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DEVELOPMENT ECONOMICS | RESEARCH ARTICLE

Firm performance in sub-Saharan Africa: What role do electricity shortages play?

Samuel Osei-Gyebi^{1*} and John Bosco Dramani²

Abstract: Electricity outages affect the performance of firms in sub-Saharan Africa (SSA) through a reduction in production capacity and over-reliance on backup generators, which raises the cost of production and render them uncompetitive. Based on this, we estimated the joint effect of electricity outage frequency and duration of outages on the performance of firms in SSA through the method of instrumental variable (IV). Employing firm-level data from the World Bank Enterprise Survey for 28 SSA countries from 2007 to 2018, the study found a unit increase in outage frequency and its duration combine to reduce yearly sales of firms in SSA by \$114.9. Also, the study revealed that small-size firms in SSA incur \$408.894 losses relative to large firms for every joint increase in outage frequency and outage duration largely because they cannot cope with electricity outages. Since electricity shortages persist in SSA, mitigation policies must target small firms as they are the worst affected by electricity outages.

Subjects: Microeconomics; Industrial Economics; Development Economics

Keywords: electricity shortages; firm performance; endogeneity; PCA; SSA

JEL Classification: C26; D24; Q49

1. Introduction

The Sustainable Energy For All (SE4ALL) program aims to provide clean and affordable energy for everyone in the world by 2030. This forms part of a broader target by the United Nations (UN) as contained in goal seven of the Sustainable Development Goals (SDG). The achievement of this goal will contribute to the attainment of other goals such as ensuring that people have good health and wellbeing. Therefore, governments at both national and international levels have made several efforts to provide clean energy like electricity for the teeming number of people around the world who still do not have access. Despite these efforts, 573 million people in sub-Saharan Africa (SSA) are still without electricity (International Energy Agency [IEA], 2018). This means more than half of the over one billion people in SSA remain in the dark and the access rate remains below 25% in 15 of the 48 countries in the region (IEA, 2018). Current data shows the number increased by

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20 million people in 2020 alone, raising the total number to 775 million people (World Bank, 2023). Countries in SSA that are fortunate to have access to electricity have to deal with rampant and erratic outages which greatly affect the operations of firms. This situation can largely be explained by the low generation capacity in SSA, which leaves most people either with no access to electricity or shortfalls in its supply.

According to the Energy Information Administration (2018), the total installed capacity for electricity generation in SSA was 96 giga-watts as of 2015, representing an increase of 40% from 68 giga-watts in 2008. However, Eberhard et al. (2008) indicated that the increase in capacity is insufficient in providing adequate access when compared to other developing regions such as Southeast Asia. Another contributing factor to low electricity access in SSA is the minimal utilization of its limited generation capacity (IEA, 2018). Only 40% of SSA's potential electricity was produced in 2015 and the percentage is even lower for countries such as Ghana, Swaziland, Nigeria, Mali, and Benin with utilization rates of 34%, 22%, 35%, 22%, and 10%, respectively (World Bank, 2015). 2018 Meanwhile, SSA has vast potential in renewable energy and can derive almost half of its power from renewable energy sources by 2040 but no concrete efforts have been initiated to harness it so far (IEA, 2018).

The utilization of electricity by firms influences their activities in several ways. First, firms can make use of capital-intensive methods of production which are mostly dependent on electricity (Torero, 2015). The efficiency and speed that such methods of production provide lead to increases in productivity, output, sales, and profits of firms in SSA (Cole et al., 2018). Electricity also enables firms to operate at full capacity to meet their demand requirement, expand production, reap the benefits of economies of scale, and be able to employ additional workers (Cole et al., 2018). Besides, the use of adequate electricity by firms in SSA makes them readier to honor their tax obligations as findings suggest that governments in SSA can generate more than \$9.5 billion in tax revenue every year just by improving the quality of electricity supply (Blimpo et al., 2019). Currently, Hannah et al. (2023) noted that corporate income tax constitutes 18.8% of government revenue while the World Bank (2023) report indicated that employment by manufacturing firms in SSA represents just 3% of total employment. These benefits can be enhanced if firms have an adequate electricity supply.

Firms are likely to switch away from grid- electricity to off-grid electricity and to less electricity-dependent production when electricity supply is unreliable (Allcott et al., 2016; Abeberese, 2013). Moreover, they experience a decrease in the productivity of labor and intensive use of machines- due to a reduction in their size and amount of production. This adversely affects their performance resulting in losses that can be as high as 23% of annual sales in the Central African Republic (Mensah, 2016). Firms in SSA may also resort to self-generation by sharing or owning a generator with more than 80% of firms in Nigeria having a backup generator. However, self-generation is estimated to be 313% more expensive than grid electricity in SSA, which does not address the problem as the increased cost of production reduces their performance (Alby et al., 2013; Mensah, 2016). Consequently, firms in SSA are uncompetitive in the world market and unable to generate more employment (Alby et al., 2013; Mensah, 2016).

Most extant studies estimated the effect of electricity outages on firm performance using the number of times a firm goes without electricity within a year to capture electricity outages (Alam, 2013; Mensah, 2016). Although the frequency of electricity outages explicitly measures the effect of outages, it is not adequate since the duration of outages, low voltage, and faulty meters are equally important factors in estimating the effect on the performance of firms (Scoth & Seth, 2013). A prolonged duration of outages has the potential to cause high losses among firms as it renders machines idle and reduces production hours. Low voltage also damages older machines causing huge financial loss to firms. Cole et al. (2018) included the duration of outages together with outage frequency in SSA but failed to examine their joint effect on firm performance.

