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ICT, Income Inequality and Economic Growth Nexus in South Africa

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A B S T R A C T

This study examined the causal relationship between ICT, income inequality and economic growth in South Africa using data from 1990 to 2021. Three measures of ICT were used in the study, namely fixed telephone lines subscription, mobile cellular subscriptions and the proportion of people using the internet to the total population. Employing the autoregressive distributed lag approach, the study found a unidirectional causal flow from income inequality to ICT across all measures of ICT employed. Another unidirectional causal flow from economic growth to ICT was found in the short run when ICT was measured by fixed telephone lines and mobile cellular. When internet access was used as a measure of ICT, a bidirectional causality between internet access and economic growth in the short run and a unidirectional causal flow from internet access to economic growth was confirmed. Across all three measures of ICT, no causal relationship was confirmed between economic growth and income inequality. The study points to the importance of economic growth in increasing ICT access and the crucial role that internet access has on economic growth in South Africa. Policy implications are discussed.

1. Introduction

The National Development Plan 2030, a long-term roadmap for the South African economy, identified the triple challenge of income inequality, unemployment and poverty (National Planning Commission, 2023). The objectives and priorities of the implementation vehicle – the Medium-Term Strategic Framework (MTSF), are built around achieving targets set around the triple challenges and economic growth. Despite the thrust of the NDP to reduce inequality, South Africa remains a highly unequal society (National Planning Commission, 2023). This has been acerbated by low economic growth levels that are insufficient to sustain the development agenda for the country and create much-needed jobs. The pressure is mounting on the government to come up with solutions to the triple challenge and, at the same time, meet the Sustainable Development Goals (SDGs), of which South Africa is a signatory. South Africa has also embraced technology as one of the outcomes of the 4th Industrial Revolution in the hope of increasing efficiency and improving other macroeconomic variables. It is against this background that this study would like to investigate the causal relationship between ICT, income poverty and economic growth. The question this study would like to answer is 'Is ICT an answer to income inequality and economic growth in South Africa? The findings of the study will inform policy on which factor should be given priority to achieve positive changes in the other variables.

There is extensive literature on the impact of ICT on economic growth and inequality, the impact of ICT on economic growth, and the impact of ICT on income inequality. The findings from these studies vary depending on the study area, methodology, data and the ICT proxies used. However, the scale is tilted towards a positive contribution of ICT to economic growth, while a negative relationship was found in most studies that explored the relationship between economic growth and inequality. A limited number of studies have investigated the causal relationship between ICT, inequality and economic growth. Most of the studies examined the causal relationship among a part of the following variables: economic growth and income inequality; and economic growth and ICT. These studies miss the link between ICT and income inequality. Including the three variables in one study adds value to the existing knowledge on the direction of causality between ICT and income inequality.

The study examined the causal relationship between ICT, income inequality and economic growth using three proxies of ICT. The inclusion of three variables gives a broad understanding of the nature of the relationship depending on the proxy used. Some studies also pointed out the variation in the findings

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depending on the inequality and ICT proxy used (see Richmond and Triplett, 2018). Fixed telephone subscription per 100 people, mobile cellular subscription per 100 people and the percentage of people with internet to the population, while the GINI coefficient was used as a measure of income inequality. The study employs the autoregressive distributed lag approach to cointegration, and error correction model (ECM) based Granger causality test. The approach was selected based on the numerous advantages that it has. For example, the approach is robust in small samples.

South Africa was selected for this study because it is one of the countries in Southern Africa and arguably in Africa, with a well-developed economic system and has also fully embraced technology. Despite the challenges that the country faces of high unemployment, high inequality and low economic growth, South Africa provides an interesting case study. The findings of this study will also inform policy direction not only in South Africa, but to other African countries that look up to South Africa as a role model. Further, the country has rolled out the National Development Plan 2030, a time that also coincides with the SDG targets, which makes the country an interesting case study as there is a limited time to achieve the targets set under each policy document. It is pertinent for the South African government to push hard to achieve the targets set in the National Plan to build a better South Africa for everyone and meet the SDGs. An investigation of the causal flow between income inequality, ICT and economic growth sets the boundary on what ICT can do to fast-track economic growth and reduce income inequality.

The study is divided as follows; Section 2 discusses dynamics in ICT, economic growth and income inequality and related empirical studies; Section 3 dwells on the estimation techniques and model specification. Section 4 presents data analysis and discussion of results, while Section 5 concludes the study.

2. Literature review

ICT, Inequality and economic growth dynamics in South Africa

South Africa has one of the leading information and communication technology (ICT) industries in Africa) according to the International Trade Administration (ITA, 2021). The South African ICT industry exhibits leadership in security software, banking services and mobile software, with major international companies operating subsidiaries in South Africa (ITA, 2021). Thus, making South Africa a regional hub to cater for neighbouring countries. Government support in the ICT industry is provided through several channels, such as networking capacity, capacity building and incubation (ITA, 2021). The ICT small-medium and micro-enterprises are also among the channels that ICT receives support from the government (ITA, 2021). In South Africa, The Independent Communications Authority of South Africa (ICASA) is an authority responsible for the regulation of electronic communication, broadcasting and postal services. The ICASA derives its authority from the Independent Communications Authority of South Africa Act No. 13 of 2005 and the Electronic Communications Act No. 36 of 2005 (ICASA, 2021). The ICASA has a mandate to collect statistics and information in the ICT sector and monitor and report the developments in the sector. The authority is also responsible for ensuring access to affordable services to South Africans (ICASA, 2021).

