Addis Ababa University, Ethiopian Journal of Business and Economics, EJBE Vol.: 13, No.: 1,
Doi: *https://dx.doi.org/10.4314/ejbe/v12i1.1* p-**ISSN:** ***2311-9772*** **e-ISSN:** ***2410-2393***
Available online: http://ejol.aau.edu.et/index.php/ejbe and https://www.ajol.info/index.php/ejbe

The Impact of Power Outages on Firm Performance: Evidence from Ethiopia

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Abstract

An unreliable electricity supply has been identified as a major barrier to doing business in Ethiopia, causing firms to face costs from power disruptions. The main objective of this study is to examine the impact of power outages on firm performance using firm-level data derived from the 2015 World Bank's Enterprise Survey database. The study employed the Dose-Response Model to assess the impact of power outages and the dosage of treatment (i.e., average total time of power outages per month) on sales, employment, and labor productivity growth rates. The descriptive statistics revealed that of the 338 participating firms, 251 firms (nearly 74%) had dealt with frequent power shortages, while 87 firms said they had not experienced any power outages. Firms experienced 12.71 times power outages per month, while the typical average duration of each power outage was around 4.5 hours. The dose-response estimation result indicated that increasing the number of doses (level of power outage exposure) had a significant negative impact on sales, employment, and labor productivity growth rates. Therefore, it suggests that the government should supply sustainable power to firms and should also consider alternative sources to manage such interruptions.

Keywords: Power outages, Firm performance, Dose-response model

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Introduction

Numerous studies have shown that many of the Sub-Saharan African (SSA) population lacks access to clean and reliable energy. Approximately 600 million people, or nearly half of SSA's population, lack electricity access (IEA, 2019). Electricity is critical for economic growth and development, though poor electricity infrastructure remains a major daily or weekly challenge for households and firms in developing nations. Despite its importance, unreliable electricity supply continues to hinder populations across Sub-Saharan Africa, underscoring the need for infrastructure improvements (IEA, 2019). Studies by Moyo (2013) and Eberhard et al. (2011) identified factors contributing to inadequate electricity supply and frequent power outages in developing countries. These include flawed privatization policies, corruption, rising fuel prices, insufficient public investment, political instability, and poor infrastructure. Outages in these regions were not only frequent and prolonged but also unpredictable. The power supply is often characterized by unreliability and inefficiency, adversely impacting firm competitiveness, sales, and productivity (Moyo, 2013).

Power outages have both direct and indirect impacts on firm performance. Direct impacts may include disruptions to production processes and reductions in intermediate and final outputs (Fisher-Vanden, Mansur, & Wang, 2015). The increased shortages in power supply stimulate firms to undertake precautionary measures like utilizing alternative power sources such as generators (Fisher-Vanden, Mansur, and Wang, 2015). Firms' coping measures to deal with outages could impose additional economic costs. More frequent and longer power disruptions can accelerate the deterioration of production equipment, leading to breakdowns and damage. High outage frequency and duration can also negatively impact labor productivity and efficiency, generating opportunity costs from idle machinery and workers (Nooij et al., 2007). Indirect impacts like reduced demand can markedly decrease sales, efficiency, and productivity.

Power outages have become a common occurrence in many Sub-Saharan African countries. Despite Ethiopia's wealth of renewable energy sources like wind, solar, hydro, and geothermal, the country's power sector remains severely underdeveloped with the lowest per capita electricity consumption in Africa (Yurnaidi & Suduk, 2018). Even though it possesses substantial renewable energy potential, Ethiopia's electricity infrastructure and supply lag far behind, contributing to frequent power disruptions that hamper the economy.

Electricity is often the dominant energy source in manufacturing, making firms highly vulnerable to supply shortages. As Cissokho and Seck (2013) reported, power outages can disrupt business activities, eventually causing negative impacts on productivity. Many developing nations have restricted access to reliable electricity and suffer frequent unscheduled power interruptions. Unstable electrical supply negatively impacts investment choices and firm location. Several empirical studies have examined how poor power quality and frequent outages affect firm performance in developing countries (Abotsi, 2015; Scott et al., 2014).

Over the past two decades, Ethiopia has made notable progress in electricity access and generation capacity. However, national electrification is still only at 48% according to ESMAP (2022), leaving approximately 57 million Ethiopians without power. To address this deficit, Ethiopia's National Electrification Program roadmap sets 2025 targets of 65% grid and 35% decentralized electrification through mini-grids and standalone systems (MoWIE, 2017). Ethiopia's technical potential for electricity generation is immense at 650 TWh annually, with 40% deemed exploitable (Federal Democratic Republic of Ethiopia, 2012). Despite recent gains, electricity consumption per capita still lags behind other Sub-Saharan African nations. Ethiopia currently has around 4,965 MW of installed electricity generating capacity, with 89% coming from hydropower sources according to Ethiopian Electric Power (2015).

