

The Productivity Cost of Power Outages for Manufacturing Small and Medium Enterprises in Senegal

Lassana Cissokho

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Abstract

This paper investigates the productivity effects of power outages on manufacturing SMEs in Senegal, using a panel data on manufacturing firms. Productivity is estimated using stochastic frontier models, and power outages measured by their frequency or their duration. We controlled for firms owning a generator as well. The main results are drawn from random effects in a linear panel model. Nonetheless, the results remain consistent to the robustness checks using different models: a double-sided truncated data model and a generalized linear model, and different productivity measures: data envelopment analysis. We find that power outages have negative significant effects on the productivity of SMEs. For example, the manufacturing sector lost up to around 11.6% of the actual productivity due to power outages in 2011, and small firms appear to be affected more than medium ones, 5% against 4.3%. Further, firms with a generator were successful in countering the adverse effect of power outages on productivity. Besides, another outstanding result is the significant positive effect of access to credit on productivity. At last, it appears that productivity increases with firms' size.

Key words: Power Outages; Productivity; SMEs; Stochastic Frontier Analysis.

JEL Classification: D24, F140, L25, L94, M21.

1. Introduction

In the World Bank's Doing Business Report (2017), Senegal ranks 147 out of a total of 190 countries for the ease of doing business index. On the index of "getting electricity", Senegal ranks even worse, that is 162, which only beats its "paying tax" index where it ranks 174. With the electricity "reliability of supply", for an index of zero to eight, Senegal scores zero. These performances of Senegal's economy take place amid many reforms the country carried out to improve the attractiveness of its business environment to investment¹. Yet, the country is not attracting lots of investment compared to other ECOWAS² members such as Nigeria, Ghana and Cote d'Ivoire (African Development Bank, 2014; World Bank, 2016a). This could be put on the other aspects of the country's business environment, among which is the reliability of electricity supply.

Until 1960, production activities in Senegal were mostly private. In the late 1960s and early 1970s, however, sectors such as water and electricity were nationalized. In the case of electricity, the first step of the nationalization process covered the period 1972-1983, with the signing of a lease contract and the creation of a state-owned company, the Senegalese Electricity Company (SENELEC). Starting from 1983, SENELEC was holding a monopoly in the sector. In the mid 1990s, the sector went through many problems, and borne heavily on public finances, triggering strong suggestion from the World Bank and the International Monetary Fund toward the privatization of electricity in Senegal (G kgür and Jones 2006). In fact, below target investment realization, combined with poor maintenance on a dilapidated generation facility led to a poor quality of service with an increasing number of power outages. The privatization process started effectively in December 1996; in March 1999, 34% of the shares of SENELEC were sold to Hydro-Quebec International and Elyo jointly. This first privatization of the electricity sector in Senegal lasted only 18 months. A new elected government in Senegal, in 2000, bought back the shares sold to Hydro-Quebec International and Elyo. In 2001, a second privatization process that weighs less on the bidding price and more on the technical and investment issues was launched, and most of the shares tendered³ (Commission de Régulation du Secteur de l'Electricité, Sénégal, 2007, 2011).

Electricity production in Senegal relies mostly on oil imports, because of an antiquated generation fleet. In fact, more than half of the machines are more than 10 years, and 80% of them function with fuel. Ninety per cent of the energy is from thermal

generation which impact highly on electricity production costs and price (Commission de Régulation du Secteur de l'Electricité, Sénégal 2007), which remains among the highest in the world. Part of the problem arises because the consumers participate barely in the financial stability of the company with a growing need for investment to update its fleet to face a demand growing at the rate of 8% a year. The government, on the other hand insists on allocating huge subsidies to SENELEC, perpetuating a system that has so far failed to structure the company towards financial sustainability.

The lack of sufficient and adequate investment led to a very inefficient distribution network, saturated and dilapidated power grids that fail to meet the growing demand. The latter, coupled with a production deficit (distributed energy amounts to 32 MW in 2011 against 266 MW in 2010) and a low storage capacity and operating difficulties of the only refinery in the country, the African Refining Company (SAR), led to deterioration in the quality of service in 2011, with regular power cuts affecting the consumers, as well as producers. This environment has most likely affected firms' production activities, especially SMEs that consist of around 95% of total firms in Senegal.

SMEs are a major contributor to Senegal's national economy. They operate in growth supporting sectors such as construction (7%), commerce (33%), industries (15%) and other services (45%) (Cissokho and Seck, 2013). As a major source of wealth creation and employment, SMEs are an important factor of social integration and a powerful lever against poverty. In fact, SMEs account for over 40% of the total sales and 42% of jobs in the modern enterprises, for more than 20% of GDP, and for around 30% of domestic value added (Direction des PME, 2014). Since the early 2000s, however, SMEs are operating in an environment characterized by electrical power outages; as a matter of fact, 57% of them reported electricity as a major concern. SMEs sustained 26 outages on average in a typical month, each lasting on average around two hours (Cissokho and Seck, 2013).

The main objective of this paper is to estimate the cost of power outages in terms of productivity loss to SMEs in Senegal. This objective is broken down in three specific objectives. First, we estimate firms' productivity using stochastic frontier analysis (SFA) (Greene, 2008; Kumbhakar and Lovell, 2000), and data envelopment analysis (DEA) (Coelli, 1996; Charnes et al, 1978; Wilson, 2008). Second, we model productivity as a function of power outages, firms' characteristics (size, age, gender, loans, etc.) and industry characteristics (sectors, etc.). And finally, we use the estimation results to compute the loss of productivity of SMEs due to power outages. The main problem in regression analysis remains the identification issue. In this instance, Senegal presents some characteristics that make this issue less problematic.

Senegal is one of the most politically stable countries in West Africa (World Bank, 2017; Villalón, 2011). Therefore, the country has the advantage to focus resources and attention more on other aspects of political governance and business environment to foster growth and be on a sustained path toward emergence. This state makes Senegal an interesting case to analyse. In fact, in the past decade, most least developed countries (LDCs) in West Africa have experienced some political or social instability,

triggering many unobservable factors that may interfere with firms' activities. The relative stability of Senegal makes the identification of the productivity effect of an unreliable electricity supply, in a West African LDC, less problematic compared to other countries with more unobservable influences in their business environment.

This paper contributes to the literature by analysing, in the case of Senegal, how the lack of reliability of a public service, specifically electricity in this case, could cost an LDC, particularly in West Africa, through its adverse effect on the productivity of manufacturing SMEs. We constructed an unbalanced panel data using firm level data of manufacturing (Cissokho and Seck, 2013; World Bank, 2007, 2014). The results point to a negative significant effects of power outage on productivity, which is in the same lines as Arnold et al (2008) for sub-Saharan Africa economies and by Fisher-Vanden et al (2015) in the case of China. Further with a loss amounting to around 11.6% of the actual productivity, 2011 stands out as the year firms were much affected.

In what follows, section two presents some elements of literature review and section three, beside productivity measurements, analyses and discusses the data. Section four deals with the regression analysis and, finally, section five concludes.

2. Literature review

Poor quality and power outages are the two main electrical disturbances firms could suffer from (Lineweber and McNulty, 2001). The first refers to the fluctuations in voltage, which could result in severe damage to machinery and equipment, and a corresponding high cost of frequent repair and replacement. The second corresponds to a complete electric power loss with a variable duration. Because of data collection issues, the present study considers only power outages.

Power outages can affect firms through a variety of channels, which eventually lead to negative effects on productivity. First, efficiency will be challenged, because discontinuous power provision is synonymous with disruption in the production process, causing productive resources to lie idle, resulting in lower output level. The second issue is related to the costs associated with power outages; for example, firms at some point must rely on alternative sources of energy, and thus they will resort to owning generators, bearing the related costs. At last, because firms could not predict with accuracy the occurrence and timing of power outages, therefore, it brings about uncertainty in their activities. This situation could translate into uncertainty in meeting deadlines, getting materials from suppliers on time, or profiting from new market opportunities. In the end, it could lead firms to invest less and idle more capital and hire fewer workers as shown in Table A2 (see in the Appendix). Consequently, firms' growth is constrained and, potentially, they will contribute less to economic growth.

