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Does the cost of energy matter for innovation? The effects of energy prices on SME innovation in Sub-Saharan Africa

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Purpose – Energy and environment has gained traction within the field of entrepreneurship literature but a comprehensive empirical study that examines the relationship between the cost of energy and small and medium sized enterprises (SME) innovation is an omission. Therefore, this novel study examines the relationship between the cost of energy and SMEs innovation in Sub-Saharan Africa (SSA) by first examining the differential impact of the various generation sources on the price of electric energy. This research has enabled us to investigate and understand the transmission mechanism of increasing/decreasing electricity price on innovation decisions and activities of SMEs in SSA.

Design/methodology/approach – Using quantitative approach, with the data from the World Bank Enterprise and Innovation Follow-up Surveys, the study utilises a Tobit model to test whether the generation mix (renewable and non-renewable generation sources) increases or decreases electricity prices and examine the impact of the cost of electric energy on SMEs innovation in Sub-Saharan Africa.

Findings – The findings of this study shows that cost of electricity affect negatively on SMEs innovation decision and activities of SMEs in SSA. The impact of renewables on price of electricity has a larger magnitude relative to that of non-renewables. This finding has implications for policy makers promoting renewable energy without a policy design to tackle the unintended price effect of promoting renewable energy.

Originality/value – This is the first study to introduce cost of energy into an innovation model and to empirically examine the role of cost of energy for innovation activities of SMEs in SSA. Further, it examines the sources of generation on electricity price in SSA. The study contributes towards the empirical literature and the findings also have implication for policy makers regarding the unintended consequences of promoting the transition to low carbon electricity generation sources on SMEs via the cost of doing business implication.

Key words: SMEs, sustainable entrepreneurship, innovation, technology

Paper type Research paper

1.0. INTRODUCTION

There is a growing interest in promoting clean energy sources to mitigate environmental degradation (Balsalobre-Lorente et al., 2018; Sharif et al., 2019; Gyamfi et al., 2021). It is considered that energy availability and cost have implications for small and medium sized (SME) innovation (Gupta & Barua, 2018; Plank & Doblinger, 2018). SMEs are the dominant business models that promote growth for most economies (Kraus et al., 2020) and there is a high prevalence of SME in Sub-Saharan Africa (SSA) (Taura & Watkins, 2014). There is a positive correlation of access to energy that facilitates adoption of new technologies to improve working environment, increased productivity and contribute towards economic prosperity (Kalantzis & Revoltella, 2019). The success of SMEs in developed economies to innovate is linked with adequate and reliable energy infrastructure that provides seamless and uninterrupted energy supply (Gupta & Barua, 2018) at affordable prices. In contrast, emerging economies suffer from long power outages and high cost that limits SMEs ability to innovate (Lin & Chen, 2019). These structural inadequacies in energy production and distribution in emerging economies inhibits the ability of SMEs to innovate and compete with their counterparts in developed economies.

Although, research examining innovation amongst SMEs has often focused on developed countries (Dechezleprêtre et al., 2016; Beynon et al., 2021), this has recently become an active theme in SSA (Salisu et al., 2019). However, the literature is focus on financial constraints (Gorodnichenko & Schnitzer, 2013) with very limited if any, on infrastructure constraints, specifically cost of electricity on SMEs' innovative activities. The objective of this study is to investigate the implication of electricity cost on SMEs innovation in SSA and determine the likely influence of renewable energy generation on the price of electricity relative to that of non-renewable electricity generation. This will provide guidance to the policy makers in SSA on the likely influence of the two generation sources on the price of electricity in this era of energy transition to low carbon energy sources.

Furthermore, due to the current energy transition, there has been a consented effort by policy makers in SSA to introduce renewable energy and government policies supporting such green energy projects without carefully assessing the likely cost implication of such green energy sources, especially solar and wind via the final energy price for SMEs.

Prior literature (Bayarçelik et al., 2014; Gherghina et al., 2020; Marino, Parrotta, & Valletta, 2019) claims energy infrastructure combined with robust legal regime and a stable micro-economic policy are pre-requisites for innovation amongst SMEs. This suggests the modern economy cannot function effectively without an adequate and affordable energy supply. Thus, affordable and reliable energy supply and the implication on energy price thereof could be considered as an essential input for innovation process to enable an economy to modernise and grow (Lin & Chen, 2019). Thus, innovation and the availability of cheap and reliable energy are intrinsically linked to potentially operationalise new ideas (Lin & Chen, 2019).

Therefore, this study contributes to the literature by introducing the cost of energy, precisely the cost of electricity into the innovation and financial constraint model developed by Gorodnichenko & Schnitzer (2013), and further test if cost of electricity in SSA has a negative implication on SMEs innovation. Furthermore, the study also contributes to the literature by first assessing whether renewable energy generation influence the rising price of electricity in SSA relative to non-renewable energy generation, which has a strong bearing on the current drive towards green energy at a time where the world is gradually embracing the fourth industrial revolution. Such a revolution will require availability of cheap electricity especially for SMEs to adapt to such a transformation, where innovation will play a key role.

This study investigates the cost of electricity via price in promoting innovation amongst SMEs in SSA countries. It also examine the implication of green electricity generation and non-renewable electricity generation on electricity prices in SSA countries. Mensah et al. (2016) notes that energy is a core input for SME innovation in SSA and if not readily available is a major constraint for firm growth. High energy cost increases the cost of innovation leading to low profitability that potentially constrains an SMEs ability to invest in clean technology (CleanTech) and research and development (R&D) (Lin & Chen, 2019). This, consequently, acts as a disincentive for SMEs to invest in innovation. However, it can also be argued that high energy cost encourages SMEs to adopt strategies and technologies enabling them to reduce their energy usage with the view of lowering the cost of innovation. Hence, how the cost of electricity impact SMEs innovation is an empirical question that this study seeks to address for SSA and determine the likely differential impact of renewable and non-renewable electricity generation on the price of electricity to inform policy maker on the current transition to low carbon energy sources and their likely implication on cost of electricity for the end-user.

