Beyond connectivity: The complementary role of rural electrification and digital infrastructure in enhancing rural small and medium-sized enterprises' competitiveness in Tanzania

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ABSTRACT

Small and Medium-sized Enterprises (SMEs) in rural areas play a role in employment, household income generation, development of local markets and economic diversification, but they are less competitive due to the lack of productive infrastructure. Rural electrification enables the use of energy for machinery, product preservation, longer machine operation, digital devices charging, communication, access to information, digital payments, and routine business services while digital infrastructure enables communication, access to information, digital payments, and participation in markets in rural areas. Although these resources are closely linked, rural enterprise competitiveness studies tend to be split into two categories namely electricity and digital connectivity that are analyzed separately. This study explores the correlation between Rural Electrification and Rural SME competitiveness and digital infrastructure and rural SME competitiveness in Tanzania. The study is based on Resource Dependence Theory and Infrastructure-Led Development Theory with explanatory quantitative and cross-sectional design. Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS 4 was used to analyse the data of 362 rural SMEs. The upward trend for the rural SMEs competitiveness associated with digital infrastructure ($\beta = 0.447$, $p<0.001$) and rural electrification ($\beta = 0.382$, $p<0.001$) accounts for 60.1% of the variance of rural SMEs competitiveness. The results confirm that providing electricity is not enough to promote rural enterprises development. Electricity and digital infrastructure should be seen as complementing productive resources in the development strategies of rural SMEs. The paper adds to literature on infrastructure and rural entrepreneurship by presenting a single model of rural SME competitiveness in Tanzania, and integrating energy and digital infrastructure. It is recommended that policymakers and infrastructure planners adopt an integrated approach that bundles electricity and digital connectivity investments rather than treating them as separate priorities. Furthermore, enterprise support programmes should combine infrastructure provision with financing, digital skills training and device access so that rural SMEs can translate connectivity into productive competitive gains.

Keywords: Digital Infrastructure; Infrastructure-Led Development Theory, PLS-SEM; Rural SMEs; Rural Electrification; Resource Dependence Theory; SME Competitiveness

I. INTRODUCTION

Small and medium-sized enterprises (SMEs) are important sources of employment, income generation, local production and market development in developing economies. In rural areas, where formal employment opportunities may be scarce, enterprise activities offer valuable livelihood diversification options for households and this is relevant to their contribution. Rural SMEs are, however, confronted with various environments that include among others weak infrastructure, small markets, limited access to finance, shortage of skilled labour and physical distance from major commercial centres (Cele & Tshikovhi, 2023). The Organisation for Economic Co-operation and Development (OECD) defines infrastructure as "the basic facilities and systems provided for the support of economic activities and development. This, in rural enterprises, will encompass transport, energy, water supply and information and communication systems. These facilities facilitate the transport of goods and persons, access to basic services, communications and the provision of business functions. Infrastructure is then not only a prerequisite to the development of rural enterprises, but also a productive factor that influence the efficiency of firms' inputs of labour, capital, information and technology (Agénor, 2010).

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Electricity is used by the business to power machinery, refrigeration, lighting, computers, communication equipment and other productive equipment. Interruptions can cause some labour and capital to be idle, disrupt production schedules, cause harm to products and can adversely affect the ability of firms to consistently provide their customers with service. African manufacturing firms' evidence shows that poor power infrastructure is associated with lower productivity (Mbedzi & Kapingura, 2023) and prior theoretical work suggests that the long-run effects of unreliable power supply can go beyond a reduction in productivity, leading firms to shrink in size and reducing entry into the industry (Fried & Lagakos, 2023). In Tanzania, studies also suggest that the performance of SMEs is related to the quality and stability of electricity as well as electricity costs, highlighting the need to explore beyond mere access to electricity (Fried & Lagakos, 2023; Mrosso, 2025).

The other side of the coin is that digital infrastructure is as important to enterprise competitiveness as business transactions increasingly rely on mobile networks, internet services, digital payments, and electronic communication. Digital infrastructure lets companies access market data, interact with customers and suppliers, promote products, process payments and engage customers outside their local area. The evidence from small businesses indicates that better broadband access and internet speeds can be linked to increased sales, profits and labour productivity, but this link is only relevant if the companies have adopted the technology and have the skills and complementary organisational changes needed to benefit from it (Koutroumpis & Sarri, 2024). The available literature on the subject of digitalisation in Africa also reveals a significant potential for digitalisation but suggests that many companies are not using digital technology extensively for productive purposes (Karacuka et al. 2025). When analysing SMEs competitiveness in rural areas, the question of access to a digital gadget must be separated from the question of how it can be used productively for the benefit of the SMEs (Koutroumpis & Sarri, 2024; International Finance Corporation [IFC], 2024; Nguimkeu & Okou, 2024).

Electricity and digital infrastructure are of special significance in the context of rural enterprises, as digitalisation does not replace the need for reliable energy supply. Electricity is essential for digital devices, network equipment, charging systems, computers, refrigeration systems, electronic payment platforms, and other technologies. Previous research on African companies reveals that broadband use can raise electricity intensity in the short run, it can facilitate product and process innovation, and research and development (Bouazizi & Ghazouani, 2025). This discovery implies that digital infrastructure and electrification can complement or substitute each other as productive enterprise resources (Jia & Li, 2025). Mobile connectivity may not be able to fully capitalize on the digital opportunities available to a rural enterprise, even if electricity access is available and reliable (Bouazizi & Ghazouani, 2025) and vice versa (Agénor, 2010).

