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The nexus between information and communication technology (ICT) and poverty status in South Africa

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Since 1994, South Africa has grappled with persistent poverty and inequality. In an effort to eradicate these social issues, the South African democratic government has implemented several policies. However, there has been little success. The advent of globalization and advancements in information and communication technologies (ICTs) present an opportunity for the South African government to bypass the traditional stages of development as suggested by the leapfrogging hypothesis. The purpose of this research article is to examine the nexus between ICTs and poverty status in South Africa. The significance of the study lies in its aim to provide empirical evidence that aligns with the social and economic realities of South Africa, ultimately informing the country's ICT policy frameworks. The study employs time series data spanning from 1990 to 2021 and a quantitative methodology. Consequently, the study conducted the Granger causality tests and Johansen cointegration analysis to explore the nature of causality and establish the long-run equilibrium relationship between poverty and ICT. The empirical findings of the study uncovered a long-run equilibrium relationship between ICT use and poverty reduction in South Africa. Furthermore, the results indicate a unidirectional causal link whereby increased access to ICT tools led to a decrease in poverty levels.

Keywords: ICT, poverty, South Africa, leapfrogging hypothesis

JEL classification: C32, I30, I32, O33

Introduction

Poverty and inequality in South Africa are largely attributed to the apartheid government system that governed South Africa for over 46 years before 1994 (Aliber 2003). One of the various ways in which the apartheid government oppressed its people was by controlling the flow of information and restricting freedom of speech. Since 1994, in an attempt to free South Africans from the legacy of the apartheid government, the democratic government has embraced the concept of the 'information society' as a main strategy to transform the economy through information and communication technologies (hereinafter ICTs) (Moodley 2005). This strategy aims to create an environment where information flows freely and is widely available to the broader society. This information can, in turn, contribute to the development of a social and economic climate that promotes inclusive and active participation in the economy within the broader society, as outlined in the National Development Plan. ICT in this perspective is epitomised as the key technology for alleviating poverty because it provides information, enhances knowledge required for livelihood, and empowers individuals to escape poverty by becoming more informed citizens. In this context poverty is defined in the 2006 ISAD (Information Society and Development plan) (p. 87) to include '… being deprived of the information to participate in the economy'. This study seeks to examine the nexus between ICT and poverty status in South Africa.

Many studies have been conducted to analyse and understand poverty in African countries. However, the single most important factor that distinguishes South Africa from its counterparts is its history of apartheid and colonization, a key factor contributing to its unequal society (Aliber 2003). The discovery of gold and diamonds in the late eighteenth century, particularly in Johannesburg and Kimberly attracted substantial British investment in the mining sector. As the sector grew, so did the demand for labour. To address this increasing demand, mine owners sought inexpensive labour. Consequently, the government introduced laws and policies to govern the labour supply, which ultimately laid the foundation of the apartheid system. The purpose of the system was to control, segregate, and marginalize black people (Thobejane 2013). The implementation of the apartheid laws had widespread consequences in the social, economic, and political spheres, and these consequences continue to impact poor South Africans today.

Poverty is a multi-dimensional concept that theoretical studies have explored to illustrate its countless dimensions (Mdluli and Dunga 2022). Over time, there have been theoretical developments aimed to define, measure, and categorize poverty (Bila and Biyase 2002). Regardless of the definition and measure used to understand poverty levels, these definitions often concentrate on the living standards of persons who live below a specific set threshold, often referred to as the poverty line. To illustrate the picture of the South African poverty levels, one could use the words of Benjamin Rowntree when he defined poverty as a generational ill that is passed down from one generation to the next. This perfectly relates to the South African context, to which poverty levels have become inherently transmitted from generation to generation, most particularly amongst the previously

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disadvantaged population and marginalized communities (Bila and Biyase 2002; Grobler and Dunga 2016; Mdluli and Dunga 2022). According to Stats SA (2017a, 2017b) people living below the national poverty line were estimated at 30.3 million people, implying that over 55.5% of the country's total population lived in poverty at the time. Recent statistics indicates that the country's poverty rate stands at 56.8% as measured by the Poverty headcount indicator. This grave concern has been prioritized by the South African government through various social and economic policies (Mdluli 2008).

This study recognizes the importance of defining ICT (Information and Communication Technology) before proceeding. ICT is defined as a 'global network in which ideas are exchanged, or information and knowledge are shared, through the use of communication technology like cell phones, and technology like computers, to connect people' (Mdlongwa 2012, 1). Roztocki, Soja, and Weistroffer (2019) drew their definition from the work of Borgmann (2006), describing ICT as a combination of hardware, software and communication networks that enable the capturing, storing, processing, and transfer of electronic information. Adeleye and Eboagu (2019) generally defined it as a term that includes any communication device or application, that includes cellular phones, computers, network hardware and software, satellite systems, etc. It encompasses the storage, recovery, conversion and transmission of information and automation of information production. In all these proposed definitions, the common theme is that ICT generally entails the use of technologies to perform activities relating to the production and distribution of information and knowledge.

The adoption of ICT has been advocated as a solution to poverty and underdevelopment in developing countries. It is believed that ICT provides developing countries with access to the global market and helps in fostering an economic climate that promotes economic growth and development (May, Waema, and Bjastad 2016). According to Gillwald, Mothobi, and Rademan (2018), the United Nations' sustainable development goals (SDGs) includes enhancing access to ICT to promote women's empowerment, increasing affordable internet access in low development countries, and supporting goals such as poverty alleviation, improved health, and access to quality education. The ongoing dialogue about the mutual causal relationship between the adoption of ICTs and its positive development has resulted in many emerging economies to align their ICT policies with their macroeconomic development objectives (Diga, Nwaiwu, and Plantiga 2013). Furthermore, since the 1990s the African continent has witnessed significant ICT infrastructure development following the deregulation and liberalization of the telecommunication sector by many African countries (David and Grobler 2020). The increase in the infrastructure development in the ICT sector attracted foreign investment capital, with investors perceiving Africa as an investment hub due to its population and emerging industries and markets (David and Grobler 2020). The increase in investment capital has led to better ICT access, usage, and efficiencies, which has brought significant positive transformation in the lives and livelihoods through employment creation, increased income, familial bonding, etc (Adeleye and Eboagu 2019). Post 2000, the African continent became the 3rd fastest-growing region globally, a growth that is largely credited to the increase in the development of ICTs, particularly in the rural areas (Adeleye and Eboagu 2019).

The end of the apartheid regime marked the dawn of a new era defined by social, economic, and political reform. However, it left behind wide levels of inequalities and poverty biased across race groups (Francis and Webster 2019; Mdluli and Dunga 2022). While there has been some improvement in the country's economic outlook since 1994, South Africa remains confined by its slow economic growth accompanied by low private investment growth and high levels of inequality and deep poverty (World Bank 2014). One might add the recent Covid-19 global pandemic to that list. Stats SA (2018) indicated that 33.8% of the adult population live below the lower-bound poverty line.

According to Francis and Webster (2019), South African society is one of the most extremely unequal across the globe, with a Gini coefficient of 0.63: a legacy of the apartheid regime. This assertion is supported by the 2014 World Bank data, which reported that South Africa has a high number of poor low-income earners and a low population of high-income earners, accompanied by a small number of middle-income earners. Oyedemi and Choung (2020) attributed the South African high unemployment rate of 29% (strict definition) and 38.5% (expanded definition) to the country's income inequality. Amongst the factors contributing to unemployment in South Africa, information, and technological gaps played a vital role. Gillwald, Mothobi, and Rademan (2018) argued that ICTs are a necessity for human development in modern society, because they facilitate citizen participation in society. The adoption of ICTs is based on the concept of 'leapfrogging' implying that countries can leapfrog stages of growth and development. This notion derived from the conventional concept of modernization and continues to inform policymaking in developing countries. However, this study highlights that South Africa's unique position warrants a context-specific approach to address current poverty levels, through effective policies. This is because in policymaking there are frequent discrepancies between research and policy practice, which often results in policy failure (Hudson, Hunter David, and Peckham 2019). The primary research question that this study intends to address is: 'Does ICT have an influence on poverty status in South Africa?' Therefore, the objective of this study is to examine the extent to which ICT tools influence poverty levels in South Africa and provide empirical evidence to validate the leapfrogging hypothesis.

Theoretical background

ICT and economic growth

Information Communication Technologies (ICTs) have been recognized for their potential developmental

opportunities in emerging economies (Fong 2009). It is argued that the gains derived from the adoption of ICTs are likely to improve the quality of life, facilitate better access to education and health care, and enhance economic opportunities for marginalized economies (Gabriels and Horn 2015). These potential benefits are commonly known as the benefits of 'technology leapfrogging' (Fong 2009). The concept of leapfrogging refers to skipping the stages of development by adopting technologies and policies similar to that of successful economies (Steinmueller 2001). In essence, this means that the adoption of technologies will bridge the economic gap between developed and developing countries, thereby providing developing countries similar social and economic opportunities as their developed counterparts (Adeleye and Eboagu 2019).

Much focus has been on developing economies because these economies tend to lag in the adoption of ICT technologies. Critics have argued that ICTs widen the digital gap not only between developed and emerging economies but also within societies themselves (Heeks 2014; Maceviciute and Wilson 2018; Steinmueller 2001). Here the digital gap refers to the inequality in access to information technologies, commonly known as the digital divide (Alzouma 2005) Research argues further that ICT adoption is influenced by geographical location (May, Dutton, and Munyakazi 2013), gender (Tiwari 2006, 2008), physical ability (Samant, Matter, and Harniss 2013), and income level (Gerster and Zimmermann 2003). Conversely, proponents of ICT adoption known as technophiles recognize ICTs as tools that have accelerated the interconnectedness of societies. They argue that ICT adoption will play a critical role in creating infrastructure that promotes development across four development indicators, namely: economic opportunities, political freedom, social facilities, and transparency guarantees (Chege and Wang 2020; Gabriels and Horn 2015).

