Productivity Losses and Firm Responses to Electricity Shortages: Evidence from Ghana

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Abstract

One of the most commonly cited obstacles to firms' operations in developing economies is inadequate access to electricity. In this paper, we explore the impact of electricity outages on firm productivity using arguably exogenous variation in outages across small and medium-sized Ghanaian manufacturing firms induced by an electricity rationing program. We find that eliminating outages in this setting could lead to a 10 percent increase in firm productivity. We further analyze the strategies firms use to cope with electricity outages. We find that while

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strategies like using a generator, switching to less electricity-intensive production processes and changing production times are commonly used by firms, none of these are able to insulate firms from the negative impacts of electricity shortages on productivity. In fact, we find that one of the most commonly used strategies, using a generator, actually exacerbates the negative productivity impact by diverting firm capital from direct productive uses to the generation of electricity.

JEL Classification Codes: D24, H54, L20, O13, O14

1 Introduction

Beginning with the seminal work of Aschauer (1989), there has been a growing literature on the impact of infrastructure on economic growth. While there is an active literature on the effects of infrastructure on various facets of growth, there has been relatively little research on how infrastructure, in particular electricity, affects the behavior of firms. Electricity has become a critical input for most production processes especially as technological advancements in production have increased the reliance on electricity-dependent technologies.

Despite its potential to promote growth, electricity provision remains poor in most developing countries. An estimated 1.3 billion people worldwide are without electricity, over 95 percent of whom live in developing countries. In Africa alone, almost 600 million people lack electricity, representing approximately 60 percent of the continent's total population (International Energy Agency, 2011). Even where consumers are connected to the electric grid, electricity supply tends to be unreliable and plagued with frequent outages. For instance, manufacturing firms in Africa report an average of 56 days without electric power in a year (International Monetary Fund, 2008). In Ghana, the setting for this study, electricity was the most commonly cited constraint to firms' operations according to a 2007 World Bank survey. Almost 50 percent of firms surveyed ranked electricity as the most severe obstacle to their operations ahead of constraints such as access to finance, taxes and crime (World Bank, 2007). Since firms are an important engine of growth and electricity has increasingly become an essential input for firms, identifying how firms respond to electricity constraints is crucial for understanding the micro-foundations of growth in developing economies.

While a growing strand of literature has sought to identify the impact of electricity provision on firms,[2] there are some gaps in this literature that our paper seeks to fill.

First, although the existing literature has investigated the potential for inadequate provision of electricity to affect firm productivity,[3] there is little evidence on the strategies firms use to cope with electricity shortages and the extent to which these strategies effectively mitigate or exacerbate any productivity impacts. This gap is partly due to lack of data. Very few firm-level datasets provide information on firms' use of generators and other strategies for coping with inadequate electricity provision. These coping strategies may influence the impacts of inadequate electricity supply on firm productivity but the lack of data has made it difficult to analyze the existence and efficacy of these strategies.

Second, most existing studies have focused on large firms[4] perhaps by virtue of the fact that data tend to readily exist for this population. However, small and medium-sized firms may differ from large firms in substantial ways, such as a lowered ability to finance generator use. In particular, since the bulk of firms in developing countries fall in this population which is responsible for the majority of employment in these countries, it is essential to understand how this particular population responds to electricity constraints. Small and medium-sized firms are estimated to account for about 90 percent of businesses and over 50 percent of employment (International Finance Corporation, 2012). In Ghana, small and medium-sized firms are estimated to provide about 85 percent of manufacturing employment and contribute about 70 percent of the country's GDP (Government of Ghana, 2017).

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[2]See, for example, Reinikka and Svensson (2002), Rud (2012a), Rud (2012b), Zuberi (2012), Alby, Dethier, and Straub (2013), Fisher-Vanden, Mansur, and Wang (2015), Allcott, Collard-Wexler, and O'Connell (2016), Hardy and McCasland (2017) and Abeberese (forthcoming).

[3]See, for example, Fisher-Vanden, Mansur, and Wang (2015) and Allcott, Collard-Wexler, and O'Connell (2016).

[4]See, for example, Fisher-Vanden, Mansur, and Wang (2015) and Allcott, Collard-Wexler, and O'Connell (2016).