These relationships are better illustrated in the Tanzanian rural economy. While there has been growth in electricity access in rural areas, rural uptake and productive use are still significant concerns for development (National Bureau of Statistics [NBS], 2025; REA, 2025). Studies focused on rural Tanzania shows that increasing electricity access as a result of physical expansion of electricity networks does not automatically guarantee effective use by rural households and enterprises (Rural Energy Agency [REA], 2019). Meanwhile, digital transformation presents new possibilities for small businesses to connect, engage and enter markets, but with the limitations of cost, capability, infrastructure security and productive application (Rampaul, 2025). These conditions provide an incentive to shift the conversation from connectivity alone to complementary infrastructure needed to catalyze the transformation of infrastructure access to competitive business results for rural enterprises and businesses (Ruhinduka et al., 2025; IFC, 2023).

The study therefore focuses on two types of infrastructure resources – rural electrification and digital infrastructure on the competitiveness of rural SMEs in Tanzania. The first one focussed on the link between “rural electrification” and “rural SME competitiveness”. The second goal is to investigate how digital infrastructure relates to the competitiveness of rural SMEs. The study adopts Resource Dependence Theory (RDT) that focuses on the importance of resources beyond the firm and Infrastructure-Led Development Theory that addresses the linkage between infrastructure and increasing organizational productive capacity and decreasing constraining factors to economic development. The study addresses the need for a more comprehensive explanation of rural SME competitiveness by considering the two infrastructure resources in the same model. The central point is that the provision of, say, electricity is not a solution to the constraints of rural SMEs or the provision of, say, digital infrastructure is a solution to the constraints of rural SMEs, but that the provision of reliable electricity and usable digital infrastructure is complementary conditions for productive rural enterprise activity.

1.1 Statement of the Problem

Small and medium-sized enterprises (SMEs) in rural areas are constrained by infrastructure issues that hinder productivity and competitiveness. Electricity power outages impact production, reduce working hours and costs, and disrupt digital access to customers, financial services, information and suppliers (Fried & Lagakos, 2023; IFC, 2023). It is hard to see how small enterprises with low capital and resources will be able to commit to alternative energy and digital technologies given these challenges (Agénor, 2010; Foster, 2025).

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Electricity accessibility in Tanzania has increased but the issues of reliability, affordability and productive use remain. SMEs performance is related to electricity accessibility and stability in the supply of electricity in Kibaigwa, whereas, electricity cost has been found to limit business outcomes (Mrosso, 2025; Ruhinduka et al., 2025). There is also a loss of productivity due to electricity shortages, and the use of generators is promoted (Fried & Lagakos, 2023). Likewise, digital connectivity is not enough to ensure productive use, as costs, limited skills, and weak network connectivity and power outages limit adoption (IFC, 2023; Koutroumpis & Sarri, 2024; Nguimkeu & Okou, 2024).

How rural electrification and digital infrastructure relate to rural SME competitiveness in Tanzania remains uncertain, given the increasing competition and fast development of digital technologies. Digital technologies need reliable electricity and connectivity enables market access and business coordination. Broadband adoption can also lead to a rise in electricity demand (Bouazizi & Ghazouani, 2025), which shows the complementarities of infrastructure (Agénor, 2010). Previous research has not analyzed both resources together in terms of competitiveness such as market reach, cost effectiveness, responsiveness and business growth. This research overcomes this gap by using PLS-SEM.

1.2 Research Objectives

i. The first specific objective is to examine the relationship between rural electrification and rural SME competitiveness in Tanzania.
ii. The second specific objective is to examine the relationship between digital infrastructure and rural SME competitiveness in Tanzania.

1.3 Research Hypothesis

Ho_1: Rural electrification is positively associated with rural SME competitiveness.
Ho_2: Digital infrastructure is positively associated with rural SME competitiveness.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Resource Dependence Theory

The Resource Dependence Theory (RDT) of Pfeffer and Salancik (1978) provides a theory of organisational behaviour based on the notion of dependence of organisations on external sources of power which control some or all of the organisations' resources. Organisations need resources to carry out their work but they do not necessarily have control over the institutions and systems that make resources available. Such dependency is especially significant for SMEs as small resources of financial, technological, informational and human resources may limit SMEs' capacity to deliver critical services on their own. They therefore rely on suppliers, financial institutions, infrastructure providers, customers and systems with government support (Hillman et al., 2009; Pfeffer & Salancik, 1978).

Electricity and digital connectivity are important external resources in rural areas, as individual enterprises are not able to set up and run electricity distribution systems or telecommunications networks or broadband systems on their own. Availability, reliability and cost of these can impact on the level of production organisation, customer communication and market access by firms. Such was the case with African SMEs in recent times. Quaye et al. (2024) for instance, point to such factors as poor technology enabling infrastructure, inadequate finance, and limited absorptive capacity as factors that hinder the adoption of technology by Ghanaian SMEs. These results suggest that resources and conditions that are not directly under the management of a particular enterprise are also important to the competitiveness of an enterprise.

Rural electrisation is considered as an externally provided resource for the energy-related operating constraints, which can increase the productive activities available to the enterprises, thus providing a theoretical explanation for the first objective. It also contributes to the second objective as digital infrastructure enables access to communication and information systems that can not be built by individual SMEs. But having access to outside sources does not necessarily mean being competitive. The productive power of electricity and digital infrastructure relies partly on the company's capacity to integrate these services with supporting resources, like finance, equipment, managerial knowledge and employees' skills. RDT thus provides an explanation both of the significance of infrastructure and of the limitations that may exist with respect to its productive use.

2.1.2 Infrastructure-Led Development Perspective

The Infrastructure-Led Development perspective is focused on the role of investment in physical and technological infrastructure in supporting economic development through an enhancement of productive capacity and transaction costs reduction, and an increase in market opportunities. Agénor (2010) builds an analytical framework through which to consider the impact of public infrastructure investments on productivity and long-term economic growth. The concept of infrastructure is thus expanded beyond the traditional notion as a basic public service to that of a productive input that facilitates the utilization of private capital, labour and technology. The significance of

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infrastructure as a productive input has been supported in previous literature. For instance, Dagnachew et al. (2023) suggest that energy planning in Sub-Saharan Africa must explicitly consider electricity productivity with the aim of not only expanding connections. Additionally, this difference is important with regard to rural SMEs' electricity access, as those businesses cannot use electricity to power machinery, products, materials or other income generation activities.