This empirical research is situated in two strands of literature: The impact of energy prices resulting from inadequate infrastructure in emerging economies particularly, SSA countries hampers firm innovation (Mensah, et al., 2014; Mensah et al., 2016) and determinants of innovation (e.g., Gorodnichenko, 2013). However, there is a paucity of literature examining the interconnected nature of energy cost and SMEs innovation for SSA countries. Given the relatively under-performing economies of SSA countries in comparison to developed economies (Rodrik, 2018), there is a need to consider the linkages between energy cost and the resulting impact on SMEs innovation. Furthermore, the likely implication of transitioning into low carbon electricity generating sources on the price of electricity in SSA. Thus, this study contributes towards a research gap that has not been previously examined and its consequences for SSA countries. To achieve the research goal and objectives, the study applies a Tobit econometric model to data from the World Bank Enterprise Survey, Innovation Follow-up Survey and World Development Indicators (WDI) for SSA countries.

The findings suggest that both renewables (excluding hydro) and non-renewable generation sources influence positively on electricity prices in SSA though, the impact of renewables has a larger magnitude relative to that of non-renewables. Furthermore, the empirical evidence also indicates that cost of energy impacts on SMEs innovation. The evidence from this research has implications for policy markers aiming to promote clean energy, especially for electricity generation. Such a promotion will impact the cost of electricity, further increasing the unit price of electricity in SSA, which may further impact negatively on SMEs innovative activities.

The following sections of the study are organised as follows: Section 2 reviews the pertinent literature to identify a gap and to frame the research questions, section 3 discusses the methodological approach employed. Following this, section 4 provides the analysis, and the findings are presented. Finally, section 5 provides conclusions and recommendations emerging from the research.

2.0. LITERATURE REVIEW

The concept of innovation and its importance for growth and development has been well established in the literature since the Schumpeterian era. Most of the literature in earlier period has been to clearly assess the link between innovation and country's economic growth and development. In recent years, the interest has extended beyond the role of innovation in economic growth and development to other areas such as at the micro level to assess the influence of innovation for firm's growth and development, determinants of firm's innovative activities, and the link between power outages and firm's innovation.

Broadly, the literature on innovation and firms can be grouped into two themes, thus, determinants of firm innovative activities (Adu-Danso et al., 2020; Berg,2021; Blind,2012; Dechezlepretre *et al.,* 2016; Gorodnichenko & Schnitzer, 2013; Karimu et al., 2018) theme, and innovation and firm productivity theme (Audretsch and Belitski, 2020; Martin, et al., 2013; Geroski et al., 1993; Koellinger 2008; Lee ,2011; Lööf and Heshmati, 2006).

Under the determinant theme, Adu-Danso et al., (2020) utilised data on manufacturing firms for SSA from World Bank Enterprise Survey to investigate the role of foreign ownership on firm's process and product innovation in SSA. Utilising a probit model, the authors find that foreign-owned firms are less likely to introduce product innovation but did not find any significant effect for the case of process innovation for the sampled firms.

Berg (2021) investigated the determinants of firm's innovation in 27 emerging countries with a focus on women in top management, R&D expenditure, political stability, and the possible moderating effect of political stability on R&D expenditure effect on innovation. The author utilised the World Bank enterprise survey, which the logistic model was used in estimating the parameters of interest. Findings suggest that, in addition to firm specific characteristics such as size and experience, R&D expenditure and political stability have positive influence on firm innovation. Furthermore, political stability tends to promote the positive effect of R&D expenditure on firm's innovation.

Furthermore, a study by Blind (2012) assessed the role of different regulations on firms' innovation in 21 OECD countries over the period 1999 to 2004. The study finds that regulation related to environmental laws and compliance and product and service legislation have a negative influence on innovation, whereas non-restrictive price regulation, efficient enforcement of Intellectual property rights and the legal and regulatory framework promote innovation in the sampled countries.

A study that has some close links to our study is that of Gorodnichenko & Schnitzer, (2013). In their study, they developed and tested whether financial constraint inhibits firm's innovation. The authors used use data from the 2002 and 2005 Business Environment and Enterprise Performance Survey (BEEPS) for 27 transition countries to test the financial constraint hypothesis. Finding from the study suggest that that financial constraint restrain the ability of domestically owned firms to innovate and export in the sampled countries.

On the other hand, Karimu et al., (2018) modified the theoretical model of Gorodnichenko & Schnitzer, (2013) by introducing infrastructrure constraint in the form of power outtages in addition to the financial contraint. Using the World Bank Enterprise Survey, the authors tested both the financial contraint and power outatges on firms' innovation in SSA, Finding from the study shows that intense power outtages causes firms to innovate (both process and product innovation). Furthermore, increase in the percentage of working capital from internal funds reduces firm innovation in the sampled SSA countries.

In the case of the second theme (innovation and firm productivity), most of the studies based on developed countries dataset (Audretsch and Belitski, 2020; Geroski et al., 1993; Koellinger 2008; Lööf and Heshmati, 2006) generally find a positive effect of innovation on productivity. For instance, the study by Lööf and Heshmati (2006) on Swedish firms finds a positive effect of innovation input on innovation output and the effect of innovation output on firm performance, both level and growth rate of production. Audretsch and Belitski (2020) study on UK firms shows that R&D is important for both innovation and productivity. Further, they find knowledge spill-over to be more important for productivity than R&D.

Other studies such as McAdam et al., (2014) explores how SMEs in challenging regions implement innovation from a path perspective. Using a cross sectional data on UK, the authors findings indicate that firm level knowledge factors influence innovation implementation include the absorptive capacity of the firms, and knowledge sharing linkages. Furthermore, antecedent factors such as lifecycle, leadership, culture, and historical propensity to innovation were found to interact with the Knowledge based factors. Martin et al., (2013) on the other hand explored the motivations of rural small business owners for eco innovation and the extent to which rurality is important. The authors utilise a qualitative study of eight firms in the UK selected based on their rural location, levels of pro-environmental behaviour, eco innovation and growth. Findings from the study are that eco innovation is focus on process innovation, particularly in changing processes to reduce waste and number of raw materials consumed.