According to the Statistics South Africa Household survey, in 2019, 63% of households had access to the Internet, with Gauteng having the highest proportion of the population with access to the Internet at 74.2% (ICASA, 2021). The 3G coverage has increased slightly from 99,7% in 2019 to 99,8% in 2020 at a national level. The same increase was recorded for 4G, from 92,8% in 2019 to 96,4% in 2020 (ICASA, 2021).

South Africa has experienced rapid growth in mobile cellular ownership from as low as 0.02 subscriptions per 100 people in 1990 to 168,9 subscriptions per 100 people in 2021 (World Bank, 2023). The same cannot be said for fixed telephone lines, where subscriptions grew steadily from 1990 to 2004 with an average of 9.8 subscriptions per 100 people before taking a downward turn until 2021 when 2.4 subscriptions per 100 people were recorded (World Bank, 2023). This reflects South Africans preferring mobile cellular use to fixed telephone lines.

Inequality Dynamics

According to the report by Sulla, Zikhali and Cuevas (2022) on Southern African Customs Union (SACU) inequality, the SACU is the most unequal in the region. South Africa is among the top countries with high-income inequality in the SACU and African countries in general (Sulla et al., 2022). The main contributing factors to a high inequality society within the SACU are lack of access to better-paying jobs and opportunities in general (Sulla et al., 2022). This is aggravated by the lack of education, means of production and skills required to get better-paying jobs (Sulla et al., 2022). Vulnerability to climate change always erodes the steps to an equal society (Sulla et al., 2022). The other factor that worsens inequality is fiscal transfers that are targeted to those in need and progressive taxation that act as a channel of income redistribution. From the report by Sulla et al. (2022), there is evidence to show government effort to redress inequality in South Africa, especially income inequality, has been recorded, although more needs to be done given the inequality gap. According to Statistics South Africa' StatsSa' (2023), the main source of income inequality is the labour market that is highly biased along racial and gender lines. Most of the South African population rely on jobs as a source of income. Thus, whenever there is an economic shock that results in the loss of jobs, income inequality also increases. For example, the COVID-19 pandemic resulted in the closure of firms and some of them downsizing as a survival strategy. This resulted in more people being unemployed. The government uses progressive taxation as a way of redistributing income from those earning high incomes to those who do not have any resources. The redistribution is done through the social safety nets. However, despite the government's support, the poverty level in South Africa calls for more government intervention. As Sulla et al. (2022) report suggested, direct income intervention needs to be complimented with policies that redress previously disadvantaged individuals. Such policies should target education, increase access to private sector jobs and strengthen the social protection systems to build resilience to fight economic and climate shocks (Commission for Conciliation, Mediation and Arbitration 'CCMA', 2002). The Employment Equity Act (EE) was passed in South Africa to redress previously disadvantaged groups on access to some jobs, wealth creation, education and promotion. The main objectives of the Employment Equity Act are creating workplaces free of discrimination and the ensure affirmative action is being implemented in the workplace (CCMA, 2002).

According to the World Bank (2023), income inequality measured by the GINI coefficient has worsened over the years. For example, in 1990, the GINI coefficient was at 0,58, and over the years, it worsened to register 0,75 in 2021(StatsSa, 2023). Thus, despite government intervention to redress the inequality and ills of the past, the country continuously struggles with income inequality, with average inequality during the study period at 0,68 (World Bank, 2023WDI). This does not come as a surprise, given the reliance of most households on wages and government grants. According to Statistics South Africa' StatsSa' (2023), female workers earn about 30% less than their male counterparts. The report also highlighted that males were more likely to be employed and secure better-paying jobs than their female counterparts (StatsSa, 2023). Generally, black Africans are the lowest paid compared to other races (StatsSa, 2023). The trends in Income inequality and ICT are reported in Figure 1.

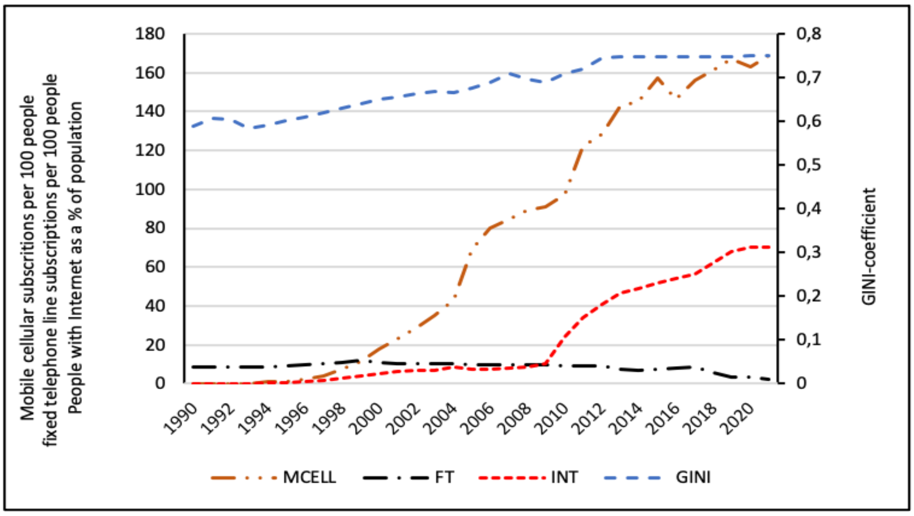

Figure 1. Trends in Income inequality and ICT 1990-2020

Sources: World Bank (2023) and Worldwide Data (2023)