The determinants of economic growth have been extensively scrutinized in the economic literature, as has been the important role of productivity in achieving long-run sustainable growth (Solow, 1956; Barro and Sala-i-Martin, 1992; Lucas, 2015; Romer, 1990; Grossman and Helpman, 1991, etc.). To better understand the sources of productivity growth, many researchers oriented their work in analysing the micro foundations of productivity differences between countries, which has led to a broad literature on productivity differences at firm level within and across countries (Syverson, 2011; Bartelsman et al, 2008, 2009).

Factors contributing to improve firms' productivity are of two main groups. The first group under the control of firms refers to firms' characteristics such as physical capital intensity, human capital, technology and the skills of managers. The second one, not under the control of firms, includes features of the business environment in which they operate such as the quality of institutions, corruption, infrastructure, regulations such as tax policy and subsidies, the availability and ease of access of

services such as electricity, water, information and communication technologies, and financing or shocks that affect the business environment (Arnold et al, 2008; Eiffert et al, 2008; Syverson, 2011; Bah and Fang, 2015). For example, Bah and Fang (2015) have investigated how different aspects of the business environment affect output and productivity in African countries, and found that firms lose large shares of their sales due to government regulations, poor infrastructure, corruption and crime. The implications of these losses are lower aggregate output and lower total factor productivity (TFP).

Electricity is one of the most important factors in the business environment; its cost and availability, not only participate in attracting firms, but mostly affect their activities. The reliability of its supply poses a real problem in most developing countries. As a matter of fact, Fisher-Vanden et al (2015) reported negative impact of electricity shortages on firms' productivity in China, making firms to outsource their energy intensive materials instead of looking for alternative electricity sources. Allcott et al (2014) and Arnold et al (2008) reported similar results for India and a sample of African countries, respectively. The authors found that electricity shortages have negative effect on output and productivity, even if the adverse effects are mitigated by generator acquisition. Eiffert et al (2008) confirm the adverse effect of electricity shortages on firms. Their report shows that, for African countries as compared to their counterparts in Asia, Latin America and in the developed countries, indirect costs, which is made of energy cost for around 58%, are a major factor for explaining the low productivity of enterprises in Africa, and dampened probably the comparative advantage most of the countries have by making the business environment less attractive.

Investigating other aspects, Reinikka and Svensson (2002) find that for many developing countries, poor complementary public capital, measured by the unreliability and inadequacy of electric power supply, significantly reduces private investment. Further, firms that cope with the deficient electric power supply by investing in generators end up investing less in productive capital.

This paper can be aligned with the above-mentioned literature because it investigates the effect of power outages on SMEs. The context of Senegal makes it more interesting because of the specificities mentioned in the introduction.

3. Data analysis

Presentation of the data

Data for this study are from two main sources: a firm survey in 2012 that we conducted⁴ and the World Bank investment climate and business environment surveys (2007 and 2014) in Senegal. The 2012 survey is conducted late 2012 (Cissokho and Seck, 2013). The sample is drawn from a population of 6,000 firms from the national agency for statistics and demography (ANSD). We used a stratified sampling method, with respect to regions and sectors. The four regions considered cover more than 90% of firms in the country. The four sectors on the other hand are wholesale and retail, manufacturing, construction, and other services. For each stratum, firms are drawn randomly for a sample of 528 firms. SMEs are defined using the same criteria used in the World Bank surveys on industries in Senegal. The World Bank surveys are conducted around the world. Data is collected at the firm level and covered a broad range of issues related to the investment climate and business environment. Small firms have from five to 19 employees, medium firms from 20 to 99 employees and large ones have hundred and more employees (World Bank, 2007, 2014). The two datasets are combined in an unbalanced panel covering only manufacturing firms. The distribution of firms across the surveys is presented in Table 1. Of the 491 units, 41% constitute the panel, which allow for a more consistent identification of the parameters, and the remaining data for more efficiency.

Table 1: Distribution of firms in the unbalanced panel

Years	2007	2012	2014	Total
2014 only			105	105
(%)			(21.38)	(21.38)
2007 only	123			123
(%)	(25.05)			(25.05)
2014 and 2007	101		101	202
(%)	(20.57)		(20.57)	(41.14)
2012 only		61		61
(%)		(12.42)		(12.42)
Total	224	61	206	491
(%)	(45.62)	(12.42)	(41.96)	(100)

Source: By author, from the World Bank data and the 2011 survey.

Several reasons justify combining the two datasets. Firstly, they are based on the same core questionnaire, which is the questionnaire of the World Bank surveys except for some questions related to details on the costs of power outages to firms, most of which can be found in Table A1 (in the Appendix). Secondly, cross sectional data raises some limits regarding how accurately they could identify the effect of a shock. In fact, as related to power outages, cross sectional differences may arise because of many other factors such as locations. Lastly, if some unobservable factors affect both productivity and power outages, endogeneity will bias the estimations. The usual instrument used to solve the issue is oil prices or hydroelectric power production, both of which are common to all firms, thus with the panel comes more variability.

Table 2: Several firms' characteristics across years

Year	2007	2012	2014	Total
Power outage frequency	10.92	26.79	7.08	11.23
Power outage duration	4.09	2.11	3.10	3.43
Generator (% of owners)	0.51	0.62	0.69	0.60
Firm size (small=1)	1.27	1.29	1.46	1.35
Firm age	12.44	14.28	18.47	15.21
Manager's experience (years)	16.00	17.97	20.01	17.94
Share of skilled workers (%)	0.62	0.67	0.56	0.60
Proportion of firms with a loan or credit line (%)	0.12	0.22	0.20	0.16
Legal ownership (proprietorship=1)	1.24	1.90	1.58	1.46
Largest owner share (%)	0.93	0.87	0.97	0.85
Domestic owners share (%)	0.95	0.99	0.86	0.94
Female owner (%)	0.20	0.19	0.14	0.18

Source: By author, from the World Bank data and the 2011 survey.

Table 2 presents some statistics on firms from the different surveys. The year 2011 stands as the most challenging in terms of power outage frequency. Firms registered 26.79 outages on a typical month, which is more than twice that of 2007 and more than thrice that of 2014. Small-size firms are as predominant as sole proprietorships. Firms still struggle to access credit, with 12%, 22% and 20% of them having a loan in 2007, 2011 and 2014, respectively.

Table 3: Power outages in Senegal, in sub-Saharan Africa and in the world

	Senegal* (2012)	Nigeria	SSA	World
Power outages frequency/month	25.8	26.3	10.7	8.6
Duration of a power outage (hours)	2.3	8.2	6.6	4.0
Losses due to electrical outages (% of annual sales)	5.1	8.9	6,7	4,8
Firms owning/sharing a generator (%)	63.4	85.7	43.6	31.6
Proportion of electricity from a generator (%)	30.8	47.5	13.8	7.1
Firms identifying electricity as a major constraint (%)	57.5	75.9	50.3	39.2

Sources: Adenikinju (2005) using the World Bank enterprises survey data; * from firms survey in 2011 including all firms (manufacturing and services); SSA: Sub-Saharan Africa.

Table 3 compares some energy related statistics of firms in Senegal to those of sub-Saharan Africa (SSA) and the world; and the figures here for Senegal include service firms. To begin with, 57.5% of firms in Senegal identified electricity as a major constraint to their activities, which is above the average for SSA and in the world, but less than in Nigeria (around 76%). In a typical month, firms faced power outages double the frequency in SSA, and thrice the world average; Nigeria, however, had around the same frequency. A typical power outage lasted 2.3 hours on average, which was less than the duration in the regions retained for comparison. The proportion of firms that own generators is much larger in Senegal than the proportions in SSA and in the world, with the alternative source of electricity accounting for 31% of total electricity used.