Moreover innovation in relation to clean energy is an underexplored area as a driver for SMEs development in emerging economies due to the limited research that decouples the impact of green and brown electricity (Csereklyei et al., 2016). The focus of recent studies on enterprise has been to investigate the relationship between innovation, economic growth and development (Capello & Lenzi, 2016; Du & O'Connor, 2021; Whitacre et al., 2019; Del Monte et al., 2020). The interconnectedness of energy and environmental implications for SMEs innovation has received limited attention (Hoogendoorn et al., 2015). The scarcity of electricity, irrespective of the source, in developing economies, has affected production, distribution and communication leading SMEs to underperform (Mensah et al., 2016). Consequently, this has a negative impact on Africa's growth potential and economic diversification (Eifert et al., 2008). To mitigate the effects of potential energy shortages, medium to large companies in developed economies have turned to self-generation as they have the financial resources to undertake self-generation (Aghion et al., 2012) to sustain their competitiveness both domestically and internationally. However, SMEs neither have access to technology or finance to enter into self-generation (Bond et al., 1999) of electricity thus, potentially creating a two-tier economy that is distinguished through firm access to electricity (Tebaldi & Elmslie, 2013).

The availability of electricity for SME's to trade and innovate is vital for effective engagement in retail, manufacturing, agriculture and education sectors (Solarin et al., 2011). Compared to the 95-100% of the population in developed economies who have access to electricity, under 85% of the population in emerging economies had access to electricity (World Bank, 2014). However, Africa represents 15% of the World population but consumes merely 3% of the world energy output (World Bank, 2014). This demonstrates SMEs in SSA are negatively impacted and unable to innovate and compete as effectively as their counterparts in developed economies (Nyarku & Oduro, 2018). Consequently, electricity shortages resulting in recurring blackouts gives rise to increased production cost that negatively impacts on SSA economies.

There is a geometric increase in African population that demands increased employment opportunities and access to greater energy supply. According to the Energy Information Association (2018) energy consumption in SSA has increased by 45%. But due to lack of energy infrastructure and weak government institutions, energy supply has not kept the pace with demand. Inadvertently, this has limited SMEs ability to innovate, create jobs and compete internationally. Figure 1 shows that electricity supply in SSA compared to other emerging economies is low. The low access to energy suggests there may be a correlation between energy availability, affordability, and economic growth in SSA.

[INSERT FIGURE 1]

The analysis of regional power consumption as depicted in figure 2 further suggests the SSA region suffers from power poverty that limits SMEs growth and innovation potential (Iyke, 2015), as electricity shortages adversely affects manufacturing firm's productivity and innovation capabilities (Allcott et al., 2014). Andersen & Dalgaard (2013) suggest there is an inverse relationship between power shortage and firm's productivity. These findings are considered applicable to SSA economies as power outage affects firm revenue and job creation (Mensah et al., 2016) although innovation is not significantly affected. Fisher-Vanden et al. (2015), in a study on China suggests power outage led firms to substitute energy sources.

[INSERT FIGURE 2]

Studies have examined the relationship between green energy and growth for Western economies (Bulut & Muratoglu, 2018) and demonstrated that green energy consumption leads to increased productivity (Rath et al., 2019). The literature suggests clean energy has a trade-off with cost (Rath et al., 2019). Clean energy is more costly and the SSA region suffers from a finance resource gap (Chirambo, 2016; Eberhard & Shkaratan, 2012; Huenteler et al., 2016). Firstly, it is suggested that to overcome the finance constraint and to address underdevelopment of financial markets, SSA should implement public-private-partnerships (PPP) in energy projects (Eberhard & Shkaratan, 2012). Secondly, the regulatory environment for clean energy in SSA lacks commitment due to poor enforcement of environmental laws, that dissuades private investors from investing in clean energy (Opeyemi et al., 2019). There are other studies that echo similar conclusions (Fadly, 2019; Apergis, 2019).

Within SSA, the bulk of electricity is produced from conventional fossil fuels and a proportion produced from hydro sources (Chirambo, 2016). However, SMEs shift towards clean energy in the form of solar and other sources has remained nascent in SSA due to underdeveloped infrastructure, finance constraints and lack of political motivation (Gorodnichenko & Schnitzer, 2013; Opeyemi et al., 2019).

There are challenges for developing economies to transit into green energy sources as it involves co-evolution of innovation, investment in technology and strategies to decarbonise energy systems (Chirambo, 2016). Such rapid transition involves R&D, adoption of clean technology for production and distribution to achieve low carbon electricity (Opeyemi et al., 2019). This level of commitment to adopt clean energy requires large capital investment to reduce the unit cost of producing green electricity (Cecere et al., 2020). Emerging economies such as SSA lack the financial resources to invest in clean technologies at the same rate as the developed countries. For example, Germany produces 26.6% and Australia 21% from renewable sources (Cecere et al., 2020); this suggests the developed economies are rapidly progressing towards renewable energy. However, the uptake in green energy adoption in SSA remains slow. The prior literature suggests clean energy at present is not easily accessible/affordable for SMEs in SSA due to high cost (Chirambo, 2016; Opeyemi et al., 2019).

The brief literature presented above in summary suggest that in the case of the determinants, credit constraints, regulation related to environmental laws and compliance, and product and service legislation and foreign ownership as the main factors hindering. Whereas power outages, non-restrictive price regulation, efficient enforcement of Intellectual property rights and the legal and regulatory framework, R&D expenditure. Knowledge spill-over as important positive factors for firms' innovation.

Moreover, the review suggest that none of the studies on the determinants of innovation consider specifically the role of cost of electricity on firms' innovation, though this is an important hurdle to cross for firms operating in SSA due to the unreliable power supply, power theft, lack of investment and the lack of competition in the generation segment and the distribution segment of the power system, creating state monopolies and the associated inefficiencies that are passed on to the price of final distributed power to the end-user. Only one study in the reviewed literature explicitly consider energy in the form of power outages and the influence of that on firm innovation in SSA. Though the study on power outages and firm innovation has close links to the current study, it however was focus on power supply unreliability and not the cost of power, which is broader and encompasses supply unreliability, generation mixed, corruption, power theft, lack competition among others. In addition, none of the above reviews also consider how impact of a transition to low carbon electricity generation sources on the price of electricity to infer the likely implication of such a transition on the firm innovation given the impact on cost of energy.