We bridge the gap in literature by making the following contributions. First, we construct an index of electricity outage using principal component analysis (PCA) which captures the frequency of electricity outage and duration of outages and analyze its effect on firm performance, instead of using a single indicator of outage as done by most past studies. Again, we analyze the effect of electricity outages on performance based on firm size. We verified the claim that small-size firms tend to suffer more because they are less resourceful to mitigate the effects of electricity shortages (Ado & Josiah, 2015; Hardy & Mccasland, 2019). Finally, recent studies such as Cole et al. (2018) and Mensah (2016) used sample data on firms from 14 and 15 countries respectively. We employ a greater sample size (28 out of the 48 countries in SSA) which provides a more comprehensive coverage of countries in estimating the effect of electricity outages on the performance of firms in the region. On that basis, the current study sought to answer two main questions. First, what is the joint effect of outage frequency and its duration on the performance of firms in SSA? Secondly, how does the effect of electricity outage on firm performance differ for large and small firms?

The findings of the study show that the joint effect of electricity shortages on the performance of firms in SSA is more pronounced than the individual effects of outage frequency and duration. Precisely, outage frequency and outage duration combine to reduce the yearly sales of firms by \$114.9 which cripple firms making them uncompetitive. Further findings show that the impact of electricity shortages on large firms is relatively low because they have the financial strength to mitigate the effects. Policies to assist firms to withstand electricity outages must therefore target small firms as they are the worst affected. Also, the regional dimension shows a “one-size-fits-all” policy to tackle the outage problem in SSA will be unsuccessful due to the peculiarities among the countries in each region.

The remainder of this paper is organized as follows. Section two reviews the relevant literature on theories and empirical studies as far as electricity outages and firm performance in SSA are concerned. The next section outlines the methodology adopted by the study while section four presents empirical results and its discussions. The paper is concluded in section five by presenting conclusions, policy recommendations, and limitations of the study.

2. Literature review

2.1. Electricity infrastructure, electricity consumption, and economic growth

Electricity as an infrastructure requires massive investment in its provision. The accelerator theory of investment postulates that investments are made out of resources available to an institution or a country (Clark, 1932). This means the smaller the funds available to a country, the lower will be their investment holding all other factors constant. Due to inadequate funds, most countries in SSA tend to have infrastructural deficits which affects the provision of electricity. Several studies have documented the link between electricity infrastructure, economic activities, and economic growth to a larger extent. The emphasis of these studies dwells on how electricity infrastructure facilitates economic activities and the drag on economies when it's inadequate.

After the findings of Kraft and Kraft (1978), studies such as Torero (2015) examined how electricity infrastructure increases hours worked, productivity, efficiency, and income. The author showed that adequate power supply allows individuals to work day and night which increases hours worked and productivity. Additionally, Ghosh (2000) noted that increases in economic growth result in improvements in the consumption of electricity in India. Even though the effect was unidirectional, it essentially implies an increase in productive economic activities due to higher income requires more electricity consumption.

In Ivory Coast, Kouakou (2000) revealed a two-way relationship between national income and electricity consumption in per capita terms. Using Granger causality, the author observes the causation of electricity consumption from increases in national output and vice versa. In a related

study, Mozumder and Marathe (2007) using a Vector Error Correction (VEC) model found a one-way effect of GDP per capita on the consumption of electricity per capita in Bangladesh. Also, Ouedraogo (2010) and Shiu and Lam (2004) noted the positive effects of electricity infrastructure on economic activities in Burkina Faso and China, respectively. These and many other studies emphasized the importance of adequate electricity in an economy and the harm it does when supply is limited.

2.2. Electricity shortages and firm performance in SSA

Roads, railways, electricity, and telecommunications are needed for the smooth operation of businesses (Arnold et al., 2008). The availability of such infrastructure has both direct and indirect effects on the operations of firms. According to Wan and Zhang (2017), the direct benefit of infrastructure emanates from the direct usage of the infrastructure. For instance, the transport system enables firms to expand their customer base by reaching out to new areas. The indirect effects consist of cost reduction advantages and positive spillovers due to the agglomeration of activities by firms. It follows that shortages in such infrastructure have damaging effects on the performance of firms.

One area of this impact is in the payment of their taxes. The internal fund theory of investment postulates firms make additional investments by ploughing back their profits (Stevens, 1994). It, therefore, means that governments' revenue will increase if businesses make more profits and undertake more investments. The operation of firms under electricity constraints hinders their expansion and reduces the potential tax base of the government in the long run. The opposite is the case when there is adequate electricity infrastructure. The literature is replete with studies that showed how infrastructure deficits affect the performance of firms.

Abdisa (2019) examined the effect of infrastructure on the investment climate and concludes SSA firms would have incurred at least 36% more losses as a result of poor electricity infrastructure in the absence of an alternative source of power. Arnold et al. (2008) also documented that infrastructure such as electricity serves as essential input for the activities of firms stressing that electricity greatly improves the productivity of manufacturing firms in Africa. Furthermore, Tuong et al. (2019) found a positive relationship between road infrastructure and the performance of firms. Their study noted road infrastructure lowers operation cost and expands market access for firms which improve their performance. 20132016201820162013

Added to the above, Blimpo and Cosgrove-Davies (2019) revealed how electricity outages impact the revenue generation of governments in SSA noting the region can increase revenue by 4.3% if electricity constraints are resolved. Several other studies have found the revenues, productivity, and profit of firms to experience massive declines as a result of electricity outages with those without stand-by generators being the most affected (Alam, 2013; Allcott et al., 2016; Cole et al., 2018; Mensah, 2016; Scoth & Seth, 2013). These findings are part of the numerous and growing evidence of the essence of electricity infrastructure to the performance of firms and how their production is hampered when its provision is inadequate.

