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Article

The impact of telecommunications development on the Trade-GDP nexus in South Africa: Application of the ARDL methodology

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Abstract: This study investigated the relationship between telecommunications development, trade openness and economic growth in South Africa. It determined explicitly if telecommunications development and trade openness directly impact economic growth or whether telecommunications strengthen or weaken the link between trade openness and economic growth using the ARDL bounds test methodology. The findings reveal that both telecommunications development indicators and trade openness significantly and positively impact South Africa's GDP in the short and long terms. The study also found that control variables like internet usage and gross fixed capital formation significantly and positively influence GDP. Conversely, inflation was found to consistently affect GDP negatively and significantly. The findings from the ARDL cointegration analysis affirm a long-run economic relationship between the independent variables and GDP. The study also established that telecommunications development slightly distorts trade in the foreign trade-GDP nexus in South Africa. Despite this, the negative interaction effect is not substantial enough to overshadow the positive impact of trade openness on economic growth. From a policy perspective, the study recommends that South African policymakers prioritise enhancing local goods' competitiveness in global markets and reducing trade barriers. It also advocates for improving the accessibility and affordability of telecommunications technologies to foster economic development.

Keywords: trade openness; telecommunications development; GDP; mobile subscriptions; internet usage; fixed telephone subscriptions; South Africa; ARDL
JEL Classification: F14; F43; O1; O14; O33; L96

1. Introduction

This study investigates the relationship between telecommunications development, trade openness and economic growth in South Africa. It aims to determine if telecommunications development and trade openness directly impact economic growth or whether telecommunications strengthen or weaken the link between trade openness and economic growth. The significant role of foreign trade and the advancement of telecommunications in modern economies is well-documented, with a consensus among scholars on their significant contributions to economic growth, especially in developing countries. This perspective is strongly supported by academic research, with notable contributions from Awad and Albaity (2022), Meijers (2014), Dahmani, Mabrouki, and Ben-Youssef (2022), Nabi, Tunio, Azhar, Syed, and Ullah (2022), Singh and Siddiqui (2023), Soylu, Adeleye, Ergül, Okur, and Lorente (2023), and Salahuddin and Gow (2016). These studies highlight

the critical role of these factors as key determinants of economic expansion in various regions. This study aims to contribute to this body of knowledge by comprehensively analysing the relationship between telecommunications development, trade openness, and economic growth in South Africa.

The argument positing foreign trade as a primary engine for economic growth precedes the focus on telecommunications development. This perspective is well-articulated by Donou-Adonsou (2019) and Myovella et al. (2020). Complementing this, Steinmueller (2001) proposes the leapfrogging hypothesis, suggesting that adopting telecommunications development can enable developing and emerging economies to bypass certain stages of economic development. This hypothesis receives support from studies by Adeleye and Eboagu (2019), Niebel (2018) and Tallon and Kraemer (2000).

Further corroborating the growth-enhancing role of telecommunications development, particularly in the African context, are studies by Singh and Siddiqui (2023), Soylu et al. (2023), Dah-mani et al. (2022), Nabi et al. (2022) and Adeleye and Eboagu (2019). The profound impact of telecommunications on socioeconomic development, including health, culture, education, and poverty alleviation, is comprehensively discussed in the works of Roztocki, Soja and Weistroffer (2019) and Lee, Shao and Vinze (2018).

Concurrently, the literature abounds with studies that show the favourable impacts of international trade on economic growth. Critical studies by Fetahi-Vehapi, Sadiku and Petkovski (2015) and Chang, Kaltani and Loayza (2009) demonstrate the superior productivity of open economies compared to closed ones. Dollar and Kraay (2004), Frankel and Romer (1999) and Sachs and Warner (1995) further provide evidence of the direct link between trade openness and economic activity and productivity in their research. However, the implications of foreign trade for inclusive growth remain subject to debate. Studies by Dollar and Kraay (2004) and Fetahi-Vehapi et al. (2015) indicate positive impacts, while those by Jawaid and Waheed (2017), Hye, Wizarat and Lau (2016) and Melitz (2003) suggest that foreign trade can sometimes adversely affect the economy.

The interaction between telecommunications development and foreign trade is increasingly pertinent in today's globalised economy. Technological advancements have streamlined and supported cross-border business transactions, thereby raising critical empirical questions to be answered by the current study. These include: (a) What are the impacts of telecommunications development and foreign trade on economic growth in South Africa? (b) Is there a long-run relationship between telecommunications development, foreign trade, and economic growth in South Africa? (c) Does the influence of telecommunications development on foreign trade boost or distort the trade-growth nexus in South Africa? Notably, very few studies have used interactive variables to study the impact of the interaction of trade openness and telecommunications development indicators on economic growth.