Several studies have examined the impacts of power outages on individual firms (Andersen & 0Dalgaard, 2013; Fisher-Vanden et al., 2015; Allcott et al., 2016). The impact of power outages on productivity and performance varies based on factors like a firm's vulnerability and response strategy (Oseni & Pollitt, 2015). Firms using generators encounter productivity impacts through reduced demand for other inputs. Meanwhile, firms that shut down or outsource have direct output reductions, often wasting non-storable inputs (Allcott et al, 2014). Power outages have both direct and indirect negative impacts on firm performance, leading to increased economic costs, lower production quantities, and reduced sales and productivity (Fisher-Vanden, Mansur, & Wang, 2015). Therefore, the overall objective of this study was to examine the impact of power outages on firm performance with a specific focus on the growth of a firm’s sales, employment, and labor productivity.

Literature Review

Technically, power outages are categorized into three types based on duration and effect: transient faults, brownouts, and blackouts (Sullivan et al., 2015). Transient faults involve power losses typically caused by issues on transmission lines, while brownouts mean voltage drops in an electrical power supply that can damage equipment. A blackout represents a severe power outage – a total loss of electricity to an area (Agarwal & Khandeparkar, 2021). Blackouts are complete power failures lasting hours or days that disrupt business operations and daily life. Blackouts may be planned or unexpected, often when transmission frequency drops too low. Rolling blackouts - regular outages rotating through areas are unfortunately common in developing nations due to supply shortfalls. As the authors explained, rolling blackouts are a measure of demand response when electricity demands exceed the power supply capability of the network. Whether unwarned or planned, blackouts and rationing symbolize system inadequacies and reliability challenges for emerging economies (Agarwal & Khandeparkar, 2021).

Studies from other regions like South Asia, East Asia, and the Pacific have also empirically analyzed the impact of electricity supply on firm productivity. Fernandes (2008) examined determinants of total factor productivity for firms in Bangladesh and found power supply problems significantly reduce firm performance. Similarly, Grainger and Zhang (2019) highlighted the negative impacts of power outages on manufacturing firms in Pakistan, indicating more reliable electricity would significantly improve productivity. Fisher-Vanden, Mansur, and Wang (2015) analyzed the economic and environmental impacts of electricity shortages in China. They found that firms facing limited power supply suffer reduced productivity. Frequent, lengthy outages may prompt companies to pursue alternatives like self-generation, purchasing intermediate goods, or improving technical efficiency. Using data on energy-intensive Chinese firms across industries, they found many firms underwent a re-optimization by shifting from energy to materials (buying vs. making) with no evidence of increased self-generation. Despite extra costs, firms partially reduced carbon emissions.

Ba Trung and Kaizoji (2017) revealed how the business environment impacts manufacturing firm productivity in Vietnam. They found that inadequate electricity supply has negative impacts on firm performance. The researchers suggested Vietnam and other developing countries need institutional reforms to improve infrastructure and public goods/services provision, including reliable power. There is a range of factors that can lead to power outages, such as overloaded systems, aging infrastructure, severe weather events, equipment failures, and accidents (LaCommare and Eto, 2006; Ouedraogo, 2017). The impacts of outages span business disruptions, economic costs, social effects, and health risks. As stated by Bruch (2011), power outages are typically caused not by a single event but by a combination of factors or deficiencies. To address the multifaceted drivers of power supply instability, experts recommend comprehensive strategies (*technical, economic, and governance interventions*) combining demand management, infrastructure upgrades, new smart grid technologies, emergency preparedness, and policy reforms (EAI, 2020). Figure 1 illustrates the potential causes of power outages and associated impacts on business firms.