Based on the review, these two important questions emanate, which this study is focus on providing answers to or clarity on. They are.

1. Is the cost of electricity a constraint to firm innovation in SSA?
2. What is the implication of increasing renewable sources of electricity generation on the cost of power?

3.0. MODEL AND DATA

3.1. Theoretical model and Empirical strategy

The theoretical framework is a modified version of the theoretical stylized model developed by Gorodnichenko & Schnitzer (2013) and modified by Karimu et al. (2018), where an SME's decision maker implements a two-stage decision process. The decision maker faces the decision to invest in innovation or not in stage 1, and the decision on the output to produce in stage 2. The first stage decision depends on the investor's liquidity constraints and likely future profits. If the investor has an adequate internal finance and the prospects of innovation on future profits are good, the likelihood of investing in innovation in the first stage will be high. Whereas the reverse is true, when there is lack of internal funds and the prospects of future profits are not good. This implies that the decision to innovate in the first stage depends crucially on two factors. Thus, how easy it is to attract external finance to support the production process in the second stage, to reduce competition by both stages for the same internal funds, and the profit margins to expect from a successful innovation.

More importantly, attracting external finance at the first stage (the innovation stage) is extremely difficult due to the high inherent risk associated with innovation and the lack of willingness of banks to grant loans for such purposes relative to direct production. In situations where it is easy to attract external finance for production purposes, it becomes easy to focus most, if not all the internal funds at the first stage, while at the second stage external finance is sourced for the production process.

In this framework, financial constraint will influence innovation decisions, which ultimately affects the profit of the firm, depending on whether the firm innovates or not and the level of internal financial constraints the firm faces. We further modify the Gorodnichenko & Schnitzer (2013) framework by incorporating the cost of electricity (power) to also influence the decision to innovate, as the innovation process depends on cost of power in rendering electricity services for the SMEs' which is an important input for doing any business, especially modern innovation processes.

Africa, where the cost of power and the associated reliability issues is considered one of the key constraints faced by firms, makes it even more relevant to include the cost of power into an innovation decision model. The reduced-form framework that will be estimated to address the objectives of the study, will also control for key determinants of innovation as suggested by previous literature (e.g., Gorodnichenko & Schnitzer, 2013). This suggests that in addition to availability of funds, the cost of electricity is another key constraint to innovation process by SMEs in SSA. Utilising the theoretical framework, a reduced form model to assess the impact of cost of power on innovation decision and activities by SMEs in SSA can be expressed as:

The is the outcome variables (process innovation and product innovation) for firm *i in country c*; *p* represents the price of power (electricity price), a proxy for cost of electricity by firms; $X_{i,c,}$ is a vector of firm controls (age, whether the firm has a quality certification, percentage of working capital from internal funds, share of foreign ownership, copyright application by firms). Country and year fixed effects are also included to absorb country specific shocks and temporal shocks across the survey years.

Each of the outcome variables (process innovation and product innovation) is potentially censored since we only observed them when it is greater than zero but below zero are not observed but assumed to be zero. To accommodate this, we adopted a Tobit regression model, which is designed for handling such censoring problems.

The decision to innovate is observed if , which is assigned a value of 1 and zero if . This implies a model that has two parts, a participation in innovation part, represented by a probit model. This determines whether y=0 (No) or y>0 (Yes) in the innovation decision / activity. The second part is a truncation regression model, where y > 0. The likelihood function that accommodates the two parts (linear and truncated parts of the data) can be express compactly as

where, D_i is a dummy variable that takes a value of 1 if $y_i > 0$, are the parameters that maximise the likelihood function and are the key Tobit parameters to be estimated in equation (2). Applying logs to equation (2), we convert the likelihood function to a log likelihood function, an approach we usually undertake to simplify the estimation of the model. From equation (2), we obtain the electricity price estimate to determine the influence of the cost of power on firm's innovation decision and activities in SSA.

Next, we consider the potential contributing factors to the cost of power from the perspective of the utilities in terms of the factors that influence the average price of power provided to the final consumer by considering the following electricity price model express as

In equation (3), p_c represent price of electricity, charge by utilities in each country, RE_c is the renewable energy generating source, NRE_c denote non-renewable energy generating source, TDL_c is the technical and distribution loses from generating and distributing electricity in each country and e_c is a composite error term that comprises country fixed effects and a random error term. The goal from equation (3) is to assess the potential role of renewables in electricity generation mixed on cost of electricity. Furthermore, what we should expect in the future, given the gradual energy transition to renewables and the implication thereof on SMEs innovation decisions and activities.

3.2. Data

The data for the study is taken from three datasets, all from the World Bank. The datasets we utilised are the World Bank Enterprise Survey dataset, the Innovation Follow-up Survey dataset and the World Development Indicator (WDI)[1] dataset (World Bank, 2020)[2]. The Enterprise Survey is a dataset on private sector firms from over 148 countries covering small, medium and large firms. The World Bank conducts the survey periodically, which contains information on firm performance, constraints to doing business and regulatory and governance indicators affecting firms. The Innovation Follow-up Survey is an extension of the Enterprise survey but focuses solely on innovation decision and activities by firms, these data were adopted from an earlier study by Karimu et al. (2018). We also utilise the WDI dataset for renewable and non-renewable sources for electricity generation for the sample countries. Our focus is on SMEs due to their contribution to growth and employment in SSA.

Combining the two survey datasets and utilising the available data on the key variables on firms located in SSA, the total number of firms reduced from 155,000 from 148 countries globally to 3,400 firms from ten (10) SSA countries. The survey covers the period between 2013 and 2014, which is pooled together for the analysis. The countries included in the dataset are Congo DRC, Ghana, Kenya, Namibia, Nigeria, South Sudan, Sudan, Tanzania, Uganda, and Zambia.