This study advances the research of Roztocki et al. (2019) and complements existing research by undertaking an in-depth analysis of the South African economy. Covering the period from 1990 to 2022, it employs semi-annual data like Salahuddin and Gow (2016), who utilised a combination of autoregressive distributed lag (ARDL)

and dynamic ordinary least squares (DOLS) methodologies for their 1991 to 2013 study. The current research incorporates critical economic indicators such as GDP, trade openness, and mobile and fixed telephone subscriptions, using the latter two variables as measures for telecommunications development. In line with Adeleye et al. (2021), the current study attempts to study the role of telecommunications development on the trade-growth nexus.

A review of extant literature shows a significant lack of specific research focused on the relationship between telecommunications development, foreign trade, and economic growth in the South African context. Studies by Adeleye et al. (2021), Abendin and Duan (2021), Adeleye and Eboagu (2019) and Donou-Adonsou (2019) offer valuable insights through panel method, yet there is a notable gap in country-specific investigations. This deficit is especially relevant for South Africa, a country characterised by distinctive economic, institutional, and developmental features. These unique attributes of South Africa may lead to different outcomes regarding how trade openness and telecommunication development affect economic growth compared to other regional trends. Therefore, this research aims to fill this gap by examining the relationship between telecommunications development, trade openness, and economic growth in South Africa, providing a comprehensive view of these factors and their specific effects on the South African economy.

The subsequent sections of the article unfold in the following manner: Section 2 summarises the relevant literature on telecommunications development, trade openness, and economic growth. Section 3 outlines our data sources and methodology. Section 4 presents our empirical findings and discusses their implications. Section 5 provides policy insights and recommendations emanating from the results.

1.1. Literature review

This section provides a concise review of relevant literature, approaching two empirical perspectives: the direct relationships between telecommunications development and trade openness with economic growth and the role of telecommunication development in the trade openness - economic growth nexus. The existing body of research in these domains reveals a range of outcomes influenced by factors such as the scope of the study, indicators of telecommunications development used, trade openness measures employed, empirical methods adopted, the period studied, and other attendant factors.

1.1.1. Trade openness—GDP Nexus

The study by Ijirshar in 2019 evaluated the trade openness and economic growth nexus in the Economic Community of West African States (ECOWAS). This study utilised secondary data from 1975 to 2017 and employed advanced econometric techniques, specifically nonstationary heterogeneous dynamic panel models. Two key methods, the Pooled Mean Group (PMG) and Mean Group (MG) estimators, were applied to understand this relationship. Findings from this research indicate that trade openness positively influences economic growth in the long term in the ECOWAS region. However, in the short term, researchers found variable effects of trade openness on growth.

Similarly, Jouini (2015) studied six Gulf Cooperation Council (GCC) nations using annual data from 1980 to 2010. The study employed the Pooled Mean Group (PMG) estimation technique and found a cointegrating relationship between the variables in their model. It also demonstrated that economic growth positively responds to trade openness in both the short- and long-run. To evaluate the robustness of their results, they employed various trade openness proxies and alternative model specifications, which produced comparable results that highlight the import of international trade to economic growth for the GCC region.

In examining the connection between trade openness and economic growth, Keho (2017) delved into the widely explored topic, noting the inconsistency in results. The study argues that the inconsistencies could be due to overlooking capital stock and labour roles in the trade-growth equation. Focusing on Cote d'Ivoire from 1965 to 2014, Keho's study incorporated these elements into a multivariate framework and utilised the Autoregressive Distributed Lag bounds test for cointegration and the Toda and Yamamoto Granger causality tests. The findings suggest that trade openness positively impacts economic growth in both short and long-term scenarios, with a noted strong, positive relationship between trade openness and capital formation in fostering economic growth.

Hye et al. (2016) investigated China's trade openness and economic growth using data from 1975 to 2009 within an endogenous economic growth model. Their study is distinctive for creating a trade openness index and applying an autoregressive distributed lag approach to cointegration and a rolling regression method. The research highlights a positive correlation between trade openness and economic growth in China in both the short and long terms. However, an analysis using the rolling window approach suggests that there were specific periods where trade openness negatively influenced economic growth.

Eriș and Ulaşan (2013) scrutinised the robustness of the trade openness-economic growth relationship from 1960 to 2000, using Bayesian model averaging techniques to address model uncertainty. Their analysis revealed no substantial or consistent correlation between trade openness and long-term economic growth. The results remained unchanged despite using various proxies for trade openness, such as current and real openness, open years based on Sachs and Warner's (1995) criteria, and tariff and non-tariff barriers. They concluded that economic institutions and macroeconomic uncertainties, like high inflation and excessive government spending, are more crucial in explaining economic growth.

Srdelic and Dávila-Fernández (2023) argued that Croatia's economic growth over the past two decades is intrinsically linked to international trade dynamics. By focusing on the dynamic Harrod trade multiplier as a predictor of long-run growth, they applied a state-space model and the Kalman smoother for time-varying parameter estimates of exports and imports. The study also employed Bayesian Model Averaging (BMA) and Weighted Average Least Squares (WALS) to address model selection uncertainty, identifying R&D investments and human capital accumulation as critical factors. They highlighted the importance of EU integration for new members, using Croatia's experience as a case study to explore regional development options,

emphasising the policy implications of their findings for understanding Croatia's EU integration process.