Figure 1 reports the trends in ICT and the GINI coefficient during the study period. The figure shows a positive relationship between ICT measured by mobile cellular subscriptions and access to the internet as a percentage of the population. Fixed telephone line subscriptions have been very low, evidenced by South African moving to mobile cellular subscriptions in 1997 (World Bank, 2023). The graph suggests ICT worsens income inequality in South Africa.

Economic growth dynamics

The National Development Plan 2030 – an economic blueprint for the South African economy spells out the long-term desired developments in different sectors of the economy, rolled out in 2012 (Department: Planning, Monitoring and Evaluation, 2023). The overarching objective of the NDP is to eliminate poverty, inequality and unemployment through high economic growth, among other economic activities (National Planning Commission, 2023). These three key elements are notoriously called the triple challenges in the economy. Thus, the government realise the importance of elimination of these three challenges as a roadmap to realise economic development shared by all South African (National Planning Commission, 2023). The NPD is a national plan, and each sector is expected to align with the NDP and change policies where deviations have been identified (National Planning Commission, 2023). The NDP is implemented through the Medium-Term Strategic Framework (MTSF), with the first one rolled out from 2009 to 2014 and 2014 to 2019 and the current MTSF spanning from 2019 to 2024. The MTSFs act as vehicles to achieve the targets set out in the NDP by breaking them down to all spheres of government where imperatives of the MTSF inform the five-year strategic plans and budgets (The Presidency, 2023, 2009-2014). The current MTSF 2019-2024 is named

'Khawuzela' meaning South Africans are working together to achieve the MTSF with speed. This shows the urgency with which the MTFS is being implemented, given the short span of the target year 2030. The President also signed Performance Agreements with Cabinet members to hold them accountable for the specific targets and indicators aligned to the priority areas (education, skills and health; economic transformation and job creation; building a capable, ethical and developmental state; spatial integration, human settlements and local government; social cohesion and safe communities; and better Africa and world (Department: Planning, Monitoring and Evaluation, 2023).

South Africa experienced negative growth from 1990 to 1993. A steady increase from 1994 was experienced to record 5,65% in 2006 (World Bank, 2023). From 2007, the economy recorded fluctuations in growth, culminating in an average of 1.5% between 2007 and 2021(World Bank, 2023). South Africa recorded a huge slump in economic growth of 6,3% in 2020, a year that coincides with the COVID-19 pandemic. Measures taken by the South African government and other countries, limited economic activities both internally and internationally, resulting in a sharp decline in production. The trends in economic growth, income inequality and ICT is exhibited in Figure 2.

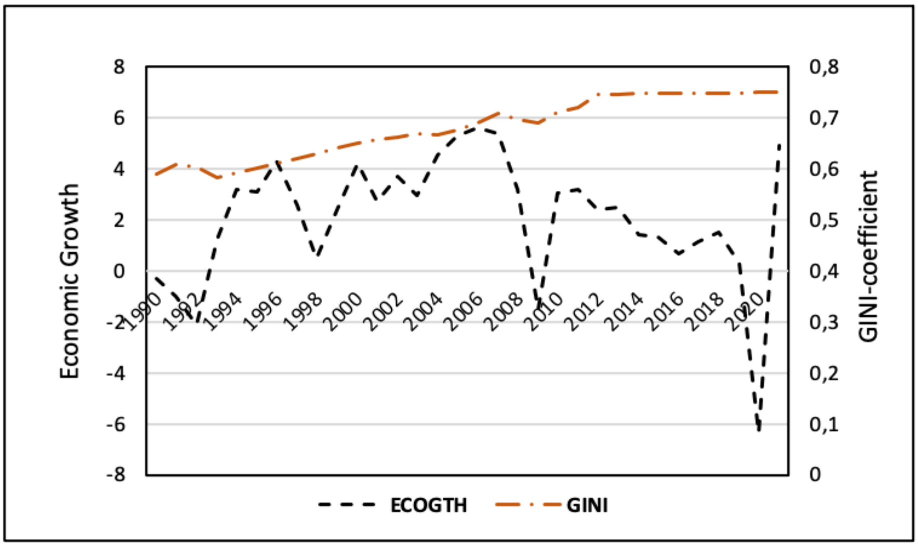

Figure 2. Trends in Income inequality and economic growth 1990-2021

Source: World Bank (2023) and Worldwide Data (2023)

Figure 2 reports a persistent income inequality gap that does not show a distinct relationship with economic growth. This suggests that economic growth may not be a panacea to income inequality, but there are other causes of inequality in South Africa. These causes could be structural factors that are not related to economic growth. Economic growth has fluctuated from 1990 with a noticeable upward trend until 2006 before taking a downward trend (World Bank, 2023). The downward trend clearly shows economic challenges and is against the high economic growth required to meet the NDP targets.