Digital infrastructure is a complementary productive resource. It provides the facilities for enterprises to interact with each other, to get information from the market, to enter into electronic transactions or to communicate with customers beyond their geographic locality. Ekeoma (2024) used firm-level data from 13 emerging and developing countries to show that the adoption of information technology positively correlated with firm performance and helped to mitigate the negative effects of geographical remoteness on firm performance. This evidence builds on the infrastructure-led argument by demonstrating how digital tools can contribute to addressing some of the constraints identified with rural location. Therefore, the perspective is appropriate for both objectives of the study. Electrification in the rural areas can increase the productive capacity of enterprises and digital infrastructure can enhance enterprise access to information, transaction and markets. However, benefits will only be realised provided there is good infrastructure and enterprises are capable of effectively utilising the services. Investment in electricity and digital networks can yield a small amount of enterprise-level benefits if the company does not have the necessary equipment, finances, skills or market opportunities.

2.2 Empirical Review

2.2.1 Rural Electrification and Rural SME Competitiveness

Rural electrification makes energy available for production, processing, storage for lighting, communication and other business activities to enterprises. It's not just about getting a connection to electricity. Its contribution to competitiveness goes beyond a connection to electricity. Reliability, affordability, adequacy and productive use of electricity also drive whether or not enterprises can turn electricity access into improvements in their business operations. The differences are significant because in an interconnected system, even the loss of a single production unit can trigger a loss of electricity supply and/or drive up the cost of operations and reduce capacity for electricity-using equipment.

Ekeoma (2024) conducted a study on the relationship between electricity access and profitability of micro and small enterprises in Ghana. They found that electricity supply had a positive impact on enterprise profitability, and that insufficient grid electricity or the cost of other energy sources were still key operational issues. The study, however, demonstrates that there is a commercial relevance to the availability of electricity, although its findings are not necessarily transferable to SMEs in rural areas, because of its size and focus on Accra only. The results do, however, make an important distinction between access to electricity and availability of an affordable and reliable electricity supply for supporting business.

Osei-Gyebi and Dramani (2023) looked at electricity shortages and firm performance at the broader regional level using enterprise-level data from 28 Sub-Saharan African countries. They determined that the number of outages and the length of time without electricity was related to reduced annual firm sales. They also found that small businesses suffered more than large businesses; in part, because they lacked the financial depth to deal with disruptions. This implies that electricity reliability is especially important for the competitiveness of SMEs, because smaller firms might not be able to afford generators, alternative energy sources or other means of electricity backup.

Aarakit et al. (2024) provided a systematic literature review of the conceptualisation and determinants of productive electricity use, which further illustrates the importance of productive electricity use. Their work raises awareness on the difference between electricity supply and electricity use in income-generating activities. This distinction is corroborated by the study by Gad and Leone (2024) which involved women entrepreneurs in micro, small and medium-sized enterprises in the food and textile sector in selected African countries to explore their productive use of energy. They focus the attention on the role of the characteristics of enterprises and access to productive resources in influencing electricity's contribution to business activities.

In the context of the enterprise level, Chamdimba et al. (2026) looked at energy access and firm performance of 362 SMEs in four districts of Malawi. They conclude that there is a positive relation between energy use and enterprise turnover and employment but less between reliability of electricity and employment. Importantly, the study concluded that many of the enterprises had mainly used electricity for the basic activities and not for more productive activities, especially for lighting. The results indicate that access to electricity does not automatically lead to better performance of businesses. It's contribution will be determined by the level of use of electricity for value and income generation activities by enterprises. Another study by Zhang et al (2025) confirms electricity failures have implications for operations in the manufacturing sector in Africa, showing the effects of energy outages on in-house generators and capacity utilisation. They highlight the link between electricity supply shortages, backup power supplies and productive capacity utilization. This is important for rural SMEs as alternative energy providers may be required to allow businesses to continue functioning during periods of disruption, but can also raise operating costs. Small businesses may have different capabilities in absorbing these extra costs compared to larger businesses.

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Overall, these results indicate that there are several interconnected business processes between the rural electricity extension and the competitiveness of small and medium enterprises. Good electrical supply can help to improve operating efficiency by minimising downtime and enable machinery and equipment to be used. It also can help to maintain the quality of products and services, such as refrigeration, processing and storage, and can enhance enterprises' operating hours by means of lighting and electronic equipment. These benefits, however, vary by industry with relatively light electric power requirements for retail and service sectors, and more heavy and reliable requirements for agro-processing and manufacturing operations. Accessibility to complementary resources and affordability also play into the relationship. A rural enterprise could be connected to the electricity grid but not able to operate electricity consuming machines due to high equipment costs, lack of working capital and/or lack of technical skills. Again, constant interruptions might force the business to buy alternate power (which will cost more and cost the company more money to expand). Hence, availability, reliability and productive use of electricity need to be discussed together in the context of its relation to competitiveness.

However, Lyakurwa (2024) studied the factors that determine the adoption of solar energy for manufacturing MSMEs in Tanzania. This study is relevant because it takes into account the energy options of the businesses operating in the business environment of Tanzania and highlights the need of alternative energy sources when the traditional energy supplies are not sufficient to satisfy business needs. The choice of energy source and competitiveness of the enterprise are different results, however. Further investigation is required to understand the linkages between access to electricity, reliability and productive use with the competitive position of rural SMEs. Based on the empirical literature, there is an expectation that there is a positive correlation between rural electrification and rural SME competitiveness. However, it also shows that the electricity connection should not be the only measure to assess relationship between the enterprises. Issues of reliability, affordability, consumption and productive applications are relevant. The study thus explores the association between rural electrification and rural SME competitiveness in the rural business environment in Tanzania.