Fetahi-Vehapi et al. (2015) conducted a study focusing on the impact of trade openness on the economic growth of South-East Europe (SEE) countries. Despite varying levels of development and EU integration across these countries, their trade policies are uniformly inclined towards regional cooperation and global economic integration. The study, covering 16 years from 1996 to 2012 across 10 SEE countries, employs the system GMM method to overcome econometric challenges like endogeneity. The study models economic growth with trade openness and includes control variables such as income per capita, human capital, capital formation, FDI, labour force, and other variables interacting with trade openness. The findings propose that the beneficial effects of trade openness on economic growth are contingent upon initial income levels and other factors, indicating a lack of robust evidence for a direct relationship between trade openness and economic growth. Notably, they found that countries with higher initial income, FDI levels, and greater fixed capital formation benefit more from trade openness.

Were (2015) explores the varied impacts of trade on economic growth and investment using cross-country data. The findings align with existing literature, showing a positive effect of trade on economic growth in developed and developing countries. However, this effect is insignificant in least-developed countries (LDCs), mainly African nations. The study also highlights trade as a crucial factor for foreign direct investment (FDI) in all country groups, including LDCs, and domestic investment in developing countries and LDCs. The study recommends transforming trade structures and patterns in LDCs, especially African countries, for greater growth benefits. It emphasises the role of trade in facilitating technological adoption and attracting FDI through active participation in regional and global value chains.

Zahonogo (2016) investigates the effect of trade openness on economic growth in developing countries, focusing on Sub-Saharan Africa (SSA). Utilising data from 42 SSA countries from 1980 to 2012 and employing the Pooled Mean Group estimation technique, the study finds a threshold in trade openness below which it positively influences economic growth, with diminishing returns above this threshold. The findings suggest an inverted U-shaped (Laffer Curve of Trade) response to trade openness, consistent across various measures and model specifications, indicating a nonlinear trade openness and economic growth relationship for SSA countries. The study advises SSA countries to manage imports effectively to enhance their economic growth through international trade.

Malefane and Odhiambo (2021) examine the impact of trade openness on Lesotho's economic growth using the ARDL bounds testing approach and four different trade openness indicators. The study concludes that trade openness does not significantly influence economic growth in Lesotho in the short or long term, regardless of the trade openness proxy used. This finding suggests that policies in Lesotho should focus on enhancing human capital and infrastructure development to achieve economic growth that can benefit from trade openness. Additionally, it advocates for policies that expand international trade and economic growth to ensure inclusive benefits from trade.

Brueckner and Lederman (2015) employ an instrumental variables approach to assess the relationship between trade openness and economic growth in Sub-Saharan Africa. Their findings reveal a significant negative contemporary effect of economic growth on trade openness but a significant positive effect of trade on economic growth. The study quantifies that a 1% increase in trade-to-GDP ratio can lead to a 0.5% short-run growth each year, with a larger long-term effect on GDP per capita.

1.1.2. Telecommunications development, trade openness and GDP

In this section, the first two studies are studies on the relationship between telecommunications development and economic growth, and the rest analyse the relationship between telecommunications development, trade, and economic growth.

Behera, Haldar, and Sethi (2023) conducted an in-depth analysis of the effects of ICT on the economic growth of 13 emerging economies from 2000 to 2020 over two decades. Their research focused on how ICT interacts with factors like institutional quality, financial development, research, foreign direct investment, and development expenditures. The study concluded that ICT use significantly boosts economic growth, especially when it intersects positively with financial development and R&D expenditures. However, the synergistic effects of institutional quality and FDI were less pronounced. This suggests emerging economies should invest more in ICT-related R&D and digitise their financial sectors to increase growth.

Adeleye and Eboagu (2019) evaluated the impact of ICT on economic expansion in 54 African countries from 2005 to 2015. The study employed various econometric models and found a statistically significant positive relationship between ICT development and economic growth. They particularly highlighted the role of mobile subscriptions as a catalyst for economic advancement in Africa. Another study by Lee, Levendis and Gutierrez (2012) also found that mobile cellular phone expansion is an essential argument for the economic growth rate in sub-Saharan Africa.

Awad and Albaity (2022) focused on identifying the channels through which ICT contributes to economic expansion, a question previously unexplored in empirical research. Their study encompassed 44 countries in Sub-Saharan Africa from 2004 to 2020 and used techniques like panel-corrected standard errors and two-step system GMM. They employed an ICT composite index and found that ICT has a direct positive impact on economic growth. Additionally, domestic investment, trade openness, and education were vital indirect channels through which ICT fosters growth. These findings underscore the importance of continued ICT expansion in Sub-Saharan Africa.