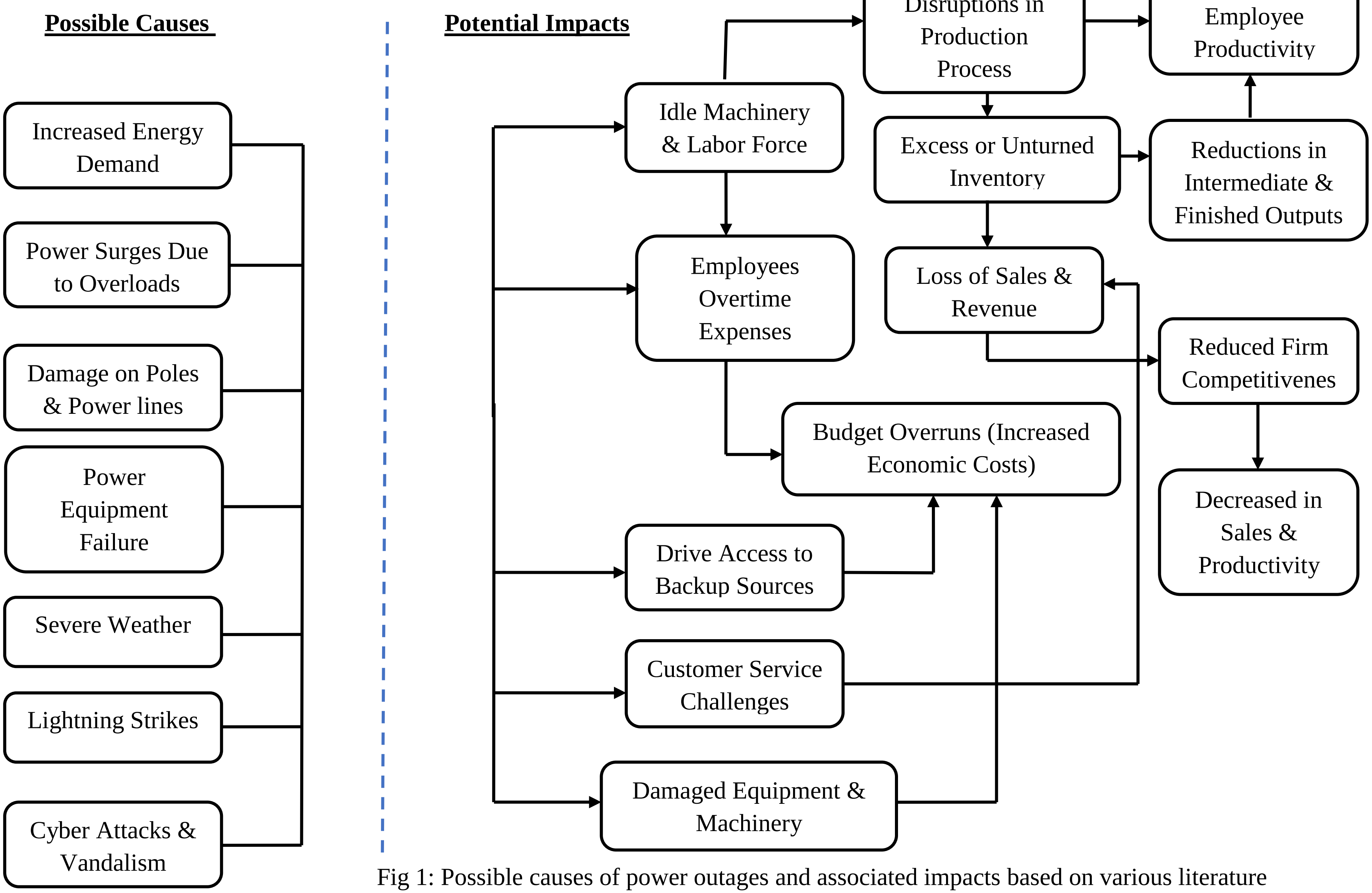

Fig 1: Possible causes of power outages and associated impacts based on various literature

To mitigate the negative impacts of power outages, firms in developing nations employed various coping strategies like adjusting operations, improving input storage capacity, and investing in backup electricity production using diesel generators. However, self-generating with diesel generators might be extremely costly for manufacturers. In Sub-Saharan Africa, studies have found that self-generating electricity costs 3-10 times more than grid electricity (Eifert et al., 2008; Foster & Steinbuks, 2009). Firms using generators still face output losses from restarting machines after outages. Self-generation may be insufficient for full-capacity production (Beenstock, 1991). Besides, diesel generators also have negative impacts on local air quality and increase noise pollution.

Studies have quantified outage costs for African manufacturers. Diboma and Tatietse (2013) estimated power interruptions cost Cameroonian industries 20-33% less with advance notices. Mensah (2016) analyzed 15 Sub-Saharan countries using World Bank Enterprise Survey (WBES) data and found a 1% increase in outages was associated with a 0.6% decrease in firm productivity. Other studies have also found negative productivity and output impacts from power outages. Allcott et al. (2014) showed outages reduced output by around 5% for Indian manufacturers, though productivity effects were smaller since inputs can be stored. Yeaple and Golub (2007) also used data on developed and developing countries and found better power infrastructure increased productivity, with outages hampering performance. Also, Um et al. (2009) revealed adequate infrastructure including reliable electricity positively impacted economic growth and total factor productivity in the Middle East and North Africa (MENA) region.

Method of Research

The study used World Bank Enterprise Survey (WBES) data to examine the impact of power outages on a firm's performance. The survey collects firsthand data from private companies in economies globally. It surveys a representative sample of the private sector in each country. The survey covers many aspects of the business climate like access to finance, trade, corruption, innovation and technology, infrastructure, competition, and business performance measures. The World Bank has conducted firm-level surveys since the 1990s through different units. The main sectors are manufacturing and services. Firms entirely government-owned are excluded. Two standardized questionnaires are used - manufacturing and services. The sampling methodology is stratified random sampling, dividing firms into strata by size, sector, and region within a country.