The variables in the dataset include key outcome variables such as decision to innovate, process and product innovation, and key control variables that are suggested in the literature (Gorodnichenko & Schnitzer, 2013; Karimu et al.,2018) to influence innovation by firms such as

[1] https://databank.worldbank.org/home
[2] https://www.enterprisesurveys.org/en/enterprisesurveys

age, quality certification, percentage of working capital from internal funds, share of foreign ownership, copyright application by firms.

Decision to innovate variable, which is a dummy variable that takes a value of 1 if the SME has taken the decision to innovate and 0 if it has not taken a decision to innovate. Another key variable in the dataset is whether the SME undertook any process innovation. This is also a dummy variable with a value of 1 if the SME undertook process innovation and 0 if it has not. The product innovation variable is also a dummy variable with a unit of either 1 if the SME undertook product innovation and 0 if it does not.

Furthermore, the working capital variable is the total working capital express as a percentage of internal funds by the SMEs, whereas foreign ownership variable is dummy variable that takes a value of 1 when the owner is non-Ghanaian and 0 if the owner is Ghanaian.

Another key variable in the dataset is copyright application. This variable is significantly linked to successful innovations as innovators tends to apply for copyright for their innovations when the innovation process leads to a successful innovative product or service. This variable is also measured on a 1 and 0 scale, where 1 denotes the SME has applied for a copyright and 0 if it has not.

The dataset also contains information on whether the SMEs undertook research and development (R&D) activity in the reference period. A key input into any innovation process. This variable is also a discrete variable which takes a value of 1 if the SME is engaged with R&D activity and 0 if it does not.

Furthermore, there is information on electricity price and on both renewable and non-renewable electricity generation. The price data is measured in US dollars (USD) per kilowatt hours of electricity whiles that on renewable generation is measured as electricity generated from all renewable sources (excluding hydro) and express as a percentage of total electricity generated in a year. That for non-renewable generation include all power generated from non-renewable sources such as coal, oil and gas. It is also expressed as a ratio over total electricity generated in a year.

Table 1 presents the summary statistics of the variables used in the analysis. The decision to innovate by SMEs is slightly above 50 per cent but Product and process innovation rates are below 40 per cent. The percentage of working capital from internal funds is relatively large, consistent with the literature on sources of funding for SMEs (Mol-Gómez-Vázquez et al., 2018; Aiello et al., 2020). This suggests that most of the firms in our study relied largely on internal source of finance for their working capital. The share of foreign ownership is about 10 per cent, whereas SMEs copyright application is less than 10 per cent in our sample.

The electricity price data ranges between 0.028 US dollar (USD) per kWh and 0.295 USD per kWh with relatively moderate variation across countries compared to product and process innovation. Moreover, the average electricity generation from renewable sources is about 2.6% (this excludes hydro), but with high variation relative to generation from non-renewables sources, depicted by the high standard deviation value above the mean. The general conclusion from the summary statistics is that the decisions regarding innovation by firms in the sampled countries is slightly above average, but that of product and process innovation is low with significant variations depicted by the higher standard deviations relative to the respective means. Moreover, quality certification and copyright application are low. Considering this together with low product and process innovation suggests that either there is low successful innovation or that the innovations are not significant to warrant copyright application.

[INSERT TABLE 1]

4.0. RESULTS

Results of this paper are presented in two steps designed to answer the two research questions. The strategy is to first answer the second question via equation (3) and later the second question via equation (2). In the first step, equation (3) is estimated to determine the drivers of the cost of electricity from the utilities and to determine if the source of electricity generation, especially renewable generating sources do influence the cost of power and in what way(s). In the second step, we estimate a Tobit model as presented in equation (2). This step is to find out the association of cost of power via electricity price and that of firm's decision to innovate by using the full sample (reported in column 2 in Table 2). Next, the Tobit model is estimated by restricting the sample to only firms that have made the decision to innovate in the first stage to examine the relationship between the cost of power and innovation activities (product innovation and process innovation). In all the estimations, key factors that influence innovation at the firm level as suggested by (Gorodnichenko & Schnitzer, 2013; Karimu et al.,2018) are controlled.

Generation sources and electricity prices in SSA

First, we assess what drives electricity prices in SSA from the perspective of the utilities. Here we are interested on whether the generation mix (renewable generation source and non-renewable generation sources) increases or decreases electricity price. This will give us the transmission mechanism of the negative impact of increasing electricity price on innovation decision and activities by SMEs in SSA.

The result from the drivers of electricity price is reported in table 2.The results demonstrate that both renewables (excluding hydro) and non-renewable generation sources influence positively on electricity price in SSA, though the impact of renewables have a larger magnitude relative to that of non-renewables. Besides the generation sources, technical and distribution losses (TDL) also contribute positively to electricity price with a much larger magnitude relative to that of electricity generation sources.

[INSERT TABLE 2]

In general, both renewable and non-renewable generating sources have a positive impact on electricity price, but the impact is much more from renewables. The reason for this may be that the electricity generating plants in SSA are not cost effective in terms of sources of generating power. Consequently, the cost inefficiencies are passed on to the final price of electricity. Secondly, the required infrastructure to support the power systems is underdeveloped further impacting the cost inefficiencies. It is the fact that renewables penetration is very low in most SSA, often less than 5 per cent excluding hydro (IEA, 2019) of the total electricity generation mix. Therefore, the required infrastructure for renewable plants in SSA is underdeveloped relative to conventional power plants, implying the cost inefficiencies are likely to be much more in this case relative to non-renewable power plants. Though the cost of solar and wind is reducing and the efficiency improving, the unit price is still high without any government support policy suct as a a feed-in-tariff system due to the high upfront cost of these renewable technologies. In SSA, such support policies at best are very minimal, making renewables an expensive alternative.

Cost of electricity and firms' innovation

Table 3 presents the results from estimating equation (2) to satisfy one of our objectives of the study thus, what is the association between cost of power and firms' innovation decision and innovation activities such as process and product innovation? Table 3 has three columns and each column present results for each of the three outcome variables (decision to innovate, product innovation and process innovation). Considering the results presented in column 1, it suggests that cost of power (p) is negatively associated with the decision by SMEs in SSA to innovate. The estimated value of the association is statistically significant even at the 1 percent significance level. We can interpret the estimated electricity price coefficient as the total effect of electricity price on firms' decision to innovate in SSA. This negative electricity price effect is consistent across the other two innovation activities, but with larger magnitudes.