2.2.2 Digital Infrastructure and Rural SME Competitiveness

Digital infrastructure consists of the physical networks and systems used for the purposes of digital communication, information exchange and electronic transactions. These include mobile telecommunications networks, internet connectivity, systems and services using broadband technology. Digital infrastructure can lower geographical barriers to providing rural SMEs access to other businesses, customers, suppliers, and financial services and market information, which are located outside of their communities. The impact on competitiveness is therefore linked to how well enterprises are able to leverage the digital connectivity to benefit business processes and market participation.

Koutroumpis and Sarri (2024) studied almost 20,000 companies in various sectors and in various sizes in Greece and analyzed the relationship between broadband access and firm performance. They discovered that boosting broadband speeds was correlated with better sales, profits and labour productivity for small firms that adopted broadband. They find their results very significant as they separate out the prevalence of broadband infrastructure from its uptake by enterprises. Overall, the findings indicate that enhancing connectivity could have restricted commercial potential in contexts where firms do not effectively subscribe to or utilise the connectivity services.

Data from Africa also suggests that digital infrastructure is relevant for enterprise productivity. Nguimkeu and Okou (2024) investigated mobile technology adoption in food suppliers in two semi-rural markets in Benin. Their research examined the potential of mobile broadband in the context of small enterprises' productivity on their mobile phones. Mobile connectivity can alleviate information and communication challenges for businesses outside the main commercial hubs, giving a valuable rural-market insight through the findings. Digital connectivity could help suppliers to access market data, to communicate with customers and to co-ordinate business transactions more efficiently.

The International Finance Corporation (IFC, 2023) conducted an analysis at the enterprise level, looking at digital technology use among 3,325 microenterprises in seven African countries, including Tanzania. Smartphone and computer usage for work was linked to greater productivity, sales, profits and wages, the report concluded. But less than 7% of the microenterprises included in the survey said they had applied these technologies to business. The potential benefits of digital technology juxtaposed with its limited use in business represents an important limitation, namely that access to digital infrastructure does not always lead to a productive use of digital technology.

Ekeoma (2024) investigates this question by looking at the impact of information technology adoption on the performance disadvantage of geographical remoteness. The study included 8,466 firm-level observations from 13 emerging and developing countries, and it revealed that the use of information technology was positively related to firm performance and reduced the negative impact of remoteness on firm performance. It is especially important to rural SMEs as geographical distance can limit the access to suppliers, customers and business information. Some of these limitations can be mitigated through the use of digital technology, as it enables enterprises to engage in some business activities without having to be physically located in main commercial centres.

Quaye et al. (2024) analyzed 300 SMEs in Ghana, relating technology adoption, competitiveness and access to new markets. This research showed that these technologies (like the social media, mobile banking and e-commerce)

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were more popular than more advanced technologies (like artificial intelligence and the Internet of Things). Lack of finance, low absorptive capacity and the lack of government support and poor technology-enabling infrastructure were also identified as constraints to adoption. While the link between technology adoption and access to new markets was positive and weak, the results indicate that digital infrastructure should come with organisational and financial resources to have an impact on business.

This is a more nuanced view of digitalization and productivity in Africa as well. Karacuka et al. (2025) analyzed digitalisation's impact on labour productivity by sector in 40 countries of Sub-Saharan Africa using a panel data set. They found that there was a positive correlation in agriculture and manufacturing and weaker or negative correlations in services. This indicates that the impact of digitalisation on productivity might vary with the type of economic activity. The relevance of digital infrastructure for rural SMEs may thus not be solely based on the access to digital but rather on the way the enterprises use it in their specific business processes.

Peter and Nnunduma (2024) investigated the performance of financial technology and SMEs in Dar es Salaam, Tanzania. They discovered positive and statistically significant relationships between the use of digital banking, mobile money service and SME performance and between crowdfunding and peer-to-peer lending with SME performance. While their research was on financial technology, and did not address the full digital infrastructure environment, it does offer local evidence of the potential role that digitally enabled financial services can play in facilitating business activities. However, in an urban context it is possible to explore the potential of rural enterprises that might have access to different levels of network availability, affordability and digital capability.

Overall, these studies suggest that digital infrastructure can help increase SME competitiveness in multiple interrelated ways. Firstly, connectivity can broaden market access by allowing businesses to promote products, accept orders and reach out to customers from outside their place of business. Secondly, digital payment systems can help improve in-transaction efficiency and financial access. Thirdly, the ability to connect with suppliers, prices and market opportunities is enhanced through the Internet. Last but not least, digital communication can enhance business coordination and responsiveness to customers. Digital services can enhance competitiveness if enterprises are skilled, equipped with the necessary devices and have the capital to use them.

But there is also evidence in the literature that digital infrastructure has unequal impacts. Financial and organisational challenges to the adoption of technology have been identified by Quaye et al. (2024) and the findings from IFC (2023) highlight the disparities between digital access and the use of technology within African microenterprises. This disparity could be accentuated in rural areas by additional factors such as network coverage, connection quality, data cost, and electricity availability. Digital infrastructure, therefore, not only needs to be looked at in terms of the presence of the network, but also its availability and usability for business use. Based on the evidence, there is a positive association between digital infrastructure and rural SME competitiveness. The relationship between these can be stronger or weaker, depending on the nature of the enterprise, the geographical environment and the capacity to embed digital services into the processes and work of the business. This study looks at this relationship between rural SMEs in Tanzania, where the value of digital connectivity to the business remains an empirical study.

2.2.3 Complementarity between Rural Electrification and Digital Infrastructure

The rural electrification and digital infrastructure are two but not separate resources (GSMA, 2026). Mobile devices, computers, routers, chargers, and other equipment that is needed to use digital services are powered by electricity. Digital infrastructure, on the other hand, allows for electricity-powered businesses to utilize electronic payments, online advertising and marketing, digital record-keeping and communication systems. The contribution of each infrastructure resource may thus be partially dependent on whether the other resources are available.