To fill these gaps in the literature, we surveyed over 800 small and medium-sized manufacturing firms in Ghana and collected data for the years 2011 through 2015. Ghana has suffered several episodes of electricity crises with the most recent one resulting in an electricity rationing program that started in 2012 and ended in 2015. In addition to data on firms' products and inputs, we elicited information on firms' strategies for coping with electricity shortages. Using these data and the random variation across firms in electricity access induced by the rationing program, we assess the magnitude of productivity losses resulting from the lack of electricity and the ability of firms to mitigate these productivity losses.

Our results indicate that firms experienced reductions in productivity as a result of the lack of electricity. The productivity losses are of significant magnitude. The firms in our sample reported an average of 10 days with no electricity in a typical month. Our estimates suggest that reducing this number to zero, which would be consistent with the situation in most developed countries, could result in a 10 percent increase in both labor productivity and total factor productivity. We go beyond the existing literature to analyze how firms cope with the electricity outages. We find that the most common strategies used by firms included using a generator, switching to less electricity-intensive production processes and changing production times. We then investigate the ability of these strategies to alleviate the adverse impacts of electricity outages on productivity and find that none of the strategies successfully do so. In fact, firms that use generators to cope with outages exhibit a reduction in total factor productivity likely due to their capital accumulation being in the form of generators rather than capital that is used directly for production.

Our paper is most closely related to Fisher-Vanden, Mansur, and Wang (2015), Allcott, Collard-Wexler, and O'Connell (2016) and Hardy and McCasland (2017), who analyze the effects of electricity outages on firms. Fisher-Vanden, Mansur, and Wang (2015) find that, in response to shortages, manufacturing firms in China shifted from producing intermediate goods in-house to buying them and experienced no substantial productivity losses. Allcott, Collard-Wexler, and O'Connell (2016) similarly find no significant impact of outages on the productivity of manufacturing firms in India. Their results are in contrast to ours which indicate that firms experience significant productivity losses. This differences stems from the fact that while these papers focus on large firms, our paper focuses on small and medium-sized firms.[5] These smaller firms, in contrast to large firms, are unlikely to be involved in the in-house production of intermediate goods and may also have a limited ability to efficiently use generators to insure against outages due to the substantial economies of scale in generator use. As discussed above, in addition to understanding the impacts of electricity shortages on large firms, it is essential to understand the impacts on smaller firms since these firms tend to constitute the bulk of producers in developing economies and may differ in their ability to weather electricity outages. A notable exception which focuses on small firms is Hardy and McCasland (2017) who study small garment makers in Ghana and find some negative impact of electricity outages on labor productivity.

Another main point of departure from the existing literature is that our paper extends the analysis in these existing papers by directly analyzing how firms cope with these outages and the ability of these coping mechanisms to influence the impacts of outages. This analysis is important because, in the absence of uninterrupted electricity supply, an understanding of the efficacy of these coping mechanisms can help inform policies on positioning firms to better weather electricity shortages.

The rest of the paper is organized as follows. In Section 2, we describe the electricity rationing program in Ghana that we exploit for our analysis. In Section 3, we describe the survey and data used for our analysis. In Section 4, we discuss our empirical strategy and results. Finally, we conclude in Section 5.

2 Electricity Rationing in Ghana

Electricity generation in Ghana is primarily conducted by the Volta River Authority (VRA), a government-owned entity. VRA is responsible for 2,434 MW of installed generation capacity, which represents about 70 percent of total installed generation capacity in the country. Another government owned-entity, Bui Power Authority, accounts for about 10 percent of total installed

[5]For instance, the average number of workers in a firm in the sample in Allcott, Collard-Wexler, and O'Connell (2016) is 79. In contrast, the average number of workers in a firm in our sample is six.

generation capacity, while privately owned independent power producers account for the remaining 20 percent. Thermal and hydro generation, mainly from the Akosombo dam, account for about 55 and 45 percent, respectively, of the electricity generated in the country (Volta River Authority, 2017).

Electricity transmission is carried out by GRIDCo, while the Electricity Company of Ghana (ECG), Northern Electricity Distribution Company (NEDCo) and Enclave Power Company (EPC) are responsible for the distribution of electricity. ECG, which is government-owned, is the main distributor, with a market share of over 70 percent. NEDCo, also government-owned, is responsible for the northern part of the country, and EPC, which is privately-owned, is responsible for a free zone enclave in the city of Tema (Electricity Company of Ghana, 2017a). The cities in our sample are all located in regions served by ECG.