A key explanation for the negative cost of power effect on innovation by firms in SSA is that such costs contribute significantly to the inability of firms to spend on processes and product development as they also compete for the limited internal funds. Ultimately, it affects the profit margins, which further limit reinvestment in the firms' activities including innovation.

Key controls that are significant determinants of innovation decision and activities in SSA includes percentage of working capital that comes from internal funds, copyright application, whether SMEs engage in R&D activities (an input for innovation production) and age of the SMEs. Consistent with model prediction, a greater percentage of working capital from internal funds is negatively associated with decision to innovate, product and process innovation, which is consistent with the findings in Bond et al. (1999) and Dechezleprêtre et al. (2016). To test for SMEs age and its effect on innovation (i.e., decision to innovate, process innovation and product innovation), we controlled for the Age of the SMEs. The results reported in table 3 suggest that age has a negative association with the SMEs decision to innovate and product innovation, whilst showing a positive association with process innovation.

[INSERT TABLE 3]

Intuitively, when a firm applies for copyright, the chances that it will be involve in innovation activities and investing in such activity is likely to be high since if the firm does not have new ideas, processes or products or involved in activities that are likely to produce such soon, there will be no need to apply for copyright. The result clearly indicates that copyright application by SMEs in SSA increase product and process innovation. It also influences positively the decision to innovate. In the case of product and process innovation, engaging in R&D activity promote these innovative activities as documented by prior literature that (Audretsch and Belitski, 2020; Lööf and Heshmati, 2006) R&D expenditure is an input into the innovation process with evidence that it promotes innovation.

Does firms' innovative decision and activities react to different levels of electricity price?

An important policy question we ask on the backdrop of a negative electricity price effect is, whether firms' involvement in innovative activities react differently to alternate electricity price levels in SSA? The importance of this question is to determine at what level (s) of electricity price do firms feel the pinch of the increasing cost of doing business due to the cost of electric power. This among other things can provide policy makers the potential solution to mitigate the cost of doing business that stems from electric power cost. To address this, we take the marginal effect of electricity price on product and process innovation at different percentiles of electricity price (25, 50, 75 and 99 percentiles), results are presented in figure 4 and 5. In figure 4, it is apparent that electricity prices below 0.081 US dollars (USD) has a positive effect on product innovation, whereas prices above 0.081 USD has a negative effect on product innovation in SSA.

[INSERT FIGURE 4]

The evidence suggests that lower cost of electricity on the average improves uptake in product innovation. To reduce the negative consequences of cost of power on firms' innovation (product innovation) in SSA, cost of electricity per kWh should be kept below 0.081 USD on the average for the countries in the sample.

In the case of process innovation (presented in figure 5), the existing price profile has a negative impact on innovation, though the magnitude of the impact is less (-2) at lower tariff rates (0.028 USD) than the effect (- 6) at higher tariff rates (0.295 USD). This suggests that the current level of electricity prices in SSA is generally high to induce any positive process innovative activity.

[INSERT FIGURE 5]

Note that in our innovation model, we did not explicitly control for macroeconomic variables such level of economic performance proxy by real GDP per capita but intuitively it is clear that such firms operate in a macroeconomic environment and therefore such macroeconomic variables such as GDP affects firms' activities and growth process, including innovation. In assessing the robustness of our results, we replaced the country fixed effects with country specific real GDP per capita and re-estimate the model. This result is reported in Table 4. Generally, the results are qualitatively the same with minor differences in the magnitude of the estimates. We therefore conclude that our main result reported in Table 3 is robust to whether macroeconomic variables are explicitly included or proxy with country fixed effects.

[INSERT TABLE 4]

5.0. CONCLUSIONS

This empirical study demonstrates the relationship between sources of electricity generation and price of electricity, and further the relationship between cost of electricity and SMEs innovation in the case of Sub-Sahara Africa (SSA). This study highlights the cost implication of increasing electricity generation from renewable sources. It further demonstrates the impact of cost electricity on firm innovation. Traditionally, literature on innovation overlooked the role of cost of energy and firms' innovation activities.

Firstly, the study examined the impact of energy prices on SMEs decision to innovate. Secondly, it considers whether energy prices impact on SMEs innovation process (i.e., the actual product innovation). Thirdly, it analyses how the energy generation mix impacted the price of electricity and the likely inference we can make on the cost of power and the implication thereof on SMEs innovation decision and innovation process.

The study utilises data from the World Bank Enterprise Survey, the Innovation Follow-up Survey and the World Development Indicator (WDI). We applied the Tobit regression model for nine SSA countries which are included in the dataset for the period between 2013 and 2014 to focus on SMEs as they contribute to growth and employment in SSA.

Firstly, the model shows that both renewables (excluding hydro) and non-renewable generation sources influence positively on electricity price in SSA, though the impact of renewables is of larger magnitude relative to non-renewables. The electricity prices are negatively associated with the SMEs decision to innovate at large (significant at the 1% level), specifically, in relationship to process and product innovation as reported in **table 3**. The results suggest there is an inverse relation between the price of electricity and SMEs innovation in SSA countries. To encourage SMEs to innovate in SSA requires a reduction in the cost of energy. This relationship, amongst other things, suggests there is a requirement to make cost of electricity cheaper to enable encourage SMEs to innovate make their products and services competitive. As evidenced in **figure 3,** cost of power below US$0.081 per kWh has a positive effect on product innovation and price above this has a negative impact on product innovation. Whereas process innovation reported in **figure 4**, suggests high electricity prices in SSA is a barrier to process innovation hence, the need to develop strategies to bring about cost reduction. However, the goal for sustainable development by promoting the transition to low carbon energy sources maybe expensive for the SMEs as it has high energy cost implication, and such a goal may have negative implication for SMEs innovation derive.