Table A2, in the Appendix, summarizes data on electricity and electricity-related issues. Around 57% of SMEs reported electricity as a major concern and more so for the manufacturing sector with 69% of firms reporting so. In a typical month, power outages occurred 26 times on average for the SMEs, with an outage lasting a little more than two hours on average; regional discrepancies can be seen in Figure A1 (in the Appendix). Consequently, firms faced a certain number of challenges, leading to some adjustment or coping strategies. For example, 41% of SMEs and 46% of large businesses reported that production stopped during power outages. Related to the latter, 96% of SMEs among those for which activities stopped during outages and all their larger counterparts reported paying wages for workers in electric outage time. That was probably because wages were, and still are, negotiated on a monthly instead of an hourly basis in Senegal. Nonetheless, it could be a major source of inefficiency since more output could have been reached for the same cost. For businesses in Agrifood, the losses could take other forms like losing stocked outputs that were heavily electricity-dependent, dairy products for example. Twenty-seven per cent of SMEs reported their product quality to be affected by power outages. In the end, SMEs reported losing around 4.8% of their total sales in 2011 due to power outages, manufacturing top the list with a 6% loss. Probably, the losses could have been worse if most firms did not use alternative sources of power supply in times of power interruption.

Besides the costs mentioned above, power outages could cause many other inconveniences that trigger uncertainty in firm activities. On the one hand, 47.4% of SMEs have experienced delivery delays from their suppliers; and on the other hand, 56% of SMEs reported to have experienced delivery delays to their customers. Around 64% and 67% of manufacturing answered yes to the same questions, respectively. The uncertainty created by these issues could have some ramifications directly related to the dynamics of the firms in terms of investing more in capital and/or hiring more workers. For example, 43.1% and 55.2% of SMEs reported that their hiring and investment decisions, respectively, are affected by power outages; manufacturing and construction firms are more affected, with for example, 68.7% and 63.3%, respectively, reporting that their investment decisions are affected by power outages.

The high frequency of power outages and the inconveniences they bore explain probably the relatively high share of firms acquiring a generator. Across sectors,

more than 62% of firms owns a generator; the figure being 80% with medium-sized firms. The proportions are 51% and 69% in 2007 and 2014, respectively (World Bank survey, 2007, 2014).

Measuring productivity

Productivity is efficiency in production, that is, the output level obtained from a given quantity of inputs and typically expressed as an output–input ratio (Syverson, 2011). Methodologies developed to estimate total factor productivity can be put in two main groups: deterministic methods and stochastic methods. The first group simply assigns any deviation from ideal productivity to inefficiency. However, room can be made for shocks that can affect productivity without being under the control of the firm. Productivity in this paper is measured using stochastic frontier analysis (SFA). Other methods of computing productivity like in Olley and Pakes (1996) and Levinsohn and Petrin (2003) cannot be used in this paper because of data limitations.

Any deviation from the ideal productivity, represented by the production frontier, could be deemed as coming from firms' inefficiency. In the SFA framework, however, some shocks from the economic environment, not under the control of firms, can affect productivity. In other words, deviations from the production frontier should not be entirely attributed to inefficiency, as part of it might be stochastic. Further, measurement errors are often an issue with production statistics, which also add onto the deviation from the production frontier. Consistent measures of productivity require thus considering these issues (Aigner et al, 1977; Meeusen and van den Broeck, 1977). A common approach in estimating productivity using stochastic frontier models (SFM) starts with formalizing the production function as follows:

$$q_i = f(z_i)TE_i e^{v_i},$$

where, q represents firms' VAD, z contains the input variables: capital and labour, v_i an unrestricted stochastic term, and TE a technical efficiency term, with $0 < TE < 1$. Reformulating this equation, assuming a Cobb-Douglas functional form, gives the following regression equation:

$$\ln q_{it} = \theta + \delta \ln z_{it} + \pi_{it}, \quad (1)$$

where, $\pi_{it} = v_{it} - u_{it}$, u_{it} is the technical efficiency term of firm i at time t , with $u_{it} > 0$; and v_{it} , the stochastic error terms, embodying the uncontrollable productivity shocks and the error terms. The objective here is to estimate the productivity term u_i , which follows a consistent estimation of the parameters

of Equation 1. The distribution of v_i is usually assumed to be normal with the observations independently and identically distributed. Using cross-section, different distributions could be assumed for u_i , among which the half-normal distribution (Aigner et al, 1977), the exponential distribution (Meeusen and van den Broeck, 1977), and the truncated normal distribution (Stevenson, 1980). The results of the estimation of Equation 1 assuming half-normal (column 1) and exponential (column 2) distributions and using Green's true fixed-effect model (Greene, 2005a, 2005b, 2008) are presented in Table 4.

The densities of the estimates are presented in Figure 1, and the descriptive statistics across firm size are in Table 5. Further, for robustness check, we estimated technical efficiency using data envelopment analysis (DEA). The DEA method, even though deterministic, has the convenience of not assuming any functional form for the efficiency frontier. The DEA scores are based on Wilson (2008); the descriptive statistics of the DEA efficiency scores are presented as well in Table 5.

Table 4: Production frontier estimation

	(1)	(2)
Frontier		
Log(capital)	0.260***	0.268***
	(0.012)	(0.012)
Log(employment)	1.074***	1.066***
	(0.081)	(0.057)
Constant	10.608***	10.462***
	(0.458)	(0.169)
N	476	476
chi2	1423.713	11528.598
p	0.000	0.000

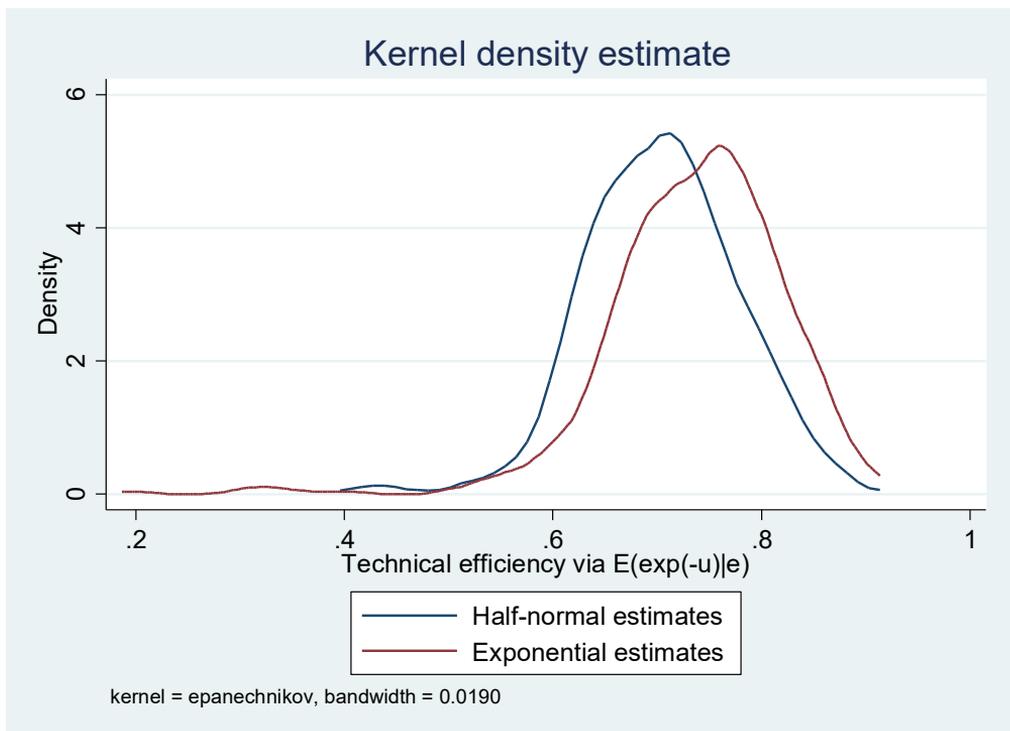
Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

All parameter estimates are significant at the 1% level, and the models are jointly significant as well. The DEA scores, however, are lower than the SFA scores, and for the letter, the frontier is made of by only large and small firms. Overall, as expected, productivity increases with firm size. Considering the half-normal efficiency scores on which the main results of this paper are based, for example, firms in general are 70.4% efficient; small firms are 67.7% efficient, against 75.1% and 83.4% for medium and large firms, respectively.