Considering the proposed benefits of technology leapfrogging, the unresolved concern revolves around the practicality of adopting such technologies for many developing nations, including South Africa. The purpose of this literature review is to highlight the empirical studies that were conducted on the topic. Furthermore, it aims to elucidate the significance and contribution of this study which is to provide empirical evidence on the role of ICTs on poverty reduction in South Africa.

Many studies have explored the digital divide from a country-to-country perspective. The study by Gillwald, Mothobi, and Rademan (2018) postulated that access to ICT tools is biased according to gender, socioeconomic status, and geographical location. On a similar note, the study by Samant, Matter, and Harniss (2013) stated that individuals living with disability lag in access and adoption of the latest communication technologies. The factors that are presented in Figure 1, which illustrates that the digital divide can exist within a nation itself, are relevant to the South African context and this study because these factors heavily influence some of the poverty indicators that are modelled in this study.

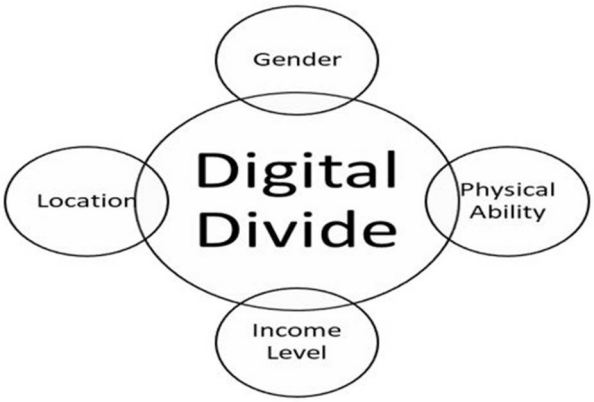

Figure 1: The causes of the digital divide within a nation.
***Source*:** Authors' compilation (2022)

Theories of economic growth, development and poverty

The evolution of the growth theory, as it influences economic development and poverty reduction started with the work of Harrod and Domar in the late 1940s. This was followed by the development of the neoclassical theory, and eventually, the alternative theory, which is founded as a reaction to the shortcomings of the neoclassical model. According to neoclassical growth theory, growth is solely determined by labour, land, and capital (Pietak 2014). One model derived from neoclassical theory is the Solow model, which is said to be narrow and vague (David 2013). The Solow model was known as the exogenous theory because it considered technology as an exogenous factor, implying that the technological factor is determined outside of the model. An alternative theory is the endogenous theory, designed by Romer (1986) in the late 1980s. It posits that long-run growth is contingent on factors like human capital, new technologies, R&D (research and development), and knowledge as a non-rival factor input (David 2013). Joseph Schumpeter presented a model that contrasted mainstream models. Schumpeter's model assumed that economic growth and development are determined by innovation. The model is based on the assumptions of private property and a competitive, efficient market but was initially designed for developed economies, although it can be adapted by developing economies like South Africa (Pietak 2014). Another growth theory, proposed by Lewis (1954), highlighted the importance of savings and investment in economic growth and was built on the concept of capital accumulation. This study will focus more on the theory of innovation as theorized by Schumpeter to model the nexus of ICT and poverty reduction.

The subsequent discussions will review existing literature, focusing on themes related to this study, such as ICT and poverty, ICT and economic development, ICT and human capital development and factors influencing ICT investments.

ICT and poverty reduction

The concept of poverty is multifaceted and frequently discussed by experts from various disciplines, resulting in diverse definitions. This subsection aims to assess the

relationship between ICTs and poverty, by reviewing the current literature that attributes poverty reduction to ICTs.

According to Adeya (2002) many poverty studies primarily concentrate on issues like insufficient nutrition, inadequate shelter, and access to basic services required for human survival. The inclusion of ICTs in poverty studies has resulted in studies that intersect these two domains. It is widely acknowledged that ICTs have the potential to enhance the knowledge required for improved livelihoods (Moodley 2005; Pigato 2001). For instance, the Poverty and Information and Communication Technologies in Urban and Rural Eastern (PICTURE) Africa study explored the impact of ICT access on poverty using a multidimensional approach. The study considered six dimensions of poverty, including digital poverty and reported that ICTs have a positive effect on poverty reduction (May, Dutton, and Munyakazi 2013). These findings align with those of Batchelor and Scott (2005).

Other studies have shown that ICTs have a positive albeit not direct impact on poverty reduction by addressing poverty indicators. Chege and Wang (2020) reported that increased ICT adoption by SMEs is positively correlated with employment creation. Mdlongwa (2012) found that ICTs improve access to and the quality of education and play a critical role in reducing illiteracy rates. Panir (2011) highlighted the role of ICTs in disseminating information on diseases, treatments, and research, contributing to reduced child mortality and improved access to healthcare services. Additionally, several studies argue that the introduction of ICTs by SMEs has the potential to improve the livelihoods of the poor, elevate socio-economic status, and increase the income of impoverished households (Heeks 2014; Kenny 2002). Conversely, some research studies argue that the adoption of ICTs alone is insufficient for eradicating poverty. They conclude that developing countries cannot leapfrog beyond the fundamental developmental challenges they currently face such as poverty and illiteracy (Alzouma 2005; Gerster and Zimmermann 2003). Alzouma's (2005) conclusions are rooted in the belief that the solutions to addressing poverty-related problems lie outside the scope of these technologies. These findings are in line with the sentiments expressed by Czerniewicz and Brown (2005), who argue that ICTs are tools and, on their own, cannot address complex and multifaceted issues like poverty.

The approach by Flor (2001) is particularly intriguing. The scholar examined the nexus of ICT and poverty by emphasizing the use of ICT tools by the government and policymakers to enhance service delivery, ultimately reducing poverty in remote areas. Flor (2001) focused on the potential gains of ICTs in relation to how policymakers could employ them to gather extensive, precise, and accurate data, enabling the design of policies that would effectively target the most vulnerable. Flor (2001), suggested that technologies such as Geographic Information System (GIS) could enable policymakers to gather data even in small geographical locations like municipalities and districts, making it easy to generate poverty and inequality profiles. These findings align with those of Diga, Nwaiwu, and Plantiga (2013), who emphasized how ICTs could provide relevant personnel with adequate statistics and reliable information for monitoring poverty.

ICTs, economic growth and development

There is a growing body of literature that explores the theoretical link between ICTs, economic growth and development in emerging economies (Avgerou 2010; Heeks 2002; Kowal and Paliwoda-Pękosz 2017; Madon 2000; Pigato 2001; Roztocki and Roland 2016). These studies are founded on the perceived potential of new social and economic development opportunities for emerging economies (Gigler 2014). According to Batchelor and Scott (2005), ICTs are epitomised as tools critical to enhancing economic growth. They argue that these technologies, because of their nature, have significant impact across all sectors and that the ICT industry as a whole could be harnessed into being a significant contributor to the GDP. Supporting this perspective, David and Grobler (2020) argue that the African continent has witnessed an increase in terms of ICT infrastructural development since the late 1990s. These infrastructural developments have resulted in significant productivity increases. Adeleye and Eboagu (2019) further corroborate that ICTs have a significant influence on the economic growth of African economies. The work of Roztocki, Soja, and Weistroffer (2019) takes a comprehensive approach by proposing a multi-dimensional conceptual framework that considers four dimensions that impact socioeconomic development: policy, business, technology, and society. Their model considered ICTs in general in both developed and emerging economies, concluding that the adoption of ICTs in conjunction with other technologies has the potential of making a considerable contribution to socioeconomic development.

Similarly, Madon (2000) introduced a multi-dimensional conceptual framework model that establishes connections between ICTs and socioeconomic development in developing countries, using the internet as an ICT indicator. Madon (2000), reported findings that the internet, as an ICT indicator positively impacts various socioeconomic dimensions, namely economic growth, social well-being, political well-being, and the physical environment. Mansell and Wehn (1998) cautioned that nations without access and capabilities to access the potential benefits offered by ICTs will be marginalized when other economies transition into 'knowledge societies'.

Adeleye and Eboagu (2019) argue that many studies that investigate the relationship between ICTs, development, and growth at a macro level report contrasting results; they further attribute such results to the scope and the econometric methodologies employed. Correspondingly, May, Dutton, and Munyakazi (2013) stated that many ICT-development studies neglect the micro-level data required for the interpretation of the macro trends, thereby, producing research evidence that is too general. Similarly, Adeya (2002) warned that there are few studies on ICTs and development that openly acknowledge their shortcomings and failures, Adeya further stated that most studies disguise their failures with the cover phrase 'lesson learnt'. Adeya (2002)

advised future researchers and all stakeholders who use these research findings to take a cautionary perspective. Heeks (2010, 2014) maintained the argument that much evidence on ICTs, growth and development is still needed, especially evidence that is well conceptualized and thoroughly researched.

ICT investment in developing nations

The purpose of this section is to provide an overview of the existing literature concerning the factors that influences investments in ICTs and ICT infrastructure. Over the past two decades, there has been a significant surge in ICT investments due to the perceived social and economic benefits of ICTs (Bankole, Shirazi, and Brown 2011). This surge has led to increased ICT investments in many countries, including those in Africa (David and Grobler 2020). According to Bankole, Shirazi, and Brown (2011), ICT investments are considered second order investments because they create opportunities and an enabling environment that supports poverty alleviation and addresses issues of marginalization by enhancing access to economic activities. David and Grobler (2020) pointed out that the extent of investment in ICT is strongly correlated with the growth and development associated with the investment. This means that ICT drives economic growth and development, meaning ICT plays a critical role in economic growth and development, and the extent of this impact depends on the scale of ICT investment. Many studies have identified various factors that hinder or encourage investment in ICTs. The work of Shehu, Wisdom, and Abubakar (2018) identified factors such as failed government policies, corruption, and poor industrialization as the key factors that hinder the increase of ICT investments. They also noted that most developing African countries grapple with inadequate knowledge, poverty, and limited resources, which hinder them from fully harnessing the potential that ICTs offer. Other studies have highlighted factors such as economic structure, human capital, complementary technology expenditure and the regulatory environment (Asongu and Biekpe 2017; Guerrieri, Luciani, and Meliciani 2011; Herselman 2013; Kruger and Rhiel 2016; Steinmueller 2001). In addition, Gillwald, Mothobi, and Rademan (2018) emphasized the role of political will and market competition in shaping ICT infrastructure investments. According to David and Grobler (2020), the growth of the African ICT sector can be attributed to market liberalization.