This relationship has been recently confirmed in Africa. The study undertaken by Chamdimba et al. (2026) highlights the significance of electricity availability and productive use for SMEs, whereas the study conducted by Karacuka et al. (2025) seeks to show the different relationship between digitalisation and productivity in different economic sectors. These results suggest that infrastructure benefits are contingent upon business activities and resources that enterprises take advantage of via the available services. However, more direct evidence of the interdependence is offered by Bouazizi and Ghazouani (2026), who studied if broadband penetration leads to an increase in electricity usage of African firms. Their country and firm level study confirmed that in the short term, broadband was significantly correlated with higher electricity intensity. They also found associations with product and process innovation as well as with research and development investments. The results of this research indicate that the digital transformation can not just replace the physical infrastructure, but can also expand the demand for reliable electricity.

This complementarity has concrete sides for rural SMEs. An enterprise may enjoy mobile network coverage, but fail to use digital services on a regular basis due to unreliable electricity. Likewise, access to electricity can facilitate production and the use of equipment, but the enterprise might be limited to its local markets if it does not have access to digital communication and marketing tools. The two resources can thus serve different components of competitiveness of a business and alleviate some of the limitations of rural location. In this study, however, two explanatory variables are considered, namely, rural electrification and digital infrastructure, with regard to rural SME

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competitiveness. The complementarity mentioned above justifies the need to study both resources together in the same study but the hypotheses pertain to the relationship of each resource with competitiveness.

2.3 Research Gap

The literature reviewed shows that electricity and digital services are relevant to enterprise productivity, market entry and business outcomes. There are a number of gaps relating to the current study, however. First, previous research has tended to focus on either electricity or digital technology. The findings on electricity access, reliability and enterprise performance are presented by Osei-Gyebi and Dramani (2023) and Chamdimba et al. (2026). However, Koutroumpis and Sarri (2024), Nguimkeu and Okou (2024) and Ekeoma (2024) investigate broadband/information technology adoption and its association with firm performance. It is needed to explore links between rural electrification and digital infrastructure to rural SME competitiveness under one analysis model.

Second, previous studies have not covered the geographical scope required. The findings from Ghana, Benin, Greece and other developing countries are relevant but cannot be directly extended to rural Tanzania because of variation in infrastructure availability and affordability, market conditions and enterprise characteristics. While there are indications presented by Peter and Nnunduma (2024) from Tanzanian SMEs, the study emphasizes financial technology and an urban business setting. More data from rural businesses with varying infrastructure is needed.

Third, the literature suggests that availability of infrastructure does not necessarily lead to productive use. The results presented by Chamdimba et al (2026) indicate that there is no direct link between enterprise performance and electricity consumption and that the link between enterprise performance and electricity reliability is weaker. The findings presented by the IFC (2023) on the other hand, show that although there is a positive correlation between digital technologies and improved enterprise outcomes, their use by the enterprises is limited. The findings indicate that the differences in competitiveness of SMEs may not be explained solely by looking at infrastructure access. The quality, cost and business use of the infrastructure services also needs to be taken into account. Last, while there is some recent literature that acknowledges the linkages between electricity and digitalisation, there is scant evidence of the linkages in the context of rural SMEs in Tanzania and their competitive position. This study fills these gaps by investigating the connection between rural electrification and rural SME competitiveness as well as the connection between digital infrastructure and rural SME competitiveness.

III. METHODOLOGY

3.1 Research Design

The study is an explanatory research with quantitative and cross-sectional approach. The study focuses on the relationships between three measurable constructs: rural electrification, digital infrastructure and rural SME competitiveness and therefore a quantitative approach is suitable. The cross-sectional design enables the data to be gathered from the rural SMEs at one point in time and provides a basis for examining the association between reported infrastructure conditions and enterprise competitiveness.

The descriptive nature of the study is suitable since the objective of the study is to determine the strength and direction of the relationships among the independent variables and the dependent variable. These results, however, are viewed as statistical relationships and not proof of cause and effect because they are cross-sectional data. In order to explain variance and check the predictive relationship, PLS-SEM is appropriate for models involving latent constructs, as explained by Hair and Alamer (2022). This will ensure the design is consistent with the analytical approach to the study.

3.2 Study Area

The study was carried out in four districts namely Mvomero and Kilosa districts of Morogoro Region and Mkuranga and Bagamoyo districts of Pwani Region. In general, the districts were chosen based on country evidence for rural electrification and electricity access and use, such as the Energy Access and Use Situation Survey (2024) conducted by the Rural Energy Agency and Ministry of Energy. Their choice is due to the differences in rural electrification and digital connectivity in similar rural settings. The relatively remote rural parts of Morogoro and Pwani have different levels of coverage of infrastructure, including electricity and ICTs. This variation offers an appropriate context for analysing the link between rural electrification and digital infrastructure and rural SME competitiveness.

3.3 Target Population

The target population consisted of 3,801 licensed, electrified and digitally oriented rural businesses in the four selected districts. These were enterprises operating in mobile money services, agency banking, Internet services, e-commerce and other electricity-enabled digital business activities. Business licensing records accessed in June 2024 show that there were 1,775 businesses in Mkuranga, 1,189 in Bagamoyo, 639 in Kilosa and 198 in Mvomero (Table 1).

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Business owners, operators or managers were selected as respondents as they were likely to have information on their businesses' electricity consumption, digital activities, and business operations.

The eligible enterprises had to meet the following criteria: They had to be located in the selected rural districts, be digitized and have access to electricity, and carry out at least one digitised economic activity. Out of scope: enterprises in the selected districts with no access to electricity, or no activity that uses digital technology. These criteria ensured the population consisted of a sample representative of the focus of the study on the impact of infrastructure on the competitiveness of rural enterprises.

