Temporal Dynamics of Transmission Channels through which Electricity Shortages Impact Firm Productivity: Evidence Across two Distinct Energy Policy Periods

Yvette DJOHA SEUKOU[1] **MOHAMMADOU NOUROU**[2]

Abstract

Climate change and extreme weather events pose a global challenge, particularly threatening the electricity supply in developing countries. Although the impact of electricity shortages on firm productivity is well-documented, the underlying transmission mechanisms remain poorly understood. Using comparative Enterprise Surveys data from the World Bank covering 30 African countries between 2006 and 2025, we analyze how these mechanisms evolve over time. Results obtained using the control function approach reveal that investment, innovation, and skilled workers are the channels through which electricity shortages impact productivity. Analysis of the temporal dynamics reveals that: (i) over time, the electricity shortage leads to a considerable reduction in firms' investment capacity; (ii) the negative influence of electricity shortages on the number of skilled workers declines over time; (iii) On the other hand, the innovation channel has a significant positive effect on productivity improvement during prolonged periods of electricity shortages. Therefore, it is imperative that countries where electricity shortages persist prioritize policies that promote innovation.

Key words: electricity shortages, temporal dynamics, transmission Channel, productivity.

JEL classification: D24, O13, L94

[1] Ph.D student, University of Maroua, Cameroon, E-mail : ydjoha@yahoo.fr
[2] Lecturer, University of Garoua, Cameroon, E-mail : mohanourou@yahoo.fr

1. Introduction

A large literature in economics focuses on analyzing the factors that explain differences in wealth between countries and links differences in per capita income to aggregate productivity (Hall and Jones, 1999). Extensions of endogenous growth models by Aghion and Howitt (1990) and Schmitz Jr (2005) attribute this productivity gap to the slow adoption and inefficient use of more efficient technologies by firms. On the other hand, a more recent literature, rooted in the neoclassical growth model, offers a new perspective on differences in aggregate productivity between countries, which it attributes to the misallocation of production factors (Prescott, 1998; Restuccia and Rogerson, 2008).

One manifestation of this inefficient allocation of production inputs is the electricity shortages that continues to hamper economic development in poor countries (Hardy and McCasland, 2021; Mensah, 2024). Despite the renewed interest in electrification in sub-Saharan Africa since the late 1990s, the electricity access rate of 53.3% as a percentage of the population in 2023 remains low[3]. According to the World Bank's Sustainable Energy for All (SE4ALL) data, it was 38% in 2013 and 25.7% in 2000[4].

Although access to electricity shows marked disparities between urban and rural areas (82.1% and 33.2% in 2023, 72.5% and 20.7% in 2013, and 61.6% and 12% in 2000), this rate is seriously compromised by losses during electricity distribution. By 2023, these losses reached 24% of production, compared to 12% in 2013 and 10% in 2000. This gradual increase in losses during electricity distribution explains why business leaders in the service and industrial sectors consider electricity instability as the second major obstacle to business growth and expansion, according to the World Bank Enterprise Survey (WBES) surveys of firms conducted from 2006 to 2013. Furthermore, from 2013 to 2025, electricity rose to the first position. This situation further underlines the argument put forward by Meles (2020) that in SSA countries, the reliability of electricity supply is often relegated to the background to problems of electricity accessibility.

[3] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?view=chart
[4] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?view=chart

There is an extensive body of literature examining the effects of electricity shortages on firm productivity in developing countries. However, the specific channels through which these disruptions occur are under-explored. While existing studies firmly establish that electricity shortages depress sales and diminish overall productivity, our comprehension of the underlying causal mechanisms is limited. Studies that evaluate these transmission channels, most notably the work of Reinikka and Svensson (2002) in Uganda, Abeberese Abeberese *et al.* (2021) in Ghana, and Guo *et al.* (2023) in China, are limited by their strict focus on specific countries. These studies provide static snapshots that omit the temporal dynamics of electricity shortages and how these transmission channels evolve over time. Knowledge of how these mechanisms shift across different political environments is essential for creating resilient, long-term energy policies in developing economies.

This paper addresses this gap through two primary contributions to the empirical literature.

First, our temporal framing uniquely captures the impact evaluation of energy policies at the firm level across Sub-Saharan Africa. Building on the methodological foundation established by Elliott *et al.* (2021), who investigated the role of energy policies on the relationship between electricity shortages and productivity within a single-country context (Vietnam). Specifically, we use comprehensive World Bank Enterprise Survey data to conduct a multi-country comparative analysis across two distinct periods characterized by significant changes in electricity access and reliability.

The first period (2006–2013) captures an era when economic growth in African nations nearly doubled, a rapid expansion that simultaneously triggered unprecedented energy crises. Conversely, the second period (2013–2023) captures a transformative era of sweeping policy interventions with the explicit objective to improve both energy accessibility and grid reliability in SSA[5]. This later period reflects the institutional

[5] The study compares two periods, starting with the 2000s, because it was between 2000 and 2012 that economic growth in African countries almost doubled. It was also during the 2000s that most African countries experienced unprecedented energy crises. It was during this period that the World Bank Enterprise Survey began investigating the business climate in Africa. The choice of the second period is justified by the implementation of several programmes aimed at improving not only access to electricity but also the reliability of electricity in SSA. Countries and international organizations such as the African Development Bank (ADB), the World Bank and Power Africa (initiated by President Barack Obama) have implemented

aftermath of major, independent electrification programs launched by national governments and international consortia, to include the African Development Bank, the World Bank, and the U.S.-led *Power Africa* initiative. Through a comparison of these two structurally distinct eras, this paper provides the first comprehensive assessment of how firm-level transmission mechanisms change in response to macro-level shifts in energy accessibility and reliability.

Second, we extend upon the existing empirical methodology through the adoption of a control function approach to address endogeneity. Previous studies in this field predominantly rely on traditional instrumental variables (IV) techniques, and frequently use variations in hydroelectric production as an instrument. However, recent work by Apeti and Ly (2024) recently demonstrated that the hydroelectric instrument is severely limited in its validity. Through the application of the control function approach, we bypass the tight structural constraints often associated with instrument relevance and weak instrument critiques in standard IV setups (Cameron and Trivedi, 2022). This approach yields more robust and reliable causal estimates[6].

The remainder of the article is organized as follows: the next section focuses on the review of related literature, followed by the methodology in Section 3. The research results and conclusions are presented in Sections 4 and 5, respectively.

2. Literature review

This section presents a review of theoretical and empirical studies documenting how electricity shortages affect business productivity.

Theoretical basis

From an endogenous growth theory perspective, investment in human capital, innovation and infrastructure is widely recognized as essential drivers of productivity growth (Lucas

these programmes independently. The data for this study are drawn from the World Bank's Enterprise Surveys (available at www.enterprisesurveys.org)

[6]See Apeti and Ly (2024) for details.