The following subsection will delve deeper into the significance of economic structure as a critical factor influencing a nation's capacity to invest in ICT. This is because the nature and structure of the economy play a crucial role in determining policies, market liberalization, level of competition, private sector involvement, government fiscus (budget on R&D on technologies), and the prioritization of macroeconomic objectives.

Economic structure

Akpan-Obong (2007) highlighted the importance of having a robust and stable economic environment to foster technological development. Kruger and Rhiel's (2016) findings also indicated an indirect relationship between per capita income and ICT, with income equality having a strong negative correlation with ICT diffusion. Conversely, Wunnava and Leiter (2009) reported that per capita income is positively and statistically significant to ICT adoption. These findings are particularly relevant in South Africa in the South African context, considering that South Africa is characterized as one of the most unequal societies worldwide, with a Gini coefficient close to 0.7, which is the highest globally, alongside a pronounced high level of income disparity (Francis and Webster 2019). The negative relations between ICT diffusion and income equality suggest that increased income inequality results in fewer people accessing and adopting technologies like the internet, mobile phones, Wi-Fi, and television. Similarly, Gillwald, Mothobi, and Rademan (2018) reported that most of the rural population lack access to ICTs due to factors such as remoteness, underdevelopment, poverty, and access to electricity.

Measuring the effects of ICTs and understanding their potential to alleviate poverty and inform policymaking have gained heightened significance particularly for developing countries. This is further emphasized as global economies adopt digital technologies and digital economic models, *especially with global economies transitioning into the 4th Industrial Revolution*, accompanied by the international commitments to eradicate poverty. Despite the extensive literature on the challenges and roles of ICTs in addressing socioeconomic issues and promoting growth and development, noticeable is the prevalent use of qualitative methodologies over quantitative ones. Furthermore, many studies lean towards descriptive rather than analytical approaches. Currently, there is a lack of empirical evidence in the existing research landscape, and this study underscores the importance of empirical evidence in shaping policies. It aims to provide empirical insights into the relationship between ICTs and poverty reduction and offers a clear analysis of how poverty indicators can be addressed in South Africa. Therefore, the empirical evidence presented in this study contributes to the academic literature and can inform social and economic policies not only in South Africa but also in other developing nations that share similar social, economic, and political challenges.

Methodology

Theoretical framework

The empirical analysis seeks to investigate the extent to which increased ICT access contributes to poverty reduction, or poverty status. To guide the study and determine the relevant variables, the research draws from the existing literature on ICT, growth theories (particularly, the Schumpeterian growth theory), and the poverty theories (particularly, Amartya Sen's theory of poverty). According to Sen (1999), poverty is conceptualized as the deprivation of basic capabilities. This definition is argued by Sen (1999) to capture the broader aspects of poverty as opposed to measuring the poverty status using income or the lack of it. This aligns with Sen's approach as it aims to explore the main poverty determinants relevant to the South African context and model

poverty using various variables including ICT access, rather than solely relying on income measures.

The study draws inspiration from growth theories developed by Paul Romer, Robert Solow, and Joseph Schumpeter. The growth theories underscore the crucial role of innovation and technology in enhancing growth and development (Aghion, Ackcigit, and Howitt 2013). The Schumpeterian growth paradigm is particularly relevant because it accounts for the relationship between technology (innovation), trade competitiveness, and growth, that the Solow or Romer models cannot capture (Schumpeter 1991). According to this theory, technological development plays a critical role in determining a nation's growth prospects. Economies with advanced technological capabilities tend to experience rapid growth, leading to increased employment opportunities, human capital development, and reduced income inequality – all factors that impact poverty status (Roztocki, Soja, and Weistroffer 2019). These concepts are highly relevant to the South African context and the objectives of this study.

Econometric model specification

The theoretical framework guided the selection of variables for this study. Poverty was modelled as a function of several factors including economic growth, human capital development, income, inequality, and ICT index. To create the ICT index, Principal Component Analysis (PCA) was employed using three indicators: mobile, internet, and land line. The rationale behind using PCA was to overcome potential issues of multicollinearity, as these variables might be correlated. To consolidate these variables into a single ICT index, the eigenvectors obtained from the PCA are used as the required weights (David 2019), resulting in the following linear equation:

$$ICT = \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 \quad (1)$$

$$ICT = \alpha_1 Mobile + \alpha_2 Internet + \alpha_3 Landline \quad (2)$$

where: ICT denotes the composite index of telecommunications and α_1, $\alpha_{2,}\alpha_3$ represent the eigenvectors derived from the PCA and X_1, X_2, X_3 denotes the three selected variables that make up the composite index of telecommunication, namely: mobile, internet, and telephone.

Poverty gap serves as a proxy for poverty, representing the intensity of the level of poverty within a country. Additionally, it can be used to illustrate the level of inequality, which is pertinent to this study due to the historical context of apartheid South Africa. Gross Domestic Product (GDP) and GDP per capita are used as proxies for economic growth and income respectively, as GDP measures economic growth, which is relevant because the level of growth in an economy directly impacts individuals and households' income, and income is closely linked to poverty status. To proxy human capital, as informed by literature, the study included secondary education general pupils, aligning with the prevailing literature that often measures human capital from an educational perspective. Income distribution, particularly the income share held by the highest 20% is used as a variable to measure inequality. Finally, unemployment is measured using the unemployment rate as a percentage of the total labour force.

In summary, the study models poverty as a function of economic growth, human development, income, inequality, unemployment, and ICT. The equations used to model the nexus between poverty and ICT are shown in Equations (2–5) respectively. The hypothesis tested by the model is specified below:

H_0: ICT does not impact poverty

H_1: ICT has an impact on poverty

$$\text{Povt} = \text{f(Eg, hd, Inc, Ineq, Unemp, ICT)} \quad (3)$$

From Equation (3), a linear econometric model is derived, hence the following equation:

$$\text{Povt} = \beta_0 \text{Eg}_r^{\beta_1} \text{Hd}_r^{\beta_2} \text{Inc}_r^{\beta_3} \text{Ineq}_r^{\beta_4} \text{Unemp}_r^{\beta_5} \text{ICT}_r^{\beta_6} + \mu_r \quad (4)$$

where: β represents the vector associated with the explanatory variables and μ represents the stochastic component at time t, t indicates that the study employed a time series data.

Equation (3) was transformed into a natural log model, hence the following equation:

$$\text{InPovt}_t = \beta_0 + \beta_1 \text{InEg}_t + \beta_2 \text{InHd}_t + \beta_3 \text{InInc}_t + \beta_4 \text{InIneq}_t + \beta_6 \text{InUnemp}_t + \beta_6 \text{InICT}_t + \mu_t \quad (5)$$

The study used Equation (4), to model poverty as a function of the specified variables, the variables in the model are expressed in the natural logarithmic form, in the model, μt represent the stochastic component at time t, and β indicates the vector associated with the independent variables

Research design and methods

To fulfil the empirical objectives of this study, a quantitative methodology approach was employed. The study used various estimation techniques to examine the nexus between ICT and poverty and other control variables, which would facilitate the attainment of the stated empirical objectives. Time series data with the yearly observations between the years 1990 and 2021 were used for the study, which allowed for the data to be normally distributed. Data mining techniques such as interpolation and extrapolation were employed to account for the missing data. Because of the time series data, the study conducted unit root tests using the Augmented Dickey Fuller (ADF) and the Phillip Peron (PP) tests to validate the data of the study. The results emanating from the unit root tests provided guidance on the model that would be used. Furthermore, the trend analysis on the variables was used to

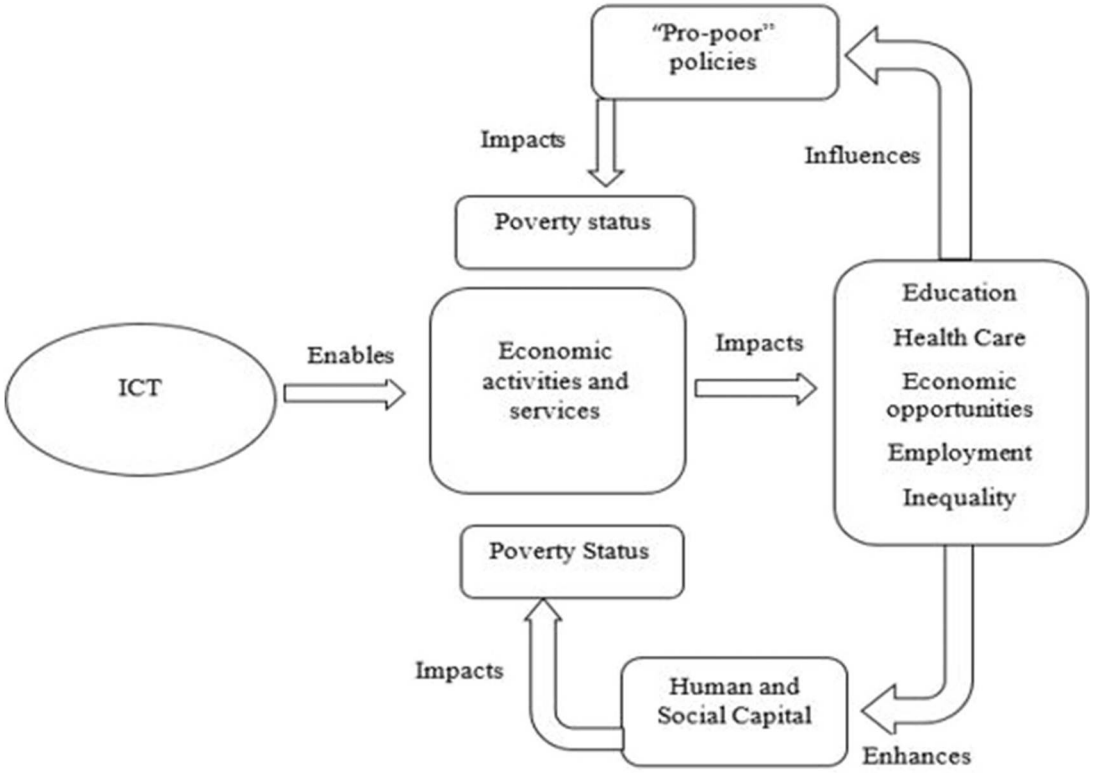

Figure 2: The framework of the link and Interaction of ICTs and socioeconomic development. ***Source*:** Adapted from Roztocki and Roland (2016)