Table 5: Descriptive statistics of productivity estimates

Size	Distribution	Mean	Standard deviation	Min	Max
Small (5-19)	DEA	0.052	0.122	0.0003	1.000
	Half-normal	0.677	0.061	0.415	0.812
	Exponential	0.712	0.080	0.186	0.849
Medium (20-99)	DEA	0.093	0.139	0.004	0.917
	Half-normal	0.751	0.041	0.634	0.827
	Exponential	0.782	0.047	0.622	0.861
Large (≥100)	DEA	0.357	0.327	0.029	1.000
	Half-normal	0.834	0.027	0.782	0.895
	Exponential	0.862	0.026	0.809	0.914
Total	DEA	0.083	0.169	0.000	1.000
	Half-normal	0.704	0.073	0.415	0.895
	Exponential	0.738	0.085	0.186	0.914

Figure 1: Kernel densities of stochastic frontier productivity estimates



4. Regression analysis

Regression model

The model we use is quite simple, it is a linear panel model regressing a productivity measure (Y) on a set of electricity related variables (frequency or duration) and other covariates (X) on firms' and sectoral characteristics as shown in model (2).

$$tfp_{it} = X_{it}\beta + \alpha_1 \log(\text{frequency})_{it} + \alpha_2 \log(\text{frequency})_{it} * \text{generator}_{it} + \varepsilon_{it}, \quad (2)$$

where, i refers to firm i , t to the period, and tfp to the productivity. Power outages are measured by their frequency or duration. Generator and its interaction with power outage measures are controlled to capture the effect of owning a generator on productivity. X_{it} includes firms' age, ownership, manager's profile, human capital, etc. γ and β are models' parameters to be estimated, and ε_{it} an error term. The descriptive statistics of the variables are presented in Table 6.

Table 6: Descriptive statistics of variables used in the model

Variable		Obs	Mean	S.D.	Min	Max
Technical efficiency	Estimated assuming half-normal distribution	476	0.704	0.073	0.415	0.895
Technical efficiency	Estimated assuming exponential distribution	476	0.738	0.085	0.186	0.914
Technical efficiency	Estimated using DEA	476	0.083	0.169	0.000	1.000
Log(frequency)	Log of the number of power outages in a typical month	475	2.092	0.837	0.000	4.564
Log(duration)	Log of the duration of a power outage	475	0.995	0.785	-2.079	2.197
Generator	Equals 1 if the firm has a generator it uses at outage times	476	0.599	0.491	0.000	1.000

continued next page

Table 6 Continued

Variable		Obs	Mean	S.D.	Min	Max
Log(frequency)*generator	Interaction variable between the log of power outages frequency and generators	475	1.243	1.212	0.000	4.159
Log(duration)*generator	Interaction variable between the power outages duration and generators	475	0.621	0.836	-1.386	2.197
Log(age)	The log of age of the firm	476	2.465	0.749	0.000	4.331
Human capital	The share of skilled labour in a business	476	0.616	0.251	0.043	1.000
Credit	Equals 1 if the firm has access to loans or credit lines	476	0.164	0.371	0.000	1.000
Female	Equals 1 if the firm has a female among owners	476	0.176	0.382	0.000	1.000
Largest owner share	In percentage of total share	476	0.849	0.307	0.020	1.000
Foreign ownership	In percentage of total share	476	0.061	0.223	0.000	1.000
Medium firms	=1 if the firm has from 20 to 99 employees	476	0.206	0.405	0.000	1.000
Large firms	=1 if the firm has 100 employees or more	476	0.074	0.261	0.000	1.000
Partnership	=1 if the firm is a partnership	476	0.292	0.455	0.000	1.000
LLC	=1 if the firm is a LLC	476	0.084	0.278	0.000	1.000

The main issue in this analysis, as mentioned earlier, is probably the endogeneity problem that may arise for power outage measures or owning a generator, which cannot be controlled for with model (2). Productivity may be influenced by firms' unobserved characteristics, which can as well affect firms' location, and/or their ability to get a generator. For example, less successful firms may report more severe power disruption compared to their less successful counterparts; or more successful firms may be spared intentionally from more severe outages. Further, spatial disparity on the occurrence and duration of power outages (Figure A1 in the Appendix) may affect prices. In fact, highly frequent outage-experiencing firms may increase their prices if spatial competition is weak. That price hike will spill in the productivity estimates and may carry some bias in the effect of power outages. On the other hand, firms with higher productivity are more likely to have generators to compensate for electricity on power outage times. Flipping the dice, it is also arguable that firms with a generator are likely to be more productive. That brings another potential source of endogeneity in model (2). Endogeneity tests are carried on exploring for these possibilities in the data.

Results and comments

Value added and capital data have been deflated using industrial price index data. Productivity is estimated first using stochastic frontier analysis. Measures of power outages considered here are their frequency and duration. We tested for endogeneity by running the Durban-Wu-Hausman test for the two measures of power outages, the frequency and duration and for owning a generator. The results of the tests show that endogeneity is not a big issue in the data at hand (Table A3 in the Appendix).

For fear of multicollinearity issues because of high variance inflation factors (Table A1 in the Appendix), generator and the interactions between generator and power outage measures have been introduced in the regression separately. The regression results are presented in Table 7 for all manufacturing, which represent the main results of this paper; and in Table 8 for only SMEs. Similar analysis is carried, but using the productivity scores assuming exponential distribution for the productivity disturbance, and the DEA scores; the results are in Table A4 and Table A5, respectively, in the Appendix.

We have introduced dummies to capture the regional effects, as well as size and sectoral effects. The different sectors are construction, commerce, other services and industries distributed across regions. The regional specific effects, for example infrastructure, are not at the same level across regions, gives firms located in different areas relatively more or less potential productive opportunities than the firms in the other regions. We notice also that one region disappears after cleaning the data for outliers and influential. All statistics presented in this paper take that into account.

Since we have a short-unbalanced panel data at hand, the main results, as well as those used for robustness check, are obtained through random effects panel data estimation. Besides, the unbalanced panel allowing for more data point to be used in the regression gives more efficient estimates. Further, Bell and Jones (2014) argue that random effects model are even preferable and that the Hausman test does not in reality settles the fixed effects vs. random effects debate. Furthermore, the Hausman test is not doable in this instance, for we are clustering the data across regions to get more efficient standard errors. Nonetheless, the fixed effects estimates are presented in the Appendix (Table A7).

Power outages, measured by their frequency and duration, have negative significant effects on productivity except in column 2 of Table 7 where duration has come out insignificant. Frequency in columns 1 and 3 and duration in column 4 have shown negative effects on productivity at the 1% significance level. As one would expect, owning a generator, in columns 1 and 2, has positive significant effects on productivity. Therefore, firms owning a generator were successful in countering some of the negative effects borne by power outages. These results are consistent with results found by Arnold et al (2008) for sub-Sahara African economies and by Fisher-Vanden et al (2015) in the case of China. Further, the interaction terms between power outages and generator are introduced to capture any differential effect on

productivity between firms owning a generator and those that do not. In columns 3 and 4, the interactions of generator with frequency and duration, respectively, came out positive and significant at the 1% level. This outcome confirms that firms with a generator have avoided the negative effect of power outage on productivity. Moreover, we cannot reject the null hypothesis that ($\chi^2 = 0.05$, with a probability of 0.8288), which shows that the productivity of firms with a generator is independent of the frequency of power outages, that is, whatever productivity they would have lost due to power outages is saved by the presence of generators. Thus, as far as manufacturing are concerned, firms with a generator did successfully counter the nuisance from power outages. Further, all 35 large firms in the data set have generator, the effect of power outages is, therefore, borne only by SMEs lacking generators to keep production on at power outages times.