The number of observations to be taken is determined as follows:

A two-stage sampling procedure was used. To identify enterprises that fulfilled the study's criteria, their official business licenses were retrieved from the four district trade and licensing offices and screened. The resulting list of 3,801 enterprises was the sampling frame. Second, the sample was proportionately distributed in the four districts and then the eligible enterprises were randomly selected from each district. The sample size was determined using Yamane's (1967) formula at a 5% margin of error:

$n=N/(1+N(e)^2$

Where n represents the sample size, N the target population and e the margin of error.

Substituting the population of 3,801 enterprises:

$n=3,801/(1+3,801(0.05)^2 =362$

The resulting sample of 362 enterprises was proportionally distributed across the four districts, as presented below.

Table 1

Sample distribution

District	Population	Allocated sample
Mkuranga	1,775	169
Bagamoyo	1,189	113
Kilosa	639	61
Mvomero	198	19
Total	**3,801**	**362**

Proportional allocation allowed for the representation of each district based on its percentage of the target population. The district-level sampling frames used by the random selection process offered opportunities to eligible enterprises to be chosen.

3.5 Data collection instruments and procedures

The primary data was gathered through the use of a structured questionnaire designed based on conceptual definitions and measurement indicators of rural electrification and digital infrastructure and rural SME competitiveness. The questionnaire was targeted to the business operators who were asked to give information on the condition of infrastructure facilities and business performance of their business enterprises. Structured enterprise questionnaires are also used in established firm-level surveys to collect information on infrastructure, sales, business operations and performance (World Bank, 2023).

The items on the questionnaire were rated on a seven-point Likert scale from 1 = strongly disagree to 7 = strongly agree. The respondents could use this scale to rate their level of agreement with items measuring the three constructs of the study. Multiple indicators were used to measure latent constructs which corresponds to the measurement approach in PLS-SEM research (Hair & Alamer, 2022). The measurement of the study variables (Table 2) was organised as follows:

Table 2: Operationalization of variables

Construct	Measurement indicators	Source
Rural Electrification	Access to electricity for business operations; reliability of electricity supply; affordability of electricity; adequacy of electricity for productive activities; continuity of electricity supply during business operating hours.	Aarakit et al. (2024); Mottram (2022); Chamdimba et al. (2026).
Digital Infrastructure	Availability of mobile network coverage; access to reliable internet connectivity; affordability of internet services; availability of digital financial services; reliability of digital connectivity for business transactions.	Ekeoma (2024); Koutroumpis and Sarri (2024); Quaye et al. (2024).
Rural SME Competitiveness	Business productivity; operational efficiency; product and service quality; market reach; sales growth; competitive position relative to other enterprises.	Osei-Gyebi and Dramani (2023); Chamdimba et al. (2026); Quaye et al. (2024).

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The rural electrification indicators (Table 2) capture access to and the practical suitability of electricity for business operations. The digital infrastructure indicators focus on connectivity and digital services that support communication, information access and business transactions. The competitiveness indicators capture enterprise-level outcomes associated with productivity, operational performance and market position. This distinction ensures that the independent variables measure infrastructure conditions, while the dependent variable captures the competitive outcomes of rural SMEs. The questionnaire was administered consistently across the participating enterprises to maintain uniformity in data collection. Respondents were informed about the purpose of the study before participating, and the information provided was used for the stated research purposes.

3.6 Data Analysis

Data were analysed using SmartPLS 4 through partial least squares structural equation modelling (PLS-SEM). The technique was selected because the study examines relationships among multiple latent constructs measured through several indicators and seeks to explain the variance in rural SME competitiveness. Hair and Alamer (2022) identify PLS-SEM as appropriate for research involving latent-variable models where explanation and prediction are relevant analytical objectives. Sabol et al. (2023) also discuss the continued development of PLS-SEM applications and the importance of applying appropriate model assessment procedures. The analysis involved two main stages: assessment of the measurement model and assessment of the structural model.

Measurement model assessment. The measurement model was assessed to establish the reliability and validity of the three constructs. Internal consistency reliability was examined using Cronbach's alpha, rho_A and composite reliability. Convergent validity was assessed using indicator outer loadings and the average variance extracted (AVE). Discriminant validity was examined using the heterotrait-monotrait ratio (HTMT), while variance inflation factors (VIF) were used to assess collinearity. These procedures follow the recommended assessment sequence for PLS-SEM measurement models (Hair & Alamer, 2022).

Structural model assessment. After establishing the measurement model's adequacy, the structural model was assessed to examine the hypothesised relationships. Path coefficients were used to establish the direction and strength of the relationships between rural electrification, digital infrastructure and rural SME competitiveness. Bootstrapping was applied to assess the statistical significance of the estimated path coefficients using t-values and p-values. The coefficient of determination (R^2) was used to assess the explanatory power of the model, while effect size (f^2) was examined to establish the contribution of each predictor. Predictive relevance (Q^2) was also assessed to determine the model's predictive relevance. These procedures are consistent with current guidance on PLS-SEM model evaluation (Hair & Alamer, 2022; Sabol et al., 2023).

3.7 Ethical Considerations

The study adhered to ethical principles governing research involving human participants. Participation was voluntary, and respondents were informed about the purpose of the study and the intended use of the information before completing the questionnaire. They were also informed that they could decline to participate. The informed consent process was intended to ensure that respondents understood what participation involved and made their decisions freely (Eeckhout et al., 2023).

Confidentiality was maintained when handling information obtained from participating enterprises. The questionnaire avoided collecting unnecessary personal identifiers, and enterprise-level information, particularly details relating to business performance, was treated confidentially. These measures were important because respondents were asked to provide information about their business operations and competitive position. The study also followed the relevant institutional ethical approval and research authorisation procedures applicable to the fieldwork.

IV. FINDINGS & DISCUSSION

4.1 Characteristics of the Rural SMEs

The study examined rural SMEs in terms of business age, enterprise size and main business activity. Table 3 presents the reported distribution.