examine the kind of trend displayed by the variables. Given the social and economic status of South Africa, it was expected that poverty would exhibit an increasing trend. Furthermore, the study conducted causality tests using the Granger causality to examine for the nature of causality between poverty and ICT.

Data, sources, limitations

The study used secondary data obtained from the World Bank, a database that contains thousands of publicly available world development indicators. The limited number of variables included in the model was identified as one of the study's limitations because it could be argued that there are more determinants of poverty than the ones stated in the model. Furthermore, the study used the poverty gap as a proxy for poverty, while many studies have used absolute poverty or poverty headcount ratio. Table 1 explicates the variables used in the study and their respective data sources.

Empirical results and discussion

The methodology and econometric techniques used to fulfill the empirical objectives of this study were introduced earlier. This portion of the article presents the results and discussion of the tests conducted and their implications. The pre-estimation results, including trend graphs, correlation matrix, descriptive statistics and stationarity tests, are presented next. Following that, the estimation results, which include the VAR model, cointegration tests, VECM model, the impluse response test, and the variance decomposition, are detailed. Finally, the post-estimation results, which are the

Table 1: Summary of the data set.

Variable	Proxy	Source of data
LNEG (economic growth)	GDP (constant 2015 US$)	World Bank
LNINC (income)	GDP per capita (constant 2015 US$)	World Bank
LNPOVT (poverty)	Poverty gap at $ 1.90 (2011 PPP)	World Bank
LNINEQ (inequality)	Income share (held by the highest 20%)	World Bank
LNICT (ICT index)	ICT index built using mobile cellular subscriptions (per 100 people), Fixed telephone subscriptions (per 100 people), and individuals using the internet (per 100 people)	International Telecommunication Union (ITU)
LNHD (human capital)	Secondary education, general pupils	World Bank
LNUNEMP (unemployment)	Unemployment, total (% of total labour force)	World Bank

***Source*:** Authors' compilation (2022)

CUSUM test, serial correlation test, and heteroscedasticity test, are presented.

Pre-estimation tests

Discussion of the trend graphs

Figure 3 depicts the results from the trend analysis of various variables that influenced poverty.

Economic growth (Figure 3B – LNEG): Economic growth has been fluctuating since 1990, leading up to 2010, possibly due to the global financial crisis that crippled many economies across the globe. From 2010, there was an uptick in economic growth, likely attributed to significant infrastructure development and an increase in tourism sector, driven by the 2010 FIFA World Cup. However, the economy experienced a sharp decline in 2019/20 due to the impact of the Coronavirus outbreak.

Human capital development (Figure 3C – LNHD): Human capital development has exhibited a consistent upward trend since 1995, possibly reflecting an increase in the number of individuals completing secondary education. There was however a sharp decline in 2020.

ICT Access (Figure 3G – LNICT): Access to ICTs has been on the rise since 1995, possibly reflecting an increase in mobile subscriptions and internet connectivity. However, there was stagnation in ICT trends in the years leading up to 2020.

Income (Figure 3D – LNINC): Income showed an upward trend over the years, with a temporary decline between 2007 and 2008. It increased steadily from 2010 until 2019 but experienced a sharp decline in 2020, likely due to the global Covid-19 pandemic. This trend is mirrored in Figure 3A (LNPOVT), which shows increased poverty levels alongside declining income in 2020.

Inequality (Figure 3E – LNINEQ): Inequality exhibited an upward trend over the years. Notably, inequality was at its lowest in the year 2000 when poverty levels were high. In contrast, in 2005, inequality levels were high while poverty levels were low. Since 2010, both inequality and poverty have generally increased, with some minor declines in inequality levels between 2010 and 2015.

Unemployment (Figure 3F – LNUNEMP): Unemployment showed a stagnant trend between 1990 and 2000, followed by an upward trend that peaked in 2003–2004 before declining significantly until 2008–2009. Since 2010, unemployment has been on the rise, aligning with the poverty trend depicted in Figure 3A (LNPOVT). This relationship between unemployment and poverty is expected, although other factors also contribute to poverty.

In summary, the observed trends reflect the complex interplay of various factors that affect poverty levels over time.

Summary statistics

Table 2 illustrates the summary statistics of the variables that are modelled in this study. The results reveal that only LNHD is normally distributed. This is evident from the *p*-value associated with the Jaque-Bera statistic that is less than the commonly used critical value of 0.05. Because the null hypothesis of the JB statistic is specified as data is normally distributed, the study rejected the null hypothesis and concluded that the data series of LNHD does not follow normal distribution.

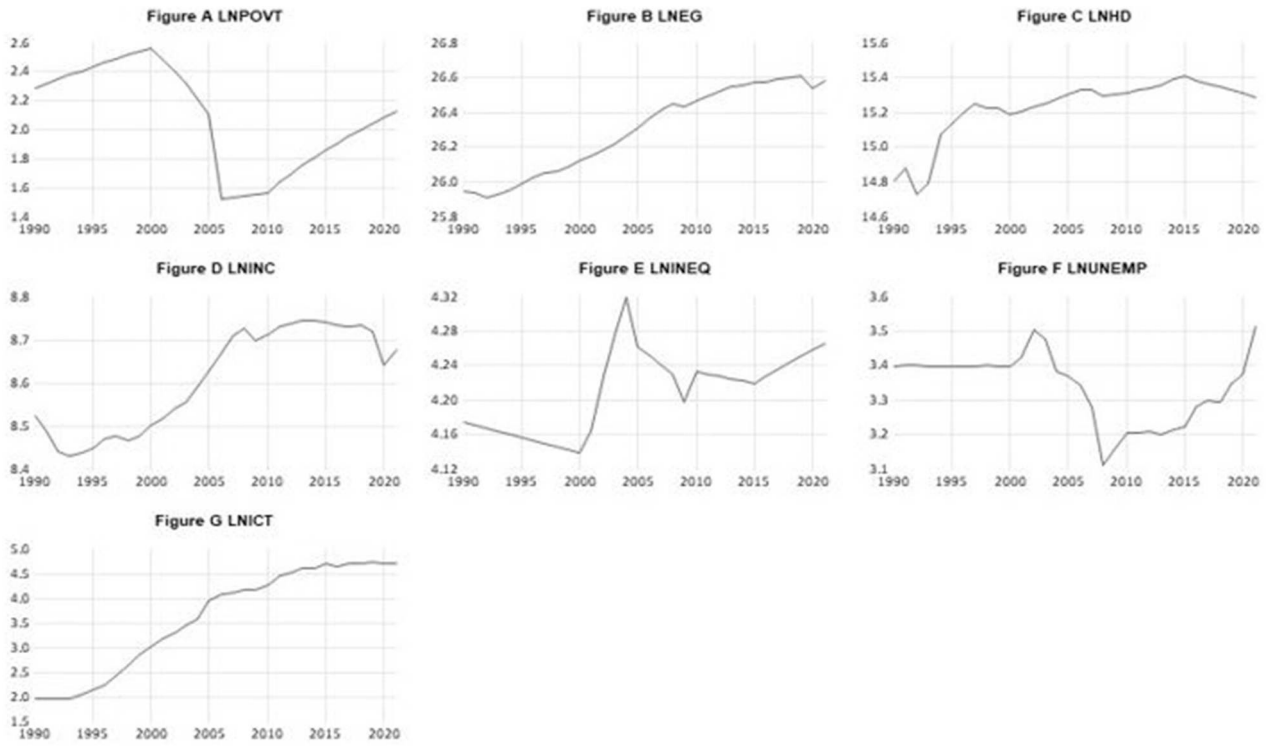

Figure 3: Stylized fact analysis.
***Source*:** Authors' computations (2022)

Table 2: Descriptive statistics.