Ghana's electricity shortage crises date back to 1983 when a drought resulted in low levels of water that hampered the generation of hydroelectric power from the Akosombo dam. In response, power supply to consumers was curtailed. This crisis reoccurred in 1997-1998 and in 2007-2008, all driven by droughts. The latest electricity crisis started in 2012 and lasted until 2015. The primary drivers of this crisis included poor rainfall impeding the operation of the hydroelectric power plants, disruptions in the supply of gas from Nigeria to the thermal power plants due to infrastructure damage and gas being diverted to the domestic Nigerian market, and deteriorating electrical infrastructure (Oxford Business Group, 2017).

The resulting electricity shortage led ECG to put in place an electricity rationing program. The design of the rationing program was as follows. Areas of the country served by ECG are divided into over 500 service areas. These areas were put into three groups, A, B and C. In a given 36-hour period, each group would experience one twelve or thirteen-hour block (typically 6pm to 6am or 6am to 7pm) with no power and one twelve or thirteen-hour block in standby mode. In areas in standby mode, the power could go off if it was determined that the available electricity supply at the time was inadequate to meet electricity demand at that time. This implied that in any given 36-hour period, there was only one twelve or thirteen-hour block in which consumers in a given area were guaranteed power. Figure 1 shows the electricity rationing schedule for February 6 to March 6, 2015, which was the typical schedule for any given month (Daily Graphic, 2015). The listed group (not in parentheses) would have no power in the indicated time block, while the group in parentheses would be in standby mode.

In addition to this rationing schedule, there could be unexpected outages as a result of electrical equipment being damaged due to a wide array of causes including adverse weather such as lightning, wind and rain, overheating, animals coming into contact with electrical equipment, fallen trees, etc. (Electricity Company of Ghana, 2017b).

The rationing schedule, with its guaranteed and standby modes, combined with sporadic outages due to damaged equipment led to a patchwork of outages that can be considered as good as random. We exploit the resulting random variation in outages across firms in our empirical analysis below.

3 Data

The main source of data for the analysis in this paper is a survey of small and medium-sized manufacturing firms in Ghana that we conducted from August to September 2016. The survey collected firm-level data for the years 2011 through 2015.

The sample for the survey was derived from the first phase of the Ghana Integrated Business Establishment Survey (IBES). The IBES is an economic census of all business establishments across all sectors of the Ghanaian economy conducted by the Ghana Statistical Service in 2014-2015. From the IBES, we selected all small and medium-sized manufacturing firms located in the cities of Accra, Tema, Kumasi and Sekondi-Takoradi, the main industrial clusters in the country, for our survey. The universe of small and medium-sized manufacturing firms obtained from the IBES was 1,244 firms. We attempted to survey all of these firms. Of these, 73 firms refused to participate in the survey, 55 had folded up and 231 could not be located using the contact information obtained from the GSS. We, therefore, ended up surveying 885 firms. These firms operated in 20 distinct ISIC Rev. 4 2-digit industries in the following sectors: food and beverage products, textiles and wearing apparel, chemicals, metal, machinery and equipment, wood and wood products, and other manufacturing.

Data collected from the firms included information on output, inputs including electricity, capital, investment, labor, electricity outages and strategies for coping with outages. We deflate all monetary values to 2006 Ghanaian cedis using producer price indices from the Ghana Statistical Service. We deflate firm output with industry-specific producer price indices. We deflate machinery with the producer price index for machinery. We deflate all other variables with the overall producer price index. To reduce the influence of outliers, we "winsorize" firm-level variables within each year by setting values below the 1st percentile to the value at the 1st percentile and values above the 99th percentile to the value at the 99th percentile.

Table 1 provides summary statistics for the sample. The average firm in our sample is relatively small, with only about 6 workers. On average, firms experience about 10 days of outages in a month. About a quarter of firms use a generator and about 16 percent of electricity consumed comes from generators.

4 Econometric Analysis

4.1 Empirical Strategy

As discussed in Section 2, given the nature of the rationing schedule and sporadic power outages, we consider the number of outages experienced by a firm to be as good as random. We, therefore, analyze the impact of electricity shortages on firm outcomes by making use of this random variation in outages.