Meijers (2014) challenged the belief that internet use directly influences economic growth. Through a fully specified growth model, the study found that the impact of Internet use on economic growth is primarily mediated through international trade. The study confirmed the positive role of internet use in enhancing trade, particularly in non-high-income countries, and established the significance of trade in economic growth for all income groups.

Dahmani et al. (2022) explored the impacts of ICT and trade openness on Tunisia's economic growth across 14 economic sectors from 1995 to 2018. Employing a cross-section augmented autoregressive distributed lag model and the Dumitrescu and Hurlin Granger causality test, they found a long-term positive relationship

between ICT use, trade openness, and economic growth. The study also identified bidirectional and unidirectional causal relationships between these variables.

Nabi et al. (2022) analysed the relationship between FDI, ICT, international trade, and economic growth in the N11 countries from 2000 to 2018. Their innovative ICT index included various communication mediums. The study used a pooled mean group estimator on a dynamic panel model and discovered that ICT expansion negatively impacts economic growth in the long run, whereas FDI and trade show a positive relationship with growth.

Singh and Siddiqui (2023) investigated the relationships between ICT penetration, trade, innovation and economic growth in 20 nations from 1995 to 2018. The study found that growth, trade, and innovation are significantly interlinked in developed countries, with ICT penetration playing a less significant role. A significant relationship exists in developing nations between growth, trade, ICT penetration and innovation.

Soylu et al. (2023) focused on the ICT-trade nexus and its effect on competitiveness in Eastern and Western European nations from 2007 to 2020. Their findings revealed that the interaction between trade and ICT boosts competitiveness, with a notable "leapfrog" effect observed in mobile phones and fixed broadband usage.

Salahuddin and Gow's (2016) study assesses the effects of Internet usage on financial development and trade openness and South Africa's economic growth from 1991 to 2013. Using structural unit root and the Johansen and ARDL cointegration tests, they establish a long-run relationship among these variables. The ARDL estimates reveal a significant positive long-term relationship between Internet usage and economic growth, as well as between financial development and growth, though the short-term relationships are not significant. The robustness of these long-term relationships is confirmed through DOLS estimation. Granger causality tests indicate that Internet usage and financial development are causative factors for economic growth in South Africa. The study recommends that the South African government should continue investing in Internet infrastructure to expand its network and usage further.

The impact of Information and Communications Technology (ICT) on trade has been a significant area of research, revealing that ICT infrastructure plays a crucial role in facilitating trade, particularly in the context of developing and least-developed countries. Studies have highlighted various aspects of how ICT, through mobile subscriptions, internet usage, and fixed telephone subscriptions, influences trade flows and economic growth. Yushkova (2014) investigated the influence of ICT infrastructure on intra-African trade, emphasising the significant role telecommunications infrastructure plays alongside other factors like Institutional Quality and Educational Attainment. This study found that telecommunications infrastructure substantially impacts intra-African trade, suggesting that improved ICT infrastructure could enhance trade.

Similarly, Xing (2018) focused on the effects of Internet and e-commerce adoption on bilateral trade flows, finding that access to modern ICT and the adoption of e-commerce applications stimulate bilateral trade flows. This is particularly relevant for the East African Community (EAC), aiming to lead in export-led economic growth.

The efficient use of ICT, equipped with high-speed internet and secure servers, was vital for unlocking e-trade potentials in developing and least-developed countries. Adeleye et al. (2021) contributed to understanding the ICT-trade nexus on economic and inclusive growth, with findings indicating that trade is a significant and positive predictor of growth. Their research underlines that ICT adoption enhances the impact of trade on growth, although the impact varies across Africa's sub-regions. This study points to the criticality of ICT innovation in strengthening the trade-growth relationship and highlights the varied impacts of ICT-trade nexus across different regions.

The review of the extant literature above predominantly reveals that most studies investigating the nexus between trade openness and economic growth and the role of telecommunications development rely heavily on panel data analysis encompassing multiple countries or regions. This approach is evident in the works of researchers like Ijirshar, Jouini, Keho, and others who have explored diverse geographical contexts collectively. Notably, there is a scarcity of research focusing specifically on individual countries, particularly South Africa, which is the focal point of the current study. This gap is significant, as the unique economic, institutional, and developmental dynamics of South Africa may offer distinct insights into how trade openness and telecommunications development interact with economic growth, which may diverge from broader regional trends. Moreover, a notable dearth of studies exists that explicitly examine whether telecommunications development and trade openness directly impact economic growth or whether telecommunications strengthen or weaken the link between trade openness and economic growth within the South African context. This lack of targeted research underscores a critical gap in understanding the specific dynamics and potential unique impacts within South Africa, which demands further exploration to enrich the existing body of knowledge.