	LNEG	LNHD	LNICT	LNINC	LNINEQ	LNPOVT	LNUNEMP
Mean	26.29607	15.22422	3.578411	8.607756	4.210351	2.090446	3.337378
Median	26.33982	15.29406	4.015501	8.634689	4.226285	2.114693	3.378774
Maximum	26.60579	15.40573	4.728672	8.745899	4.318344	2.564949	3.513305
Minimum	25.91265	14.72405	1.946197	8.429720	4.138361	1.526056	3.109507
Std. Dev.	0.250231	0.179048	1.053139	0.118526	0.047065	0.351967	0.102262
Skewness	−0.0208553	−1.657827	– 0.407185	−0.188522	0.060373	−0.307172	−0.448329
Kurtosis	1.476370	4.712547	1.591829	1.352915	2.104747	1.681051	2.351056
Jarque-Bera	3.327232	18.56850	3.528192	3.806735	1.088076	2.822727	1.633499
Probability	0.189453	0.000093	0.171342	0.149066	0.580400	0.243811	0.441866
Sum	851.47.42	487.1751	114.5092	275.4482	134.7312	66.89427	106.7961
Sum Sq. Dev.	1.941076	0.993809	34.38217	0.435501	0.068669	3.840305	248.0390
Observations	32	32	32	32	32	32	32

***Source*:** Authors' computations

Stationarity analysis

The study conducted stationarity tests using the Augmented Dickey Fuller (ADF) (1979) and the Phillipe Peron (PP) to determine the order of integration and the level of stationarity for each data series. The unit root tests assume the presence of a unit root, meaning, $\gamma = 0$. The null hypotheses tested in the model are specified below:

$$H_0{:}|\gamma| = 0 \text{ There is presence of unit root,}$$

$$H_1{:}|\gamma| < 0 \text{ There is no presence of unit root}$$

According to Asteriou and Hall (2016), the ADF test uses the special MacKinnon critical tables. In the case that the ADF statistical value is smaller than the critical value, then the study will reject the null hypothesis and conclude that y_t is a stationary process (ADF 1979).

The tests were conducted at none, intercept, trend, and intercept at level for all variables. The analysis of the unit root test results showed that most data series suffered from unit root problem at level, as shown in Table 3. The existence of unit root meant that the study could not reject the null hypothesis; therefore, further stationarity tests were conducted at first difference, none, trend, trend and intercept. Table 5 shows the results of the ADF and PP tests at first difference. The results show that most of the data series are statistically significant at least at (10%) MacKinnon significance level, which means the data series is stationary at first difference; this further means the data series is of order integration 1. The results emanating from the stationarity tests guided the study in selecting the appropriate model to examine the nexus between ICT and poverty, namely the VAR model.

The ADF and PP unit root test results show that none of the variables was stationary at level. ADF test results conducted at first difference are shown in Table 4.

The results emanating from the ADF and PP shown in Table 4 revealed that the data series was stationary at first difference. This implies that the data series did not suffer from unit root problems and that the data series was valid to conduct further required tests and regressions.

Estimation results

VAR lag model selection

According to Asteriou and Hall (2016), the importance of obtaining the appropriate lag length for the model is to enhance the model's predictive accuracy whilst minimizing the model biases. The appropriate lag length is obtained by inspecting the Akaike Information Criterion (AIC) and the Schwartz's Bayesian Criterion (SBC) of the estimated VAR model. The lag length that minimizes the AIC and the SBC is considered to be the appropriate lag length (Asteriou and Hall 2007, 2016).

The results from the VAR lag order selection criteria depict that lag 2 was the appropriate lag to use for examining cointegration in the study.

Cointegration results analysis

The study conducted the Johansen (1988) cointegration test, which was employed to identify cointegrating relationships between non-stationary time series data (Asteriou and Hall 2007). This specific test allows one to test and examine for more than one cointegrating relationship (Asteriou and Hall 2016). The Johansen (1988) test uses the two-step estimators to test for multiple cointegrating relationships, namely: the Trace test and the Maximum Eigenvalue test (Asteriou and Hall 2007). The hypotheses tested are specified below:

H_0: There is no cointegration among the variables,

H_1: There is cointegrating relationship among the variables

Trace test

$$H_0{:}K = K_0 \text{ There is no cointegrating relationship}$$

$$H_1{:}K > K_0 \text{ There is cointegrating relationship}$$

Maximum Eigenvalue test

$$H_0{:}K = K_0 \text{ There is no cointegrating relationship}$$

$$H_1{:}K = K_0 + 1 \text{ There is cointegrating relationship}$$

In the case that the null hypothesis of the trace test statistic is greater than the critical value from the trace test, then

Table 3: Stationarity tests at level.

Series	Model	Fisher ADF		Fisher PP	
		t – stat	*P*-value	Adj. *t*-stat	*P*-value
	None	4.576136	1.0000*	3.871026	0.9999
LNEG	Constant	−3.661661	0.7879	−0.822688	0.7985
	Constant & trend	−0.533863	0.9761	−0.944478	0.9375
	None	1.292971	0.9469	1.207387	0.9382
LNHD	Constant	−1.797825	0.3735	−3.357663	0.0206**
	Constant & trend	−0.504318	0.9762	−1.250325	0.8815
	None	1.271210	0.9447	2.444864	0.9954
LNICT	Constant	−1.668519	0.4368	−1.345325	0.5956
	Constant & trend	0.623754	0.9992	−0.032507	0.9938
	None	1.032241	0.9169	0.802903	0.8808
LNINC	Constant	−0.667570	0.8405	−0.825607	0.7977
	Constant & trend	−1.138194	0.9057	−1.663674	0.7431
	None	0.734491	0.8682	0.638624	0.8489
LNINEQ	Constant	−1.777412	0.3839	−1.138730	0.6875
	Constant & trend	−2.641354	0.2661	−1.805956	0.6775
	None	−0.409930	0.5275	−0.395830	0.5330
LNPOVT	Constant	−0.983333	0.7467	−1.277333	0.6273
	Constant & trend	−0.737054	0.9609	−1.276298	0.8752
	None	0.366509	0.7843	0.315966	0.7706
LNUNEMP	Constant	−0.945678	0.7594	−1.214619	0.6553
	Constant & trend	−0.091312	0.9927	−0.393347	0.9834

***Source*:** Authors' computations (2022)

the null hypothesis will be rejected. Rejecting the null hypothesis is an indication that there are cointegrating relationships. Furthermore, the number of cointegrating relationships is determined by the number of statistically significant eigenvectors. Table 6 reports the estimate results of the Johansen cointegrating test. The results as shown in Table 6 reveal at least four cointegrating equations between the specified variables. This means that there is a long run equilibrium relationship between the series of poverty, economic growth, human development, income, inequality, unemployment, and ICT. This was evident because most of the variables were statistically significant at least at the (10%) significance level.

VECM analysis

The previous section of the study reported at least four cointegrating equations; therefore, the Vector Error Correction Model (VECM) was conducted on the specified VAR

Table 4: Unit root tests results at first difference.

Series	Model	Fisher ADF		Phillips Perron	
		t – statistic	*P*-value	Adj. *t*-stat	*P*-value
	None	−1.673912	0.0884*	−2.419345	0.0173
LNEG	Constant	−4.670170	0.0039	−4.052789	0.0039
	Constant & trend	−4.155578	0.0139	−4.061309	0.0172
	None	−4.545785	0.0000	−4.545785	0.0000
LNHD	Constant	−4.613052	0.0009	−4.602664	0.0009**
	Constant & trend	−4.955298	0.0028	−5.518207	0.0005
	None	−1.969058	0.0483	−1.795679	0.06830
LNICT	Constant	−2.912754	0.0557	−2.912754	0.0557
	Constant & trend	−3.368420	0.0749	−3.192488	0.1050
	None	−3.743755	0.0005	−3.672958	0.0006
LNINC	Constant	−3.878530	0.0060	−3.878530	0.0060
	Constant & trend	−3.863878	0.0266	−3.791527	0.0312
	None	−3.856190	0.0004	−0.799093	0.0004
LNINEQ	Constant	−3.854395	0.0064	−3.684556	0.0097
	Constant & trend	−3.788473	0.0314	−3.608907	0.0460
	None	−3.950089	0.0003	−3.960031	0.0003
LNPOVT	Constant	−3.890173	0.0058	−3.900030	0.0057
	Constant & trend	−3.888501	0.0252	−3.891651	0.0251
	None	−3.531875	0.0009	−3.557772	0.0009
LNUNEMP	Intercept	−3.473443	0.0160	−3.499062	0.0150
	Trend & Intercept	−3.684194	0.0392	−3.616276	0.0453

***Source*:** Authors' computation (2022)

Table 5: VAR lag order selection criteria.

Lag	LogL	LR	FPE	AIC SC	HQ
0	251.1112	NA	2.02e-16	−16.27408 −15.94713	−16.16949
1	526.2076	403.4747	6.29e-23	− 31.34717 −28.73160	− 30.51043
2	696.7346	1705270*	3.47e + 26*	−39.44897* − 34.54478*	−37.88008*

***Source*:** Authors' computation (2022)

model, the results emanating from the VECM as shown in Table 10 revealed that the previous year's deviation from the long run equilibrium is corrected at the adjustment speed of 186. Moreover, the results show that a percentage change in ICT is associated with a 0.91% decrease in poverty. This finding is similar to the findings of Gillwald, Mothobi, and Rademan (2018), May, Dutton, and Munyakazi (2013), and Diga, Nwaiwu, and Plantiga (2013). The implication of this findings suggest that access to ICTs has a positive impact on poverty status, which implies further that they have the potential of reducing poverty levels in South Africa as suggested by the leapfrogging hypothesis. Moreover, the results in Table 9 reveal that economic growth is positively associated by a 7.63% decrease in poverty, *ceteris paribus*, in the short run. Furthermore, the results depict that human development is associated with a 0.13% decrease in poverty in the short run, *ceteris paribus*. The VECM results in Table 10 reveal further that income is associated with a 7.22% decrease in poverty in the short run, *ceteris paribus*. This result validates the poverty theory proposed by Amartya Sen. The relevance of this finding to this study is that ICTs should be introduced in a manner that enhances the chances of receiving income to reduce poverty levels in South Africa.

