owns a back – up generator losses about 3% more of her sales due to power outages in a given year than the ones that do not have. The effect varies according to the model used for the estimation. It is evident that selectivity in generator ownership is at work in both the OLS and the type 1 Tobit models. The effect of selection bias in this case is to inflate the generator effect but the statistically significant positive effect is common to all models. This effect is controversial in itself since it is assumed that firms install back-up generators as insurance against outage losses. This finding is consistent with related literature (Oseni and Pollit, 2015; Pasha et al., 1989). In terms of the sectoral variations in outage losses (Table 5), we benchmark outage losses from other sector against losses from the manufacturing sector. The results show that hotel and restaurant sector experienced the largest outage loss. Belonging to this sector is associated with 3.6% more outage losses compared to the manufacturing sector. Non-metal works, wholesale, retailing and transport are less affected compared to the reference sector. The transport sector lost the least of all the sector and lost approximately 6% less than the manufacturing sector.

Table 5: Regression estimates of power outage losses (sector of production)

Sector	OLS Coefficient	Tobit Marginal effect	IVTobit Marginal effects
Fabricated metal	1.34	−0.11	−1.31
	(0.15)	(−0.06)	(−0.79)
Food and beverage	−1.78	−1.64	−0.82
	(−0.24)	(−1.01)	(−0.59)
Furniture	−1.66	5.72	−2.30
	(−0.20)	(1.27)	(−1.43)
Garments	−1.80	0.16	−1.60
	(−0.22)	(0.09)	(−1.07)
Non metal works	−6.68	−3.57*	−3.59**
	(−0.73)	(−1.79)	(−2.06)
Publishing	4.52	1.08	1.87
	(0.55)	(0.66)	(1.24)
Other services	−3.60	−1.20	−0.77
	(−0.38)	(−0.62)	(−0.43)
Vehicle sales and repairs	−0.64	3.05	−1.19
	(−0.07)	(1.07)	(−0.70)
Wholesale	−4.07	−2.56	−3.67**
	(−0.42)	(−1.31)	(−1.98)
Hotel and restaurant	26.40***	0.17	3.57**
	(3.01)	(0.08)	(2.18)
Retailing	−4.59	−0.60	−3.28**
	(−0.53)	(−0.31)	(−2.01)
Transport	−9.68	−2.34	−6.03**
	(−0.93)	(−1.07)	(−3.13)
Other retails	2.73	0.69	0.53
	(0.41)	(0.50)	(0.42)
Services	24.39***	−0.26	0.60
	(3.12)	(−0.72)	(0.45)

***, **, *Denotes statistical significance at the 0.01, 0.05 and 0.10 level, respectively using two-tailed tests, standard error in parenthesis

Table 6: Regression estimates of power outage losses (random parameter tobit estimation)

Variables	Marginal effect	Standard error	z-stats	P-value
Age of firm	0.09	0.07	1.35	0.18
Number of outages	0.01***	0.00	2.67	0.01
Energy consumption	0.00	0.00	1.54	0.12
Exporter	−0.63	1.55	−0.41	0.68
Generator	0.07***	0.03	2.33	0.00
Micro FIRM	4.51	3.68	1.23	0.22
Small firm	0.55**	0.07	2.24	0.03
Medium firm	2.41	3.42	0.71	0.48

***, **, *Denotes statistical significance at the 0.01, 0.05 and 0.10 level, respectively using two-tailed tests

6. ROBUSTNESS CHECK

Empirical estimates based on cross-sectional analysis are rarely treated as causal. Based on this and bearing in mind that our estimates are meant to inform policies, we need to validate the robustness of our results. In this regard, we took advantage of the panel data associated with this dataset to check the robustness of our findings. Ignoring sectoral analysis for want of space, Table 6 reports on random parameter Tobit model using the panel of firms in Nigeria. The panel contains 1, 566 firms surveyed in two periods; 2007 and 2014. The variables contained in the panel dataset is the same as those contained in the cross-sectional dataset. We employed random parameter approach in order to correct for cross-sectional heterogeneity (Carlsson et al., 2003).

The results largely confirm the cross-sectional evidence; losses increases in number of outages, small firms loose larger proportion of their sales than micro and large firms. Most importantly, generator ownership is associated with larger losses as a proportion of sales. On average and ceteris paribus, a firm that owns generator incurs 7% more losses due to power outage than those who operate without backup. The losses to the generator owners due to power outage is 3% point higher when the random parameter tobit model is used than when the cross-section based instrumental variable tobit model is used. Part of the reasons could be uncorrected endogeneity in the random parameter tobit model which does not allow the use of instruments. However, the comparable results confirm that the effect of generator ownership is positive and significant.

7. CONCLUSION AND POLICY RECOMMENDATIONS

This study examined how much more firms are willing to pay to secure uninterrupted power supply in Nigeria. It also sought to ascertain whether firms are able to mitigate most of their outage losses by investing in backup generation. These objectives were pursued using a sample of 2676 compiled from WBES. The WBES follow a stratified random sampling method and focus on the weaknesses in an economy's infrastructure, law enforcement, public administration, and regulatory framework. Electricity supply obstacle was specified as a function of firm characteristics and the model was estimated using ordered the probit regression while power outage loss as a function of firm characteristics and the model was estimated using linear and non-linear regression procedures. We found that firm owners of generators are 24% more likely to perceive electricity supply as a very severe obstacle to business than non-owners. Micro, small and medium scale enterprises are at least 5% more likely than large firms to report power supply as very severe obstacle to business. Firms in publishing and garments making sectors are more likely to perceive power supply as very severe obstacle while firms in non-metal works, wholesales, transport and retailing are less likely to perceive it as such.

Further, our analysis indicated that generator ownership, number of outages per month, export participation and firm size are the factors affecting outage losses suffered by firm. The IVTobit regression revealed that the conditional mean power outage loss in the Nigeria industrial sector is 15% of annual sales, though it varies with firm characteristics. Hotel and restaurant sector experienced 3.6% more outage losses that the manufacturing sector. Non-metal works, wholesale, retailing and transport are less affected compared to the reference sector. The transport sector lost approximately 6% less than the manufacturing sector. Our robustness check validates the empirical findings of the study. We therefore recommend power sector reforms to guarantee uninterrupted power supply. For firms, this study suggests that captive power generation does not have good insurance value except if the firm is fully covered which is not the case in any of the firms we studied.

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