The estimating equation we use is as follows:

$$y_{ijct} = \beta_0 + \beta_1 outage\,days_{ijct} + \lambda_i + \eta_{jt} + \delta_{ct} + \epsilon_{ijct} \tag{1}$$

y_{ijct} is an outcome for firm i in industry j in city c in year t and $outage\,days_{ijct}$ is the average number of days on which the firm experienced power outages in a month.

Despite the arguably random nature of outages, we take several precautions to address any potential endogeneity. First, we include firm fixed effects in all regressions to account for any time-invariant firm characteristics which could potentially simultaneously affect both a firm's outage frequency and its other outcomes. Second, we include industry-year fixed effects to control for shocks that affect all firms in a particular industry. We also include city-year fixed effects to control for shocks that affect all firms in a particular city. Thus, β_1 is an estimate of the effect of an increase in the outages experienced by a firm on its outcomes, controlling for any other shocks in the firm's industry and location. We cluster standard errors at the firm level to account for serial correlation within firms.

4.2 Effect of Outages on Productivity

Table 2 reports the results from estimating equation (1) with labor productivity and total factor productivity as the outcomes of interest. We calculate labor productivity as the ratio of the firm's value added to its number of workers. We calculate total factor productivity following the method in Levinsohn and Petrin (2003).[6] The firm is considered to follow a production function with capital, labor, electricity and raw materials as its inputs. In estimating total factor productivity, the firm's raw materials are used as a proxy for its unobserved productivity shocks.

The estimates in Table 2 indicate that power outages result in a reduction in labor productivity and total factor productivity. The magnitudes of the estimates suggest economically meaningful impacts. One extra day of outages each month results in about a one percent reduction in labor productivity and total factor productivity. The average number of days with outages in a month in the sample is 10.[7] Thus, the estimates suggest that reducing this number to zero, which is a common scenario in most developed countries, could increase productivity by a non-trivial 10 percent.

We try to unpack this negative impact of outages on productivity by looking at the impact on output and production inputs. Table 3 presents the results from this analysis. The results indicate

[6]This calculation is implemented in Stata using the *levpet* command. The estimations are carried out separately by industry.

[7]This number is consistent with the data from the World Bank's enterprise surveys in Ghana, which show that the number of outages in a typical month reported by Ghanaian firms was 9.5 and 8.4 in 2007 and 2013, respectively (World Bank, 2007, 2013).

that while output falls due to outages (Column 1), there is no statistically significant impact of outages on the number of workers used by the firm (Column 2). The estimates in Columns 3 and 4 indicate that outages result in a reduction in raw materials and some reduction in the firm's stock of machinery. These results suggest that, while firms may flexibly alter inputs such as machinery and raw materials in response to electricity shortages, some inputs such as labor tend to be less flexible potentially owing to rigidities in the labor market. In particular, the reduction in labor productivity may stem from the reduction in the amount of capital available to workers.

4.3 Firms' Strategies in Response to Outages

We next analyze the strategies firms use to mitigate the impacts of electricity shortages and the effectiveness of these strategies in curtailing negative productivity impacts. In the survey, we asked firms if they had used any of eleven strategies to cope with power outages. The eleven strategies are as follows:

1. Used a generator
2. Changed time of day during which production took place
3. Changed production process to a less electricity-reliant one
4. Stopped producing electricity-intensive products
5. Started producing less electricity-intensive products
6. Laid off workers
7. Changed location of enterprise
8. Took insurance policy
9. Reduced shifts
10. Operated fewer hours
11. Temporarily suspended production

Table 4 reports the results from estimating equation (1) where the outcome variable is a dummy variable equal to one if the firm used the indicated strategy and zero otherwise. The results show that firms used a generator, changed the time of day during which production took place, changed their production process to a less electricity-reliant one, stopped producing electricity-intensive products, operated fewer hours and temporarily suspended production in response to power outages. The most common responses were using a generator and operating fewer hours.

While firms stopped producing electricity-intensive products, they were unlikely to start producing less electricity-intensive products suggesting that it is more feasible for firms to reduce rather than expand their product scope. Corroborating the result in Column 2 of Table 3 that there was no change in the number of workers used by the firm, Column 6 of Table 4 shows that firms were unlikely to lay off workers in response to power outages. Although unable to lay off workers, firms were able to modify the amount of labor used by cutting down the number of hours of operation as shown in Column 10 of Table 4. Other strategies unlikely to be used by firms included changing location, taking an insurance policy and reducing shifts. Overall, firms appear to cope with electricity outages by producing their own electricity via generators, reducing the amount of time they operate and reducing their reliance on electricity by changing their production processes and dropping products.