Alongside power outages, access to credit, another business environment variable, shows a positive significant effect on productivity in all specifications. Firms with access to credit are more productive than otherwise. The firm-related attributes that show significant effect on productivity are size, the structure of ownership and the legal status. In fact, and firstly, medium and large firms are significantly more productive than small ones. The magnitude of the coefficient for large firms is bigger than that of medium firms, which confirms that productivity tends to increase with firm size. Secondly, the share of the principal owner also has a positive significant effect on firm's productivity. Lastly, with respect to legal status, partnerships and LLCs are more productive than sole proprietorships, but at the 10% significance level. In the main results, in column 3 of Table 7, female ownership shows a positive significant effect at the 5% level on productivity.

The same regression is run, but this time for only SMEs; the results are reported in Table 8. The outcomes remain globally the same. It appears, however, that female ownership in this case is significant in all specifications, except in the last column. Therefore, female ownership matters more when it comes to SMEs.

Table 7: The effects of power outages on productivity (full sample)

	(1)	(2)	(3)	(4)
Log(frequency)	-0.0073***		-0.0153***	
	(0.0025)		(0.0054)	
Generator	0.0330***	0.0325***		
	(0.0106)	(0.0113)		
Log(duration)		0.0024		-0.0143***
		(0.0015)		(0.0048)
Log(frequency)*generator			0.0137***	
			(0.0045)	
Log(duration)*generator				0.0242***
				(0.0082)

continued next page

Log(age)	0.0025	0.0033	0.0030	0.0034
	(0.0049)	(0.0050)	(0.0046)	(0.0057)
Human capital	0.0055	0.0059	0.0056	0.0037
	(0.0175)	(0.0154)	(0.0181)	(0.0154)
Credit	0.0137***	0.0142***	0.0144***	0.0153***
	(0.0020)	(0.0018)	(0.0018)	(0.0017)
Female owner	0.0038	0.0031	0.0047**	0.0016
	(0.0024)	(0.0024)	(0.0019)	(0.0030)
Largest owner share	0.0054	0.0139***	0.0082*	0.0106***
	(0.0042)	(0.0029)	(0.0045)	(0.0019)
Foreign ownership	0.0076	0.0063	0.0066	0.0077
	(0.0102)	(0.0100)	(0.0103)	(0.0094)
Medium	0.0554***	0.0561***	0.0555***	0.0552***
	(0.0070)	(0.0070)	(0.0075)	(0.0055)
Large	0.1193***	0.1201***	0.1215***	0.1202***
	(0.0090)	(0.0097)	(0.0109)	(0.0084)
Region 1	0.0006	0.0012	0.0004	-0.0013
	(0.0023)	(0.0027)	(0.0020)	(0.0023)
Region 2	0.0033*	0.0019	0.0048*	0.0005
	(0.0018)	(0.0015)	(0.0026)	(0.0008)
Partnership	0.0142*	0.0154*	0.0162*	0.0162*
	(0.0083)	(0.0088)	(0.0089)	(0.0084)
LLC	0.0034	0.0090*	0.0049	0.0107*
	(0.0031)	(0.0048)	(0.0038)	(0.0059)
Constant	0.6570***	0.6294***	0.6715***	0.6545***
	(0.0115)	(0.0021)	(0.0142)	(0.0101)
N	475	475	475	475
r2_w	0.0200	0.0257	0.0190	0.0300
r2_b	0.5628	0.5541	0.5550	0.5439
r2_o	0.4795	0.4748	0.4750	0.4674

Table 8: The effects of power outages on productivity (SMEs only)

	(1)	(2)	(3)	(4)
Log(frequency)	-0.0066**		-0.0138**	
	(0.0028)		(0.0055)	
Generator	0.0330***	0.0325***		
	(0.0108)	(0.0113)		
Log(duration)		0.0026		-0.0138***
		(0.0017)		(0.0048)
Log(frequency)*generator			0.0141***	
			(0.0045)	
Log(duration)*generator				0.0246***
				(0.0084)
Log(age)	0.0017	0.0022	0.0021	0.0024
	(0.0052)	(0.0052)	(0.0049)	(0.0059)
Human capital	0.0070	0.0071	0.0070	0.0045
	(0.0163)	(0.0146)	(0.0167)	(0.0147)
Credit	0.0146***	0.0140***	0.0145***	0.0152***
	(0.0020)	(0.0022)	(0.0019)	(0.0023)
Female owner	0.0052**	0.0051**	0.0064***	0.0036
	(0.0022)	(0.0021)	(0.0014)	(0.0026)
Largest owner share	0.0077	0.0153***	0.0121*	0.0113***
	(0.0063)	(0.0045)	(0.0071)	(0.0031)
Foreign ownership	0.0064	0.0057	0.0058	0.0074
	(0.0152)	(0.0153)	(0.0153)	(0.0152)
Medium	0.0558***	0.0565***	0.0559***	0.0553***
	(0.0073)	(0.0075)	(0.0078)	(0.0059)
Region 1	0.0010	0.0014	0.0010	-0.0010
	(0.0023)	(0.0027)	(0.0020)	(0.0023)
Region 2	0.0035	0.0021	0.0049*	0.0006
	(0.0021)	(0.0017)	(0.0028)	(0.0008)
Partnership	0.0146	0.0157	0.0171	0.0165*
	(0.0098)	(0.0102)	(0.0106)	(0.0096)
LLC	0.0034	0.0087*	0.0050	0.0109*
	(0.0033)	(0.0051)	(0.0042)	(0.0063)
Constant	0.6537***	0.6293***	0.6650***	0.6548***
	(0.0120)	(0.0026)	(0.0140)	(0.0114)
N	440	440	440	440
r2_w	0.0208	0.0278	0.0215	0.0347
r2_b	0.3713	0.3613	0.3611	0.3471
r2_o	0.3025	0.2983	0.2983	0.2894

Robustness check

Due to the nature of the productivity scores we have, through SFA or DEA, in this section we try other types of modelling to check for the robustness of the main results (column 3 in Table 7). In fact, the productivity numbers are bounded between zero and one; therefore, we use two types of modelling that consider this nature of the data.

We begin with truncated data models; thus, the productivity scores are considered two-sided truncated since they are bounded between zero and one. The layout of the model supposes that there is a latent variable y^* we could consider, in this instance, as “potential productivity” which depends on a set of observable characteristics and an error term. Some examples of the use of this model can be found in Alan and Leth-Petersen (2006), Andrews et al (2005), Gifford and Bernard (2005), and Officer (2004). The model then can be written as:

$$y_{it}^* = \begin{cases} 0 & \text{if } y^* < 0 \\ y^* & \text{if } 0 \leq y^* \leq 1 \\ 0 & \text{if } y^* > 1 \end{cases}$$

Besides considering the productivity data as truncated, another model to handle these types of data was developed by Papke and Wooldridge (1996) and the generalized linear model (Baum, 2008). The results of the estimations for these models are presented in Table 9 and Table 10. The OLS regression results for each year are also reported in Table A6 (in the Appendix).

Starting with the truncated data model, we estimated the model using productivity scores assuming half normal distribution (columns 1 and 2) and exponential distribution (columns 3 and 4). The results remain the same. Power outages, measured by their frequency or duration, have again shown negative significant effects on productivity. The interactions terms, between power outages and generators, have also the same sign as before, i.e., positive significant effects. The other variables, credit access, female ownership, the structure of ownership, size and legal status, have all come out with positive significant effects, consistent with the results in Table 7 (column 3). Again, we reject the null hypothesis that for the models in columns (1) and (3) of Table 9, which are the replication of the main results.

In Table 10, we check for the robustness for only the main results, by running three regressions using the efficiency scores assuming half normal (column 1) and exponential (column 2) distributions, and DEA. The results again stay consistent with what we have seen in Table 7, except for column (3) where the interaction term did not show a significant effect. Access to credit, size and legal status also came out with positive significant effect. As for the effects of power outages, the cross-sectional regressions for 2007, 2011 and 2014 confirm the results that we have gotten previously.