The 2015 Enterprise Survey used stratified random sampling, stratifying firms by size, sector, and geographic region following the standard methodology (World Bank, 2015). Industries were stratified into four manufacturing sectors (food/beverages, textile/garments/leather, non-metallic mineral products, and other manufacturing) and three service sectors (transportation, retail, and other services). Size stratification classified firms as small (5-19 employees), medium (20-99), or large (100+). Regional stratification was across four regions and two administrative cities: Addis Ababa, Dire Dawa, Amhara, Oromia, Southern Nations, Nationalities and People's (SNNPR), and Tigray. The survey ensured representation across key firm characteristics and geographic areas.

The study used data analysis to transform raw data into relevant, valid, and meaningful summaries that align with the study objectives. For this study, both descriptive and inferential statistics were used to analyze the data. Descriptive statistics were used to summarize the basic properties and patterns in a dataset through numerical calculations and graphs, while inferential statistics were employed to assess relationships between/among variables, compare groups using methods like t-tests, and test theoretical models or hypotheses. This study utilized a Dose-Response estimation to analyze the dosage of power outages on firm performance.

The dose-response model was originally developed by Hirano and Imbens (2004) to assess the effects of programs or interventions where the treatment exposure is continuous. The model expands on existing propensity score methods used for binary treatment group assignments (Rosenbaum and Rubin, 1984) and treatments with multiple levels (Imbens, 2000). It also estimates a dose-response relationship using a generalized propensity score (GPS). The GPS has a balancing property similar to the binary propensity score. A dose-response function can be calculated using regression when treatment is continuous, individuals respond differently to observable confounders, and treatment selection is endogenous. For program evaluation, what is often relevant is not just binary treatment status but the level of exposure or dose from an agency.

Dose-response functions are usually estimated to check resilience to different intervention levels. Consider a policy program where treatment is not randomly assigned and the program provides varying exposure levels after setting who is treated. This forms two groups - untreated, with a zero dose, and treated, with a dose above zero. When estimating a dose-response function, the goal is to determine the causal relationship between the level of a treatment (t) and an outcome (y). To do this for an observed sample, accounting for differences in how units may respond to observable confounders and the intensity of the treatment. The aim is to estimate the dose-response function whether treatment selection is exogenous (depends only on observables) or endogenous (depends on unobservable too). Overall, it's crucial to quantify the dose-response relationship while addressing the potential endogeneity of treatment selection and heterogeneous responses to confounders and treatment intensity. The dose-response function characterizes how the outcome changes across different levels of treatment exposure given the following variables.

Power outages: It is the "dose" variable being treated as continuous in the context of the dose-response analysis. The incidence ranges from 0 to 100, where '0' shows no power outages and '100' depicts a maximum frequency of power outages. It is the average total time of power outages per month and is calculated as the interaction of the number of outages and duration of outages.

Firm age: It's a covariate that represents the age of a typical firm in years.

Frequency of power outages: It refers to the number of power outages that a firm experiences in a typical month.

Duration of power outages: It's the amount of time that a typical power outage lasts in hours.

%_electricity generator: It refers to the share/percentage of electricity that a firm gets from a generator.

Material inputs origin: It's the percentage/proportion of material inputs and/or supplies that are of domestic origin.

Product innovation: It's a dummy variable that shows whether a firm introduced new or significantly improved products or services over the last three years, and takes value 1 when a firm introduced product innovation, and 0 otherwise.

Fixed assets: It's a dummy variable that depicts whether a firm purchased any new or used fixed assets, such as machinery, vehicles, equipment, land, or buildings in the last fiscal year. It takes a value of 1 when a firm purchased any fixed assets, and 0 otherwise.

Length of temporary workers: It's the average length of full-time seasonal or temporary workers employed last fiscal year, in months.

Annual sales growth: It's defined as the percentage change in real total sales between the last completed fiscal year and a previous period for both control and treated firms (firms experienced power outages). All sales values are deflated to 2009 using Ethiopia's GDP deflator.[2] The annual sales growth rate is calculated by the following formula (World Bank, 2015):

$$Annual\ sales\ growth = \left(\frac{1}{t}\right) * \frac{(d2' - n3')}{(d2' + n3')/2} * 100 \quad (1)$$

Where,

t = the number of years between the current and previous periods (i.e., 3 years),

d2 = the total annual sales for all products and services end of the last fiscal year,

n3 = the total annual sales three fiscal years ago, and *d2'* and *n3'* are deflated values of *d2* and *n3* variables.

Annual employment growth: This refers to the change in permanent full-time employment reported in the current fiscal year from a previous period for both control and treated firms. For Ethiopia, the difference between the two fiscal year periods is three years. The annualized growth is determined by the following formula (World Bank, 2015):

$$Annual\ employment\ growth = \left(\frac{1}{t}\right) * \frac{(l1 - l2)}{(l1 + l2)/2} * 100 \quad (2)$$

Where,

t = the number of years between the current and previous periods (3 years),

$l1$ = the number of full-time permanent workers end of the last fiscal year, and

$l2$ = the number of full-time permanent workers three fiscal years ago.