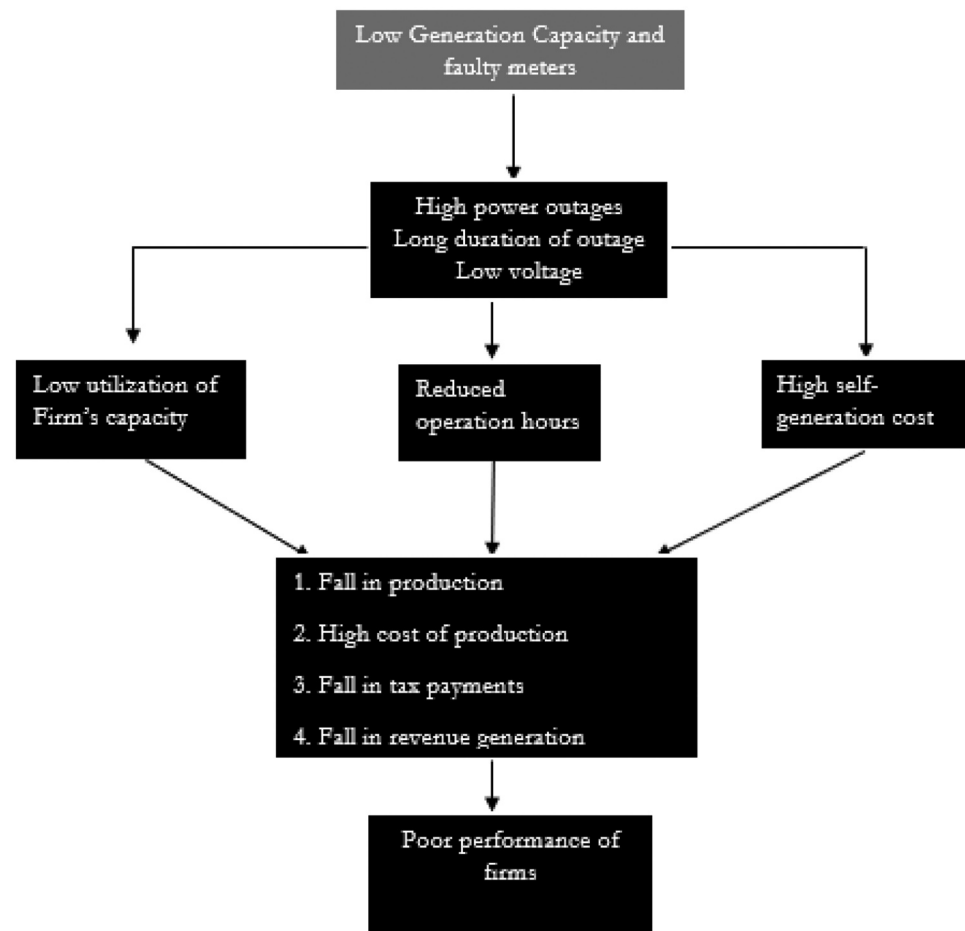
Most recently, Elliott et al. (2021) used data on Vietnam to show how electricity shortages affect firm performance. Employing Instrumental Variable (IV) approach to the World Bank Enterprise Survey (WBES) data, their findings showed that reducing electricity outages will increase the firm's contribution to Vietnam's revenue. Similar to other studies, their findings revealed that firms are constrained by power outages, which reduce their contribution to revenue generation in Vietnam. Introducing electoral outcomes into the discussion, Pinar et al. (2021) showed that power outages are low in regions where the incumbent receives more votes, which means firms located in those areas are less affected by electricity shortages. It noted that such firms have higher sales compared to firms in other regions.

Similarly, Guo et al. (2023) indicated that power outages reduce the ability of enterprises to undertake research and development in China. This reduces their productivity level in the long run as they are unable to take advantage of new and emerging innovations. Finally, another group of studies examined various factors that influence the performance of firms. Shouyu (2017) looked at how innovation affects firm performance emphasizing that innovations have different effects on different firms based on their type. The findings show that some of these effects of innovation can be mediating or moderating given the type and the firm involved. 2023 Cicea et al. (2019) also examined the influence of socioeconomic factors on the performance of firms in selected European countries.

The literature reviewed failed to account for some very important issues in discussing electricity outages and firm performance. First, most studies such as Alam (2013), Scott et al., (2014), Mensah (2016), Cole et al. (2018), and Elliott et al. (2021) used a single indicator (number of outages per month) of electricity outages to estimate its effect on firm performance. Also, the extant literature failed to disaggregate firms into small and large sizes. Disaggregating firms into small and large sizes have the potential to unearth the magnitude of the effect of electricity problems on different firms due to the differences in the capacity to withstand shocks. We fill these gaps by constructing an index using the number and duration of electricity outages to estimate the joint effect of electricity shortages on firm performance. In addition, we disaggregate firms into small and large sizes and evaluate the joint effect of electricity outages on their performance.

Figure 1. Conceptual framework of how electricity shortages affect firm performance.

Source: Author's Construct.