2. Research design and data analysis

2.1. Data and variable definitions

This study employs semi-annual data for South Africa from 1990 to 2022, primarily sourced from the World Development Indicators (WDI), as presented in **Table 1**. The rationale behind this selection is the data's consistent availability and reliability throughout the specified period, which renders time series analysis suitable. Opting for secondary data analysis is justified by the established empirical correlation between telecommunications, trade openness, and economic growth (see Adeleye et al., 2021; Xing, 2018; Yushkova, 2014). This approach facilitates a comprehensive review based on historical data, leveraging the extant research to substantiate and enrich the study's findings. The data's consistency makes the methodology practical and robust, enabling an in-depth exploration of the economic indicators' interrelations over time. In line with analogous studies, this research designates Gross Domestic Product (GDP) as the principal indicator of economic growth. Additional critical variables encompass Trade Openness (TOP), Mobile Cellular Subscriptions (MOB), and Fixed Telephone Subscriptions (TEL). The analysis further integrates three control variables: internet usage as a percentage of the population (NET), Gross Fixed Capital Formation (GFCF), and Inflation (CPI).

Table 1. Variable descriptions and expected signs.

Variables	Description	Obs.	Signs	Source
GDP	Gross Domestic Product (constant 2015 US$)	66	N/A	WDI
TOP	Trade (% of GDP) [(exports + imports)/GDP] × 100	66	+	WDI
MOB	Mobile cellular subscriptions (per 100 people)	66	+	WDI
NET	Internet usage (as a % of the population)	66	+	WDI
TEL	Fixed telephone subscriptions	66	+	WDI
GFCF	Gross fixed capital formation (constant 2015 US$)	66	+	WDI
INF	Consumer Price Index Proxies' inflation	66	+/-	WDI

Note: WDI stands for World Development Indicator (World Bank, 2023).
Source: Authors' compilations.

Trade Openness measures the level of integration between South Africa and the global market. The study expects increased trade to positively influence growth. Internet users access various communication services from any location using internet-enabled devices such as computers, mobile phones, digital televisions, and gaming consoles. These services include the World Wide Web, email, news, entertainment, and data files. Mobile Cellular Subscriptions refer to the subscription numbers of public mobile phone services using cellular technology to access a public switched telephone network (PSTN). The category excludes subscriptions through data cards or USB modems, public mobile data, private trunked mobile radio, radio paging, and telemetry services. Fixed telephone line subscriptions include active analogue fixed telephone lines, voice-over-IP (VoIP), fixed wireless local loop (WLL), ISDN voice-channel equivalents, and fixed public payphones.

Gross Fixed Capital Formation reflects the net increase in physical assets within a given period, excluding fixed capital depreciation and land purchases. This indicator plays a crucial role as it signifies production capacity, which, in turn, influences economic growth. The study anticipates a positive relationship between GFCF and economic growth. Inflation, indicated by rising price levels, likely has a nonlinear relationship with economic growth. While initial inflation may stimulate economic growth, beyond a certain threshold, it becomes detrimental. In this study, inflation is proxied by the consumer price index. Consequently, the study posits an indeterminate expected sign for the coefficient of inflation. Before settling for the variables described above, we experimented with many variables, such as labour force participation rate, foreign direct investment and government consumption expenditure, which did not perform well in our models and were therefore dropped.

2.2. The ARDL bounds testing method

The Autoregressive Distributed Lag (ARDL) model bounds testing approach, developed by Pesaran and Shin in 1995 and further elaborated by Pesaran et al. in 2001, is utilised in this study to analyse the cointegration relationship among variables. This method is selected due to its superiority over traditional cointegration techniques like Johansen's cointegration, which may face limitations amid structural breaks in macroeconomic dynamics, a scenario discussed by Lutkepohl (2006). The ARDL approach offers several advantages: it applies to studies with small sample sizes, as

emphasised by Pesaran, Shin and Smith (2001), can handle variables of mixed integration orders (both I(0) and I(1)), and uniquely estimates both short-run dynamics and long-run equilibrium concurrently through a dynamic unrestricted error correction model (UCEM), achieved via simple linear transformation of variables. This dual estimation addresses potential issues like omitted variables and autocorrelation. Furthermore, the technique is known for providing unbiased estimates for the long-run model and valid t-statistics, even in the presence of endogeneity, as noted by Harris and Sollis (2003). The empirical formulation of the ARDL equations in this study is thus aligned with these methodological strengths and considerations.

In alignment with the preceding explanations, the empirical formulations of the ARDL models used in this study are specified as follows:

$$\begin{aligned}\Delta LNGDP_t = {} & \alpha_0 + \alpha_1 LNGDP_{t-1} + \alpha_2 TOP_{t-1} + \alpha_3 MOB_{t-1} + \alpha_4 NET_{t-1} + \alpha_5 GFCF_{t-1} + \alpha_6 INF_{t-1} + \sum_{i=1}^{o} \alpha_7 \Delta LNGDP_{t-i} \\ & + \sum_{j=1}^{p} \alpha_8 \Delta LNTOP_{t-j} + \sum_{h=1}^{q} \alpha_9 \Delta LNMOB_{t-h} + \sum_{k=1}^{u} \alpha_{10} \Delta LNNET_{t-k} + \sum_{l=1}^{v} \alpha_{11} \Delta LNGFCF_{t-l} \\ & + \sum_{m=1}^{w} \alpha_{12} \Delta LNINF_{t-n} + \varepsilon_{1t}\end{aligned} \quad (1)$$