Table 9: The effects of power outages on productivity, truncated data model (full sample)

	(1)	(2)	(3)	(4)
Log(frequency)	-0.0153***		-0.0159**	
	(0.0054)		(0.0066)	
Generator	0.0137***		0.0152***	
	(0.0044)		(0.0057)	
Log(duration)		-0.0143***		-0.0147**
		(0.0047)		(0.0067)
Log(frequency)*generator		0.0242***		0.0274**
		(0.0081)		(0.0108)
Log(duration)*generator	0.0030	0.0034	0.0002	0.0008
	(0.0045)	(0.0056)	(0.0065)	(0.0077)
Log(age)	0.0056	0.0037	0.0119	0.0099
	(0.0178)	(0.0152)	(0.0209)	(0.0184)
Human capital	0.0144***	0.0153***	0.0165***	0.0173***
	(0.0018)	(0.0017)	(0.0018)	(0.0018)
Credit	0.0047**	0.0016	0.0066***	0.0031
	(0.0018)	(0.0030)	(0.0023)	(0.0036)
Female owner	0.0082*	0.0107***	0.0068	0.0074*
	(0.0045)	(0.0018)	(0.0077)	(0.0044)
Largest owner share	0.0066	0.0077	0.0063	0.0073
	(0.0102)	(0.0093)	(0.0105)	(0.0099)
Foreign ownership	0.0554***	0.0552***	0.0526***	0.0518***
	(0.0074)	(0.0054)	(0.0089)	(0.0064)
Medium	0.1216***	0.1204***	0.1195***	0.1174***
	(0.0108)	(0.0084)	(0.0138)	(0.0105)
Region 1	0.0004	-0.0013	0.0047*	0.0029
	(0.0019)	(0.0023)	(0.0028)	(0.0028)
Region 2	0.0048*	0.0005	0.0052*	0.0005
	(0.0026)	(0.0008)	(0.0031)	(0.0009)
Partnership	0.0162*	0.0162**	0.0197*	0.0196**
	(0.0088)	(0.0083)	(0.0107)	(0.0099)
LLC	0.0049	0.0107*	0.0043	0.0113*
	(0.0038)	(0.0058)	(0.0040)	(0.0060)
_cons	0.6714***	0.6544***	0.7072***	0.6910***
	(0.0140)	(0.0100)	(0.0156)	(0.0134)
sigma				
_cons	0.0527***	0.0530***	0.0693***	0.0695***
	(0.0018)	(0.0019)	(0.0029)	(0.0033)
N	475	475	475	475

Table 10: The effects of power outages on productivity, generalized linear model

	(1)	(2)	(3)
Log(frequency)	-0.0715***	-0.0786**	-0.3076*
	(0.0254)	(0.0328)	(0.1866)
Log(frequency)*generator	0.0633***	0.0752***	0.1002
	(0.0206)	(0.0283)	(0.1799)
Log(age)	0.0145	0.0014	0.3953***
	(0.0221)	(0.0336)	(0.0979)
Human capital	0.0292	0.0645	0.4344
	(0.0842)	(0.1052)	(0.5962)
Credit	0.0770***	0.0947***	0.3925***
	(0.0087)	(0.0093)	(0.0999)
Female owner	0.0227***	0.0348***	-0.0042
	(0.0088)	(0.0121)	(0.0607)
Largest owner share	0.0443	0.0415	0.4076**
	(0.0279)	(0.0494)	(0.1995)
Foreign ownership	0.0402	0.0400	0.3148***
	(0.0608)	(0.0670)	(0.0623)
Medium	0.2743***	0.2815***	0.3471***
	(0.0363)	(0.0468)	(0.1050)
Region 1	0.6967***	0.7389***	1.5163***
	(0.0556)	(0.0733)	(0.1116)
Region 2	0.0036	0.0245*	0.2381***
	(0.0086)	(0.0136)	(0.0861)
Partnership	0.0212*	0.0245	0.1830*
	(0.0124)	(0.0160)	(0.0941)
LLC	0.0825*	0.1074*	0.3249***
	(0.0475)	(0.0625)	(0.1119)
	0.0207	0.0180	0.0863
	(0.0188)	(0.0214)	(0.1120)
_cons	0.7050***	0.8690***	-4.1792***
	(0.0638)	(0.0785)	(0.3554)
N	475	475	475
deviance	6.1460	10.7867	75.1219
ll	-191.7661	-184.0703	-97.3417

Productivity cost of power outages

The cost of power outages can be estimated from the first derivative of tfp_{it} with respect to $\log(\text{frequency}_{it})$ in model (1), and taking the discrete version as in Equation 2.

$$\Delta tfp = \frac{\Delta \text{frequency}}{\text{frequency}} * \alpha_1 + \frac{\Delta \text{frequency}}{\text{frequency}} * \text{generator} * \alpha_3 \quad (2)$$

Considering that the null hypothesis that $\alpha_1 + \alpha_2 = 0$ cannot be rejected, the net cost of power outages is thus born only by firms without generators. Equation 2 can be reduced further in that case for the net effect as $\Delta tfp = \frac{\Delta \text{frequency}}{\text{frequency}} * \alpha_1$. This equation can help estimate the productivity effect of power outages. However, with an unbalanced panel at hand, this exercise can be done only with the balanced panel part, but with gaps in the periods it becomes not handy. To overcome this limitation, we estimate the average marginal effect of power outages on productivity as indicated in Equation 3, and use it to estimate the cost of power outages in terms of productivity.

$$\theta_1 = \frac{\Delta tfp}{\Delta \text{frequency}} = \frac{1}{\text{frequency}} * \alpha_1 \quad (3)$$

The productivity loss, in terms of actual productivity, can be estimated as $\frac{tfp_{freq}}{tfp}$, where $tfp_{freq} = \theta_1 * \text{frequency}$ is the loss of productivity due to power outages. The results of the estimations are presented in Table 11. With almost 12% of net productivity loss, 2011 stands as the year with the higher losses, and small enterprises, with around 5% loss, are more affected than the medium ones with 4.3% of productivity loss. These numbers should not be considered trivial; further adding on top of this the access and usage cost of electricity will make the economy of Senegal less attractive to both domestic and foreign investment, and impede their competitiveness (Eiffert et al, 2008).

Table 11: The productivity cost of power outages

	2007	2012	2014	Small	Medium
TFP loss (stand error)	-3.14	-1.69	-1.33	-5.45	-0.71
	(0.21)	(0.28)	(0.10)	(0.37)	(0.23)
Actual TFP (stand error)	70.98	14.58	41.98	111.28	16.27
	(0.45)	(0.22)	(0.75)	(0.79)	(0.20)
TFP loss (%)	4.4	11.6	3.2	4.9	4.3

5. Conclusion

This paper investigates the productivity effect of power outages on SMEs in Senegal using an unbalanced panel on manufacturing firms. The political and social stability of Senegal makes identification issue of the net productivity cost of power outages less problematic. The main results are drawn from random effects in a linear panel model. Nonetheless, the results remain consistent to the robustness check we did using a double-sided truncated data model and a generalized linear model.

The results show that power outages have significant negative effects on firms' productivity. However, this effect is mitigated for firms owning a generator; in fact, firms owning a generator avoided the loss due to power outages. Further, the results also point out that firms with access to credit are more productive than their counterparts. These results agree with firms' responses in Table A2 (in the Appendix). Further, the results also show that productivity tends to increase with firm size and the share of the principal owner. Some very important policy implications can be drawn from these outcomes for the development of a competitive business environment and relevant policy supports for SMEs.

They suggest first that reforms should be undertaken to resolve the electricity problem. In fact, a more reliable electricity supply will help firms avoid the productivity loss it causes, making electricity less costly besides the relatively expensive monetary cost it bears. Thus, it will contribute in making the business environment more attractive to investment. Further, solving the electricity outage problems would allow firms to save on the efforts and resources diverted to coping strategies. Moreover, in reducing uncertainty in the economic environment, a reliable power supply will put businesses in a more dynamic growth path since it will interfere less with investment and hiring decisions as states.

The second policy implication concerns improving businesses' access to credits and loans. Banks usually lend to promising businesses. The results show, however, that access to credits and loans promotes productivity. The government can, in this matter, work to facilitate the bank-firm relationship to facilitate firms' access to credits and loans. Besides, this policy implication would strengthen the effects from a reliable electricity service, giving businesses a greater growth opportunity.