To assess the accuracy of firms' reports of the strategies used, we check if there are changes in variables that would be consistent with the strategies reported. In Table 5 we regress various firm outcomes on the number of outage days and dummy variables for each of the strategies listed above. In Column 1, we find that the generated share of electricity went up for firms that reported using generators as a coping strategy as indicated by the statistically significant and positive coefficient on the dummy variable for generator use. In Column 2, we find that the number of workers used fell for those firms that reported laying off workers and temporarily suspending production in response to power outages.

Finally, in Column 3, the amount of machinery is positively related to using a generator and negatively related to laying off workers. Although firms may have reduced their use of electricity-reliant machinery as suggested by the negative impact of outages on machinery seen in Column 3 of Table 3, they may have increased their use of machinery, specifically generators, to generate their own electricity to cope with the power outages. This is consistent with the result in Column 3 of Table 5 that there was an increase in machinery for firms that used generators. In summary, firm outcomes change in ways that are consistent with the strategies reported by firms, validating firms' reports of how they coped with electricity shortages.

Are these strategies effective in mitigating the negative impacts of power outages? We turn to this question in Table 6. We regress firm output and productivity measures on dummy variables for each of the strategies, controlling for the number of days with outages. In Column 1 of Table 6, none of the dummy variables for the strategies have a statistically significant positive coefficient indicating that none of the strategies were effective in reducing the negative impact of outages on output. The same is true for the regressions for labor productivity and total factor productivity in Columns 2 and 3, respectively. In fact, in Column 3, we find that total factor productivity fell for firms that used generators as a coping strategy. This suggests that while the addition of generators increased the capital stock, the amount of electricity firms were able to generate themselves was inadequate for boosting output significantly.

4.4 Firms' Willingness to Pay for Uninterrupted Electricity

We asked firms how much more they would be willing to pay for uninterrupted electricity from the public grid. As shown in Column 1 of Table 7, firms report that they are willing to pay, on average, 12.6 percent more for uninterrupted electricity. We also find that firms pay a high premium to generate their own electricity relative to buying electricity from the public grid, in line with the fact that electricity generation entails high fixed costs and these firms are relatively small. As shown in Column 2 of Table 7, the cost of self-generated electricity is on average 322 percent more than the cost of electricity from the public grid. Interestingly, the premium firms are willing to pay for uninterrupted electricity from the public grid is substantially smaller than the premium for generating electricity on their own. This large difference suggests a lack of trust in the public utility improving the quality of electricity even with higher electricity prices.

5 Conclusion

Despite the potential for the pervasiveness of power outages in many developing economies to hamper growth, there has been relatively little work on understanding the implications of power outages for firms. Using random variation in power outages among manufacturing firms in Ghana induced by a rationing program, we attempt to understand the impact of power outages on the productivity of firms and the effectiveness of firms' coping mechanisms. We draw two main conclusions from the analysis in this paper.

First, power outages have a significant negative impact on productivity. Our estimates suggest that, for instance, reducing the number of days in a month with outages from the average of about 10 in Ghana to none, as is the typical case in most developed countries, has the potential to increase productivity by 10 percent.

Second, the strategies that firms employ to cope with power outages are unable to insulate them from the negative productivity impacts of these outages. The most commonly used strategies include using a generator, switching to less electricity-intensive production processes, changing production times and temporarily suspending production. In fact, we find that one of the most common strategies employed worldwide, the use of a generator, is unable to alleviate the negative productivity impact by potentially diverting firm resources from direct productive uses to in-house generation of electricity which tends to be far costlier than purchasing electricity from the public grid due to the substantial economies of scale in electricity generation.

Our findings carry some policy implications. The significant productivity losses and the inability of firms to employ effective strategies to cope with outages suggest that reliable electricity supply can generate increases in productivity. Since firms report that they are willing to pay a premium for uninterrupted electricity, policymakers can make key investments in infrastructure to improve electricity supply even if that implies increasing electricity prices. It should however be noted that the premium firms are willing to pay for uninterrupted electricity is far lower than the premium they pay to generate their own electricity relative to buying electricity from the public grid. This large discrepancy suggests a lack of trust in the public utility's ability to follow through on improving electricity reliability. Policymakers should therefore consider addressing this potential lack of trust.