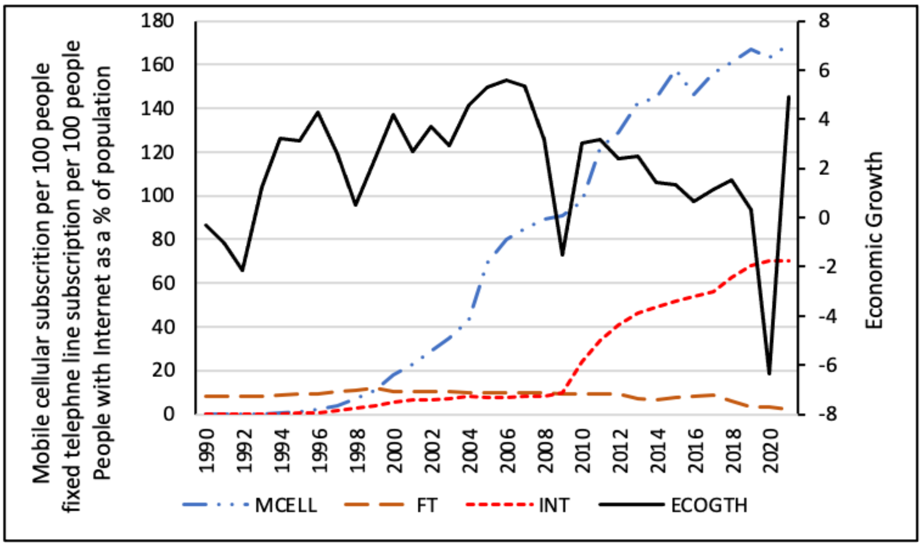

Figure 3. Trends in ICT and economic growth 1990-2021

Source: World Bank (2023)

Figure 3 reports a surge in ICT across all proxies in the late 1990s, with mobile cellular subscriptions growing at a fast pace compared to other ICT measures. However, economic growth remained depressed and took a downward trend from the mid-2020s, a time that ICT was booming. This suggests other factors play a key role in influencing economic growth or that the proxies used do not pick the major ICT related to economic growth. Among the ICT measures, fixed telephone line use declined significantly between 2018 and 2020. This could be a result of most households and businesses using other means of communication apart from traditional fixed telephone lines.

Review of related literature

Kurniawati (2021) examined the causal relationship between ICT and economic growth for 25 middle-income and high-income Asian countries using data from 2000-2018. The study used panel cointegration, endogeneity and cross-sectional dependence. Four proxies for ICT were used: telephone lines, fixed telephone lines per 100 inhabitants, mobile cellular subscribers per 100 inhabitants and internet use per 100 inhabitants. The study found the use of mobile devices, internet, and telephone lines to have a positive impact on economic growth. An increase in telephone penetration was found to have a high impact on economic growth in middle-income countries, while internet penetration was lower in middle-income countries in comparison to telephone penetration. Causality results for high-income countries show a bidirectional causality between ICT internet and economic growth in middle-income countries. A unidirectional causality from ICT mobile and ICT telephone to economic growth. The study also found a bidirectional causality between economic growth and ICT mobile, GDP and ICT Internet and ICT telephone. Sawng, Kim and Park (2021) examined how investment in ICT affects GDP growth in South Korea using seasonally adjusted quarterly data from 1999 to 2016. The study found a bidirectional causality between ICT and GDP growth in the long run and unidirectional causality from ICT to GDP growth in the short run. An increase in ICT 1% results in a 0,4% increase in GDP growth. GDP increases by 0.4% when ICT investment increases by 1%. In the short run, ICT leads to GDP growth in the long run. Pradhan et al. (2017) analysed the causal relationship between economic growth, financial development and information, communication and technology for Next-11 countries using data from 1961-2012. Using the panel vector regressive model, the study found bidirectional causality between internet user penetration and growth; internet server penetration and growth; fixed broadband and growth; and growth and ICT penetration. A unidirectional causal flow from telephone penetration and mobile phone penetration to growth.