2.3. Transmission mechanisms of electricity outages to firm performance

Figure 1 presents the conceptual framework of the study which estimates the joint effect of electricity outages on firm performance in Sub-Saharan Africa (SSA).

Figure 1 depicts the various channels through which shortages in the supply of electricity influence the performance of firms. All other things being equal, the accelerator theory of investment posits that output depends on the total amount of capital inputs available for production (Knox, 1952). It, therefore, follows that electricity provision varies directly with generation capacity in each country and SSA as a whole. This means power supply will be poor if generation capacity is small and vice versa. The case of SSA has been of low and inadequate generation capacity which makes electricity supply very poor. The supply of electricity in SSA is characterized by frequent and erratic outages, longer durations of such outages, and very low voltages.

The first channel through which electricity outages influence firm performance is the noticeable reduction in working hours during blackouts. Lack of constant supply of power in its right voltage also destroys productive equipment which is very costly to repair. Again, productive machines are rendered inactive and workers can only idle because there is no electricity to work with (Elliott et al., 2021; Torero, 2015). This means a small fraction of the firm's capacity will be utilized which greatly impacts their production because productive machines are costly and workers will still get paid. Firms without the ability to self-generate have to shut down some production plants which reduces their capacity as well as their sales. Self-generation by firms increases their cost of production not to talk of the fall in productivity as productive hours are wasted during such outages. Profit-maximizing firms may outsource part of their production or switch to less-electricity-intensive industries to remain in business (Abeberese, 2013). Poor power supply, therefore, constrains firms, hinders their expansion, and leads to poor performance. Based on these transmission paths, we sought to show how electricity outages impact firm performance in SSA and how this effect varies based on firm size.

3. Materials and methods

This section discusses the type and source of data used for the study, the methodology, and the empirical strategy employed to achieve the research objectives.

3.1. Type and source of data

The study employs firm-level data from the World Bank Enterprise Survey (WBES) datasets on selected countries in SSA. The WBES compiles microdata on the activities of firms such as their performance, informality, and competition since 2002. Data were collected through extensive interviews with owners and managers of businesses with particular interests in the manufacturing and service sectors (World Bank, 2020). Data availability influenced the selection of countries in the sample. The study employed cross-sectional data on over 3,000 firms from 28 SSA countries¹ from 2007 to 2018. Essentially, this data is a combination of cross-sectional datasets from each of the 28 SSA countries. The WBES data on monetary variables such as total annual sales and the value of raw materials were all denominated in the local currencies of every country. The study converted them to US dollars to allow for uniform interpretations. The outcome variable for the study is total annual sales measured as the monetary value of the total amount of output sold for the previous year (World Bank, 2020). We used the total annual sales of firms as a proxy for their performance.

Electricity outage is measured by an index that was created using the Principal Composite Analysis (PCA) index. WBES asked firms to state the number of outages experienced in a month. This stated value is multiplied by 12 to obtain the outage frequency experienced by firms in a year (FO). Again, firms provided the average duration of outages experienced in a month. This value is multiplied by 12 to obtain the total duration of outages in a year (DO). We then multiplied the frequency of outages experienced by firms in a year (FO) by the duration of these outages in the year (DO) to obtain the total length of time firms have to operate without electricity from the

grid (Cole et al., 2018). The PCA index was then created from the estimated outage frequency and total duration of outages experienced by firms in a year. This index consists of uncorrelated components of outage frequency and the duration of these outages for firms in the selected countries and captures their joint effect on firm performance which past studies failed to consider.

The total value of capital, labor, and raw materials are provided in the WBES data. Ross (2019) noted economic growth emanates from increases in the quantity and quality of inputs employed by firms in their production process. They are hence very essential in explaining the total annual sales of firms. The output varies directly with the capacity utilization of firms. The capacity utilized explains variations in the performance of firms. The study included capacity utilization as a percentage of their establishment for the last year in the estimated model.

Torero (2015) argued that electricity increases the working length of workers as they can work both day and night. Based on this, we include hours of operation as an important variable that influences firm performance. The WBES data ask firms whether they are part of a larger parent company or not and whether they are a large, medium, or small firm. The study, therefore, included a dummy for firm type and size based on these responses. We capture the type as 1 if a firm is part of a larger parent company and zero if otherwise, and 0 for a large firm and 1 for a small size firm.

The Enterprise Survey is conducted on countries separately and at different times and so the study controlled for the year and country-fixed effects. This is to account for certain specific effects in each country and year that may influence the performance of firms apart from electricity outages. Indicators of electricity outages and firm performance in SSA are presented in Tables 1 and 2 respectively. Table 3 describes the joint variable (PCA index) created for electricity outages.

Table 1 shows firms in SSA experienced an average of 917.25 power outages within the year with these outages lasting as long as 22 days per year. This means a total of 22 days of no work greatly reduces the productivity of firms assuming no alternative source of power. It is hence not surprising that more than 82% of firms in SSA consider electricity as an obstacle to their operations. Power outages cause firms to incur losses which constitute an average of 52.61% of their total sales. These statistics depict the extent of damage to firms when they have to cope with electricity insecurity. More than 55% of firms in SSA therefore own or share generators and their self-generation accounts for more than 41% of the total electricity used for their production. Separate datasets for each sub-region in SSA also revealed that Eastern SSA recorded the highest number of outages per year followed by Western SSA, and Central SSA, with Southern SSA recording the least number of outages.