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Table 3

Characteristics of Rural SMEs (n = 362)

Characteristic	Category	Frequency	Percentage
Business age	≤5 years	116	32.0
6–10 years	139	38.3	
> 10 years	108	29.8	
> Enterprise size	Micro	197	54.3
> Small	130	35.8	
> Medium	36	9.9	
> Main activity	Trade	138	38.0
> Manufacturing/processing	94	25.9	
> Services	82	22.6	
> Agriculture-related business	49	13.5	
> Total			**100.0**

The distribution indicates that micro and small enterprises constitute the largest proportion of participating businesses. Trade is the most common business activity, followed by manufacturing and processing, services, and agriculture-related activities. The enterprises also represent different stages of business development, with both relatively new and established businesses included.

The predominance of micro and small enterprises is relevant to this study because smaller firms may have fewer internal resources with which to address infrastructure constraints. From a Resource Dependence Theory perspective, their reliance on electricity and digital connectivity supplied by external providers makes infrastructure availability and reliability important considerations in their business operations. The enterprise characteristics therefore provide a useful basis for interpreting the relationships examined in the structural model.

4.2 Assessment of the Measurement Model

The measurement model was assessed to establish the reliability and validity of the three constructs before examining the hypothesised relationships. The assessment covered indicator reliability, internal consistency reliability, convergent validity and discriminant validity.

4.2.1 Indicator Reliability and Convergent Validity

Table 4 presents the reliability and convergent validity results. Outer loadings range from 0.718 to 0.902, indicating that the indicators meet the commonly applied minimum loading criterion of 0.70. Cronbach's alpha values range from 0.881 to 0.914, while rho_A ranges from 0.886 to 0.918. Composite reliability values are between 0.913 and 0.934, indicating satisfactory internal consistency.

Table 4

Reliability and Convergent Validity Results

Construct	No. of items	Loading range	Cronbach's α	rho_A	Composite reliability	AVE
Rural Electrification	5	0.746–0.891	0.889	0.893	0.919	0.694
Digital Infrastructure	5	0.731–0.884	0.881	0.886	0.913	0.677
Rural SME Competitiveness	6	0.718–0.902	0.914	0.918	0.934	0.704

The AVE values range from 0.677 to 0.704, exceeding the recommended minimum of 0.50. This indicates that each construct explains more than half of the variance in its respective indicators. The results support the reliability and convergent validity of the measurement model. Hair and Alamer (2022) emphasise that indicator reliability, internal consistency and convergent validity should be established before interpreting structural relationships.

4.3 Discriminant Validity

Discriminant validity was assessed using the heterotrait-monotrait ratio (HTMT). The results are presented in Table 5.

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Table 5
HTMT Results

Constructs	Rural Electrification	Digital Infrastructure	Rural SME Competitiveness
> Rural Electrification	-	0.642	0.741
> Digital Infrastructure	0.642	-	0.783
> Rural SME Competitiveness	0.741	0.783	-

The HTMT values range from 0.642 to 0.783, remaining below the conservative threshold of 0.85. The results indicate that rural electrification, digital infrastructure and rural SME competitiveness are empirically distinguishable constructs. Although electricity and digital infrastructure are conceptually related, their HTMT value of 0.642 indicates that they capture different infrastructure conditions. This distinction supports their inclusion as separate predictors in the structural model. The use of HTMT as a discriminant validity assessment is consistent with the measurement-model guidance discussed by Hair and Alamer (2022).

4.4 Collinearity Assessment

The inner VIF values (Table 6) for Rural Electrification and Digital Infrastructure are both 1.702. These values are substantially below conventional levels (<5) at which multicollinearity becomes a concern (Koutroumpis & Sarri, 2024). The result suggests that the two infrastructure predictors can be entered into the same structural model without excessive statistical redundancy. This is particularly relevant because electricity and digital infrastructure are theoretically complementary and could otherwise be expected to correlate strongly. The result therefore supports retaining both predictors simultaneously.

Table 6
Collinearity Results

Predictor	VIF
> Rural Electrification	1.702
> Digital Infrastructure	1.702

The low VIF values also strengthen the interpretation that the two infrastructure dimensions capture related but distinguishable resources. This distinction is consistent with the conceptual framework, which does not treat digital infrastructure as a substitute for electricity. Instead, the model recognises that digital infrastructure can require reliable electricity while electricity-enabled enterprises can gain additional market and coordination opportunities through digital connectivity. The empirical model therefore remains consistent with the theoretical argument of complementary infrastructure.

4.5 Structural Model and Hypothesis Testing

The structural model was assessed to examine the relationships between the two infrastructure predictors and rural SME competitiveness. The assessment considered path coefficients, bootstrapped standard deviations, t-values, p-values, effect sizes and the model's explanatory and predictive performance.

Table 7
Structural Model Results

Hypothesis	Relationship	β	SD	t-value	p-value	f^2	Decision
> H1	Rural Electrification → Rural SME Competitiveness	0.382	0.071	5.380	<0.001	0.184	Supported
> H2	Digital Infrastructure → Rural SME Competitiveness	0.447	0.069	6.478	<0.001	0.252	Supported

$R^2 = 0.601$; Adjusted $R^2 = 0.597$; $Q^2 = 0.417$.

The results (Table 7) indicate that both rural electrification and digital infrastructure have positive and statistically significant relationships with rural SME competitiveness. The model explains 60.1% of the variance in rural SME competitiveness, while the adjusted R^2 is 0.597. The Q^2 value of 0.417 indicates predictive relevance. The effect sizes of 0.184 for rural electrification and 0.252 for digital infrastructure indicate that both predictors make meaningful contributions to the model. Digital infrastructure has the larger path coefficient and effect size, suggesting a stronger relative contribution within the estimated model.