In addition to the generation sources, technical and distribution losses (TDL) also contribute positively to electricity price with a much larger magnitude relative to that of electricity generation sources. These findings are of significance for policy makers to focus on TDL to reduces loses and to improve electricity infrastructure to lower the cost of electricity, especially renewable as it is underdeveloped when compared to conventional power plants.

SMEs financial constraints are reported as major concerns for SMEs. The empirical findings in table 3 suggests there is a negative correlation between the percentage of working capital from internally generated funds and the decision to innovate. The findings of this study are corroborated by Bond et al. (1999) and Dechezleprêtre et al. (2016).

SMEs, due to finance constraint tend to rely on internal finance for working capital. However, the study suggests internal working capital is negatively corelated with innovation. Thus, negatively impacting on SMEs growth and competitiveness. This suggests in promoting sustainable innovation amongst SMEs, SSA government and policy makers need to intervene through reducing cost of electricity, to affect innovation amongst SMEs and economic prosperity for the region. These findings have implications for policy markers across emerging economies where electricity infrastructure is underdeveloped.

The main limitation of this study is the lack of data availability for a longer duration that will enable researchers to undertake a more robust data evaluation. Secondly, the data used for the study is for 2013-2014, a more recent data will enable us to study the impact of changes in the energy mix. Future research should consider implications of green energy infrastructure and access for developing economies such as SSA countries to maintain their economic competitive advantage.

6.0. Declarations

Finding

The authors declare that there is no received for this work.

Competing interest

The authors declare that there is no competing interest.

Availability of data and material

Raw data were generated at [https://www.enterprisesurveys.org/en/enterprisesurveys]. Derived data supporting the findings of this study are available from the corresponding author [S.S] on request.

Code availability

The data Codes are available from the corresponding author on request.

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Tables

Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Innovation (1/0)	4830	0.558	0.497	0	1
Product Innovation (1/0)	4798	0.396	0.489	0	1
Process Innovation (1/0)	4796	0.335	0.472	0	1
Working Capital (% internal)	4467	75.437	33.528	0	100
Quality Certification (1/0)	4618	0.110	0.313	0	1
SMEs engage in R&D Activity (1/0)	4830	0.191	0.393	0	1
Age of SME (years)	4577	13.930	10.151	1	76
Share of Foreign Ownership (1/0)	4637	0.096	0.272	0	1
SMEs Copyright Application	4720	0.087	0.327	0	3
Electricity price (USD per kWh)	4830	0.152	0.096	0.028	0.295
Renewable electricity generation (ratio of total)	4418	2.597	7.402	0.000	24.842
Non-renewable electricity generation (ratio)	4418	38.908	36.482	0.109	99.590

Note: USD denotes United State Dollar, kWh is kilowatt-hours

Table 2: Renewables and no-renewables generation sources and electricity price in SSA

	(1) Electricity price (log)
Electricity generation from renewables (excluding hydro)	0.006***
	(15.19)
Electricity generation from non-renewables	0.003***
	(7.05)
Technical and distribution losses (TDL)	0.067***
	(138.74)
Constant	1925.8***
	(93.63)
Fix effect	yes
Number of observations	2529
F-statistic	8925.5
P-value	(0.000)

R-square	0.895

t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Determinants of SMEs Innovation decision and activities in SSA

	(1) Innovation decisio	(2) Product innovation	(3) Process innovation
Electricity Price	-1.100***	-2.008***	-1.764***
	(-6.78)	(-8.49)	(-6.59)

Age of SMEs (log)	-0.045**	-0.051*	0.059*
	(-2.32)	(-1.86)	(1.86)
SMEs engage in R&D Activity (1/0)		0.579***	0.799***
		(14.05)	(18.22)
Quality Certification (1/0)	0.175***	0.059	0.092
	(4.56)	(0.93)	(1.34)
Working capital (% internal funds)	-0.001***	-0.002***	-0.002***
	(-3.32)	(-2.73)	(-3.29)
Share of Foreign Ownership	0.001**	0.001*	-0.001
	(2.07)	(1.66)	(-1.37)
SMEs Copyright Application (1/0)	0.297***	0.211***	0.384***
	(7.36)	(3.63)	(5.98)
Constant	0.710***	0.227*	-0.207
	(8.12)	(1.74)	(-1.41)
Country & Firms fix effects	yes	yes	yes
Sigma	0.788***	1.003***	1.087***
	(78.8)	(74.77)	(71.83)
N	4176	3874	3875
F-statistic	8.432	13.74	20.21
P-value	(0.000)	(0.000)	(0.000)
R-square	0.025	0.043	0.062
Loglikelihood	-4317.2	-3643.2	-3287.8

t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, International Standard Industrial Classification (ISIC) code is used for the firm fixed effects.

Table 4: Determinants of SMEs Innovation decision and activities in SSA, control for GDP

	(1)	(2)	(3)
	Innovate	Product innovation	Process innovation
Electricity Price	-1.112***	-2.071***	-1.758***
	(-6.42)	(-8.71)	(-6.55)
Age of SMEs (log)	-0.0537***	-0.0456*	0.0583*
	(-2.63)	(-1.67)	(1.84)
SMEs engage in R&D Activity (1/0)		0.575***	0.799***
		(13.93)	(18.22)
Quality Certification (1/0)	0.158***	0.0606	0.0923
	(3.60)	(0.96)	(1.34)
Working capital (% internal funds)	-0.001***	-0.002***	-0.002***
	(-2.98)	(-2.76)	(-3.29)
Share of Foreign Ownership	0.001*	0.001*	-0.001
	(1.88)	(1.65)	(-1.36)
SMEs Copyright Application (1/0)	0.299***	0.212***	0.384***
	(6.92)	(3.64)	(5.98)
lnGDP	-0.0241	-0.0790**	0.00802
	(-0.90)	(-2.34)	(0.21)
Constant	0.844***	0.795***	-0.265
	(3.89)	(2.89)	(-0.85)
Firms fix effects	yes	yes	yes
Sigma	0.802***	1.002***	1.087***
	(71.79)	(74.66)	(71.83)
N	4176	3874	3875
F-statistic	7.059	13.57	19.56
P-value	[0.000]	[0.000]	[0.000]