Table 1. Summary statistics on electricity outages in SSA

Region	Indicators of Electricity Outages					
	Number of outages	Duration of outages (Days)	% of firms citing electricity as an obstacle	% of losses due to outages	% of firms using generators	% of power from self-generation
Central	304.5	9.82	82.08	26.06	60.80	24.53
Eastern	420.5	8.04	83.89	29.60	48.71	24.21
Southern	199.9	15.43	67.88	30.20	38.21	32.88
Western	317.05	9.73	89.95	25.30	58.96	2.40
SSA	917.25	22.49	82.08	52.61	55.67	41.78

Data source: WBES (2007–2018).

Table 2. Indicators of firm's performance in SSA

Region	Indicators of Firm's Performance						
	Total annual sales (\$)	Hours of operation per week	Capacity utilization (%)	Cost of labor (\$)	Cost of raw material (\$)	Cost of capital (\$)	Cost of electricity (\$)
Central	339.02	38.25	28.72	263.42	56.97	28.18	217.17
Eastern	836.29	72.64	47.16	760.12	235.76	94.94	505.07
Southern	463.95	46.55	31.25	441.03	168.35	85.91	302.79
Western	491.53	57.49	29.39	430.92	82.85	42.75	396.22
SSA	1,997.66	71.28	85.23	1,059.67	694.62	357.64	1,186.83

Data source: WBES (2007–2018).

Table 3. Statistics of PCA index for electricity outages

PCA (EO)	Region				
	(1) Central	(2) Eastern	(3) Southern	(4) Western	(5) SSA
Eigenvalue	1.564	1.479	1.835	1.574	1.683
KMO	0.5000	0.5000	0.5000	0.5000	0.5000
Proportion	0.7820	0.7398	0.9179	0.7874	0.8418
Obs.	1,005	3,827	1,893	2,132	10,954

Data source: WBES (2007–2018).

Even though Eastern SSA recorded the highest frequency of outages, it had the least duration of outages. Southern SSA, which had the least outages rather recorded the highest duration of outages spanning over 15 days per year. Some regions have a smaller number of outages but those outages last very long whilst some have a higher frequency of outages but last relatively short. This underscores the importance of estimating the joint effect of outages and their duration as an examination of their individual effects might not reveal much information. Whatever the dynamics of outages, the bottom line is that it leads firms to incur significant losses which reduce their productivity and profits and hinders their ability to expand their production. This explains why at least 60% of firms in each sub-region of SSA cite electricity as their major obstacle to doing business. It also explains why at least 38% of firms in each sub-region either owned or shared a generator as a strategy for mitigating the effects of electricity outages on their businesses.

Table 2 shows firms in SSA on average have total sales of \$1, 997.66 per year, operate a mean of 71.28 h per week, and had an average of 85.23% of their capacity utilized. Evidence shows that hours operated per week by SSA firms are small (about 42% of total hours in a week). This can be explained among other factors by the unreliable power supply that reduces their hours of operation (Mensah, 2016). It also shows labor and electricity form a bigger portion of the firm's cost in SSA.

Among the sub-regions in SSA, Eastern SSA tends to have the biggest annual total sales on average, followed by Western SSA, then Southern with Central SSA recording the least total sales on average. Similar to the information on SSA as a whole, electricity, and labor form a greater share of the total cost for firms. For instance, the cost of electricity alone forms at least 60% of total annual sales in each of the sub-regions. This confirms the assertion of Eberhard et al. (2008) about the costly nature of electricity in SSA. The authors confirmed that SSA firms pay multiple times what is charged elsewhere for electricity and this greatly impedes their progress.

Table 3 describes the Principal Component Analysis (PCA) index created from the frequency and duration of outages experienced by SSA firms in a typical year. Information such as the eigenvalue, proportion of original variables explained, and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of the index for each region and entire SSA is presented.

Columns 1 to 5 of Table 3 describe the PCA index created from outage frequency and duration of outage for Central SSA, Eastern SSA, Southern SSA, Western SSA, and SSA respectively. The eigenvalues for component 1 in each case were greater than unity which is good according to the Kaiser criterion and can therefore be retained. The study predicted the scores of the first component in each case for its analysis.

The results in Table 3 also show all the Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy were at least 0.500 which justifies the use of principal composite analysis. The proportion of original variables explained by the principal component 1 was at least 73% in each case. The

majority of outage frequency and its' duration is explained by the principal composite index created for electricity outages making it very representative (Adu, 2012).

4. Methodology

4.1. The model

Firms consider electricity input in their production process. Electricity as an input contributes directly to the firm's output. Following Allcott et al. (2016), the study uses a Cobb-Douglas production function which is expressed as follows;

$$Y_{ijt} = A_{ijt} K_{ijt}^{\alpha} L_{ijt}^{\beta} M_{ijt}^{\delta} E_{ijt}^{1-(\alpha+\beta+\delta)} \quad (1)$$

where Y_{ijt} is the output of firm i in country j at time t . It shows the output of a firm depends on technology, capital, labor, raw materials, and electricity which are represented by A, K, L , and E respectively with α, β , and δ as their factor shares. But firms incur costs to assemble these factors of production which is given by the function as;

$$C_{ijt} = P_K K_{ijt} + P_L L_{ijt} + P_M M_{ijt} + P_E E_{ijt} \quad (2)$$

where P_K , P_L , P_M , and P_E represent factor prices of capital, labor, raw materials, and electricity, respectively. Since firms are rational, they have the optimal decision of maximizing their profits. The decision is to optimize their profit which is given by;

$$\pi_{ijt} = P_Y Y_{ijt} - [P_K K_{ijt} + P_L L_{ijt} + P_M M_{ijt} + P_E E_{ijt}] \quad (3)$$

where Equation 3 is the profit function of the firm which it seeks to maximize. The first part on the right-hand side represents the firm's total revenue from producing output Y and selling it at the market price (P). This explains the decisions and actions of firms that are essentially geared towards cutting down their cost of production and increasing their sales with the sole aim of maximizing profits. The optimal condition for production is that firms will employ inputs up to the point where the price of the firm's input is equal to the marginal revenue product (Sloman & Wride, 2009). It follows that infrastructure constraints such as electricity outages that increase the cost of operation and reduce the use of inputs limit the ability of firms to maximize their profits.