The study also found through the results emanating from the VECM that inequality is associated with a 0.81% increase in poverty, in the short run, *ceteris paribus*. These findings resonate with the status quo of South Africa where poverty levels are biased according to race, gender, and social class. This finding is similar to the findings of Moodley (2005) and Gillwald, Mothobi, and Rademan (2018) which indicates that ICTs should be introduced and adopted to reduce inequality levels within the country in order to eventually eradicate poverty levels. Moreover, the study reported that unemployment is associated with a 0.20% increase in poverty in the short run, *ceteris paribus*. This finding implies that ICTs should be adopted to promote employment creation in South Africa in order to attend to the country's inherent poverty levels.

Table 7 reports the estimation results of the Granger and William (1969) causality test, employed to identify the causal relationships between sets of two or more time series (Granger and William 1969). A causal relationship is identified if a variable, say, X_t, can be predicted with greater accuracy by using the past values of another variable, say, y_t. The null hypothesis tested is stated below in addition to the criteria for testing the hypothesis.

$$H_0: \sum_{i=1}^{n} \beta_i = 0 \; x_t \text{ does not granger cause } y_t$$

$$H_1: \sum_{i=1}^{n} \beta_i \neq 0 \text{ This means that } x_t \text{ granger causes } y_t$$

The Granger causality test follows the *F*-test methodology for the normal Wald test. The null hypothesis will be rejected if the computed *F*-value exceeds the *F*-critical value. A rejection of the null hypothesis implies that x_t causes y_t.

Causality results analysis

As discussed earlier, the variables exhibited a long-run equilibrium relationship. The causality tests were conducted to determine the causal relationship between poverty and ICT, while the null hypothesis for the test was *ICT does not cause poverty*. The results from the Granger causality test as shown in Table 9 reported the *F*-statistic at 7.61115, an indication that there is evidence of causality between ICT and poverty. In addition, the *p*-value associated with the *F*-statistic is recorded at 0.026, which is less than the commonly used 0.05 significance level, which is further evidence to suggest that the evidence of causality is statistically significant. Hence, the study could not reject the stated null hypothesis. The implication of the results indicated that ICT causes poverty and that the relationship between ICT and poverty is unidirectional.

Table 6: Cointegration test.

Trace test				Max Eigen value			
Ho:	H1:	λ trace statistic	Prob.	Ho:	H1:	λ max statistic	Prob
$r = 0$	$r = 0$	433.6665	0.0000	$r = 0$	$r = 0$	142.9853	0.0000
$r \leq 1$	$r \geq 1$	290.6812	0.0000	$r \leq 1$	$r \geq 1$	80.17450	0.0000
$r \leq 2$	$r \geq 2$	210.5067	0.0000	$r \leq 2$	$r \geq 2$	67.43375	0.0000
$r \leq 3$	$r \geq 3$	143.0730	0.0000	$r \leq 3$	$r \geq 3$	56.43369	0.0000
$r \leq 4$	$r \geq 4$	86.63928	0.0000	$r \leq 4$	$r \geq 4$	42.30526	0.0002
$r \leq 5$	$r \geq 5$	44.33401	0.0001	$r \leq 5$	$r \geq 5$	31.43707	0.0006
$r \leq 6$	$r \geq 6$	12.89694	0.0432	$r \leq 6$	$r \geq 6$	12.89694	0.0432

***Source*:** Authors' computation (2022)

Table 7: Granger causality test.

Pairwise Granger Causality Tests Null Hypothesis:	Obs	*F*-Statistic	Prob.
LNPOVT does not Granger Cause LNICT	30	0.15968	0.8533
LNICT does not Granger Cause LNPOVT		7.61115	0.026

***Source*:** Authors' computations (2022)

Table 8: Long run estimates.

Variable	coefficient	*t*-statistic	Prob
LNEG	1.416229	1.589420	0.1245
LNHD	0.133558	0.520604	0.6072
LNINC	−3.447102	−2.957220	0.0067
LNINEQ	−1.256035	−1.355873	0.1873
LNUNEMP	1.265357	2.593562	0.0157
LNICT	−0.122680	−0.610195	0.15472
Adjusted *R*-sq	0.862838		

***Source*:** Authors' computations (2022)

Long run estimate analysis

The results in Table 8 show the results of the long run regression output as specified by Equation (4), revealing that only income and unemployment were statistically significant, at least at the (10%) significance level, while other variables ICT, human development, income, inequality, and economic growth were statistically insignificant. The results reveal that economic growth and poverty have a positive relationship, which goes against a priori expectations because it is expected that poverty levels will decrease when economic growth increases due to their negative relationship. Furthermore, the results show that when economic growth increases by 1%, poverty will increase by 1.42%. This finding is counter-intuitive and could be ascribed to the fact that the level of economic growth in South Africa has not been sufficient and consistent enough to have a significant impact on poverty status. The World Bank (2014) data revealed that the average GDP growth rate in South Africa is 2.6% for the period 1994–2021. Also, with reference to Figure 3a (POVT) and b (LNEG), there is evidence that the growth rate in South Africa has coincided with rising poverty rates since 2010. This explains the positive relationship observed between economic growth and poverty status. The results show that human development has a positive relationship with poverty levels. Table 8 shows that when human development increases by 1%, poverty levels will increase by 0.13%, again going against a priori expectations. This finding contradicts the empirical evidence of Moyo, Mishi, and Ncwadi (2022), who reported an inverse relationship between human capital development and poverty in South Africa, particularly in rural areas. This observed relationship could be linked to the fact that education access in South Africa remains unequal in addition to increased dropout rates of high school pupils in the country. According to Stats SA (2022), at least 3% of 15-year-olds and almost 9% of 17-year-olds dropped out of school in 2021. The results further reveal that income and poverty have a negative relationship, which supports a priori expectations because it is expected that poverty levels will decrease when income increases. The connection between ICT and income in conjunction with the observed negative correlation between income and poverty implies that for ICTs to be effective at reducing poverty, they need to be used to enhance the income level of poor people and also ICT tools and services have to be made affordable and widely accessible. Various studies such as Tiwari (2008) and Lechman and Popowska (2022) have also reached similar conclusions on the connection between digital technologies, poverty, and income.

The results revealed that inequality and poverty have a negative relationship, which goes against a priori expectations because it is expected that inequality levels will increase poverty levels. Furthermore, the results show that when inequality increases by 1%, poverty will decrease by 0.12%. The results reveal that ICT and poverty have a negative relationship, which is supported by a priori expectations because it is expected that poverty levels will decrease when ICT access increases. Furthermore, the results show that when ICT access increases by 1%, poverty will decrease by 0.12%. Because of this empirical evidence, the study rejects the stated hypothesis that ICT does not impact poverty status referred to in the methodology section.

Table 9: Heteroskedasticity tests.

Model Tests Null Hypothesis: Homoskedasticity	Obs*r-squared	F-Stat	Prob. Chi-square	Prob. *F*
Breusch – Pagan-Godfrey	8.189568	1.433120	0.2245	0.2416
Harvey	8.103939	1.413053	0.2306	0.2488
Glejser	8.130877	1.419351	0.2287	0.2466

***Source*:** Authors' computation (2022)

Table 10: VECM results.

Error Correction:	D(LNPOVT)	D(LNICT)	D(LNEG)	D(LNHD)	D(LNINC)	D(LNINEQ)	D(LNUNEMP)
CointEq1	0.048696	0.024899	−0.000656	−0.002847	0.000175	0.001679	0.021111
	(0.02622)	(0.02156)	(0.00699)	(0.01996)	(0.000701)	(0.00548)	(0.01237)
	[1.85739]	[1.15472]	[−0.09388]	[−0.14266]	[0.02493]	[0.30646]	[1.70691]
D(LNPOVT(−1))	−0.001618	−0.022934	−0.067775	−0.012411	−0.069036	−0.007429	0.012175
	(0.17645)	(0.14512)	(0.04704)	(0.13432)	(0.04718)	(0.03687)	(0.08324)
	[−0.00917]	[−0.15803]	[−1.444073]	[−0.09240]	[−1.46337]	[−0.20150]	[0.14627]
D(LNICT(−1))	−0.919556	0.479872	0.107691	0.000352	0.106745	0.003435	0.011584
	(0.25382)	(0.20875)	(0.06767)	(0.19321)	(0.06786)	(0.05303)	(0.11974)
	[−3.62292]	[2.29876]	[1.59146]	[0.00182]	[1.57301]	[0.06477]	[0.09674]
D(LNEG(−1))	7.630411	4.824410	−0.217149	7.333271	−1.073936	−0.814653	−2.854619
	(5.76255)	(4.73945)	(1.53630)	(4.38660)	(1.54067)	(1.20398)	(2.71846)
	[1.32414]	[1.01793]	[−0.14134]	[1.67174]	[−0.69706]	[−0.67664]	[−1.05009]
D(LNHD(−1))	−0.131573	−0.054627	0.055769	−0.041294	0.055826	−0.013465	0.061955
	(0.31340)	(0.25776)	(0.08355)	(0.23857)	(0.08379)	(0.06548)	(0.14784)
	[0.41983]	[−0.21194]	[0.66747]	[−0.17309]	[0.66626]	[−0.20564]	[0.41906]
D(LNINC(−1))	−7.226821	−4.311672	0.078367	−6.718016	0.939225	0.804351	1.429594
	(5.54579)	(4.56117)	(1.47851)	(4.22160)	(1.48272)	(1.15869)	(2.61620)
	[−1.30312]	[−0.94530]	[0.05300]	[−1.59134]	[0.63345]	[0.69419]	[0.54644]
D(LNINEQ(−1))	0.814404	1.734817	0.106746	0.215699	0.108439	0.168029	−0.129352
	(0.83056)	(0.68310)	(0.22143)	(0.63224)	(0.22206)	(0.17353)	(0.39181)
	[0.98055]	[2.53963]	[0.48208]	[0.34116]	[0.48834]	[0.96830]	[−0.33014]
D(LNUNEMP(−1))	−0.202507	−0.314254	−0.018198	0.044342	−0.018878	0.284897	−0.097931
	(0.43041)	(0.35399)	(0.11475)	(0.32764)	(0.11507)	(0.08993)	(0.20304)
	[−0.47050]	[−0.88775]	[−0.15860]	[0.13534]	[−0.16405]	[3.16815]	[−0.48232]
C	−0.045140	−0.036289	0.014159	−0.105439	0.012349	0.015802	0.053055
	(0.09578)	(0.07877)	(0.02553)	(0.07291)	(0.02561)	(0.02001)	(0.04518)
	[−0.47132]	[−0.46069]	[0.55450]	[−1.44623]	[0.48225]	[0.78971]	[1.17426]

Variance decomposition analysis

The study conducted the variance decomposition and impulse response analysis of the unrestricted VAR. The orthogonalized Cholesky ordering method was employed, the essence of the variance decomposition was to further substantiate the magnitude of causation. The results of the variance decomposition are shown in Table 11, 4 periods were used in the study for poverty, ICT, economic growth, human development, income, inequality, and unemployment. Period 1 is considered to be the short run, whereas period 4 is considered to be the long run.