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4.5.1 Rural Electrification and Rural SME Competitiveness

The result for H1 indicates a positive association between rural electrification and rural SME competitiveness. The coefficient of 0.382 suggests that higher levels of rural electrification are associated with higher levels of competitiveness within the model. This relationship is consistent with the argument that electricity enables firms to operate productive equipment, maintain lighting, preserve products and extend business activities. It is also consistent with evidence that electricity disruptions can reduce productive capacity and firm performance in developing-country settings. The finding consequently provides theoretical support for treating reliable electricity as a productive resource rather than only a basic infrastructure service (Fried & Lagakos, 2023; Mrosso, 2025).

The relationship can also be interpreted through Resource Dependence Theory. Rural SMEs generally cannot control the electricity network on which their operations depend, meaning that they are exposed to the reliability and affordability of an externally supplied resource. Where electricity is available and reliable, enterprises can make greater use of machinery, refrigeration, lighting and electronic equipment. Where electricity is unstable, firms may experience interruptions, incur additional costs for alternative energy or limit the scale of their activities. The H1 result therefore provides a plausible empirical expression of the theoretical expectation that access to important external resources can shape the ability of small firms to compete.

4.5.2 Digital Infrastructure and Rural SME Competitiveness

The result for H2 indicates a positive association between digital infrastructure and rural SME competitiveness. The coefficient of 0.447 indicates that higher levels of digital infrastructure are associated with higher levels of rural SME competitiveness in the model. Digital infrastructure can support customer communication, digital payments, market information, supplier coordination and access to customers beyond the immediate locality. These mechanisms are consistent with evidence showing that broadband access can improve economic outcomes among adopting small firms and that mobile technologies can support productivity among small-scale businesses in semi-rural markets. The result therefore supports the theoretical proposition that digital infrastructure constitutes a productive business resource rather than simply a communication facility (Koutroumpis & Sarri, 2024; Nguimkeu & Okou, 2024).

The result also fits Resource Dependence Theory because rural SMEs depend on external communication and information systems that they cannot independently provide. Digital infrastructure reduces some of the disadvantages created by geographical distance by allowing firms to communicate with customers and suppliers without physical travel. It can also improve the speed of information exchange and support electronic financial transactions. The competitive value of these services, however, depends on affordability, reliability and the ability of entrepreneurs to use them effectively. The H2 result should therefore be interpreted as evidence supporting the proposed relationship, not as evidence that connectivity alone guarantees competitiveness.

4.5.3 The Complementary Infrastructure Argument

The two results together support the main argument that rural SME competitiveness requires attention to both energy and digital infrastructure. Electricity provides the physical energy base for production and for many digital activities, while digital infrastructure provides communication, information and market connections that can increase the commercial value of productive capacity. The study by Bouazizi and Ghazouani (2025) in Scientific African, directly supports this claim. The research found that broadband access increases electricity intensity in the short run among African businesses. A related finding from the same paper notes that connected firms show a higher electricity intensity of around 0.3 to 0.5% compared to non-connected firms. It is also consistent with infrastructure-led development theory, which emphasises network effects and complementarity among infrastructure components. Rural infrastructure policy should consequently move beyond treating connectivity as an isolated objective and consider the infrastructure stack required for productive enterprise use (Bouazizi & Ghazouani, 2025; Agénor, 2010).

The model's R^2 of 0.601 indicates that the two predictors jointly explain a substantial proportion of the variance in rural SME competitiveness. This does not mean that infrastructure is the only determinant of competitiveness because financial resources, managerial capability, human capital, market conditions and institutional factors remain relevant. The result instead suggests that the infrastructure dimensions included in the model provide an important explanatory component within the setting. The positive coefficients for both predictors also reinforce the theoretical distinction between energy and digital resources. Their coexistence in the model provides a basis for viewing rural SME competitiveness as partly dependent on the interaction between physical productive infrastructure and digital connectivity.

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V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

Rural SME competitiveness is shaped partly by the infrastructure conditions within which enterprises operate, produce and conduct business transactions. Rural electrification provides the energy required for productive equipment and routine business operations, while digital infrastructure supports communication, access to information, electronic payments and wider market reach. The value of these resources depends on their availability, reliability, affordability and productive use, particularly in rural areas where geographical and market constraints may limit business opportunities.

Drawing on Resource Dependence Theory and Infrastructure-Led Development Theory, the study examined rural electrification and digital infrastructure as distinct but complementary resources for rural SME competitiveness in Tanzania. The study's conceptual approach recognises that electricity supports productive operations and digital activities, while digital connectivity creates opportunities for communication, business transactions and market access. It concludes that improving rural SME competitiveness requires an integrated approach that addresses both infrastructure provision and enterprises' ability to use these resources productively.

5.2 Recommendations

Rural infrastructure planning should integrate electricity and digital infrastructure rather than treating them as separate development priorities. Electricity investments should address supply reliability, affordability, outage duration and suitability for productive equipment, while telecommunications programmes should improve network coverage, internet affordability and connectivity reliability. Decentralised energy solutions may also be considered in areas where grid extension is difficult, subject to their technical and economic suitability.

Digital infrastructure programmes should promote productive business applications through access to appropriate devices and training in digital marketing, customer communication, electronic payments, market information and supplier coordination. SME development initiatives should complement infrastructure provision with financing for machinery, digital devices and business software, alongside managerial and technical training. Basic cybersecurity and data protection should also be incorporated into digital skills programmes to help enterprises manage risks associated with technology adoption.

Finally, infrastructure programmes should be evaluated using enterprise-level outcomes rather than access indicators alone. Monitoring should cover business continuity, operating costs, productivity, sales, market reach, customer responsiveness and digital transaction activity. Evaluations should distinguish between electricity availability and reliability, and between digital network coverage and productive use. This would help policymakers assess whether infrastructure investments are translating into improved rural enterprise competitiveness and identify areas requiring additional support.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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