Consequently, we regress sales of firms on the combined variable of an outage frequency and duration and control for their use of capital (K), labor (L), raw materials (M), capacity utilization (CU), hours of operation (HO), manager's experience (ME) and type of establishment (KE). The basis for the variable selection is the empirical literature where studies such as Cole et al. (2018) used similar variables. This specification is given as;

$$Y_{ijt} = \beta_0 + \beta_1 EO_{ijt} + \beta_2 \sum_{i=1}^n X_{ijt} \quad (4)$$

where Y_{ijt} is sales of firm i in country j at time t , β_s are the regression parameters, EO_{ijt} is the combined variable of an outage frequency and its duration and X_{ijt} represents the control variables. The expectation is that electricity shortages reduce the sales of firms which eventually reduces their profit.

4.2. Empirical strategy

The Enterprise Survey Data is plagued with self-selection bias because firms choose to participate in the survey. Also, information about firm characteristics is provided by the firms themselves. Self-reported figures by firms about the number and duration of outages in particular make the

measure of electricity outage endogenous (Cole et al., 2018). Again, the nature of power outages is such that it may be correlated with other factors such as hours of operations which influence the outcome variable. Alternatively, increases in sales increase the electricity demand which may lead to shortages in its supply (Mensah, 2016). This raises issues about simultaneity bias and therefore means using the ordinary least squares method will lead to biased, inconsistent, and invalid conclusions about the causal effect of electricity outage on the performance of firms in SSA (Wooldridge, 2005).

The study employed the method of Instrumental Variable (IV) to determine the effect of electricity outages on firm performance in SSA. A valid instrument that satisfies the exclusion restriction of the instrumental variable approach is used to estimate the effect of electricity outages on sales in SSA. Essentially, the instrument must be significantly and directly correlated with the endogenous variable but uncorrelated with the outcome variable and affects the outcome variable only through the endogenous variable (Wooldridge, 2005). A two-stage IV model is specified as follows;

$$EO_{ijt} = \alpha + \psi(LDO_{ijt}) + \beta_1 \ln(K_{ijt}) + \beta_2 \ln(L_{ijt}) + \beta_3 \ln(M_{ijt}) + \beta_4(CU_{ijt}) + \beta_5(HO_{ijt}) + \beta_6(ME_{ijt}) + \beta_7(KE_{ijt}) + \gamma_j + \eta_t + \mu_{ijt} \quad (5)$$

$$Y_{ijt} = \phi + \theta(EO_{ijt}) + \varphi_1 \ln(K_{ijt}) + \varphi_2 \ln(L_{ijt}) + \varphi_3 \ln(M_{ijt}) + \varphi_4(CU_{ijt}) + \varphi_5(HO_{ijt}) + \varphi_6(ME_{ijt}) + \varphi_7(KE_{ijt}) + \gamma_j + \eta_t + \varepsilon_{ijt} \quad (6)$$

where LDO_{ijt} is the loss of firm i in country j at time t due to outages, which is the instrument employed by the study to resolve the problem of endogeneity. $AccessisdeniedAccessisdenied$ is sales of firm i in country j at time t . ψ and θ are coefficients of outage-induced losses (LDO) and electricity outage (EO), respectively. β_1 - β_7 and φ_1 - φ_7 are coefficients of capital (K), labor (L), raw materials (M), capacity utilization (CU), hours of operation (HO), manager's experience (ME), and type of establishment (KE), respectively in Equations 5 and 6. α and ϕ are constants, μ and ε are the error terms in both equations, γ_j and η_t as country and time-fixed effects. The instrumental variable model is estimated to achieve the objectives of the study. But for the second objective, we sliced the data according to size to check if variations in the effect of electricity outages exist based on size. The World Bank categorizes firms with at most 19 workers as small, while those with at least 100 workers as large (World Bank, 2021). The division of firms for this study was based on this official grouping by the World Bank.

Outage-induced losses are used as the instrument because power outages cause firms to incur losses that affect their sales. The losses incurred by firms also limit their ability to honor their tax obligation which reduces the tax revenue of the government. Because tax revenue represents the largest share of government revenue, the government's ability to fund electricity infrastructural projects is greatly hampered which leads to electricity outages (Blimpo & Cosgrove-Davies, 2019). Electricity outage which is the endogenous variable is positively related to outage-induced losses of firms. However, outage-related losses can only affect the sales of firms when electricity outages occur. This satisfies the relevance and exclusion restriction conditions of IV estimations (Wooldridge, 2005).