The empirical analysis of the variance composition shows that in Table 11, panel A, the response of poverty to shocks in itself in the short run will cause 100% fluctuations, in period 1, in the long run the response of poverty to shocks in itself is 41.69% fluctuations. The response of poverty on shocks of ICT will cause 0.00% fluctuations in the short run, but in the long run it contributes 28.31% fluctuations in poverty status in South Africa. The response of poverty on unemployment shocks will cause 0.00 variations in the short run, but in the long run unemployment shocks account for 14.46% fluctuations on the South African unemployment levels.

In panel B of Table 11, the response of ICT to shocks in itself in the short run will cause 96.60% fluctuations, in period 1, in the long run the response of poverty to shocks in itself is 53.70% fluctuations. The response of ICT on shocks of poverty will cause 3.39% fluctuations in the short run, but in the long run it contributes 3.06% fluctuations in poverty status in South Africa. The response of ICT on human development shocks will cause 0.00 variations in the short run, but in the long run unemployment shocks account for 29.74 human development in South Africa.

In panel C of Table 11, the results show that the response of economic growth to shocks in itself in the short run will cause 95.32% fluctuations, in period 1, in the long run the response of economic growth to shocks in itself is 32.80% fluctuations. The response of economic growth on shocks of ICT will cause 4.31% fluctuations in the short run, but in the long run it accounts for 32.88% variation in ICT level in South Africa. The response of economic growth on human development shocks will cause 0.00 variations in the short run, but in the long run unemployment shocks account for 18.96% fluctuations the human development.

In panel D, as shown in Table 11 the empirical analysis shows that the response of human development to own shocks in the short run will cause 78.16% fluctuations, in period 1, in the long run the response of poverty to shocks in itself is 78.77% fluctuations. The response of human development on shocks of ICT will account for 8.23% fluctuations in the short run, but in the long run it causes 6.4% fluctuations in ICT. The response of human development on the shocks of poverty will cause 2.94 variations in the short run, but in the long run human development shocks account for 5.45% fluctuations on the poverty status in South Africa.

The results in Table 11 show that in panel. in panel E, the response of income to own shocks in the short run will cause 0.40% fluctuations, in period 1, in the long run the response of poverty to shocks in itself is 0.92% fluctuations. The response of income on shocks of ICT will account for 8.43% fluctuations in the short run, but in the long run it causes 35.62% fluctuations in ICT level in South Africa. The response of income on the shocks of economic growth will cause 93.72 variations in the short run, but in the long run unemployment shocks on

Table 11: Variance decomposition results.

Period	S.E.	POVT	ICT	EG	HD	INC	INEQ	UNEMP
Variance Decomposition of POVT:								
1	0.705802	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	1.181809	93.36325	3.874980	0.409316	0.334274	1.867270	0.140889	0.010022
3	1.650751	87.05661	4.758151	0.211580	0.241456	7.492583	0.081154	0.158468
4	2.061242	82.61788	4.660436	0.142432	0.160550	12.11072	0.056923	0.251054
Variance Decomposition of ICT:								
1	4.591275	5.029364	94.97064	0.000000	0.000000	0.000000	0.000000	0.000000
2	7.369523	9.076104	81.47909	5.639825	0.128689	1.544377	1.640308	0.491609
3	9.240887	10.95034	78.56699	4.519904	0.286122	2.304968	2.941356	0.430317
4	10.80401	11.79346	75.73352	4.410074	0.236683	2.987414	4.459010	0.379836
Variance Decomposition of EG:								
1	7.11E + 09	0.273666	18.20567	81.52066	0.000000	0.000000	0.000000	0.000000
2	9.92E + 09	9.861865	19.28067	65.51629	1.467212	3.551706	0.081573	0.240680
3	1.33E + 10	12.54866	18.62776	58.54875	1.579073	8.079324	0.049213	0.567216
4	1.61E + 10	14.67210	17.45799	52.34268	2.027617	12.62726	0.051411	0.820936
Variance Decomposition of HD:								
1	189075.0	1.479488	4.903695	9.250670	84.36615	0.000000	0.000000	0.000000
2	327900.6	5.397608	3.502259	14.09478	71.70903	3.160204	0.156131	1.979990
3	442205.1	4.318167	2.688035	11.68038	72.71464	4.916810	0.091038	3.590926
4	539143.0	3.069965	2.412574	14.85220	71.61019	4.017698	0.138094	3.899283
Variance Decomposition of INC:								
1	126.8367	0.619368	15.93990	81.76224	0.105593	1.572893	0.000000	0.000000
2	187.7274	12.49726	14.06795	59.64482	1.871008	11.64673	0.010768	0.261471
3	259.1431	15.47678	12.36037	48.77802	1.992778	20.69824	0.048572	0.645244
4	322.1615	16.94356	10.57782	41.00653	2.371988	28.05222	0.119594	0.928278
Variance Decomposition of INEQ:								
1	1.195225	6.827242	11.17375	3.693234	5.984179	1.690013	70.63158	0.000000
2	2.218170	2.756482	13.48573	1.422283	2.237893	2.858071	71.26116	5.978381
3	3.187126	2.482208	15.56619	8.061551	2.340298	1.461578	64.12779	5.960393
4	3.964247	1.655422	16.71851	11.52311	2.490910	1.003211	61.34916	5.259677
Variance Decomposition of UNEMP:								
1	1.083707	0.775435	3.074604	6.206274	15.82461	25.25598	30.79215	18.07094
2	1.847998	0.438173	5.916447	41.60933	10.45978	9.886322	23.20188	8.488069
3	2.392673	6.592406	7.102687	40.28632	9.433207	7.784911	22.85739	5.943070
4	3.014321	11.57033	8.447265	35.88596	7.994169	10.66011	20.38518	5.056997

***Source*:** Authors (2023).

economic growth decreases and accounts for 25.42% fluctuations on the economic growth of South Africa.

The results in Table 11 show that in panel F inequality response to own shocks in the short run will cause 92.38% variations, in period 1, in the long run it decreases and the response of inequality to shocks in itself is 57.78% fluctuations. The response of inequality on shocks of unemployment will account for 0.00% variation in the short run, but it steadily increases and in the long run it accounts for 16.60% fluctuations in poverty status in South Africa. The response of inequality on ICT shocks will cause 0.07 variations in the short run, but in the long run inequality shocks account for 2.52% fluctuations on the poverty status in South Africa.

The empirical evidence from the variance decomposition has established a nexus between ICT and poverty status: the causal relationship between ICT and poverty is present in the short run as well as in the long run. Therefore, the study rejects the stated null hypothesis that ICT does not impact poverty status. This evidence contradicts the findings of other studies, for instance Alimi and Okunade (2020), who reported that ICTs only have an impact on poverty status in the long run. The disparity in the findings between this study and the Alimi and Okunade study (2020) could be attributed to the differences in estimation techniques as well as the proxies used to measure poverty. A similar study conducted by Verma et al. (2023) also revealed evidence of a short run and long run impact of ICT and economic development, although the impact of ICT on poverty proved to be more significant in the long-run.

The empirical evidence also revealed that the ICTs have a direct and indirect impact on poverty status, which is attributed to the multidimensional nature of poverty. The indirect impact of ICT on poverty is evident through the transmission mechanism of economic growth and human capital. Similar studies have reported similar evidence, for instance Verma et al. (2023) reported the findings that ICT increase labour productivity, which enhances the performance of SMEs, expands business sectors, and generate employment which eventually reduces poverty. The study of Ndjobo and Otabela (2023) provided empirical evidence that the nexus between ICT and human capital is critical in reducing income inequality, particularly in the context of developing countries. The findings of Njobo and Otabela (2023) are relevant to this study particularly because income (affordability) has been identified as one of the determinants of the digital divide in South Africa (refer to Figure 1).

Figure 4 depicts the VAR system's reaction on one standard deviation innovation shock.