Jr, 1988; Barro, 1990; Romer, 1990). However, for these determinants to contribute effectively to productivity growth, their allocation within the production process needs to be optimized. input output theory show that one of the key inputs that promotes this efficient allocation is electricity (jone, 2011). According to Perroux (1955) theory of driving industries, electricity plays an inductive role on other production inputs. This is due to its complementary attributes with tools and machines, as well as its role as a substitute for labor (Griffin and Gregory, 1976; Berndt and Wood, 1979; Berndt, 1990). However, the absence or failure of electricity supply can influence the allocation of other production inputs and, consequently, negatively affect business productivity.

When electricity shortages are recurrent in a country, the resulting uncertainty can play an important role in firms' decision-making regarding investment in productive capital and innovation. The key concepts of prospect theory Kahneman and Tversky (1979), namely risk aversion, the isolation effect and the reflection effect, can explain the investment behavior of entrepreneurs during periods of electricity shortage. Risk aversion often leads companies to adopt a cautious stance in the face of potential losses caused by power shortages, particularly in developing countries where insurance contracts against such shortages are not commonly available (Beenstock, 1991).

This uncertainty leads them to limit their investments. Rather than taking risks by embarking on innovative initiatives, they prefer to allocate their resources to more immediate needs, such as the acquisition of emergency generators (Abdisa, 2018). According to Beenstock (1991), companies see this investment as a form of insurance against equipment damage and indivisible risks[7].

Furthermore, according to standard economic theory, companies find it profitable to invest if the marginal product of capital is higher than the cost of capital. Consequently, all other things being equal, a reduction in the marginal cost of capital leads to a reduction in investment. Since electricity is an essential input for most forms of capital, a reduction in

[7] An indivisible risk is a type of risk that cannot be effectively reduced or shared.

the supply of electricity induced by frequent electricity shortages should reduce the productivity of capital and labor that depends on electricity, and therefore the incentives to invest.

The modeling of entrepreneurs' investment decisions under uncertainty through the extension of real options theory by Prastacos (1983) and O'donoghue and Rabin (1999), shows that time-biased preferences, manifested by a variation in the value placed on rewards depending on the time of their receipt, can have a significant impact on investment decisions under uncertainty. These temporal biases may influence the way entrepreneurs evaluate investment opportunities and make decisions in a context of uncertainty caused by electricity shortages. This could lead to choices that are not aligned with the company's long-term objectives, and consequently reduce the company's investments.

Regarding the channel of worker qualification, the multidimensional nature of human capital and its interconnection with its environment, as explained by Sen (1990) capability approach, points to the inactivity of qualified workers when there is an electricity shortages.

Empirical literature

The issue of electricity shortages and their effects on firm performance is at the heart of much debate in the economic literature. While the direct impacts of these shortages on productivity are well documented, their indirect influence, including the role of investment, innovation, and worker skill as channels of transmission of these electricity shortages to productivity, are relatively underexplored. By reviewing key studies, including those of Gulyani (1999); Baafra Abeberese (2020); and Guo *et al*. (2023), as well as recent research by Mensah (2024), we highlight contrasting results across various regional and sectoral contexts.

Baafra Abeberese (2020) identifies the effect of the electricity shortage from the public grid by assessing the evolution of business investment during the electricity crisis period compared to other periods. The author uses data on manufacturing firms in Ghana and exploits the electricity-rationing program that took place in the country during the period 1991 to 2002. As a result of his analysis, he finds a decline in investment in plants and

machinery during the electricity shortage period due to the electricity shortage. This decline is more pronounced for firms in sectors with high electricity consumption. This result is consistent with the theory of investment reaction to shocks, which predicts that, given the irreversibility and possibility of delaying investments, investment may fall if the uncertainty about the return of future investments is high. This means that electricity shortages increase the uncertainty about the return of investments.

Along the same lines, Guo *et al.* (2023) study the impact of electricity shortage on the innovation capability of firms in China. Using the text analysis method and using a Chinese city-level electricity shortage index, they were able to establish that electricity shortage reduces the probability, quantity, and quality of R&D investments, and has a negative impact on the total factor productivity (TFP) of Chinese firms. They also show that when electricity shortage increases by 10%, the probability of firms investing in R&D decreases by 0.5%.

Hardy and McCasland (2021) in Ghana focuses on the effects of electricity shortages on employment and incomes of skilled and unskilled workers in small garment industries (less than 5 employees). Their results indicate an increase in working hours for unskilled employees and a decrease in wages for skilled workers, highlighting the differentiated effects of electricity shortages on the two categories of workers. These results corroborate those of Xiao *et al.* (2022) on a set of developing countries, which show that electricity shortages reduce the firm's TFP by compromising the productive activities of skilled workers.

In contrast, Mensah (2024) study on a panel of 20 African countries examines the impact of electricity shortages on employment. This study highlights a significant negative effect of electricity shortages on employment, with a more pronounced decrease in non-agricultural sectors and for skilled positions. Furthermore, Mensah highlights that electricity shortages have a discouraging impact on entrepreneurship, reducing the likelihood of individuals starting their own business by 32%.

Therefore, it is imperative to integrate a temporal perspective into the analysis of how electricity shortages affect firm productivity through various channels. This approach will

enable the development of more relevant economic policies tailored to firms operating in an environment characterized by ongoing uncertainty. It is precisely this gap that our research seeks to fill.

3. Methodology, estimation technique, data

Methodology

To identify the transmission channels through which electricity shortages impact on firm productivity, we estimate the following regression model derived from the theoretical model of Hsieh and Klenow (2009) and adapted to the style of Elliot et al. (2021)and Xiao *et al.* (2022) and is as follows:

$$\mathbf{Z_{i,j,t} = \alpha_0 + \alpha_1 Energie_{i,j,t} + \beta X_T + \delta_{year} + \delta_{Pays} + \varepsilon_{i,j,t}} \quad (1)$$

Where, i, j and t represent industry, country and year respectively.$\mathbf{Z_{i,j,t}}$ is the dependent variable. Z represents each transmission channel. Energy denotes a vector of energy-related variables, such as electricity shortage and generator ownership. X is a vector of other control variables. $\delta_{year}$and δ_{pays} are the year and country fixed εeffects , respectively. represents the residue.

Estimation technique

One of the main challenges this study seeks to address is to explain the variation in power outages within firms due to endogeneity issues. Moreover, since the WBES data are an pooled cross section, the choice of estimation method must take these constraints into account.

To overcome these difficulties, several previous studies (Fisher-Vanden *et al.*, 2015; Allcott *et al.*, 2016; Elliott *et al.*, 2021; Mensah, 2024) have used the instrumental variables (IV) method as the best estimation approach. The hydroelectric instrument conditional on the flow of precipitation in the dams is the one adopted by these different studies. The objective of this instrument is to make fluctuations in electricity supply exogenous with respect to sales generation and other business results.

However, this instrument is only applicable in a limited number of countries, as not all have access to hydropower as their primary source of electricity generation. This is particularly relevant to our study, which covers 30 SSA countries, each with a different energy mix. Moreover, countries that rely primarily on hydropower tend to use fossil-fuel power plants to compensate for hydropower generation during low-flow periods, a practice that is increasingly common due to climate change. This limitation of the instrument justifies the adoption of the control function approach, a method that avoids instrument relevance problems (Cameron and Trivedi, 2022).