Additionally, in the absence of reliable electricity supply from the public grid, our analysis of the effectiveness of firms' coping mechanisms in alleviating the impacts of electricity shortages highlight potential ways in which policymakers can position firms to better cope with outages. For instance, generator sharing among firms could be encouraged to unlock economies of scale in in-house generation of electricity and allow firms to direct more of their resources towards capital directly used for production rather than generators.

Finally, while entry and exit are dimensions along which firms may respond to electricity constraints, we are unable to analyze these since our study uses a retrospective panel. Entry and exit are important responses that future research could explore.

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Figure 1: Sample Electricity Rationing Schedule

LOAD-SHEDDING GUIDE

The Electricity Company of Ghana wishes to inform its cherished customers that due to generation shortfall it has become necessary to publish this load shedding guide.

All Communities in the bracket are on loadshedding, but all or some may not go off depending on the quantum of power to be shed.

	FRIDAY 06/02/2015	SATURDAY 07/02/2015	SUNDAY 08/02/2015	MONDAY 09/02/2015	TUESDAY 10/02/2015	WEDNESDAY 11/01/2015	THURSDAY 12/02/2015
DAY 6AM TO 7PM	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)
NIGHT 6PM TO 6AM	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)
	FRIDAY 13/02/2015	**SATURDAY 14/02/2015**	**SUNDAY 15/02/2015**	**MONDAY 16/02/2015**	**TUESDAY 17/02/2015**	**WEDNESDAY 18/01/2015**	**THURSDAY 19/02/2015**
DAY 6AM TO 7PM	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)
NIGHT 6PM TO 6AM	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)
	FRIDAY 20/02/2015	**SATURDAY 21/02/2015**	**SUNDAY 22/02/2015**	**MONDAY 23/02/2015**	**TUESDAY 24/02/2015**	**WEDNESDAY 25/01/2015**	**THURSDAY 26/02/2015**
DAY 6AM TO 7PM	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)
NIGHT 6PM TO 6AM	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)
	FRIDAY 27/02/2015	**SATURDAY 28/02/2015**	**SUNDAY 01/03/2015**	**MONDAY 02/03/2015**	**TUESDAY 03/03/2015**	**WEDNESDAY 04/03/2015**	**THURSDAY 05/03/2015**
DAY 6AM TO 7PM	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)
NIGHT 6PM TO 6AM	A; (C)	B; (A)	C; (B)	A; (C)	B; (A)	C; (B)	A; (C)
	FRIDAY 06/03/2015						
DAY 6AM TO 7PM	C; (B)						
NIGHT 6PM TO 6AM	B; (A)						

Source: Daily Graphic (2015).

Table 1: Summary Statistics

	(1)	(2)	(3)
	mean	standard deviation	number of observations
no. of workers	6.32	9.45	4,261
output (GHS)	85,760	259,443	4,195
machinery (GHS)	5,682	24,207	4,221
raw materials (GHS)	19,522	68,917	4,234
outage days	10.65	5.34	4,124
use a generator	0.26	0.44	4,224
generated share of electricity	0.16	0.28	4,024

Notes: All monetary values are in 2006 Ghanaian cedis (GHS).

Table 2: Effect on Productivity

	(1)	(2)
	log(labor productivity)	log(tfp)
outage days	-0.0116***	-0.0103***
	(0.00350)	(0.00370)
no. of observations	3,907	3,752
no. of firms	812	773

Notes: *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the firm level. All regressions include firm fixed effects, industry-year effects and location-year effects.

Table 3: Effect on Output and Inputs

	(1)	(2)	(3)	(4)
	log(output)	log(labor)	log(machinery)	log(raw materials)
outage days	-0.0104***	-0.00307	-0.00648*	-0.0136***
	(0.00334)	(0.00196)	(0.00359)	(0.00333)
no. of observations	4,063	4,120	4,011	3,974
no. of firms	830	838	818	809

Notes: *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the firm level. All regressions include firm fixed effects, industry-year effects and location-year effects.