$$\begin{aligned}\Delta LNGDP_t = {} & \beta_0 + \beta_1 LNGDP_{t-1} + \beta_2 TOP_{t-1} + \beta_3 TEL_{t-1} + \beta_4 NET_{t-1} + \beta_5 GFCF_{t-1} + b_6 INF_{t-1} + \sum_{i=1}^{o} \beta_7 \Delta LNGDP_{t-i} \\ & + \sum_{j=1}^{p} \beta_8 \Delta LNTOP_{t-j} + \sum_{h=1}^{q} \beta_9 \Delta LNTEL_{t-h} + \sum_{k=1}^{u} \beta_{10} \Delta LNNET_{t-k} + \sum_{l=1}^{v} \beta_{11} \Delta LNGFCF_{t-l} \\ & + \sum_{m=1}^{w} \beta_{12} \Delta LNINF_{t-n} + \varepsilon_{1t}\end{aligned} \quad (2)$$

To test for cointegration, we employ the Wald Test or the F-Test for joint coefficient significance of the lagged variables with the null hypotheses H_0: $\alpha_1 = \alpha_2 = \alpha_3 \ldots = \alpha_6 = 0$ and H_0: $\beta_1 = \beta_2 = \beta_3 \ldots = \beta_6 = 0$, indicating no cointegration against the alternative hypothesis of cointegration between the variables. F-statistics are computed to compare the upper and lower bounds critical values provided by Pesaran et al. (2001). If cointegration among the variables included in the models is established, the following error correction models will be specified and estimated:

$$\begin{aligned}\Delta LNGDP_t = {} & \theta_0 + \theta_1 ECT_{t-1} + \sum_{i=1}^{o} \theta_2 \Delta LNGDP_{t-i} + \sum_{j=1}^{p} \theta_3 \Delta LNTOP_{t-j} + \sum_{h=1}^{q} \theta_4 \Delta LNMOB_{t-h} + \sum_{k=1}^{u} \theta_5 \Delta LNNET_{t-k} \\ & + \sum_{l=1}^{v} \theta_6 \Delta LNGFCF_{t-l} + \sum_{m=1}^{w} \theta_7 \Delta LNINF_{t-n} + \varepsilon_{1t}\end{aligned} \quad (3)$$

$$\begin{aligned}\Delta LNGDP_t = {} & \phi_0 + \phi_1 ECT_{t-1} + \sum_{i=1}^{o} \phi_2 \Delta LNGDP_{t-i} + \sum_{j=1}^{p} \phi_3 \Delta LNTOP_{t-j} + \sum_{h=1}^{q} \phi_4 \Delta LNTEL_{t-h} + \sum_{k=1}^{u} \phi_5 \Delta LNNET_{t-k} \\ & + \sum_{l=1}^{v} \phi_6 \Delta LNGFCF_{t-l} + \sum_{m=1}^{w} \phi_7 \Delta LNINF_{t-n} + \varepsilon_{1t}\end{aligned} \quad (4)$$

2.3. The interactive ARDL model

To analyse whether the impact of trade openness on GDP is enhanced or hindered by telecommunications development in South Africa, we follow the interactive model specifications explained by Brambor, Clark and Golder (2006) and applied by Donou-

Adeonsou (2019) and Adeleye et al. (2021) shown in Equations (5) and (6). ARDL specifications of these equations similar to the ones shown in Equations (1)–(4) (not shown here) are employed to estimate these models.

$$\mathrm{LNGDP_t} = \alpha_0 + \alpha_1 \mathrm{LNTOP_t} + \alpha_2 \mathrm{LNMBO_t} + \alpha_3 \mathrm{LN(MOB_t TOP_t)} + \alpha_{4i}\Phi_{it} + \varepsilon_{1t} \quad (5)$$

$$\mathrm{LNGDP_t} = \theta_0 + \theta_1 \mathrm{LNTOP_t} + \theta_2 \mathrm{LNTEL_t} + \theta_3 \mathrm{LN(TEL_t TOP_t)} + \theta_{4i}\Phi_{it} + \varepsilon_{2t} \quad (6)$$

Where all the variables follow the definitions provided in previous sub-sections, Φ is a set of control variables, including gross fixed capital formation (GFCF), internet usage (NET), inflation (INF), α_i and θ_i are the parameters of the two equations, and ε_{1t} and ε_{2t}- are the general residuals of the two equations. We utilise the signs on the coefficients of the interaction terms α_3, and θ_3 to evaluate whether the interaction of telecommunications development (MOB and TEL) on trade openness boosts or distorts the impact of trade openness on economic growth. Positive signs of coefficients of the interaction terms imply that telecommunications development enhances trade performance on South Africa's economic growth and vice versa.