Furthermore, given that the data use in this study is a pooled cross section, we will also use the "pooled" *regression"*. Xiao *et al.* (2022) used this approach in their analysis of the effects of electricity shortages on firm productivity.

The *"Pooled regression* "is an appropriate method when observation units are observed over several periods, but individual units are not observed repeatedly over different periods. In the typical case of our study, country data are observed over different years, but the surveyed firms are not observed repeatedly over different years. In this case, a pooled regression allows us to see the effect of the independent variables on the dependent variables, without taking into account that the data are both cross-sectional and temporal. This method differs from a panel (or longitudinal) sample where the same observation units are observed repeatedly. In this case, a fixed-effects or random-effects estimator is appropriate in order to eliminate unobserved heterogeneity of individuals. The assumption underlying *pooled* regression is as follows: The spatial and temporal dimensions create no distinction between observations and there are no fixed effects in the data.

This method was chosen based on the results of the Hausman test (results section). In addition, all monetary values were converted to US dollars using the 2015 GDP deflator and the purchasing power parity index available on the WDI website.

Nature and source of data

The data used in this study come from the *World Bank Enterprise Survey (WBES)* [8]and those relating to real GDP per capita adjusted to purchasing power parity (PPP) at constant 2015 prices come from the *World Development* database. *Indicators* (*WDI, 2023*). Regarding the temporal aspect, our research work covers two periods: (2006-2013)[9] and the period (2013-2023), in order to assess the evolution of the transmission channels of the electricity shortage over time. Our sample covers 30 countries in sub-Saharan Africa. All the companies covered by our analysis belong to the manufacturing industries. Companies in the agricultural and service sectors represent a small percentage of the raw data and are excluded from the processing of the latter.

Measurement of variables and description

Three variables are identified as transmission channels. Investment is the sum of capital expenditures or purchases of long-term assets. In this study, investment is understood as a binary variable that takes the value 1 if a company allocates amounts to expansion projects, modernization or development of new activities or already existing activities. Innovation is measured by a binary variable that takes the value 1 if the company has introduced new products or processes, and 0 otherwise. The qualification of workers is measured by the ratio of qualified employees to all employees of the company.

We estimate the average number of fluctuations in electricity shortages during a month by summing the number of outages per day in a month. This variable is linearized. Control variables include firm age, determined by the number of years the firm has been in

[8] In Africa, this survey is the only one administered identically across all countries. Furthermore, it contains information that allows us to capture business performance.

[9] The study compares two periods, starting in the 2000s, because it was between 2000 and 2012 that economic growth in African countries almost doubled. It was also from the 2000s onwards that most African countries experienced unprecedented power crises. The choice of the second period is justified by the implementation of several programs to improve not only access to electricity but also the reliability of electricity in SSA. These programs have been implemented both individually by countries and by international organizations such as African Development Bank (ADB) and the World Bank. The aim of this study is to assess the state of progress of electricity reliability and its impact on firm's productivity during these two periods. The data source is World Bank Enterprise Surveys, www.enterprisesurveys.org

business. Generator use is a binary variable that takes the value 1 if a firm has access to a backup generator and 0 otherwise. Export is a dummy variable that takes the value 1 if the firm exported more than 1% of its main products during the previous production year and 0 otherwise. Firm size is measured by the number of employees. Firms are classified into three categories: small firms have 19 or fewer employees, medium firms have between 20 and 99 employees, and large firms have more than 99 employees. Manager experience is measured by the number of years of professional experience of the firm's CEO. Tables (1) and (2) above present the descriptive statistics of the different variables used in the two periods of the study.

Table 1: Descriptive statistics (period 1)

VARIABLES	obs	Mean	sd	min	Max
Countries	30				
GDP (log)	8541	24.41	1.516	20.78	26.53
TFP (log)	8541	3.765	1.794	3.436	17.82
export	8541	0.165	0.371	0	1
Generator	8541	0.525	0.489	0	1
Leadership experience	8541	14.86	9.849	1	70
skilled workers	8541	2.94	6.340	0	166
Company size	8541	1.611	0.748	1	3
age_entreprise	8541	16.59	15.38	0	124
Innovation	8541	0.181	0.385	0	1
Investment	8541	0.432	0.495	0	1
Bank concentration (log)	8541	4.250	0.243	3.572	4.605
Cut off frequency (log)	8541	1.994	1.078	0	5.480

Source: Authors based on study data. NB: We control for different sample sizes across countries by using the sampling weight from the data. As Asiedu et al. (2021), we log some of our macroeconomic variables to mitigate the effect of outliers.

Table 1: Descriptive statistics (period 2)

VARIABLES	(1) N	(2) Mean	(3) Sd	(4) min	(5) Max
Countries	30				
Company size	8771	1.665	0.768	1	3
Generator	8771	0.535	0.499	0	1
investment	8771	0.415	0.492	0	1
Innovation	8771	0.279	0.449	0	1
GDP (log)	8771	24.46	1.496	20.78	27.08
TFP (log)	8771	3.703	1.954	6,342	18.61
Bank concentration (log)	8771	4.155	0.302	3,482	4,605
Export	8771	0.178	0.383	0	1
Skilled workers	8771	3.468	8.110	0	407
Property type	8771	1.830	0.379	1	3
Executive Experience	8771	14.86	9.849	1	75
Cutoff frequency (log)	8771	2.070	1.088	0	7.601

Source: Authors based on study data. NB: We control for different sample sizes across countries by using the sampling weight from the data. As Asiedu et al. (2021), we log some of our macroeconomic variables to mitigate the effect of outliers.

4. Results and discussion

The results of the various tests are presented followed by the results of the empirical analyses.

The results of the Hausman test

In order to verify the method is suitable for the types of our data, we will check whether the nominal variables (the companies) have no joint effect on the results. If this hypothesis is verified, the pooled regression is adopted. On the other hand, if they have joint effects, the pooled regression estimates are not viable. In order to verify the joint hypothesis of the variables used, the Hausman test is performed. This test allows us to determine whether it is appropriate to use a fixed effects model, a random effects model or a pooled regression. The null hypothesis of the Hausman test is: The joint effect of all the " *dummies* " of the firm variables is zero. Therefore, the effects of the alternative that come from variations in the data due to the distinction of firms do not affect this model. The results of the test present respectively an F (9437, 2758) = 0.97 and a Prob > F = 0.8679 and F (8235, 347 8) = 0.086 and a Prob > F = 0.7539. The P-value of the Hausman test is not significant, we

reject the null hypothesis and the pooled regression model is appropriate. Following the Hausman test, we will check whether our estimates are subject to potential endogeneity.

Endogeneity test

The aim here is to determine the possible correlations between the error terms of the different equations of the specified model, in order to detect potential biases that could hinder the estimation of the model, and thus to propose, considering this prerequisite, the estimation procedure that best allows us to arrive at interesting and reliable results.