Table 4: Strategies for Coping with Outages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	used generator	changed production time	switched to less electricity-reliant process	stopped electricity-intensive products	started less electricity-intensive products	laid off workers	changed location	took insurance policy	reduced shifts	operated fewer hours	temporarily sus-pended produc-tion
outage days	0.00516***	0.00377***	0.00125**	0.00118**	0.000743	0.00123	6.06e-05	7.40e-05	0.00105	0.00609***	0.00245**
	(0.00115)	(0.00106)	(0.000608)	(0.000481)	(0.000725)	(0.00106)	(0.000238)	(0.000232)	(0.000696)	(0.00139)	(0.00109)
no. of obs.	4,056	4,107	4,106	4,096	4,097	4,083	4,093	4,078	4,080	4,097	4,081
no. of firms	825	835	835	833	833	830	832	829	830	833	830

Notes: *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the firm level. All regressions include firm fixed effects, industry-year effects and location-year effects.

Table 5: Checking Validity of Reported Strategies

	(1)	(2)	(3)
	generated share of electricity	log(labor)	log(machinery)
outage days	0.00413***	-0.00245	-0.00846**
	(0.000735)	(0.00202)	(0.00351)
used generator	0.493***	0.00517	0.147**
	(0.0293)	(0.0418)	(0.0661)
changed production time	-0.0120	0.00676	-0.0186
	(0.0182)	(0.0568)	(0.0569)
switched to less electricity-reliant process	-0.0110	-0.0185	0.138*
	(0.0203)	(0.0814)	(0.0823)
stopped electricity-intensive products	-0.0446	0.0112	0.0264
	(0.0308)	(0.0559)	(0.109)
started less electricity-intensive products	-0.0122	0.00399	-0.0959
	(0.0225)	(0.0457)	(0.0827)
laid off workers	-0.0120	-0.141**	-0.200***
	(0.0203)	(0.0597)	(0.0472)
changed location	-0.0340	-0.0537	-0.150
	(0.0624)	(0.114)	(0.104)
took insurance policy	-0.0369	0.255	-0.0196
	(0.0369)	(0.182)	(0.233)
reduced shifts	-0.0391	0.111*	-0.00195
	(0.0250)	(0.0632)	(0.0648)
operated fewer hours	0.00838	0.0201	0.00785
	(0.0129)	(0.0323)	(0.0525)
temporarily suspended production	0.0206*	-0.0816**	-0.118
	(0.0120)	(0.0405)	(0.0738)
no. of observations	3,800	3,948	3,846
no. of firms	780	805	787

Notes: *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the firm level. All regressions include firm fixed effects, industry-year effects and location-year effects.

Table 6: Effectiveness of Strategies

	(1)	(2)	(3)
	log(output)	log(labor productivity)	log(tfp)
outage days	-0.0107***	-0.0130***	-0.00973***
	(0.00342)	(0.00363)	(0.00377)
used generator	0.0104	0.00804	-0.146*
	(0.0734)	(0.0768)	(0.0793)
changed production time	-0.0484	0.0299	0.0612
	(0.121)	(0.104)	(0.125)
switched to less electricity-reliant process	-0.00671	-0.0158	-0.0225
	(0.144)	(0.147)	(0.155)
stopped electricity-intensive products	0.0200	-0.0528	-0.0959
	(0.102)	(0.162)	(0.118)
started less electricity-intensive products	0.0208	0.0974	0.0891
	(0.101)	(0.101)	(0.105)
laid off workers	-0.136*	0.0388	-0.0306
	(0.0792)	(0.0844)	(0.0827)
changed location	0.0313	0.0943	0.133
	(0.0892)	(0.159)	(0.222)
took insurance policy	0.138	0.158	0.129
	(0.223)	(0.289)	(0.233)
reduced shifts	0.0289	-0.0681	-0.130
	(0.261)	(0.126)	(0.292)
operated fewer hours	0.0137	0.0368	-0.000534
	(0.0869)	(0.0668)	(0.0934)
temporarily suspended production	0.0841	-0.0449	0.122
	(0.118)	(0.0826)	(0.138)
no. of observations	3,901	3,745	3,606
no. of firms	799	781	745

Notes: *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level. Robust standard errors, in parentheses, are clustered at the firm level. All regressions include firm fixed effects, industry-year effects and location-year effects.

Table 7: Willingness to Pay

	(1)	(2)
	How much more are you willing to pay for uninterrupted electricity?	Difference between cost of self-generated and public grid electricity
mean	12.58%	322.22%
standard deviation	20.83%	525.60%
no. of firms	796	435