Among the studies that investigated the impact of ICT on economic growth, Awad and Albaity (2022) examined the relationship between ICT and economic growth for 44 countries in sub-Saharan Africa using data from 2004-2020. The study used the ICT composite index and employed the GMM techniques. The study found ICT to contribute to economic growth directly. Latif et al. (2018), in a separate study on the relationship between ICT, foreign direct investment, economic growth, trade and globalisation for BRICS countries using data from 2000 to 2014 found the same results as Awad and Albaity (2022). Liu et al. (2021) investigated the relationship between globalisation, economic growth and ICT for Pakistan using data from 1990-2015. Using the autoregressive distributed lag (ARDL) and vector error correction model (VECM) the study found ICT measured by internet penetration and mobile phone usage to have a positive impact on economic growth. Kallal, Haddaji and Ftiti (2020) analysed the diffusion of ICT on economic growth for Tunisia employing sectorial data from 1997-2015. Using the panel pooled mean group autoregressive distributed lag, the study found a positive long-term effect of ICT on economic growth, while in the short run, a negative effect was confirmed. Albiman and Sulong (2017) investigated the impact of ICT on economic growth for three income categories (lower, upper and lower middle) in Sub-Saharan Africa using data spanning from 1990-2014. The study used fixed telephone lines, internet penetration and mobile phone as measures of ICT. Using the Pooled Mean Group (PMG) the study found lower-middle income countries to have an advantage over lower- and upper-income countries in absorbing the benefits of ICT. The results from telephone lines and mobile phones were found to be higher compared to internet penetration and usage. In the same vein, Kumar, Stauvermann and Samitas (2016) studied the effect of ICT on output per worker in the Chinese economy using data from 1980-2013. The study used the autoregressive distributed lag approach to cointegration and the Yoda Yamamoto Granger causality test to examine the relationship. The study found all ICT indicators – mobile cellular, telecommunication and fixed broadband- had a positive and elasticity ranging from 0.01 to 0.80. The study found bidirectional causality between mobile cellular, telecommunication and economic growth. The most dominant ICT drivers were mobile cellular and telecommunication technology. Spiezia (2013) investigated the contribution of three types of ICT – computer, software and communication- to growth in businesses for 26 industries in 18 OECD countries using data from 1995-2007. The study found the contribution of ICT investments to growth in businesses varies from 1% to 0,4% across the countries under the study. The contribution of ICT was found to be higher or equal to non-ICT investments. For most of the countries under study, computing equipment account for the largest contribution and account for a substantial proportion of overall ICT contribution.

3. Estimation techniques

This study uses the autoregressive distributed lag and the error correction (ECM) based Granger causality to examine the causality between ICT, income inequality and economic growth for South Africa. The ARDL approach was selected because of the numerous advantages that the methodology possesses compared to other statistical methods. For instance, the approach does not require all variables included in the model to be integrated of the same order. The approach allows a combination of variables integrated of order 1 and order 2 (Pesaran, Shin and Smith, 2001). However, the approach falls away if variables have an order of integration above 1.

Variables

The key variables in this study are ICT measured by mobile cellular subscriptions per 100 people, fixed telephone lines per 100 people and people with access to internet as a percentage of the population; inequality measured by the GINI-coefficient –a measure of inequality derived from the Lorenz curve (The World Bank, 2023). The Lorenz curve is a hypothetical line of absolute equality expressed as a percentage of the area under the curve (The World Bank, 2023); and coefficient and economic growth captured by the rate of change of the gross domestic product (GDP).

Model specification

The variables included in this model are trade openness (TOP); economic growth (ECOG); urbanisation (URB) and three proxies for ICT namely fixed telephone lines per 100 people (FT); mobile cellular subscription per 100 people (MCEL) and people with access to internet as a proportion of the population (INT).
The Cointegration Model [ICT, GINI, ECOG, URB, TOP]

$$\Delta ICT_{mt} = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta\, GINI_{t-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \beta_1 ICT_{mt-1} + \beta_2 GINI_{t-1} + \beta_3 ECOG_{t-1} + \beta_4 URB + \beta_5 TOP_{t-1} + \mu_{1t} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\Delta GINI_{t} = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=1}^{n} \varphi_{2i}\Delta\, GINI_{t-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \beta_1 ICT_{mt-1} + \beta_2 GINI_{t-1} + \beta_3 ECOG_{t-1} + \beta_4 URB + \beta_5 TOP_{t-1} + \mu_{2t} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\Delta ECOG_{t} = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta\, GINI_{t-i} + \sum_{i=1}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \beta_1 ICT_{mt-1} + \beta_2 GINI_{t-1} + \beta_3 ECOG_{t-1} + \beta_4 URB + \beta_5 TOP_{t-1} + \mu_{3t} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\Delta URB_{t} = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta\, GINI_{t-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=0}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \beta_1 ICT_{mt-1} + \beta_2 GINI_{t-1} + \beta_3 ECOG_{t-1} + \beta_4 URB + \beta_5 TOP_{t-1} + \mu_{4t} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\Delta TOP_{t} = \varphi_0 + \sum_{i=0}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=0}^{n} \varphi_{2i}\Delta\, GINI_{t-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=0}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \beta_1 ICT_{mt-1} + \beta_2 GINI_{t-1} + \beta_3 ECOG_{t-1} + \beta_4 URB + \beta_5 TOP_{t-1} + \mu_{5t} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

ICT is captured by fixed telephone lines (FT), mobile cellular subscription per 100 people (MCEL) and people with access to internet as a percentage of the population (INT). Each of the ICT proxies enters the equation one at a time whilst all the other variables remain unchanged.
URB= population living in urban areas as a percentage of the total population.
TOP= trade openness (expressed as a sum of export and imports as a proportion of GDP).
φ_0 is a constant; $\varphi_1 - \varphi_6$; $\beta_1 - \beta_5$ are coefficients; and $\mu_1 - \mu_5$ are error terms.
Equation 6 - 10 specify the Granger-causality models given in Equation 1-5.