Annual labor productivity growth: It's measured by a percentage change in labor productivity between the last completed fiscal year and a previous period, where labor productivity is sales divided by the number of full-time permanent workers. All sales values are deflated to 2009 using

[2] GDP deflators are from the World Development Indicators,

Ethiopia's GDP deflator. The annual labor productivity growth rate is calculated by the following formula (World Bank, 2015):

$$Annual\ labor\ productivity\ growth = \left(\frac{1}{t}\right) * \frac{\left(\frac{d2'}{l1}\right) - \left(\frac{n3'}{l2}\right)}{\left\{\left(\frac{d2'}{l1}\right) + \left(\frac{n3'}{l2}\right)\right\}/2} * 100 \qquad (3)$$

where 't' is the number of years between the current and previous periods (3 years), *l1* and *l2* are the number of full-time permanent workers end of the last fiscal year and three fiscal years ago respectively, and *d2'* and *n3'* are deflated values of *d2* and *n3* variables.

Data Presentation, Analysis, and Interpretation

Descriptive Statistics

The study comprised 251 treated groups with power outage and 87 control groups, and it accounted for 74.26% and 25.74 % of the total population of the study as indicated in the table below. The summary for continuous variables indicated that the average age of firms was 13 years and the standard deviation of the whole sample was 10.92 years.

Table 1: Frequency distribution of power outage incidence

Power_Out_Inc	Freq.	Percent	Cum.
0	87	25.74	25.74
1	251	74.26	100.00
Total	338	100.00	

Table 2: Summary of continuous variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Firm Age	338	13.092	10.918	3	83
Electricity Generator	338	10.731	23.343	0	98
Domestic Material	338	30.68	43.456	0	100
Temp Workers Emp	338	1.482	2.524	0	12

The descriptive statistics revealed that, on average 10.73% of firms obtained their electricity demand from generators due to power outages. On average, 30.68% of firms also obtained their main inputs domestically, while 33.43% of firms introduced new or significantly improved products and services (innovations) over the last three years. Also, on average, 26.03% of firms purchased fixed assets such as land, machinery, and buildings during the last fiscal year. The World Bank Enterprise Survey provides data on the number of power outages in a typical month, the duration of a typical single outage incident, and the total monthly duration of power outages as indicated below. The last metric is calculated by combining the data on outage frequency and average incident duration. Table 3 indicated that on average, firms experienced 12.71 times power outages per month, while the typical average duration of each power outage was around 4.5 hours. The data revealed that on average, firms in Ethiopia experienced a total of 57 hours of power outages per month.

Table 3: Summary of power outage variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Num Power Outages	338	12.713	14.371	0	16
Duration Power Outage	338	4.508	4.083	0	24
Total Time Power Outage	338	57.325	43.548	0	384

The descriptive statistics also revealed the average annual sales and labor productivity growth rates of -2.83% and -3.73% accompanied by standard deviations of 17.84% and 16.90% respectively.

The average annual employment growth rate stands at 3.37% with a standard deviation of 12.29% as indicated below.

Table 4: Summary of dependent variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Sales Growth Rate	338	-2.834	17.846	-60.284	58.333
Employment Growth	338	3.369	12.296	-40.86	50.98
Labor Productivity	338	-3.733	16.904	-55.657	58.333

These power disruptions are predicted to negatively impact firms' performance, as reflected in decreased productivity and lower production/sales (Moyo 2013; Fisher-Vanden, Mansur, and Wang 2015). The impact of power outages on employment levels is debatable and could have ambiguous effects. Frequent power outages could restrict firms' potential for growth, resulting in slower job creation. However, when outages leave machinery and equipment inoperative, firms may be forced to offset these losses by hiring additional labor.

The study conducted t-tests to show which covariates need to be included in the dose-response estimation. For instance, the following table shows the t-statistic for firm age is -3.0212, indicating that the mean of the control group is lower than the treated group thereby the difference between the group means is statistically significant (P<0.05) as indicated below.

Table 5: Two-sample t-tests with equal variances - Firm_Age

	obs1	obs2	Mean1	Mean2	dif	St Err	t value	p value
Firm_Age by Power	87	251	10.081	14.136	-4.055	1.342	-3.02	.003

Results of Dose-Response Estimation

The study employed a dose-response estimation technique to investigate the potential impact of the level of treatment (i.e., power outages) on sales growth rate, employment growth rate, and labor productivity growth based on the 2015 World Bank Enterprise Survey (WBES). The study used a "**ctreatreg**" command, a dose-response model with continuous treatment, endogeneity and heterogenous response to observable confounders estimates the Dose-Response-Function (DRF) of a given treatment on a specific variable, within a model where units are treated with different levels. The DRF is the average treatment effect, given the level of the treatment ‘t’ (i.e., ATE (t)). The impacts of power outages on sales growth, employment growth, and labor productivity growth using the dose-response method are presented below.