The explained variable innovation in our study may have a bidirectional causal relationship with TFP, which leads to a simultaneity problem (Xiao *et al.*, 2022). Firms that benefit from innovation, invest heavily, and have a large proportion of skilled employees tend to be more productive. Meanwhile, firms with a higher productivity level choose to innovate more, invest more, and employ more skilled personnel. As mentioned by Xiao *et al.* (2022) in their study on the effect of electricity shortages on TFP in China, product quality certification is exogenous, and the firm's innovation activity is not entirely exogenous. We adopt the variable that reflects whether a firm has international certification as an instrumental variable like Xiao *et al.* (2022), and conduct the instrumental variable estimation and the two-stage GMM estimation. To ensure the relevance of the instrumental variable, we use the control function approach. An approach for which constraints related to the relevance of the instruments do not arise (Cameron and Trivedi, 2022).

Given the endogeneity problem mentioned in the previous paragraph, the OLS estimates differ significantly from the IV and GMM estimates in Tables (2); (3); (4); (A.2); (A.3). For example, the coefficient on investment has an OLS estimate of -0.000545, while the IV and GMM estimates are -0.0124. According to Cameron and Smith (2022), this constitutes strong evidence that investment is endogenous. Furthermore, it is also worth noting the loss of precision when using IV. In particular, the standard error of the instrumented regressor increases from 0.000503 for OLS to 0.00809 for IV, a sixteen-fold increase, indicating the potential loss of efficiency due to the IV and GMM estimation.

Furthermore, we observe that the Kleibergen -Paap rk LM statistic (Tables 2; 3 and 4) passes the significance test at the 1% level, which indicates that the instrumental variable

selected in our study is not under-identified. In addition, the Kleibergen -Paap rk Wald F statistics (Tables 2; 3 and 4) of the instrumental variable is the critical value of the F statistic proposed by Stock and Yogo (2002), which indicates that the variable passes the weak instrumental variable test. This result reinforces the choice of conducting a robustness analysis through the pooled method and mainly interpreting the results of the IV method.

a. Analysis of econometric results

Assessment of the quality of the fit

The empirical strategy adopted to evaluate the transmission channels of the electricity shortage on firm's productivity consists of estimating the instrumental variable method and the GMM estimation in two stages: first, a direct estimation between the electricity shortage and the different channels, then an indirect estimation through an interaction between the electricity shortages and the different channels on productivity.

The choice of these models compensates for the endogeneity bias, and the choice of the second approach compensates for the indirect effect on productivity measured by the first approach. For all models estimated with the pooled regression model, the P-value suggests that the estimated specifications are globally significant at the 1% threshold. This means that all the independent variables used reliably predict the transmission channel of the effects of electricity shortages on business productivity. Tables 4 below present the results obtained using the instrumental variable (IV) technique. We interpret only the variables of interest, since we are evaluating the transmission channel of the electricity shortages in this regression. Results relating to worker qualifications are interpreted in terms of elasticity, since the variables are expressed in logarithms.

The results presented in Table 3 above show a negative influence of electricity shortages on investment, number of skilled worker during both periods, and on innovation during the first period. On the other hand, electricity shortages has a positive influence on firms' innovation capacity in the second period (period 2). The negative effects of electricity shortage on investment support the theory of real options (Myers, 1977). According to this theory, when firms face electricity shortages, they prefer to postpone their investments in productive capital and opt for self-production of electricity (the investment postponement

option, according to Dixit and Pindyck (1994), or else reduce the size of the firm or conclude an outsourcing agreement (the scale-up option, according to Trigeorgis (1996). These results are in line with theoretical contributions that emphasize the need to take into account the irreversibility of investments when firms are subject to uncertainties (Huchzermeier and Cohen, 1996; Trigeorgis, 1996).

This analysis in terms of temporal dynamics can also be carried out. The analyses reveal that, over time, firms innovate to counter the negative effect of electricity shortages on their productivity. The sign associated with the innovation coefficient is positive in the second period of the study and negative in the first period of the study. This positive effect of electricity shortages on firms' innovative capacity during the second period of the study supports Schumpeter's (1943) innovation theory, which posits that crises and constraints would promote creativity and innovation. According to Schumpeter (1943), innovation is a key driver of economic development, and firms, faced with challenges, are often encouraged to adopt new technologies and rethink their production processes to remain competitive.

Furthermore, the temporal analysis of the investment channel shows that the negative impact of electricity shortages on investment decisions intensifies over time. Indeed, this impact is more pronounced during the second period of the study, with a coefficient of 0.0558, compared to 0.0124 for the first period. This represents an increase of 4.34 percentage points. This observation indicates that electricity shortages exert an increasing negative influence on firms' investment choices. This finding corroborates the results of Abeberese *et al.* (2021) in Ghana and raises an important question for further research: the need to integrate an indicator to better understand this phenomenon (Xiao *et al.*, 2022; Guo *et al.*, 2023). This result supports theoretical contributions that emphasize the need to reduce the climate of uncertainty in which companies operate, or to improve the business climate, in order to promote productivity growth (Abeberese, 2020; Restuccia and Rogerson, 2013; Reinikka and Svensson, 2002).

Regarding the temporal analysis of the skilled employee channel, an interesting trend emerges: the impact of electricity shortages on this channel appears to diminish over time. Indeed, this impact is less pronounced during the second period of the study, with a

coefficient of 0.864 compared to 0.831 for the first period. This represents a significant decrease of 3.3 percentage points. These results suggest that over time, the decrease in the number of skilled employees due to these shortages is mitigated. Companies appear to be adopting effective strategies to stabilize their workforce and maintain productivity.

Table 3: Investment channel for transmission of electricity shortages on business productivity (period 1)

	(MCO)	*(2SLS-VI)*	*(2SLS GMM)*	*function approach)*
VARIABLES	***Investment0***	***Investment0***	***Investment0***	***Investment0***
Frequency of shortages	-0.000545	-0.0124*	-0.0124*	-0.0124**
	(0.000388)	(0.00638)	(0.00638)	(0.00600)
Estimated residues				0.0130**
				(0.00602)
Generator	0.0704***	0.169***	0.169***	0.169***
	(0.0126)	(0.0505)	(0.0505)	(0.0474)
Age of the firm	-5.89e-05	-0.000634	-0.000634	-0.000634
	(0.000500)	(0.000582)	(0.000582)	(0.000565)
Medium- sized firm	0.0720***	0.0293	0.0293	0.0293
	(0.0142)	(0.0260)	(0.0260)	(0.0244)
large firm	0.143***	0.0678	0.0678	0.0678*
	(0.0200)	(0.0431)	(0.0431)	(0.0403)
Executive experience	2.43e-05	4.00e-06	4.00e-06	4.00e-06
	(1.71e-05)	(2.01e-05)	(2.01e-05)	(1.95e-05)
Innovation	0.0892***	0.106***	0.106***	0.106***
	(0.00967)	(0.0131)	(0.0131)	(0.0123)
Skilled workers	0.000452***	0.000775**	0.000775**	0.000775***
	(0.000114)	(0.000357)	(0.000357)	(0.000187)
Bank concentration	-0.00583	0.0186	0.0186	0.0186
	(0.0263)	(0.0312)	(0.0312)	(0.0287)
GDP	-0.00309	0.0172	0.0172	0.0172*
	(0.00406)	(0.0110)	(0.0110)	(0.0102)
Constant	0.405***	-0.0361	-0.0361	-0.0361
	(0.153)	(0.277)	(0.277)	(0.256)
Country fixed effect	Yes	Yes	Yes	Yes
Years Fixed effect	Yes	Yes	Yes	Yes
R -squared	0.037			0.038
Wald chi2(21)		257.22	257.22	0.000
Prob > F				
Prob > chi2		0.0000	0.0000	

Source: Author based on WBES data (2006, 2023).