The use of the instrumental variable approach requires that certain tests are carried out to ascertain and justify the validity of the results for policy formulation and implementation. The following tests were carried out to ensure the validity of the study results. First, the Durbin-Wu-Hausman Test of Endogeneity. This test was performed because self-reported figures and measurement errors give enough reasons to suspect that electricity outage suffers from endogeneity. The study performed the Durbin-Wu-Hausman Test of Endogeneity to verify if the variable is endogenous. Second, identification tests of under-identification, over-identification, and weak

Table 4. Results of identification tests

Tests	(1) Endogeneity test	(2) Under- identification test	(3) Over- identification test	(4) Weak identification test
(1) Statistic	11.041	163.035	N/A	190.499
Chi-sq.(1) P-val.	0.0009	0.0000	0.0000	N/A
(2) Statistic	7.908	286.047	N/A	419.770
Chi-sq.(1) P-val.	0.0049	0.0000	0.0000	N/A
(3) Statistic	8.336	215.081	N/A	294.754
Chi-sq.(1) P-val.	0.0039	0.0000	0.0000	N/A

identification were performed to ensure the endogenous variable is properly identified and a strong instrument is employed as the use of weak instruments will lead to inconsistent estimators and large standard errors (Wooldridge, 2005).

5. Empirical results and discussions

We present the results of the identification and endogeneity tests in Table 4. The estimation technique required that the independent variable perceived to be endogenous is tested for endogeneity. The results of the endogeneity test for the PCA index are shown in row 3 column 1 of Table 4. The P-value shows a 1% level of significance implying a non-acceptance of the null hypothesis of exogeneity of the PCA index. Similarly, the null hypothesis of exogeneity of outage frequency and duration of outage are both rejected at a 1% level of significance (see column 1 row 1 & column 1 row 2). This means the PCA index of electricity outage, outage frequency, and duration of outage are all endogenous and the use of the ordinary least square (OLS) method will yield biased, inconsistent, and invalid results and conclusions. The presence of endogeneity is addressed through the use of the instrumental variable (IV) approach.

The second column of Table 4 gives the results of the under-identification test for each variable. In each case, the null hypothesis of under-identification is rejected at a 1% level of significance. This means the number of endogenous variables in each case does not exceed the number of instruments employed. The third column also gives results for over-identification tests for each of the three variables of power outage. In each case, the null hypothesis of valid instruments cannot be rejected. Essentially, the number of instruments employed does not exceed the number of endogenous variables, and the instrument does not correlate with the error term. This means that results from such estimations are valid since the equations are neither over nor under-identified (Wooldridge, 2005)

The results for weak identification tests are presented in column 4 of Table 4. In each case, the Cragg-Donald Wald F (CDF) statistic far exceeded all the Stock-Yogo weak ID test critical values at all maximal IV sizes. This implies the rejection of the null hypothesis of weak instruments for each of the three variables of electricity outage. The study can hence rely on its results with confidence because the instrument (s) employed in the models are strong and therefore have the explanatory power to explain the endogenous variable (s).

Part A of Table 5 summarizes results from six regression equations consisting of 3 OLS and 3 IV regressions. Results of how other factors apart from the joint effect of electricity outage (PCA) captured in model 4 influence the performance of firms in SSA are presented in Table 5B.

Table 5. Effect of electricity outages and other factors on sales of firms in SSA

A.	OLS			IV regression		
	(1) PCA (EO)	(2) Number of outages	(3) Duration of outage	(4) PCA (EO)	(5) Number of outages	(6) Duration of outage
SALES (\$)	2.856 (1.546)	0.012 (0.01935)	−0.00005 (0.00027)	−114.9*** (43.6364)	−0.337*** (0.11155)	−0.0024*** (0.000921)
Constant	837.477*** (1.140)	808.318*** (92.193)	848.018*** (104.024)	1005.214*** (123.9071)	1299.55*** (180.3612)	1125.984*** (152.3886)
<i>B. Results of control variables from model 4.</i>						
Labor (ln)	Raw material (ln)	Capital (ln)	Hours operated per year	Capacity Utilized	Type of Firm	Experience of manager
45.862*** (6.069)	28.193*** (5.964)	15.495*** (5.192)	0.00133 (0.029)	−.047 (.4115)	−24.886 (8.7536)	0.357 (0.6233)
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Obs.	4,810	5,674	4,810	4,333	5,050	4,333

Notes: Robust std. errors in parenthesis. *, ** & *** represents 10, 5 & 1 percentage significant levels. PCA is the Principal Composite Analysis index created for electricity outages (EO). FE is fixed effects.

The joint and individual effects of outage frequency and its duration on the performance of firms in SSA are shown in Table 5A. Columns 1 to 3 give the OLS results which show total annual sales of firms in SSA are positively related to the number of outages but negatively related to the duration of the outage. It also showed both outage frequency and duration had a positive joint effect on total annual sales of firms in SSA but none of these effects is significant and deviates from the a-priori expectations. The OLS results hence cannot be relied on and therefore justifies the use of the IV approach to effectively estimate the effect of power outages on the performance of firms in SSA. IV results show total annual sales of firms fall significantly by \$0.337 for every increase in outage frequency and by \$0.0024 for an increase in the duration of the outage.

The individual effect of outage frequency and its duration is significant but small in magnitude relative to their joint effect. Total annual sales of firms fall by \$114.9 for every increase in the combined variable for outage frequency and duration. This means firms in SSA face a significant reduction in their sales every year due to a joint increase in both outage frequency and duration. As explained earlier under the conceptual framework, this reduction occurs via a fall in productive hours of operation, capacity utilization, and adjustment costs incurred through self-generation. The impact is poor performance of firms evidenced by their low employment, low tax contribution, and general contribution to the growth of their respective economies (World Bank, 2023). The findings are similar to several studies such as Mensah (2016), Cole et al. (2018), and Elliott et al. (2021) which documented the negative effects of electricity outages on the performance of firms. However, Scott et al. (2014) suggested the joint effect of outage frequency and its duration yields a much deeper insight into the effect of power outage and emphasized that estimating the individual effect of outage frequency and its duration underestimates the damage to firms. Hence, the point of departure of the current research from the existing literature is that we showed the joint effect of outage frequency and its duration on firm performance is more pronounced than their individual effects.