$$\Delta ICT_{mt} = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=1}^{n} \varphi_{2i}\Delta\,GINI_{mt-i} + \sum_{i=1}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \gamma_1 ECM_{t-1} + \mu_{1t} \ldots\ldots\ldots\ldots (6)$$

$$\Delta GINI_{t} = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=1}^{n} \varphi_{2i}\Delta\,GINI_{mt-i} + \sum_{i=1}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \gamma_2 ECM_{t-1} + \mu_{2t} \ldots\ldots\ldots\ldots (7)$$

$$\Delta ECOG_{t} = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=1}^{n} \varphi_{2i}\Delta\,GINI_{mt-i} + \sum_{i=1}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \gamma_3 ECM_{t-1} + \mu_{3t} \ldots\ldots\ldots\ldots (8)$$

$$\Delta URB_{t} = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=1}^{n} \varphi_{2i}\Delta\,GINI_{mt-i} + \sum_{i=1}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \gamma_4 ECM_{t-1} + \mu_{4t} \ldots\ldots\ldots\ldots (9)$$

$$\Delta TOP_{mt} = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta ICT_{mt-i} + \sum_{i=1}^{n} \varphi_{2i}\Delta\,GINI_{mt-i} + \sum_{i=1}^{n} \varphi_{3i}\,\Delta ECOG_{t-i} + \sum_{i=1}^{n} \varphi_{4i}\,\Delta URB_{t-i} + \sum_{i=1}^{n} \varphi_{5i}\,\Delta TOP_{t-i} + \gamma_5 ECM_{t-1} + \mu_{5t} \ldots\ldots\ldots\ldots (10)$$

Where $\gamma_1 - \gamma_5$ are error correction coefficients.
ECM= error correction model
The other variables remain the same as specified in Equation 1-5.

Data Sources

In this study, the causal flow between ICT, income inequality and economic growth is analysed using data from 1990 -2021. Data for ICT – fixed telephone line per 100 people (FT), mobile cellular subscription per 100 people (MCEL) and people access to internet as a percentage of the population (INT); trade openness (TOP); urbanisation (URB); and economic growth (ECOG) were retrieved from the World Bank Development Indicators. The GINI -coefficient (GINI) was extracted from the Worldwide Database.

4. Data analysis and discussion of results

Unit Root Test

The Phillip Perron (PP) and Augmented Dickey Fuller-GLS unit root test were used to analyse the stationarity of the variables. Although the ARDL approach does not require stationarity test, this was carried out to ascertain all the variables have order of integration less than one. The ARDL falls away if variables have a higher order of integration than one. Table 1 reports the unit root test results.

Table 1. Unit Root Test Results

Dickey-Fuller (DF) Unit Root Test				
Variable	Stationarity of all Variables in Levels		Stationarity of all variables in First Difference	
	Without Trend	With Trend	Without Trend	With Trend
FT	-0.645	-0.289	-3.658**	-4.286**
MCEL	-0.461	-2.369	-4.729***	-4.798***
INT	-0.158	-1.018	-3.115**	-4.321***
GINI	-0.967	-1.749	-4.954***	-4.866***
ECO	-1.045	-2.143	-5.423***	-5.666***
URB	-0.223	-1.045	-4.231***	-5.134***
TOP	-1.845	-0.362	-6.387***	-6.354***

Dickey-Fuller-GLS Unit Root Test				
Variable	Stationarity of all Variables in Levels		Stationarity of all variables in First Difference	
	Without Trend	With Trend	Without Trend	With Trend
FT	-0.847	-0.286	-3.643**	-4.342***
MCEL	-0.462	-2.368	-4.976***	-4.979***
INT	-1.033	-1.398	-4.523***	-4.310***
GINI	-0.974	-1.885	-4.942***	-4.848***
ECO	-1.9751	-2.0974	-6.544***	-6.454***
URB	-1.058	-1.914	-3.712**	-4.843***
TOP	-1.632	-2.916	-6.387***	-6.354***

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

Cointegration

After confirming the stationarity of variables included in the model to be integrated of order one, the next step is to establish if variables in each function have a long-run relationship. The cointegration results are presented in Table 2.

Table 2. Cointegration Results

Dependent Variable	Function	F-Statistic	Cointegration Status
Model 1: ICT measured by mobile cellar (MCEL)			
MCEL	F (MCEL|GINI, ECO, URB, TOP)	3.323	Not Cointegrated
GINI	F (GINI|MCEL, ECO, URB, TOP)	1.855	Not cointegrated
ECO	F (ECO|MCEL, GINI, URB, TOP)	5.103**	Cointegrated
URB	F (URB|MCEL, GINI, ECO, TOP)	2.725	Not Cointegrated
TOP	F (TOP|MCEL, GINI, ECO, URB)	6.598**	Cointegrated
Model 2: ICT measured by fixed telephone lines (FT)			
FT	F (FT|GINI, ECO, URB, TOP)	3.544	Not Cointegrated
GINI	F (GINI|FT, ECO, URB, TOP)	3.744	Not Cointegrated
ECO	F (ECO|FT, GINI, URB, TOP)	3.818	Not Cointegrated
URB	F (URB|FT, GINI, ECO, TOP)	2.468	Not Cointegrated
TOP	F (TOP|FT, GINI, ECO, URB)	6.691***	Cointegrated
Model 3: ICT measured by access to internet (INT)			
INT	F (INT|GINI, ECO, URB, TOP)	3.015	Not Cointegrated
GINI	F (GINI|INT, ECO, URB, TOP)	3.195	Not Cointegrated
ECO	F (ECO|INT, GINI, URB, TOP)	7.704***	Cointegrated
URB	F (URB|INT, GINI, ECO, TOP)	9.178***	Cointegrated
TOP	F (TOP|INT, GINI, ECO, URB)	7.043***	Cointegrated