Note: FE denotes fixed effects. Fixed effects include individual (firm) effects and year fixed effects. Robust standard errors clustered by firm location are in parentheses, ***, ** and * indicate the significance level at 1%, 5% and 10% respectively[10].

[10] The introduction of fixed effects and the option of robust standard errors in the analysis aims to control for firm heterogeneity (Xiao et al., 2022).

Table 4: Investment transmission channel of electricity shortage on productivity of enterprises period (2)

VARIABLES	*(MCO)*	*(2LSV)*	*function approach)*
	Investment1	***Investment1***	***Investment1***
Frequency of shortages	-0.0189***	-0.558**	-0.558***
	(0.00562)	(0.279)	(0.166)
Estimated residues			0.578***
			(0.166)
Generator	0.0537***	0.115***	0.115***
	(0.0143)	(0.0383)	(0.0226)
Small firm	0.0406***	-0.00521	-0.00521
	(0.0148)	(0.0342)	(0.0197)
Medium firm	0.104***	-0.0320	-0.0320
	(0.0190)	(0.0727)	(0.0437)
Large firm	0.112	-0.225	-0.225
	(0.134)	(0.284)	(0.165)
Age of the firm	-9.73e-05	-0.000374	-0.000374***
	(9.83e-05)	(0.000398)	(0.000116)
Manager's experience	-6.25e-06	3.44e-05	3.44e-05*
	(1.35e-05)	(3.01e-05)	(1.78e-05)
Innovation	0.186***	0.222***	0.222***
	(0.0141)	(0.0297)	(0.0172)
Skilled workers	0.00500	0.0356**	0.0356***
	(0.00569)	(0.0167)	(0.0105)
Bank concentration	-0.205***	-0.459***	-0.459***
	(0.0303)	(0.132)	(0.0787)
GDP	-0.0665***	-0.0639***	-0.0639***
	(0.00597)	(0.0103)	(0.00601)
Constant	2,832***	4,889***	4,889***
	(0.231)	(1,066)	(0.633)
Country fixed effect	Yes	Yes	Yes
Years Fixed effect	Yes	Yes	Yes
R -squared	0.095		0.097
Prob > F			0.0000
Wald chi2(10)		237.61	
Prob > chi2		0.0000	

Source: Author based on WBES data (2006, 2023).

Note: FE denotes fixed effects. Fixed effects include individual (firm) effects and year fixed effects. Robust standard errors clustered by firm location are in parentheses, ***, ** and * indicate the significance level at 1%, 5% and 10% respectively[11].

A specific interpretation of each transmission channel, consistent with many previous studies, highlights the fact that the results in Tables (3) and (4) show that investment within firms decreases when they face electricity shortage. This electricity shortage has a negative and statistically significant effect on investment levels in the first and second periods of the study. More precisely, an increase in the frequency of power outages by one percent leads to a decrease in firm investment of 0.0124% and 0.558% respectively, all other things being equal. This result is consistent with the argument of Abeberese (2021) that restrictions on the availability of electricity during the electricity crisis encourage firms to reduce their investments.

Regarding skilled employees, the estimations carried out (Tables 5 and 6) show that the electricity shortage has a negative and statistically significant influence on the productivity

[11] The introduction of fixed effects and the option of robust standard errors in the analysis aims to control for firm heterogeneity (Xiao et al., 2022).

of skilled workers. Specifically, a one-unit increase in the frequency of outages leads to a decrease in the size of skilled workers of 0.864% and 0.831%, respectively, all other things being equal. This result suggests that skilled employees play a key role in how electricity shortages modifies the productivity of the company. This decrease in skilled employees could be attributed to the fact that electricity shortages reduce the working hours of skilled employees.

Firms with a higher proportion of skilled employees may be more dependent on electrical energy. Therefore, the electricity shortages has a greater impact on the production efficiency of these firms. This result is consistent with the contributions of neoclassical growth theory Ramsey (1928) which places human capital at the heart of the productivity growth process. From an empirical point of view, this result constitutes additional evidence after the work of Xiao et *al*. (2022).

These results are consistent with those of Hardy and McCasland (2019) who observed that electricity shortages in Ghana led to an increase in the use of unskilled labor input and a decrease in the wages of skilled workers. Moreover, it is interesting to note that the decline in skilled employees appears to be attenuating over time. These results may be explained by a possible adaptation of firms to electricity shortages and the search for alternative solutions to maintain the productivity of skilled employees despite electricity interruptions.

Table 5: Skilled employees as a transmission channel of the electricity shortages on the productivity of companies, period (1)

	MCO	*2SLS-VI*	*2SLS-GMM*	*Control function approach*
VARIABLES	***Skilled workers***	***Skilled workers***	***Skilled workers***	***Skilled workers***
Frequency of shortages	-0.0493***	-0.864***	-0.864***	-0.864***
	(0.0157)	(0.153)	(0.153)	(0.135)
Residues				0.922***
				(0.136)
Generator	0.228***	0.823***	0.823***	0.842***
	(0.0336)	(0.119)	(0.119)	(0.0974)
Medium size firm	0.843***	0.582***	0.582***	0.547***
	(0.0325)	(0.0670)	(0.0670)	(0.0565)
Large firm	2,069***	1,720***	1,720***	1,631***
	(0.0588)	(0.0957)	(0.0957)	(0.0890)
Age of the firm	0.00527***	0.00173	0.00173	0.00187
	(0.00153)	(0.00191)	(0.00191)	(0.00162)
Manager's experience	0.000642	-0.00348	-0.00348	-0.00528***
	(0.00178)	(0.00238)	(0.00238)	(0.00196)
Innovation	-0.0476**	0.204***	0.204***	0.0746***
	(0.0197)	(0.0552)	(0.0552)	(0.0267)
Investment	0.0811***	0.0787**	0.0787**	0.0849***
	(0.0286)	(0.0378)	(0.0378)	(0.0284)
Bank concentration	-0.236***	-0.416***	-0.416***	-0.266***
	(0.0813)	(0.107)	(0.107)	(0.0806)
GDP	-0.00779	-0.0459***	-0.0459***	0.0523***
	(0.00888)	(0.0141)	(0.0141)	(0.0129)
Constant	3,203***	6.001***	6.001***	3,179***
	(0.435)	(0.750)	(0.750)	(0.432)
Country fixed effect	Yes	Yes	Yes	Yes
Years Fixed effect	Yes	Yes	Yes	Yes
R -squared	0.472	0.073	0.073	0.480
Prob > F				0.0000
Wald chi2(10)		1716.18	1716.18	
Prob > chi2		0.0000	0.0000	

Source: Author based on WBES data (2006, 2023).