R-square	0.024	0.044	0.062
Loglikelihood	-4029.2	-3640.6	-3287.8

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figures:

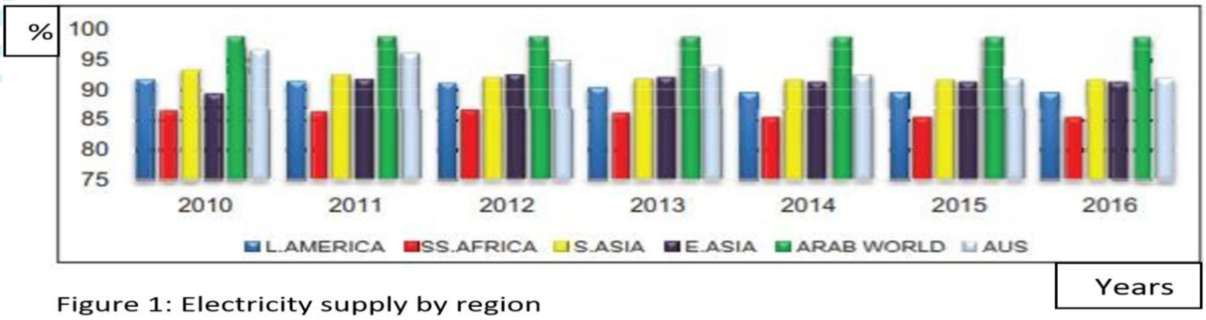

Figure 1: Electricity supply by region
Sources: *OECD (2019)*

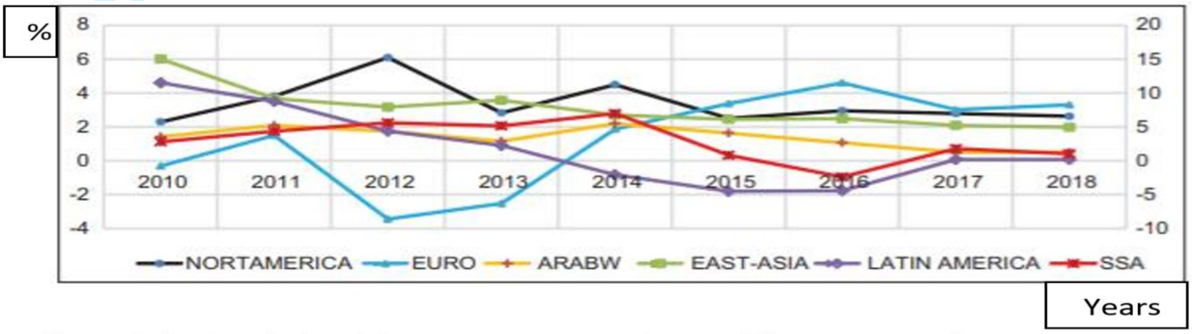

Figure 2: Regional electricity power consumption per kilowatt per capita
Sources: *World Bank Development Indicators (2019)*

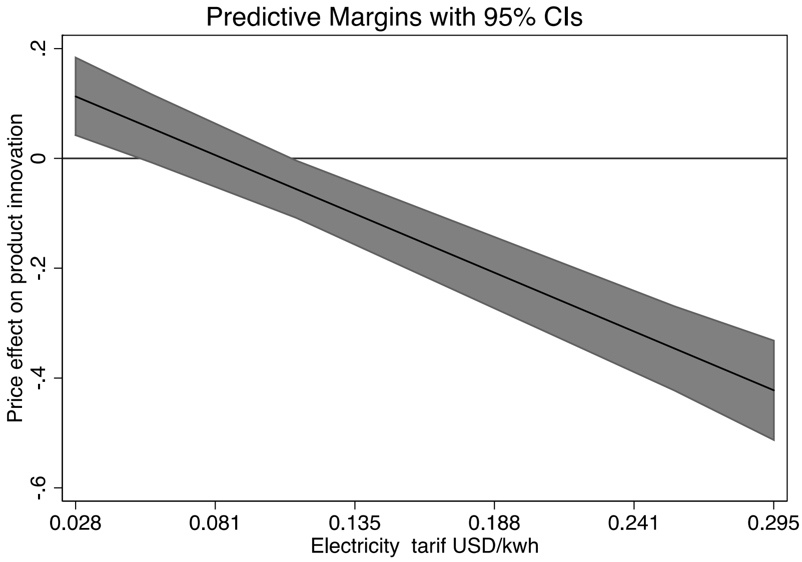

Figure 4: Predicted impact of electricity price on product innovation at the 25, 50,75 and 99 Percentile of electricity price

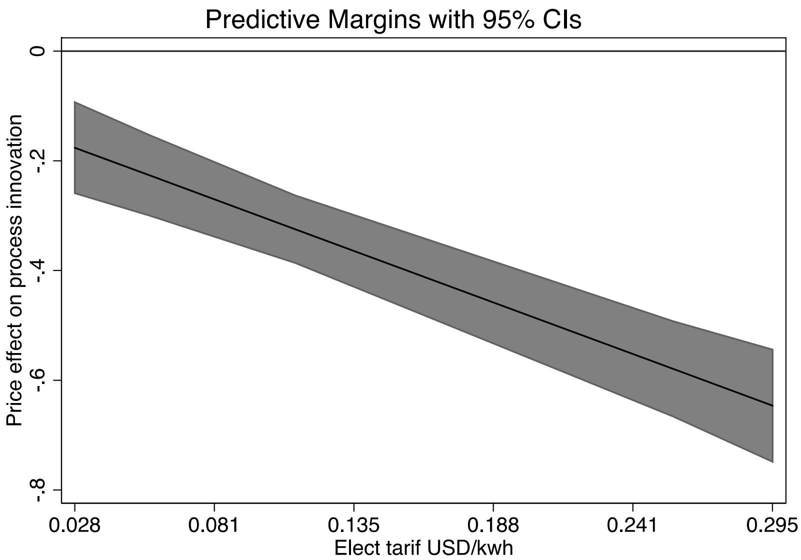

Figure 5: Predicted impact of electricity price on process innovation at the 25, 50,75 and 99 percentile of electricity price.