In section B of Table 5, labor, raw material, and capital have a significant and positive effect on the sales of firms in SSA. A unit increase in labor, raw material, and capital increases sales by \$0.4586, \$0.2819, and \$0.1549 respectively. Essentially, an increase in the total number of factor inputs employed in production will increase total output and consequently increase sales made

Table 6. Effect of electricity outage on sales of large and small firms in SSA

Sales	Outage*firm size	Firm size	Capital (ln)	Labor (ln)	Raw material (ln)	_constant
Coef.	-408.894*** (159.3036)	47.591 (44.98183)	4.3675 (6.2915)	37.763*** (6.9706)	42.516*** (7.3344)	956.565*** (146.7509)
Other stats.	Obs. 3194	F (9, 3184) 13.26	Country FE Yes	Year FE Yes		

Notes: Robust std. errors in parenthesis *, ** & *** represents 10, 5 & 1 percent levels of significance FE is fixed effects.

(Sloman & Wride, 2009). Other factors such as hours operated per year, capacity utilized, type of firm, and manager's experience had no significant effect on the sales of firms in SSA.

In Table 6, the coefficient of the interacted variable for firm size and electricity outage is significant and negative which suggests that the effect of outages on small firms is bigger than it is for large firms. Specifically, small firms experience a fall of \$408.894 in their sales more than large firms for every increase in electricity outages. This is consistent with studies such as Alam (2013), Hardy and Mccasland (2019), and Ado and Josiah (2015) which asserted that the impact of electricity outages on firms depends on their adaptation abilities, which often than not goes with their size. That is, small firms tend to suffer more from electricity shortages because they do not have much capacity to adapt by outsourcing or generating their electricity. This finding differs from the extant literature because we showed that the relative joint effect of electricity outages on small firms is significantly large which was not clearly measured until now

6. Conclusions, policy recommendations, and limitations of the study

This section concludes the study which sought to analyze how outage frequency and duration jointly influence the performance of firms in SSA. This last section presents the conclusion made based on the findings of the study, policy implications for relevant authorities, and limitations of the study to inform future studies.

7. Conclusion

This study examined the effect of electricity shortage on firm performance in SSA. Even though there has been a plethora of studies in this area, the emphasis has been on the individual effect of outage frequency and its duration on firms' performance. However, the application of separate indicators of electricity outages does not reveal much about the damage of electricity outages to firms. In light of this, we constructed an index using the frequency of electricity outages and the duration of outages. We then estimated the joint effect of outage frequency and duration of outage on the performance of firms in SSA in an instrumental variable (IV) framework. Finally, we divided firms into small and large sizes and estimated the effect of electricity outages on their performance.

The conclusion is that the joint effect of outage frequency and its duration has a much bigger impact on firms' performance than their individual effects. Increases in outage frequency and duration jointly reduce sales of firms in SSA by \$114.9 while their individual effects did not sum to \$0.5. Based on this, estimating the individual effect of the outage and its duration underestimates the damage to firms in SSA. Finally, the study concludes that small firms in SSA experience higher losses than large firms as a result of electricity outages. Unlike large firms, small firms cannot self-generate their power and would have to totally downsize production or simply fold up as they incur \$408.894 more losses than large firms during power outages.

7.1. Policy recommendation

We recommend that policymakers expedite efforts to improve the provision of electricity in SSA as the damage of outages to firms until now has been understated. Specifically, the budget allocation for electricity infrastructure must be increased to explore renewable alternatives to enhance electricity provision in the region. Also, existing legislative instruments in support of electricity infrastructure must be reviewed to give more legal backing to policies initiated to improve electricity provision.

Again, we recommend that policies geared towards improving electricity in SSA should be region and country-specific. The sub-regional differences revealed different dynamics and hence a "one size fits all" solution may not be effective. For instance, electricity outages are more pronounced and widespread in Nigeria compared to countries like Ghana. So, measures initiated by the Nigerian government cannot be the same as those by the Ghanaian government. Also, the political, economic, and social settings in each country differ which demands policies that are specifically tailored for each country.

Also, the study revealed small firms in SSA suffer more than large firms during power outages. The study, therefore, recommends special offers like subsidies for small firms to reduce their cost of production and help them remain in business. This will go a long way to save most small firms in SSA from folding up.

7.2. Limitations of the study

The first consideration for future studies is to estimate the joint effect of outage frequency and duration on other indicators of firm performance. The current study only concentrated on just sales due to data availability. The effect can be measured on other performance indicators like the firm's profit, employment, and tax payments.

Also, the study had to reduce the number of countries to 28 due to the unavailability of data for some countries. Future studies must include as many countries as possible in their sample to make it more representative.

We also entreat future studies to employ other methods and instruments aside from the IV approach in treating the endogeneity of electricity outages. This will not only advance knowledge but also verify the findings in the literature.

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Note

1. The countries include Angola, Botswana, Burundi, Burkina Faso, Cameroon, DR. Congo, Ethiopia, Eswatini, Gambia, Ghana, Ivory Coast, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Niger, Nigeria, Senegal, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

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