Note: FE denotes fixed effects. Fixed effects include individual (firm) effects and year fixed effects. Robust standard errors clustered by firm location are in parentheses, ***, ** and * indicate the significance level at 1%, 5% and 10% respectively[12].

[12] The introduction of fixed effects and the option of robust standard errors in the analysis aims to control for firm heterogeneity (Xiao et al., 2022).

Table 6: Skilled employees as a transmission channel of electricity shortages on business productivity period (2)

VARIABLES	*MCO*	*2SLS-VI*	*2SLS-VI*	*Control function approach*
	Skilled workers	*Skilled workers*	*Skilled workers*	*Skilled workers*
Frequency of shortages	-0.0513***	-0.831*	-0.831*	-0.831**
	(0.0159)	(0.488)	(0.488)	(0.356)
Estimated residues				-0.781**
				(0.357)
Generator	0.183***	0.151***	0.150***	0.151***
	(0.0396)	(0.0578)	(0.0578)	(0.0418)
Small firm	-0.148***	-0.0501	-0.0506	-0.0501
	(0.0437)	(0.0858)	(0.0859)	(0.0639)
Medium firm	-0.463***	-0.266*	-0.267*	-0.266**
	(0.0592)	(0.144)	(0.144)	(0.107)
Large	0.650***	0.574***	0	0.574***
	(0.0683)	(0.106)	(0)	(0.0760)
Age of firm	0.00190	0.00679*	0.00679*	0.00679**
	(0.00136)	(0.00349)	(0.00349)	(0.00266)
Manager experience	-0.000118***	-0.000258**	-0.000257**	-0.000258***
	(4.10e-05)	(0.000104)	(0.000104)	(7.64e-05)
Investment	-0.112***	-0.129**	-0.129**	-0.129***
	(0.0392)	(0.0547)	(0.0548)	(0.0400)
Innovation	-0.0513	-0.0852	-0.0858	-0.0852**
	(0.0387)	(0.0577)	(0.0577)	(0.0408)
Bank concentration	0.423***	0.377***	0.377***	0.377***
	(0.0646)	(0.0866)	(0.0866)	(0.0667)
GDP	0.106***	0.0467	0.0464	0.0467
	(0.0152)	(0.0419)	(0.0419)	(0.0308)
Constant	-5.196***	-5,484***	-5,484***	-5,484***
	(0.542)	(0.720)	(0.720)	(0.559)
Country fixed effect	Yes	Yes	Yes	Yes
Years Fixed effect	Yes	Yes	Yes	Yes
Observations	2,446	2,446	2,446	2,446
R -squared	0.100			0.102
Prob > F				0.0000
Wald chi2(10)		696.84	696.84	
Prob > chi2		0.0000	0.0000	

Source: Author based on WBES data (2006, 2023).

Note: FE denotes fixed effects. Fixed effects include individual (firm) effects and year fixed effects. Robust standard errors clustered by firm location are in parentheses, ***, ** and * indicate the significance level at 1%, 5% and 10% respectively[13].

Regarding the innovation channel, it follows from the econometric estimations in Table (7) and (8) above that the electricity shortage reduces the innovation capacity of firms in the first period of the study and stimulates it in the second period of the study. Indeed, a 1% increase in the electricity shortages leads to a decrease of 0.0384% (period (1)) and an

[13] The introduction of fixed effects and the option of robust standard errors in the analysis aims to control for firm heterogeneity (Xiao et al., 2022).

increase of 0.1% in (period (2)) in the innovation capacity of firms, all other things being equal.

The result of the innovation channel Table (7) of the first period of the study is consistent with that of Guo et *al*. (2023) in China who found significant and negative effects of the decline in firms' TFP due to the shortage of electric power through the reduction of innovation activities. In their studies, the coefficient of the interaction term (between the indicator of the shortage of electric power and the indicator of innovation) is statistically significant and negative, which suggests that the shortage of electric power affects the productivity of firms by interfering with the reduction of investment in innovation and the innovation process. The higher the shortage of electric power, the greater the reduction of innovation activities.

Moreover, the positive result of the second period of the study corroborates the findings of Alam (2013) in India, where rice-growing firms managed to counter the negative effects of electricity shortages on their productivity by implementing process innovations. They are also consistent with the work of Karimu et al. (2018), who highlight the argument that " *necessity is the mother of invention* " and show that firms innovate

Table 7: Innovation channel of transmission of electricity shortage on the productivity of firm's period (1)

VARIABLES	*(MCO)*	*(2LSV-IV)*	*(2LSV-GMM)*	*(Control function approach)*
	Innovation	*Innovation*	*Innovation*	*Innovation*
Frequency of shortages	-0.00206***	-0.0384***	-0.0384***	-0.0384***
	(0.000503)	(0.0117)	(0.0117)	(0.00809)
Estimated residues				0.0406***
				(0.00813)
Generator	0.265***	0.586***	0.586***	0.586***
	(0.0155)	(0.0965)	(0.0965)	(0.0658)
Age of the firm	-0.00313***	-0.00508***	-0.00508***	-0.00508***
	(0.000510)	(0.000878)	(0.000878)	(0.000646)
Small firm	0.128***	-0.00103	-0.00103	-0.00103
	(0.0186)	(0.0452)	(0.0452)	(0.0314)
Medium firm	-0.00444	-0.244***	-0.244***	-0.244***
	(0.0230)	(0.0744)	(0.0744)	(0.0511)
Manager experience	2.34e-05	-0.00253*	-0.00253*	-0.00253***
	(0.000801)	(0.00137)	(0.00137)	(0.000955)
Skilled employees	0.00376***	0.00495**	0.00495**	0.00495***
	(0.00143)	(0.00233)	(0.00233)	(0.00145)
Investment	0.136***	0.163***	0.163***	0.163***
	(0.0150)	(0.0220)	(0.0220)	(0.0159)
Bank concentration	-0.338***	-0.278***	-0.278***	-0.278***
	(0.0273)	(0.0468)	(0.0468)	(0.0301)
GDP	-0.0264***	0.0359*	0.0359*	0.0359***
	(0.00496)	(0.0196)	(0.0196)	(0.0131)
Constant	2,267***	0.990**	0.990**	0.990***
	(0.181)	(0.461)	(0.461)	(0.309)
Country fixed effect	Yes	Yes	Yes	Yes
Years Fixed effect	Yes	Yes	Yes	Yes
Observations	7,279	7,279	7,279	7,279
R -squared	0.099			0.103
Prob > F				
Wald chi2(10)		394.98	394.98	
Prob > chi2				

Source: Author based on WBES data (2006, 2023).