The overall effect of openness to trade on economic growth, given the usage of mobile phones, is calculated as follows:

$$\frac{\partial \mathrm{LNGDP}}{\partial \mathrm{LNTOP}} = \alpha_1 + \alpha_3 \mathrm{LNMOB} \quad (7)$$

Similarly, the overall effect of trade openness on economic growth, given the usage of telephones, is calculated as follows:

$$\frac{\partial \mathrm{LNGDP}}{\partial \mathrm{LNTOP}} = \theta_1 + \theta_3 \mathrm{TEL} \quad (8)$$

The current paragraph explains the conditions that assist in explaining the results using this methodology derived from Equations (7) and (8). Firstly, if $\alpha_3 > 0$ and $\theta_3 > 0$, this implies that telecommunications development is a booster of trade openness on economic growth. However, if $\alpha_3 < 0$ and $\theta_3 < 0$, the overall impact of trade openness on growth depends on the magnitudes of these negative signs. Secondly, if the negative signs of α_3 and θ_3 are greater than the positive signs of α_1 and θ_1, respectively, then telecommunications development distorts the effect of trade openness on economic growth. Thirdly, if the negative signs α_3 and θ_3 are less than the positive signs of α_1 and θ_1, respectively, then the distortionary influence of telecommunications development is insufficient to inhibit trade openness's positive effect on economic growth. Lastly, if $\alpha_3 = 0$ and $\theta_3 = 0$, this signifies that the interaction of telecommunications development with trade openness has no significant impact on economic growth.

3. Results

In this section we outline the stages followed in this study in presenting the results. Firstly, the study analyses the summary statistics to determine if the data behaves as expected. Secondly, the study conducts unit root tests using the Augmented Dickey-Fuller and Phillips-Perron tests. Thirdly, the study conducts the bounds test for cointegration to establish whether a long-run equilibrium economic relationship exists among the variables included in the models. Fourthly, the study runs the long and short-run ARDL models to establish the impact of telecommunications development and foreign trade on economic growth in South Africa. Fifthly, the study runs the long

and short-term models with interactive variables to ascertain whether telecommunications development enhances or hinders trade in the foreign trade-growth nexus in South Africa. Lastly, the study conducts various diagnostic tests to establish the robustness of the estimations.

3.1. Descriptive statistics

Table 2 presents the log economic variables' summary statistics, including the means, standard deviations, Jarque-Bera statistics, and probability values. While the transformation of variables into logarithms limits what can be inferred from the means, the Jarque-Bera test is critical for assessing normality. This test uses the null hypothesis of normal distribution versus the alternative hypothesis of non-normality. According to these results, all variables except LNTEL are normally distributed, as their Jarque-Bera probability values are above 5%. It is important to note that econometric models perform better statistically when incorporating normally distributed variables.

Table 2. Summary statistics.

	LNGDP	LNTOP	LNGFCF	LNINF	LNMOB	LNNET	LNTEL
Mean	28.8514	–4.1444	24.4110	4.3650	2.5170	2.2279	15.1814
Median	28.9126	–4.0631	24.5809	4.3394	2.6781	2.4032	15.3513
Std. Dev.	0.25260	0.34079	0.39690	0.5505	1.1062	1.1101	0.3539
J-B Statistic	3.47722	3.15435	3.64310	1.5320	2.0461	2.2976	28.6719
Prob	0.17576	0.20655	0.16177	0.46486	0.35949	0.31701	0.0000
Obs.	66	66	66	66	66	66	66

Source: Authors' compilation.

3.2. Unit root tests

The article employed the Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration to examine the estimated models' long-term relationships among the variables. It is crucial to assess the stationarity properties of the variables, ensuring that none of the series is integrated of order two [I(2)] or higher, as per Quattara (2004). This precaution is necessary because the validity of the ARDL bounds testing approach is compromised if any series is integrated of the second order. As previously indicated, the ARDL bounds testing method for cointegration is notably adaptable for use when the variables are either integrated of order one [I(1)], order zero [I(0)], or a combination thereof.

The formal unit root test results, as shown in **Table 3**, were conducted using the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) methods. These tests aimed to evaluate the null hypotheses, which posit the existence of unit roots, against the alternative that the series is stationary. The findings confirmed that the series LNGDP, LNTOP, LNGFCF, LNTEL, and LNTOPLNTEL are integrated of order one [I(1)], whereas the series LNMOB, LNNET, LNINF, and LNTOPLNMOB are integrated of order zero [I(0)]. Consequently, these results suggest the potential for cointegrating relationships within the ARDL models, thereby justifying proceeding

with the specification and estimation of the ARDL Error Correction Models (ARDL-ECM).

Table 3. Unit root results.