Impact of Power Outages on Sales Growth

The power outage incidence had a significant negative impact on the sales growth rate as the dose (treatment) increased; this significant negative impact became higher (13.19), as shown in Table 1 (ref. Appendix A). This quantifies the impact of rising power interruptions - for each additional outage, the model predicts a 13.19-unit reduction in sales growth. Compared to non-treated groups, firm age and acquisition of fixed assets have a significant positive impact on a firm’s sales growth. This revealed that firm age is statistically significant at a 10% level, and increases by 0.633 as the dose increases, on average. This can be due to the fact that older firms tend to experience higher sales growth compared to younger firms. The study also revealed that the level of fixed assets is statistically significant at the 1% level, and increases by 2.885 as the average dose increases, while variables such as share of electricity generator, domestic material inputs, product innovation, and length of temporary workers' employment do not show significant impacts on sales growth. The impact of level of power outage incidence (treatment variable) on firms’ sales growth rate was demonstrated using a dose-response model, as illustrated in Figure 2 below.

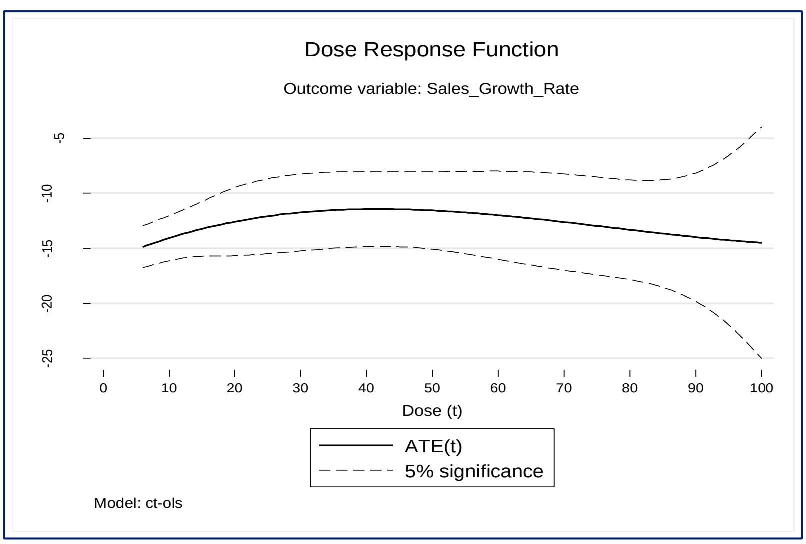

Fig. 2: Dose-response function: power outages intensity & firm's sales growth

The plot of the Dose-Response Function (DRF) graph also demonstrates the negative relationship between power outages and sales growth, and the impact becomes greater when the dose of treatment increases. This implies that for firms that had experienced recurring power outages per month, its impact on sales growth would be greater compared with those firms that had experienced a few power outages per month. This finding is in line with the arguments from Allcott et al. (2016), Steinbuks and Foster (2010), and Andersen and Dalgaard (2013) that power outages may have a significant negative impact on sales growth. This can be because outages may limit a firm's ability to produce goods and services, damage unfinished products and inventory, and expend resources on backup power and other outage mitigation efforts. The plot of the DRF also showed that the sales growth is weakly increasing (positive relationship), but then after forty doses of power outages (hours), it's more strongly decreasing for higher levels of the dose (i.e., their relationship becomes negative). This can be due to the fact that during prolonged power outages, firms may be unable to serve customers and resulting in a loss of sales opportunities and potential customers switching to competitors.

Impact of Power Outages on Employment Growth

An increase in power outages is associated with a decrease in a firm's employment growth as indicated in Table 2 (ref. Appendix A). The coefficient (-3.343) represents a firm's employment growth decreases by 3.343 as the dose increases, on average. The table also shows that material inputs of domestic origin and the length of temporary employment have a positive significance on the employment growth rate at a confidence level of 95%. However, product innovation and the purchase of fixed assets decrease the employment growth rate of firms significantly. This argument is consistent with the argument from descriptive statistics that power outages and the purchase of fixed assets have a negative correlation with the employment growth rate. This finding is also in line with the arguments from Smith et.al (2021), Lee and Park (2019), and Rodriguez and Sanderson (2020) that temporary employment and material inputs of domestic origin have a positive impact on employment growth rate. They argue this is due to domestic inputs supporting more labor-intensive production processes, especially for smaller firms. Also, a study conducted by Harrison et.al (2014) suggested that innovation drastically changes workflows that can displace workers in the short run, thereby impacting short-term employment growth rates.

The impact of power outage intensities on the firm's employment growth rates, as plotted in Figure 3 below shows the firm's employment growth decreases and becomes insignificant as power outage intensities range from 30% to 80%. This result may be due to prolonged power outages can substantially force some businesses to lay off or hire freezes to cut costs until operations can return to normal (more reliable power supply is restored). In addition, when power outage intensities are not yet sufficiently high (below 60 %), it may be that the cost of introducing alternative power sources is so high that labor needs to be saved to cut down the costs to survive. This argument is in favor of Barthold et al. (2019) that frequent power outages declined output and thereby firms started to lay off workers.