Critical values	10%		5%		1%	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
	2.752	3.994	3.354	4.774	4.768	6.670

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

The cointegration results presented in Table 2 confirmed cointegration in the economic growth function - F(ECO|MCEL, GINI, URB, TOP) and trade openness- F(TOP|MCEL, GINI, ECO, URB) functions for Model 1; trade openness function - F(TOP|FT, GINI, ECO, URB) for Model 2; and economic growth - F(ECO|INT, GINI, URB, TOP), urbanisation - F(URB|INT, GINI, ECO, TOP) and trade openness function - F(TOP|INT, GINI, ECO, URB) function for Model 3. To proceed with the estimation, for those functions where cointegration was found, short-run and long-run causality is estimated, while for the remaining functions where cointegration was not found, only short run estimation is done. The Granger-causality results are presented in Table 3.

Table 3. Granger-causality results

Panel 1		**Model 1: Mobile Cellular as a measure of ICT**				
	ECM t-statistics					**ECM (t-stat)**
	ΔMCEL	ΔGINI	ΔECO	ΔURB	ΔTOP	
ΔMCEL	-	3.425* [0.076]	3.784* [0.063]	0.207 [0.650]	1.111 [0.302]	-
ΔGINI	0.068 [0.797]	-	0.960 [0.337]	3.191* [0.087]	0.573 [0.457]	-
ΔECO	1.095 [0.305]	0.046 [0.832]	-	0.061 [0.808]	5.796** [0.024]	-0.769*** [-5.014]
ΔURB	5.474** [0.028]	0.042 [0.838]	0.043 [0.838]	-	2.243 [0.148]	-
ΔTOP	0.025 [0.875]	3.980* [0.058]	9.117*** [0.006]	0.453 [0.508]	-	-0.837*** [-5.292]

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

Results reported in Table 3, where ICT was measured by mobile cellular ownership, a unidirectional causal flow from GINI to MCEL was confirmed in the short run. The results confirmed the negative impact that income inequality has on ownership of mobile cellular in South Africa. Given the high-income inequality in South Africa, the impact cannot be underestimated. The study also found a unidirectional causal flow from economic growth to mobile cellular ownership. This result is not surprising as high economic growth results in an increase in household earnings, positively affecting ownership of mobile cellular in general and ownership of cellular phones that have multiple functionalities. No causality was found between economic growth and the GINI coefficient. This finding confirmed inequality in South Africa could be attributed to other factors, such as structural factors and not economic growth.

Other results reported in Table 3 confirmed the following: i) a unidirectional causal flow from MCEL to urbanisation; ii) unidirectional causal flow from GINI to trade openness in the short run and in the long run; iii) a unidirectional causal flow from urbanisation to GINI in the short run, iv) No causality between MCEL and TOP; urbanisation and trade openness, and urbanisation and economic growth, irrespective of the time considered; and v) a bidirectional causality between trade openness and economic growth in the short and long run.

Table 4. Granger-causality results when fixed telephone is used as a measure of ICT

Panel 1		**Model 2: Fixed Telephone Lines as a measure of ICT**				
	ECM t-statistics					**ECM (t-stat)**
	ΔFT	ΔGINI	ΔECO	ΔURB	ΔTOP	
ΔFT	-	1.734 [0.204]	5.743** [0.027	4.395** [0.049]	0.018 [0.894]	-
ΔGINI	9.784*** [0.005]	-	0.994 [0.330]	9.985*** [0.003]	0.192 [0.666]	-
ΔECO	0.018 [0.893]	0.207 [0.654]	-	1.243 [0.279]	3.460* [0.078]	-
ΔURB	3.583* [0.071]	5.476** [0.028]	2.601 [0.120]	-	-2.767* [0.083]	-
ΔTOP	0.217 [0.646]	5.009** [0.035]	9.100*** [0.006]	-	0.766 [0.390]	-0.937*** [-6.825]

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

Results presented in Table 4 where fixed telephone lines measured ICT, confirmed a unidirectional causal flow from FT to GINI coefficient in the short run. Thus, ICT can be used to reduce income inequality in South Africa when ICT is measured by fixed telephone lines. Another unidirectional causal flow from economic growth to fixed telephone lines was confirmed in the short run. The findings of the study revealed the positive contribution of economic growth to advancement in ICT through ownership of fixed telephone lines. No causality was found between economic growth and the GINI coefficient, suggesting economic growth is not the main source of high inequality in South Africa. Economic growth is a necessary but not sufficient condition to reduce inequality in South Africa.