Notes

1. In fact, the country has made four major reforms: increased transparency of information needed for property transactions, established a new credit bureau, reduced profit tax rate and simplified tax compliance processes, and introduced a new restructuring procedure to make insolvency easier to resolve (World Bank, 2016).
2. ECOWAS: Economic Community of West African States composed of Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal and Togo.
3. As of early 2017, SENELEC was still a public company.
4. We acknowledge the financial support of TrustAfrica and IRCD in funding the survey.

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Appendix

Figure A1: Average number (shades) and duration (charts) of outages across areas

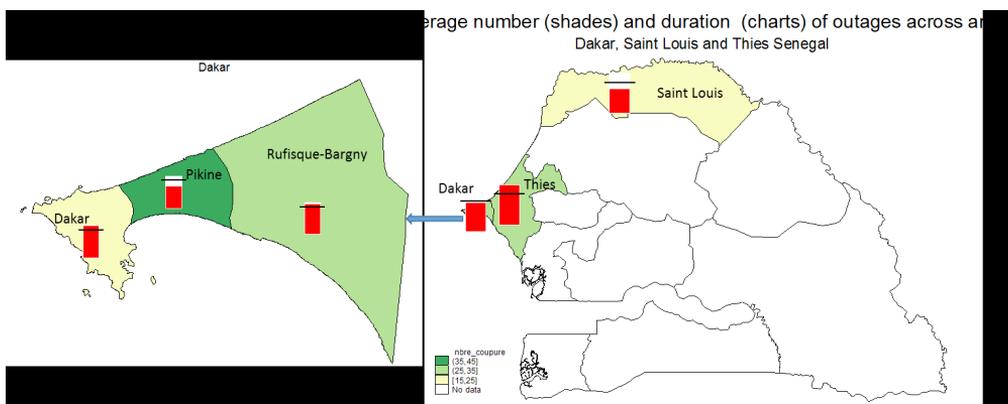


Table A1: Variance inflation factors of covariates

Variable	VIF	Tolerance	Variable	VIF	Tolerance
Log(frequency)	2.74	0.3656	log(duration)	3.56	0.2805
Log(frequency)*generator	8.92	0.1121	log(duration)*generator	5.72	0.1749
Generator	7.57	0.1322	generator	2.89	0.3456
log(age)	1.08	0.9293	log(age)	1.06	0.943
Human capital	1.05	0.9518	Human capital	1.05	0.9509
Credit	1.12	0.8956	Credit	1.11	0.9005
Female owner	1.02	0.9772	Female owner	1.03	0.9729
Largest owner share	1.26	0.7918	largest owner share	1.07	0.9386
Foreign owner share	1.09	0.9163	foreign owner share	1.09	0.9135

Table A2: Power outages and related issues in Senegal

	SMEs			Sectors				Total
	Very small	Small	Medium	Manufacturing	Retail and wholesale	Construction	Other Services	
Supplied by SENELEC (%)	98.6	99.6	100.0	98.5	98.7	100.0	100.0	99.3
Electricity is a major concern (% of firm/sector)	47.1	60.8	61.5	68.7	57.4	41.4	54.5	56.8
Power outages frequency (monthly)	22.9	26.6	26.1	27.0	25.5	20.8	27.2	25.5
Duration of a typical electrical outage (hours)	2.2	2.2	2.3	2.0	2.5	2.7	2.3	2.2
Firms owning/ sharing a generator (%)	36.7	70.9	80.2	62.7	62.8	63.3	61.5	62.3
Does production stop in case of a power outage? (% of yes)	34.1	40.5	50.0	52.2	23.4	40.0	49.8	40.8
Are wages paid in case of a power outage? (% of yes)	99.3	98.7	97.8	98.5	100.0	96.7	98.0	98.7
Losses due to electrical outages (% of annual sales)	5.2	5.0	4.7	6.0	3.9	5.1	5.3	5.0
Do power cuts affect hiring decisions (% of yes)	36.2	44.0	51.7	56.7	32.5	60.0	44.3	43.1
Do power cuts affect investment decisions (% of yes)	48.2	57.0	61.5	68.7	46.2	63.3	56.5	55.2
Delivery delays from suppliers due to power outages (% of yes)	39.6	51.4	51.1	64.2	40.7	53.3	46.8	47.7
Delivery delays to customers due to power outages (% of yes)	46.9	56.0	68.5	67.7	38.7	81.8	60.3	55.7
Number of firms	139	223	92	67	156	30	201	454

Table A3: Endogeneity test, second stage results

	log(frequency)	log(duration)	generator
resid1	-0.0936		
	(0.0947)		
resid2		0.0042	
		(0.0034)	
resid3			0.0033
			(0.1046)
Log(frequency)	0.0869	-0.0072**	-0.0067*
	(0.0946)	(0.0035)	(0.0035)
Medium	0.0744***	0.0613***	0.0606**
	(0.0149)	(0.0073)	(0.0246)
Large	0.1478***	0.1308***	0.1308***
	(0.0189)	(0.0122)	(0.0126)
Region 1	0.0012	-0.0063	-0.0053
	(0.0112)	(0.0079)	(0.0295)
Region 2	-0.0146	-0.0012	-0.0006
	(0.0159)	(0.0076)	(0.0205)
Log(age)	0.0101	0.0025	0.0025
	(0.0081)	(0.0036)	(0.0039)
Human capital	0.0057	0.0019	0.0022
	(0.0112)	(0.0106)	(0.0148)
Credit	0.0224**	0.0164**	0.0161
	(0.0096)	(0.0077)	(0.0135)
Proprietorship	0.0291*	0.0137	0.0139
	(0.0168)	(0.0091)	(0.0103)
LLC	0.0544	0.0039	0.0041
	(0.0508)	(0.0101)	(0.0104)
Female	-0.0003	0.0046	0.0046
	(0.0086)	(0.0068)	(0.0068)
Largest owner share	0.1278	0.0041	0.0050
	(0.1241)	(0.0128)	(0.0147)
Foreign ownership	.	0.0124	0.0116
	.	(0.0124)	(0.0269)
Constant	0.3445	0.6786***	0.6745***
	(0.3346)	(0.0211)	(0.0740)

continued next page

Table A3 Continued

	log(frequency)	log(duration)	generator
N	475	475	475
chi2	357.5677	359.3937	356.7938
p	0.0000	0.0000	0.0000
r2_w	0.0128	0.0161	0.0128
r2_b	0.5096	0.5110	0.5096
r2_o	0.4368	0.4386	0.4368

Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01

Table A4: The effects of power outages on productivity, exponential productivity scores

	(1)	(2)	(3)	(4)
Log(frequency)	-0.0070**		-0.0158**	
	(0.0029)		(0.0067)	
Generator	0.0358**	0.0352**		
	(0.0141)	(0.0146)		
Log(duration)		0.0042**		-0.0147**
		(0.0017)		(0.0068)
Log(frequency)*generator			0.0152***	
			(0.0057)	
Log(duration)*generator				0.0273**
				(0.0109)
Log(age)	-0.0003	0.0006	0.0002	0.0007
	(0.0069)	(0.0071)	(0.0066)	(0.0077)
Human capital	0.0115	0.0121	0.0116	0.0097
	(0.0206)	(0.0186)	(0.0211)	(0.0186)
Credit	0.0154***	0.0157***	0.0161***	0.0169***
	(0.0020)	(0.0018)	(0.0018)	(0.0018)
Female owner	0.0056*	0.0047	0.0065***	0.0030
	(0.0029)	(0.0030)	(0.0024)	(0.0037)
Largest owner share	0.0035	0.0109*	0.0066	0.0072*
	(0.0064)	(0.0062)	(0.0076)	(0.0043)
Foreign ownership	0.0071	0.0055	0.0059	0.0069
	(0.0099)	(0.0099)	(0.0101)	(0.0094)
Medium	0.0526***	0.0529***	0.0525***	0.0517***
	(0.0081)	(0.0083)	(0.0089)	(0.0064)
Large	0.1131***	0.1135***	0.1153***	0.1131***
	(0.0108)	(0.0116)	(0.0134)	(0.0099)

continued next page

Table A4 Continued

	(1)	(2)	(3)	(4)
Region 1	0.0047	0.0053	0.0046	0.0028
	(0.0032)	(0.0036)	(0.0029)	(0.0029)
Region 2	0.0034	0.0019	0.0052*	0.0005
	(0.0022)	(0.0019)	(0.0031)	(0.0009)
Partnership	0.0173*	0.0184*	0.0194*	0.0194**
	(0.0099)	(0.0104)	(0.0107)	(0.0099)
LLC	0.0028	0.0094**	0.0045	0.0113*
	(0.0030)	(0.0044)	(0.0040)	(0.0060)
Constant	0.6920***	0.6641***	0.7075***	0.6915***
	(0.0117)	(0.0025)	(0.0159)	(0.0135)
N	475	475	475	475
r2_w	0.0129	0.0187	0.0150	0.0226
r2_b	0.4230	0.4162	0.4154	0.4098
r2_o	0.3384	0.3361	0.3359	0.3322