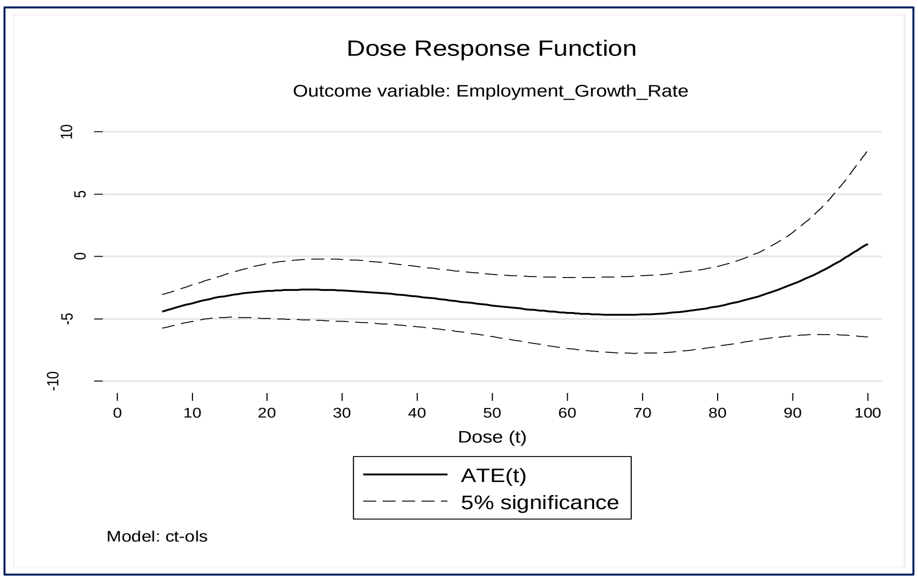

Fig.3: Dose-response function: power outage intensity & firm's employment growth

Impact of Power Outages on Labor Productivity Growth

When firms experience frequent or prolonged power outages, it will have a significant negative impact on labor productivity growth as the dose (treatment) increases. This significant negative impact becomes higher (7.999), as shown in Table 3 (ref. Appendix A). This argument is in favor of Allcott et al. (2016), Fisher-Vanden et al. (2015), and Arnold et al. (2008) that power outages directly halt or slow production processes, reducing output per worker (i.e., due to work time wastage during outages), thereby lowering productivity. The plot of the dose-response function as illustrated in Figure 4 also exhibits the negative relationship between power outage doses and labor productivity growth of firms, and the impact becomes greater when the dose increases.

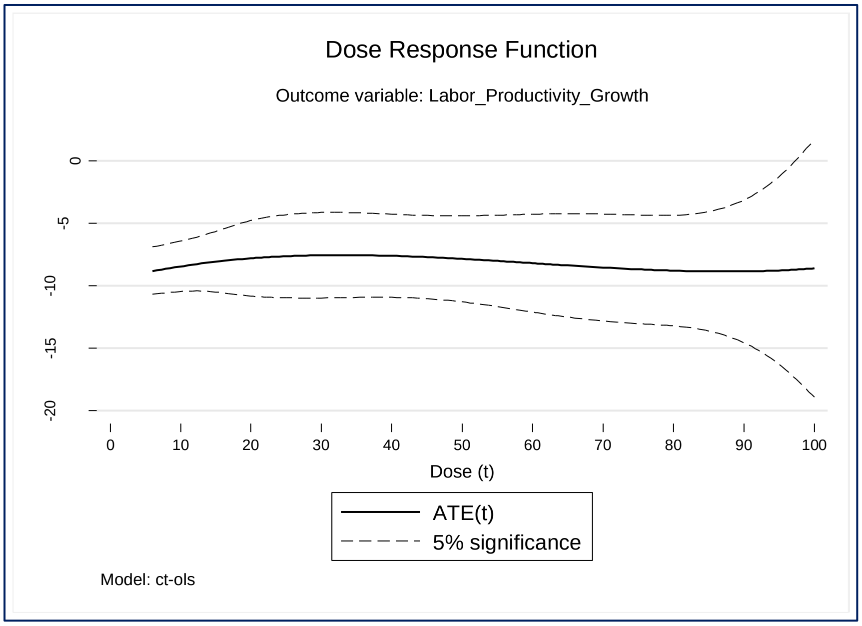

Fig.4: Dose-response function: Power outage intensity and firm's labor productivity growth

This implies that for firms that had experienced prolonged power outages per month, its impact on labor productivity growth would be greater compared with those firms that had experienced a few power outages per month. This finding is in line with the arguments from Andersen and Dalgaard (2013), Allcott et al. (2016), and Oseni and Pollitt (2015) that frequent power outages may have a significant negative impact on a firm's labor productivity growth. The plot of the DRF indicated that power outage intensity is associated with a 10 percent lower level of labor productivity growth rate. The labor productivity growth decreases and becomes insignificant as power outage intensities range from 25% to 90%.