Other results presented in Table 4 confirmed the following: 1) a bidirectional causality between urbanisation and economic growth; ii)unidirectional causal flow from urbanisation to fixed telephone lines in the short runs; iii) bidirectional causality between urbanisation and GINI in the short run; iv) no causality between fixed telephone lines and trade openness, and between economic growth and urbanisation in the short run; v) unidirectional causal flow from trade openness to urbanisation; and vi) bidirectional causality between economic growth and trade openness in the short run and a unidirectional causal from economic growth to trade openness in the long run.

Table 5. Granger-causality results when internet access is used as a measure of ICT

Panel 1		**Model 3: Internet Access as a measure of ICT**				
	ECM t-statistics					**ECM (t-stat)**
	ΔINT	ΔGINI	ΔECO	ΔURB	ΔTOP	
ΔINT	-	6.742** [0.016]	3.450** [0.049]	1.632 [0.214]	4.613** [0.021]	-
ΔGINI	0.353 [0.558]	-	0.794 [0.382]	4.995** [0.035]	0.112 [0.742]	-
ΔECO	8.233*** [0.008]	0.219 [0.644]	-	2.090 [0.161]	8.497** [0.002]	-0.830*** [-6.704]
ΔURB	9.442*** [0.006]	2.802 [0.107]	0.616 [0.440]	-	3.369* [0.079]	-0.003*** [-6.625]
ΔTOP	0.939 [0.343]	5.778** [0.025]	3.579* [0.071]	0.029 [0.866]	-	-0.916*** [-7.073]

Note: *, ** and *** denote stationarity at 10%, 5% and 1% significance levels, respectively.

Results reported in Table 5, where ICT was measured by access to internet, confirmed a unidirectional causal flow from GINI to internet access in the short run. The findings of the study suggest the importance of ICT in availing economic information, such as job opportunities and markets, which increase the economic participation of the poor, thereby closing the inequality gap. The study also found a bidirectional causality between internet access and economic growth in the short run and a unidirectional causal flow from internet access to economic growth in the long run. This finding suggests the significant role ICT has assumed in stimulating economic growth through a plethora of channels such as availing of information, facilitation of transactions, marketing platform, sourcing of raw material and monitoring of stock and supply chain in real time, among other benefits. No causality was found between economic growth and the GINI coefficient in the short run and the long run.

Other results reported in Table 5 confirmed the following: i) unidirectional causal flow from internet access to urbanisation in the short run and the long run; ii) unidirectional causal flow from GINI to trade openness in the short and long run; iii) unidirectional causal flow from urbanisation to GINI and another unidirectional causal flow from trade openness to internet access in the short run; iv) and another unidirectional causal flow from trade openness to urbanisation in the short; v) unidirectional causal flow from trade openness to urbanisations in the short run and the long run; vi) no causality between economic growth and urbanisation in the short run and the long run; and vii) bidirectional causality between economic growth and trade openness. The results suggest that as an economy experience economic growth, the interaction with other countries also grows.

The results across the three proxies for ICT suggest a unidirectional causal flow from GINI to ICT. These results reveal the impediment of high inequality in South Africa to embrace information and technology that has the potential to transform people's lives. The finding points to the importance intentional government policies to reduce inequality in South Africa. Two out of three ICT proxies also confirm the causal flow from economic growth to ICT, suggesting the importance of economic growth as a necessary condition for the expansion of ICT. This could be increasing the affordability of different ICT like mobile cellular and fixed telephone lines. An interesting finding in this study was no causality between economic growth and urbanisation. This was against expectations, suggesting limited role of economic growth in urbanisation, there could be other reasons that attract people to urban areas apart from economic growth.

5. Conclusions

This study examined the causality between economic growth, income inequality and ICT in South Africa using data from 1990 to 2021. The ARDL approach to cointegration and the ECM-based Granger-causality test was employed to explore the causality between the three. Income inequality was captured by the GINI coefficient. The study was motivated by the need to establish if ICT can play a role in reducing high-income inequality in South Africa; and if economic growth can be a panacea to income inequality and access to ICT. Three proxies of ICT, namely, mobile cellular subscription per 100 people, fixed telephone subscription per 100 people and access to internet we used. To fully specify the models, urbanisation and trade openness were included to form a multivariate causality framework. The study found a unidirectional causal flow from income inequality to ICT across all the proxies of ICT used. Two out of the three ICT measures (fixed telephone lines and mobile cellular) confirmed a unidirectional causal flow from economic growth to ICT in the short run. Only when internet access was used as a measure of ICT was a bidirectional causality confirmed in the short and a unidirectional causal flow from internet access to economic growth in the long run. Across all three proxies of ICT, no causality was found between economic growth and income inequality. It can be concluded that economic growth has an influence on ICT in South Africa. The higher the economic growth, the more accessible ICT. However, economic growth has no influence on income inequality in South Africa. It can be recommended that South Africa may continue to implement policies that support economic growth to increase ICT in the country. To increase economic growth and recover momentum lost during COVID-19, the government may put in place policies that ensure data becomes cheaper to increase internet access to positively influence economic growth. Although South Africa is a highly unequal country, the government should look at other economic variables to reduce income inequality. The study confirms that economic growth is a necessary but not a sufficient solution to income inequality.

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