Note: FE denotes fixed effects. Fixed effects include individual (firm) effects and year fixed effects. Robust standard errors clustered by firm location are in parentheses, ***, ** and * indicate the significance level at 1%, 5% and 10% respectively[14].

[14] The introduction of fixed effects and the option of robust standard errors in the analysis aims to control for firm heterogeneity (Xiao et al., 2022).

Table 8: Innovation transmission channel of electricity shortage on firm productivity period (2)

	MCO	2SLS-VI	2SLS-GMM	Control function approach
VARIABLES	Innovation	Innovation	Innovation	Innovation
Frequency of shortages	0.00131***	0.100***	0.100***	0.100***
	(0.000379)	(0.0280)	(0.0280)	(0.00763)
Estimated residues	-	-	-	-0.0994***
	-	-	-	(0.00764)
Generator	0.0813***	-0.0771	-0.0771	-0.0771***
	(0.0144)	(0.0692)	(0.0692)	(0.0187)
Age of the firm	-0.000261***	0.000640	0.000640	0.000640***
	(9.51e-05)	(0.000831)	(0.000831)	(0.000116)
Small firm	0.0270*	0.121*	0.121*	0.121***
	(0.0147)	(0.0626)	(0.0626)	(0.0161)
Medium firm	0.0337*	0.421***	0.421***	0.421***
	(0.0192)	(0.126)	(0.126)	(0.0354)
Large firm	-0.0290	0.798***	0.798***	0.798***
	(0.133)	(0.302)	(0.302)	(0.154)
Manager experience	0.000117	-0.00391	-0.00391	-0.00391***
	(0.000620)	(0.00261)	(0.00261)	(0.000684)
Certification	0.0564***	0.140*	0.140*	0.140***
	(0.0205)	(0.0725)	(0.0725)	(0.0211)
Skilled workers	0.00284	-0.0382*	-0.0382*	-0.0382***
	(0.00529)	(0.0195)	(0.0195)	(0.00596)
Bank concentration	-0.103***	0.413**	0.413**	0.413***
	(0.0304)	(0.178)	(0.178)	(0.0497)
GDP	-0.0231***	-0.0621**	-0.0621**	-0.0621***
	(0.00601)	(0.0269)	(0.0269)	(0.00663)
Constant	0.997***	-1.109	-1.109	-1.109***
	(0.231)	(1,071)	(1,071)	(0.278)
Country fixed effect	Yes	Yes	Yes	Yes
Years Fixed effect	Yes	Yes	Yes	Yes
Observations	5,352	5,352	5,352	5,352
R –squared	0.108			0.137
Prob > chi2				
Wald chi2(20)		76.40	76.40	

Source: Author based on WBES data (2006, 2023).

Note: FE denotes fixed effects. Fixed effects include individual (firm) effects and year fixed effects. Robust standard errors clustered by firm location are in parentheses, ***, ** and * indicate the significance level at 1%, 5% and 10% respectively[15].

[15] The introduction of fixed effects and the option of robust standard errors in the analysis aims to control for firm heterogeneity (Xiao et al., 2022).

Robustness analysis

The identification of comparative analysis of transmission channels of electricity shortages on firm productivity in sub-Saharan Africa was estimated using instrumental variable and a function approach which avoids constraints related to the relevance of the instruments (Cameron and Trivedi, 2022). To verify the relevance of our results, we will conduct robustness analyses using the pooled method. We generally note that the indirect effect of energy shortages on firm productivity is globally significant and negative, regardless of the transmission mechanism chosen. The main results of the different estimations of the specified model are presented in Tables 2 and 3. Specifically, and in line with many studies, the results in Tables 3, 4 and 5 suggest that innovation, worker skills and investment are the main channels through which electricity shortages affect firm productivity. These results are statistically significant and negative, both by the direct approach (the effect of the shortage of electric power on the different channels) and by the indirect approach (the interaction between electric power and the different channels on total factor productivity). However, it is important to note that the indirect effect of electricity shortages on productivity is higher in the estimation based on IV than in the estimation based on pooled regression. However, although differences are found in terms of the magnitude of the coefficients, no significant differences are observed in terms of signs and levels of statistical significance. This result is consistent with the extensive review of studies provided by Psacharopoulos and Patrinos (2004). These authors indeed observed that estimates based on the IV method are often higher than those based on the pooled regression method.

Table 9: Transmission channels of electricity shortage on the productivity of ASS companies (periods (1) and (2)) with generator (pooled regression)

	Period (1)			*Period (2)*		
VARIABLES	***(1) Innovation***	***(2) Investment***	***(3) Skilled employees***	***(4) Innovation***	***(5) Investment***	***(6) qualified employees***
Frequency of shortages	-2,887*	-0.0131**	-0.0115*	0.0558*	-0.0134*	0.00127**
	(0.00583)	(0.00601)	(0.749)	(0.000324)	(0.00586)	(0.00545)
Generator	0.222***	0.105***	13.20***	0.0681***	0.0654***	6,055***
	(0.0139)	(0.0115)	(3.237)	(0.0111)	(0.0112)	(2.010)
Company size	0.0642***	0.0771***	27.14***	0.00590	0.0419***	13.13***
	(0.00993)	(0.00861)	(2,482)	(0.00689)	(0.00693)	(2.309)
Age of the firm	-0.00217***	0.000590	0.878***	-8.36e-05	-0.000147	0.146
	(0.000432)	(0.000442)	(0.245)	(0.000143)	(0.000103)	(0.116)
Manger's experience	1.53e-05	2.87e-05*	-0.00831	1.05e-05	8.84e-06	0.00280
	(1.62e-05)	(1.53e-05)	(0.00534)	(1.07e-05)	(1.10e-05)	(0.00235)
Property type	0.00907	-0.0582***	-18.97***	-0.0494***	-0.0284*	-14.77***
	(0.0192)	(0.0173)	(6,064)	(0.0152)	(0.0153)	(4.125)
Investment	0.112***	-	4,064*	0.176***	-	2,638*
	(0.0131)	-	(2.141)	(0.0114)	-	(1,593)
Skilled workers	0.00336***	0.000387***	-	0.00174	0.00521	-
	(0.00126)	(0.000117)	-	(0.00500)	(0.00485)	-
Innovation	-	0.0837***	-0.577	-	0.182***	3,906**
	-	(0.00950)	(1,850)	-	(0.0117)	(1,938)
Bank concentration	-0.229***	0.179***	11.54	-0.109***	-0.216***	12.69**
	(0.0754)	(0.0608)	(14.57)	(0.0246)	(0.0250)	(4,938)
GDP	-0.00347	0.0175***	2.016**	-0.0229***	-0.0682***	3,394***
	(0.00512)	(0.00522)	(0.839)	(0.00488)	(0.00483)	(1.139)
Constant	1,407***	-0.816**	-95.77	1,063***	2,882***	-120.4***
	(0.421)	(0.333)	(81.81)	(0.185)	(0.188)	(40.71)
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	8,541	8,541	8,541	8,188	8,188	8,188
R –squared	0.163	0.054	0.068	0.153	0.116	0.024

Source: Author based on WBES data (2006, 2023).