Conclusion and Policy Implication

The objective of this study was to examine the impact of the level of power outages on firm performance. The study used 2015 World Bank Enterprise Survey data with the specific objective of examining the impact of power outages on a firm's sales growth, employment growth, and labor productivity growth. The descriptive statistics revealed that of the 338 participating firms, 251 firms (nearly 74%) had dealt with frequent power shortages, while 87 firms said they had not experienced any power outages. The dose-response estimation indicated that increasing the number of doses (level of power outage exposure) had a significant negative impact on the performance of firms. Compared to non-treated groups, the firm's sales growth. Employment growth and labor productivity growth decreased by 13.19, 3.343, and 7.999 as the dose increased, on average respectively. Firm age and acquisition of fixed assets have a significant positive impact on a firm's sales growth, while the share of electricity generators, domestic material inputs, product innovation, and length of temporary workers' employment do not show significant impacts on sales growth. Domestic material inputs and the length of temporary employment have also a positive significant impact on employment growth at a confidence level of 95%. However, product innovation and the purchase of fixed assets decreased the employment growth rate of firms significantly.

Based on the research findings and conclusions mentioned above, the researcher suggests some recommendations for future related studies.

- Power outages are typically caused by a range of factors. The government or police makers need to implement a comprehensive strategy including technical, economic, and governance interventions to address the multifaceted challenges.
- The significance of the impact of power outages on firm performance conveys the need to improve the power infrastructure and the reliability of power supply could be enhanced through the implementation of market-based reforms to the energy sector in Ethiopia.
- Manufacturing firms should have an emergency plan to withstand the impact of power outages by installing alternative backup sources like diesel generators to maintain operations during power outages and adjust their working behavior as well as outsourcing energy-intensive activities.
- Further empirical studies are still required to examine how firms in Ethiopia adapt to power outages, and what are the main firm characteristics that determine the capacity of adjustments to power outages.
- The government of Ethiopia should create the environment to enhance private sector participation in the power sector to boost competition and efficiency in the supply of power for the firms and ensure long-term finance for energy projects.

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Appendix A

Table 1: Power outages and sales growth

VARIABLES	Sales_Growth_Rate
Power_Out_Inc	-13.19***
	(2.796)
Firm_Age	0.633*
	(0.326)
_Electricity_Generator	0.0814
	(0.0718)
Domestic_Material_Inputs	-0.0328
	(0.0517)
Product_Innovation	0.663
	(2.094)
Fixed_Assets	2.885
	(2.194)
Tempo_Workers_Employment	-0.594
	(1.576)
_ws_Firm_Age	-0.529
	(0.338)
_ws__Electricity_Generator	-0.0309
	(0.0881)
_ws_Domestic_Material_Inputs	-0.00504
	(0.0573)
_ws_Tempo_Workers_Employment	-0.414
	(1.621)
Tw_1	0.268
	(0.280)
Tw_2	-0.00441
	(0.00731)
Tw_3	1.91e-05
	(5.16e-05)
Constant	-1.425
	(3.847)
Observations	338
R-squared	0.137

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2: Power outages and employment growth

VARIABLES	Employment_Growth_Rate
Power_Out_Inc	-3.343*
	(1.984)
Firm_Age	-0.0849
	(0.231)
_Electricity_Generator	0.0131
	(0.0509)
Domestic_Material_Inputs	-0.0637*
	(0.0367)
Product_Innovation	2.726*
	(1.486)
Fixed_Assets	-2.505
	(1.557)
Tempo_Workers_Employment	3.035***
	(1.119)
_ws_Firm_Age	-0.0557
	(0.240)
_ws__Electricity_Generator	-0.0283
	(0.0625)
_ws_Domestic_Material_Inputs	0.0730*
	(0.0406)
_ws_Tempo_Workers_Employment	-3.663***
	(1.150)
Tw_1	0.288
	(0.199)
Tw_2	-0.00777
	(0.00519)
Tw_3	5.58e-05
	(3.66e-05)
Constant	4.193
	(2.730)
Observations	338
R-squared	0.084

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Power outages and labor productivity growth

VARIABLES	Labor_Productivity_Growth
Power_Out_Inc	-7.999***
	(2.734)
Firm_Age	0.551*
	(0.319)
_Electricity_Generator	-0.0343
	(0.0702)
Domestic_Material_Inputs	0.0809
	(0.0506)
Product_Innovation	-0.303
	(2.047)
Fixed_Assets	2.160
	(2.145)
Tempo_Workers_Employment	-2.347
	(1.541)
_ws_Firm_Age	-0.528
	(0.331)
_ws__Electricity_Generator	0.111
	(0.0862)
_ws_Domestic_Material_Inputs	-0.106*
	(0.0560)
_ws_Tempo_Workers_Employment	1.557
	(1.585)
Tw_1	0.141
	(0.273)
Tw_2	-0.00294
	(0.00714)
Tw_3	1.63e-05
	(5.05e-05)
Constant	-3.933
	(3.762)
Observations	338
R-squared	0.080

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1