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A5: The effects of power outages on productivity, DEA scores

	(1)	(2)	(3)	(4)
Log(frequency)	-0.0222***		-0.0234**	
	(0.0056)		(0.0096)	
Generator	0.0234	0.0229		
	(0.0160)	(0.0181)		
Log(duration)		-0.0079		-0.0210***
		(0.0050)		(0.0080)
Log(frequency)*generator			0.0026	
			(0.0086)	
Log(duration)*generator				0.0190**
				(0.0076)
Log(age)	0.0251***	0.0262***	0.0252***	0.0263***
	(0.0064)	(0.0080)	(0.0069)	(0.0085)
Human capital	0.0325	0.0326	0.0306	0.0311
	(0.0369)	(0.0303)	(0.0376)	(0.0300)
Credit	0.0358***	0.0375***	0.0374***	0.0382***
	(0.0122)	(0.0124)	(0.0117)	(0.0118)
Female owner	-0.0054**	-0.0056***	-0.0048*	-0.0068***
	(0.0021)	(0.0012)	(0.0026)	(0.0015)

continued next page

Table A5 Continued

	(1)	(2)	(3)	(4)
Largest owner share	0.0226	0.0551***	0.0228	0.0527***
	(0.0140)	(0.0183)	(0.0145)	(0.0163)
Foreign ownership	0.0527***	0.0512***	0.0549***	0.0520***
	(0.0154)	(0.0134)	(0.0152)	(0.0123)
Medium	0.0156***	0.0201***	0.0188***	0.0190***
	(0.0045)	(0.0050)	(0.0058)	(0.0039)
Large	0.2270***	0.2334***	0.2335***	0.2327***
	(0.0092)	(0.0099)	(0.0089)	(0.0050)
Region 1	0.0169***	0.0181***	0.0133**	0.0167***
	(0.0060)	(0.0064)	(0.0057)	(0.0045)
Region 2	0.0085*	0.0061*	0.0064	0.0053**
	(0.0047)	(0.0034)	(0.0052)	(0.0027)
Partnership	0.0265***	0.0302***	0.0266***	0.0309***
	(0.0098)	(0.0102)	(0.0103)	(0.0102)
LLC	-0.0009	0.0057	-0.0003	0.0070
	(0.0090)	(0.0145)	(0.0095)	(0.0157)
Constant	-0.0251	-0.0968***	-0.0121	-0.0788***
	(0.0221)	(0.0242)	(0.0182)	(0.0130)
N	475	475	475	475
r2_w	0.0198	0.0214	0.0163	0.0214
r2_b	0.3323	0.3178	0.3284	0.3176
r2_o	0.2625	0.2546	0.2588	0.2547

Standard errors in parentheses; starts: * p < 0.1, ** p < 0.05 and *** p < 0.01

Table A6: The effects of power outages on productivity by year

	2007	2012	2014
Log(frequency)	-0.0134***	-0.0190**	-0.0209**
	(0.0034)	(0.0093)	(0.0086)
Log(frequency)*generator	0.0147***	0.0072*	0.0207***
	(0.0023)	(0.0040)	(0.0060)
Log(age)	0.0059*	0.0073	0.0049
	(0.0033)	(0.0068)	(0.0082)
Human capital	-0.0065	0.0433**	0.0120
	(0.0105)	(0.0204)	(0.0218)
Credit	0.0118	0.0201	0.0139
	(0.0081)	(0.0143)	(0.0144)

continued next page

Table A6 Continued

	2007	2012	2014
Female owner	0.0019	-0.0155	0.0046
	(0.0060)	(0.0140)	(0.0151)
Largest owner share	-0.0167	0.0382	-0.0365
	(0.0257)	(0.0338)	(0.0532)
Foreign ownership	0.0130	-0.4539**	-0.0055
	(0.0146)	(0.2199)	(0.0205)
Medium	0.0572***	0.0479***	0.0660***
	(0.0077)	(0.0128)	(0.0140)
Large	0.0970***		0.1329***
	(0.0119)		(0.0221)
Region 1	-0.0178**	0.0061	0.0299
	(0.0071)	(0.0136)	(0.0194)
Region 2	0.0113	0.0198	0.0104
	(0.0074)	(0.0199)	(0.0146)
Partnership	0.0167	-0.0370**	0.0188
	(0.0104)	(0.0172)	(0.0185)
LLC	0.0697**		0.0060
	(0.0348)		(0.0154)
_cons	0.7004***	0.7017***	0.6954***
	(0.0282)	(0.0412)	(0.0619)
N	217	58	200
r2	0.6868	0.5984	0.4298
F	31.6324	5.5886	9.9600
prob_F			

Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01

Table A7: The effects of power outages on productivity, fixed effects

	(1)	(2)	(3)	(4)
Log(frequency)	0.0006		-0.0038	
	(0.0080)		(0.0095)	
Log(duration)		-0.0004		-0.0094
		(0.0072)		(0.0107)
Log(frequency)*generator			0.0070	
			(0.0069)	
Log(duration)*generator				0.0129
				(0.0111)

continued next page

Table A7 Continued

	(1)	(2)	(3)	(4)
Generator	0.0196	0.0197		
	(0.0158)	(0.0158)		
Log(age)	-0.0213*	-0.0218*	-0.0211*	-0.0223*
	(0.0121)	(0.0128)	(0.0122)	(0.0128)
Human capital	0.0528*	0.0528*	0.0544*	0.0485*
	(0.0280)	(0.0280)	(0.0281)	(0.0284)
Credit	-0.0263	-0.0261	-0.0271	-0.0296
	(0.0252)	(0.0253)	(0.0252)	(0.0252)
Female	0.0193	0.0192	0.0188	0.0181
	(0.0172)	(0.0174)	(0.0173)	(0.0174)
Largest owner share	-0.0297	-0.0299	-0.0206	-0.0241
	(0.0622)	(0.0621)	(0.0613)	(0.0614)
Foreign ownership	0.0207	0.0211	0.0224	0.0182
	(0.0446)	(0.0448)	(0.0447)	(0.0452)
Medium	0.0367	0.0371	0.0387	0.0350
	(0.0264)	(0.0264)	(0.0263)	(0.0270)
Large	0.0060	0.0068	0.0059	0.0052
	(0.0665)	(0.0663)	(0.0668)	(0.0665)
Partnership	0.0331	0.0331	0.0345	0.0336
	(0.0299)	(0.0299)	(0.0299)	(0.0299)
LLC	0.0150	0.0146	0.0159	0.0167
	(0.0206)	(0.0207)	(0.0207)	(0.0205)
_cons	0.7169***	0.7198***	0.7191***	0.7326***
	(0.0687)	(0.0663)	(0.0693)	(0.0682)
N	475	475	475	475
r2_w	0.1848	0.1848	0.1799	0.1829
r2_b	0.0300	0.0318	0.0250	0.0151
r2_o	0.0502	0.0519	0.0446	0.0331

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$



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