Note: FE denotes fixed effects. Fixed effects include individual (firm) effects and year fixed effects. Robust standard errors clustered by firm location are in parentheses, ***, ** and * indicate the significance level at 1%, 5% and 10% respectively[16].

[16] The introduction of fixed effects and the option of robust standard errors in the analysis aims to control for firm heterogeneity (Xiao et al., 2022).

5. Conclusion

The aim of this study was to highlight the assessment of the transmission channels of electricity shortages on firm productivity in Sub-Saharan Africa over time, and through this to appreciate the extent to which underutilization of skilled labor, innovation and reduced investment due to power shortages influence the productivity of SSA firms. We use WBES survey data on firms in 30 SSA countries. The cross-sectional nature of the data and the endogeneity problem lead us to adopt the control function approach and the pooled regression to perform the empirical analyses. We find that investment, innovation and worker skills are the main channels through which electricity shortages affect firm productivity in SSA.

Moreover, analysis of the temporal dynamics reveals that: (i) over time, the electricity shortage leads to a considerable reduction in firms' investment capacity. (ii) the negative influence of electricity shortages on number of skilled workers decline over time. On the other hand, the innovation channel has a significant positive effect on productivity improvement during prolonged periods of electricity shortages. It is therefore imperative that policies that promote innovation be prioritized in countries where electricity shortages persist.

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Appendix

Table A.1: Transmission channels of electricity shortages on firm productivity (pooled regression method, indirect approach)

	Use of the generator			No generator use	
	LTFP	LTFP	LTFP	LTFP	LTFP
equency)	-0.0117***	-0.0215***	-0.0176***	-0.0148***	-0.0247***
	(-5.125)	(-6.225)	(-7.255)	(-6.592)	(-7.052)
	0.378***	0.393***	0.389***		
	(8.425)	(8,700)	(8,657)		
ges	-7.69e-05***			-7.83e-05***	
	(-8.293)			(-8.485)	
ges		-0.00936**			-0.00890**
		(-2.363)			(-2.153)
ges			-0.000708		
			(-0.122)		
	0.306***	0.324***	0.326***	0.347***	0.367***
	(9.221)	(9,757)	(9,772)	(10.61)	(11.22)
	-0.00848***	-0.00802***	-0.00795***	-0.00775***	-0.00723***
	(-5.368)	(-5.076)	(-5.031)	(-4.928)	(-4.608)
ce	-0.000109**	-9.79e-05**	-9.57e-05**	-0.000123***	-0.000113**
	(-2.313)	(-2.087)	(-2.037)	(-2.582)	(-2.364)
	-0.237***	-0.245***	-0.250***	-0.258***	-0.267***
	(-3,880)	(-3.992)	(-4.078)	(-4.186)	(-4.318)
	0.186***	0.308***	0.187***	0.214***	0.331***
	(4,698)	(4,879)	(4,691)	(5,406)	(5.158)
	0.0638	0.0900	0.0995	0.107*	0.135**
	(1.003)	(1,406)	(1,047)	(1,657)	(2,082)
	-0.00151***	-2.09e-05	-2.16e-05	-0.00153***	-2.20e-05
	(-8.319)	(-0.932)	(-0.961)	(-8.505)	(-0.903)
rate	-1.371***	-1.296***	-1.296***	-1.371***	-1.295***
	(-12.57)	(-11.79)	(-11.53)	(-12.54)	(-11.74)
duct	-0.281***	-0.279***	-0.276***	-0.259***	-0.255***
	(-20.53)	(-19.64)	(-19.99)	(-18.60)	(-17.59)
	16.27***	15.68***	15.68***	15.81***	15.19***
	(23.45)	(22.34)	(22.20)	(22.54)	(21.37)
	7,822	7,822	7,822	7,822	7,822
	0.145	0.131	0.129	0.136	0.121

Source: Author based on WBES 2006-2013 survey. **Notes:** Z statistics in parentheses ***, **, * indicate significance at 1%, 5%, 10% respectively.

Table A.2: Transmission channels of electrical energy on the TFP of companies (grouped regression method, direct approach)

	Use of the generator			**No use of the generator**		
S	**Innovation**	**Investment**	**Skilled employees**	**Innovation**	**Investment**	**Skilled er**
t-off frequency)	-0.00123***	-0.000739*	-0.163***	-0.00178***	-0.000916**	-0.14
	(-4.068)	(-1.768)	(-3.635)	(-6.256)	(-2.172)	(-3.4
	0.0619***	0.112***	10.42***			
	(7.253)	(8,890)	(2,999)			
e	0.0362***	0.0732***	30.71***	0.0434***	0.0895***	32.14
	(5,453)	(8.214)	(12.81)	(6,500)	(10.21)	(12.
e	-0.00139***	0.000467	0.879***	-0.00127***	0.000591	0.890
	(-4,870)	(1,071)	(3.428)	(-4,479)	(1.346)	(3,4
perience	-5.61e-06	2.27e-05	-0.00931*	-8.01e-06	2.26e-05	-0.00
	(-0.618)	(1,588)	(-1.829)	(-0.880)	(1,547)	(-1.8
e	-0.0255**	-0.0679***	-22.54***	-0.0291**	-0.0818***	-23.7
	(-1.995)	(-4.130)	(-3.475)	(-2.276)	(-5.003)	(-3,6

		0.107***	-0.806		0.115***	-0.1
		(5,770)	(-0.160)		(6.198)	(-0.0
oyees	-6.06e-06	4.90e-06**		-6.26e-06	4.60e-06**	
	(-1.611)	(2.243)		(-1.528)	(1,962)	
	0.0369***		2,319	0.0418***		3,2
	(4,603)		(0.908)	(5.206)		(1.2
tration rate	-0.521***	2,244***	-59.82***	-0.525***	2,184***	-264.
	(-24.11)	(5,783)	(-3.065)	(-24.17)	(5,637)	(-4.6
tic product	-0.0330***	-1,569***	32.11***	-0.0296***	-1.514***	280.2
	(-12.76)	(-4.363)	(3,906)	(-11.43)	(-4.213)	(4.2
	3,141***	26.56***	-486.5***	3,086***	25.59***	-5,28
	(27.48)	(4.019)	(-3.123)	(26.75)	(3,873)	(-4.1
	7,822	7,822	7,822	7,822	7,822	7,8
	0.147	0.089	0.081	0.141	0.080	0.0
d effect	Yes	Yes	Yes	Yes	Yes	Ye
ears	Yes	Yes	Yes	Yes	Yes	Ye
	0.0000	0.0000	0.0000	0.0000	0.0000	0.00

Source: Author from WBES 2013-2023 survey. Notes: Z statistics in parentheses ***, **, * indicate significance at 1%, 5%, 10% respectively.

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