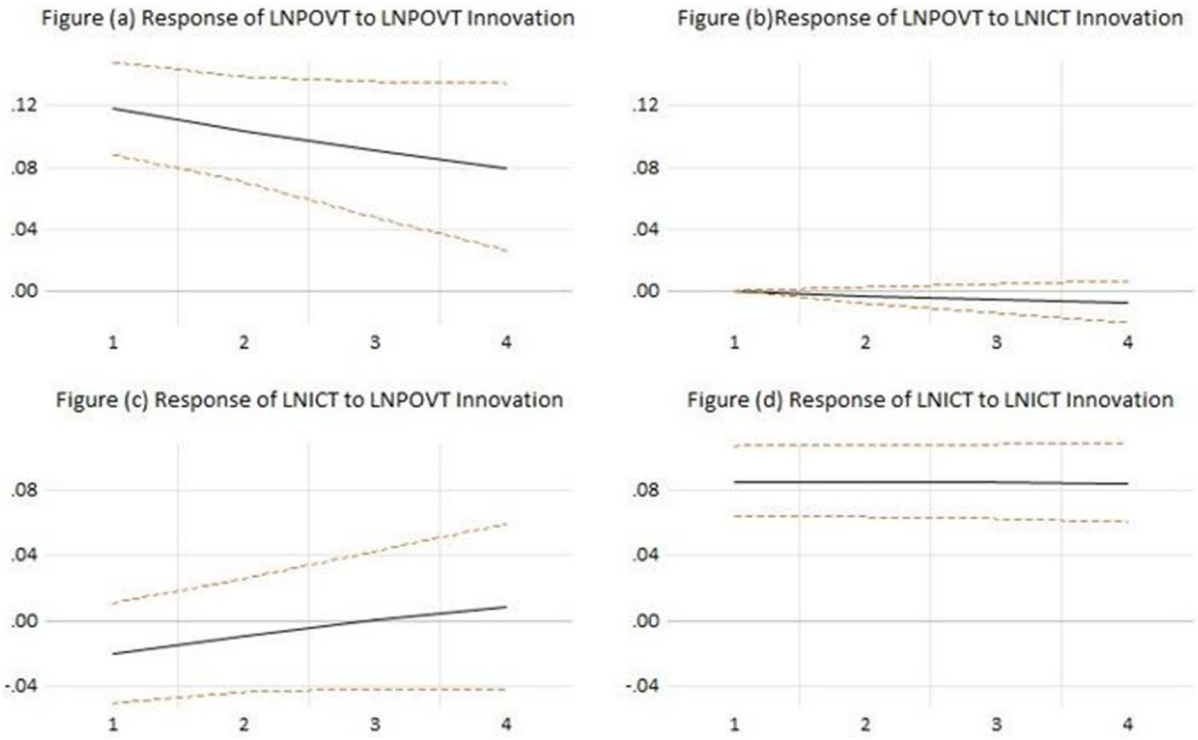

Figure 4: Impulse response results.
***Source*:** Authors' computation (2022)

Impulse response analysis

The study conducted the impulse response test to determine the degree of reaction of the endogenous variables in the VAR system to innovation shocks. The nature of the test is to examine the time of the shock and the manner the VAR reacted to the shock. Figure 4(a) shows that poverty responded positively to its own standard deviation shock, though the relationship declines steadily. The results validate the variance decomposition results of poverty responding to its shock. Figure 4(b) shows a negative response of poverty to a one standard deviation shock to ICT in the short run and the long run. This negative relationship aligns with the prior expectation and the long run regression analysis. However, the direction of the causal relationship differs from the results presented earlier. This counter-intuitive finding could be attributed to the statistical insignificance of ICT noted previously. A potential solution to this discrepancy is to re-valuate the proxy used to measure ICT. Figure 4(c) show a positive response of ICT to one standard deviation of poverty, in the short run and the long run, though the relationship increases at a slow pace. Figure 4(d) show a stagnant response of ICT to its own one standard deviation shock. The results validate the response observed in the variance decomposition in Table 11.

Post-estimation results

As indicated in the methodology section of the article, the study conducted post-estimation tests on the data series. The essence of the tests was to validate the data series to ensure that the data used in the study was good fitted for the requirement of the study and that the tests conducted to fulfil the research question using the data series are reliable and credible.

CUSUM test result

Figure 5 depicts the results emanating from the CUSUM test, which show that the model series is stable. This is evident in the blue trend line that lies within the 5% significance level; therefore, the model is good fitted.

Heteroskedasticity tests

The study conducted heteroscedasticity tests to examine the variance of the residuals, the tests conducted are the Breusch-Pagan LM (1979) Harvey-Godfrey (1976), and the Glejser tests (1961). These tests are used to measure the spread and variance of the residuals (Asteriou and Hall 2016). The null hypothesis as well as the test criteria are specified below:

$$H_0\colon \alpha_1 = \alpha_2 = \cdots = \alpha_p = 0 \text{ Or } H_0\text{:homoscedastic}$$

All tests follow the X^2 (chi-square) distribution test statistic with a degrees of freedom of p–1. The null hypothesis will be rejected if the computed Lagrange Multiplier (LM) test stat is greater than the critical value of the chi-square. The rejection of the null hypothesis means that there is evidence of heteroscedasticity, which means the variance of the residual is unequal (Asteriou and Hall 2007, 2016). Table 9 depicts the results emanating from the heteroskedasticity tests, which reveal that the data series is heteroskedastic. This is evident of the probability values associated with the F-statistic that are greater than 0.05 for all the three tests, respectively.

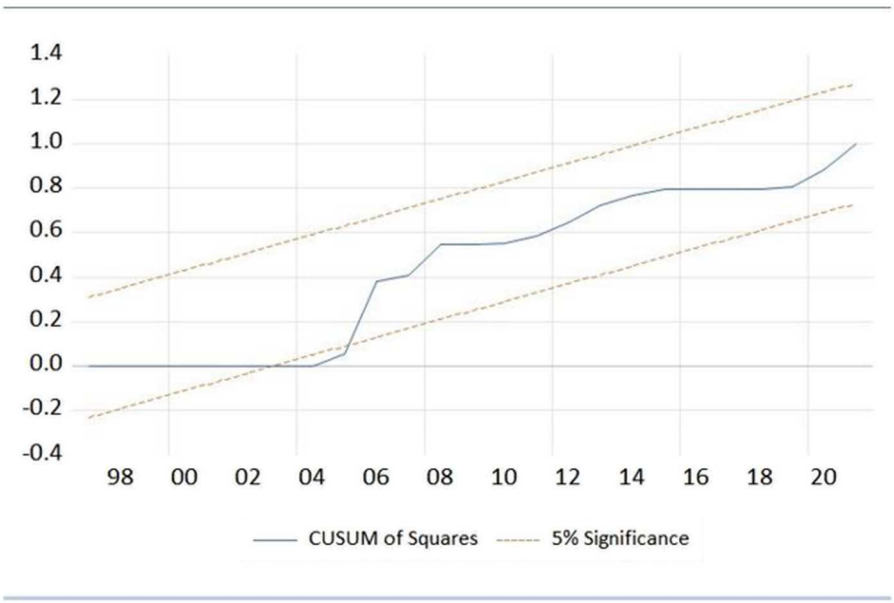

Figure 5: CUSUM test.
***Source*:** Authors' computation (2022)

Therefore, the study failed to reject the null hypothesis that the data series is homoscedastic.

Practical implications of the results

The empirical evidence presented in this study can be described as somewhat ambiguous, as the test results occasionally contradict each other at some stage. This implies that the findings of this study may not be considered unequivocal. Nonetheless, the established relationship between ICT and poverty status could contribute to the existing literature and inform policy and practice. Thus, it is crucial to interpret the implications of this study with caution, and policy recommendations should be viewed as guidelines only.

The direct and indirect relationship between ICT and poverty along with the short-run and long-run impact of ICT on poverty, offer a broad-range of possible policies, frameworks, and strategies. These strategies aim not only to alleviate poverty but also to address the root causes of digital divide, as identified in Figure 1. For instance, the South African government could enhance the regulation of the ICT sector to ensure that ICT services, such as internet, become more affordable and accessible to the public. Increased accessibility would benefit women in rural areas, who often have limited income. Various studies have also highlighted the potential of ICTs in promoting social inclusion.

In the context of human capital development, ICTs could be integrated into the South African education framework, particularly in rural secondary schools and Adult Basic Education and Training (ABET) centres. This integration would ensure that individuals acquire the necessary skills to use ICT services for income generation and other purposes. Additionally, expanding ICT centres and infrastructure, especially in rural areas, is essential. This expansion would provide people in remote region with access to knowledge, information, and economic opportunities, ultimately helping alleviate poverty. This recommendation also addresses the challenge of geographical location as a factor contributing to digital inequality, as identified in Figure 1.

Conclusion

The advancement of information and communication technologies (ICTs) has fundamentally reshaped various aspects of human interaction, including human-to-human interaction, human-to-business interaction, business-to-business interaction, and international interaction in the context of globalisations. The leapfrogging hypothesis posits that ICTs provide developing countries the opportunity to bypass traditional of development. While this argument is theoretically sound, empirical support for the hypothesis is limited, and existing literature often presents conflicting findings alongside methodological limitations.

The primary objective of this research paper was to examine the nexus between ICTs and poverty status, and to test the leapfrogging hypothesis within the unique context of South Africa. The study's findings suggest that ICTs have a positive impact on poverty status, implying they have the potential to reduce poverty levels in South Africa. However, the long run estimate indicates that ICTs are statistically insignificant at least at the 10% significance level.

Notably, the study yielded interesting findings regarding the relationship between inequality and poverty. Contrary to a priori expectations and existing literature, the results show a negative relationship, implying that when inequality increases, poverty levels decline. Additionally, the long run estimates indicate that human development is positive but statistically insignificant. This contradicts a priori expectations as well as the existing literature, as it is typically anticipated that inequality and poverty would exhibit a positive relationship, while human development would show a negative relationship with poverty

levels due to the impact of education on employment opportunities.

The variance decomposition results reveal that poverty rates respond more to the ICT shocks in the long run than in the short run. Furthermore, human development is more responsive to ICT shocks in the long run than in the short run. These findings suggest that South African policymakers should prioritize creating an environment conducive to economic growth that encourages substantial investment in ICTs. These technologies should be channelled into the education sector, particularly in remote areas to enhance human capital. This, in turn, would impact employment levels, ultimately reducing poverty and inequality in the country. Moreover, the empirical findings indicate that ICT tools have both a direct and indirect impact on poverty status. Therefore, South African policymakers have multiple avenues to address the country's poverty challenge using ICT tools.

Disclosure statement

No potential conflict of interest was reported by the authors.

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