Variable	Model	Level		First difference		Decision
		ADF	PP	ADF	PP	
LNGDP	C	–0.8357	–0.8028	–4.306***	–4.272***	I(1)
	C&T	–0.6127	–0.9731	–4.407***	–4.349***	
LNTOP	C	–0.7659	–0.7472	–5.206***	–5.194***	I(1)
	C & T	–1.5992	–2.1057	–5.109***	–5.092***	
LNGFCF	C	–1.7043	–1.1535	–3.4005**	–3.4004**	I(1)
	C&T	–0.1993	–0.7525	–3.6477**	–3.5588*	
LNINF	C	–1.5805	–3.5561**			I(0)
	C&T	–3.3496*	–7.480***			
LNMOB	C	–5.3887***	–4.708***			I(0)
	C&T	–4.0535**	–6.937***			
LNNET	C	–5.5876***	–4.509***			I(0)
	C&T	–5.0373***	–2.2651			
LNTEL	C	2.0432	2.4511	–3.927***	–3.919***	I(1)
	C&T	0.3941	1.4821	–4.917***	–4.935***	
LNMOBLNTOP	C	–5.4040***	–7.517***			I(0)
	C&T	–2.0983	–4.1284**			
LNTELLNTOP	C	–0.0513	0.0910	–5.592***	–5.600***	I(1)
	C&T	–2.0744	–2.0843	–5.682***	–5.697***	

Note: ***, ** and * signify statistical significance at 1%, 5% and 10%, respectively. C and C &T represent models constant only and Constant and Trend, respectively.
Source: Authors' compilation.

3.3. Bounds test results

In **Table 4**, the bounds test for cointegration provides empirical evidence supporting long-run relationships among the model variables. This test, employing the null hypothesis of no cointegration against the alternative of its presence, reveals that for each equation, the computed *F*-statistics exceed the upper critical bounds at the 5% significance level. Specifically, Equation 1 exhibits an *F*-statistic of 6.5389, surpassing the critical value range of 2.220–3.390, and similarly, Equations (2) and (3) (Interactive), and 4 (Interactive) show *F*-statistics of 3.9291, 5.5501 and 4.2989, respectively, all exceeding the upper bound of 3.390. These outcomes decisively reject the null hypothesis, affirming the presence of cointegration and thereby legitimising the specification and estimation of ARDL-Error Correction Models for each equation (integrating both short-run and long-run equilibrium in the analysis).

Table 4. Bounds test results.

Equation	*F*-statistic	Asymptotic Critical Values
Equation 1	6.5389	1.950–3.060 (10% level) 2.220–3.390 (5% level) 2.790–4.100 (1% level)
Equation 2	3.9291	1.950–3.060 (10% level) 2.220–3.390 (5% level) 2.790–4.100 (1% level)
Equation 3 Interactive equation	5.5501	1.950–3.060 (10% level) 2.220–3.390 (5% level) 2.790–4.100 (1% level)
Equation 4 Interactive equation	4.2989	1.950–3.060 (10% level) 2.220–3.390 (5% level) 2.790–4.100 (1% level)

Source: Authors' compilation.

3.4. Diagnostic tests

The ARDL-ECM results presented in **Tables 5** and **6** have successfully passed a series of diagnostic tests, indicating the reliability of the estimated models. First, the autocorrelation tests demonstrate the absence of serial correlation in the residuals of these models, ensuring that the model's errors do not display any systematic patterns over time. Second, the ARCH heteroscedasticity tests indicate that the residuals do not exhibit heteroscedasticity, implying that the variance of errors remains constant. Third, the normal distribution of residuals in both estimated models assures that the underlying assumptions of normality are met. Fourth, the Ramsey RESET test results affirm the validity of the model specifications, suggesting that the functional forms are appropriate. Lastly, **Figure 1**, illustrating the CUSUM of squares tests for Equations 3 and 4 in **Tables 5** and **6**, confirms the stability of parameters for all three models, indicating that the estimated relationships remain consistent over the observed period. These diagnostic tests collectively validate the robustness of the ARDL-ECM models and the reliability of their findings.

Table 5. Long-run and short-run analysis.

Equation 1				**Equation 2**			
Dependent variable = LNGDP (Lon-run)				**Dependent variable = LNGDP (Long-run)**			
Variable	**Coef.**	**Std. Error**	***t*-Stat**	**Variable**	**Coef.**	**Std. Error**	***t*-Stat**
C	−0.2014	0.574	–0.350	C	–1.827	0.536	–3.409***
LNTOP	0.336	0.190	1.767*	LNTOP	0.525	0.094	5.569***
LNMOB	0.042	0.020	2.088**	**LNTEL**	0.044	0.006	7.834***
LNNET	0.042	0.015	2.788***	LNNET	–0.0101	0.009	–1.050
LNGFCF	1.299	0.220	5.901***	LNGFCF	1.749	0.135	12.90***
LNINF	–0.0038	0.010	–0.346	LNINF	–0.024	0.009	–2.487**
Adj. *R*-squared		0.66		Adj. *R*-squared		0.72	
DW-statistic		0.901		DW-statistic		1.340	

Table 5. (*Continued*).

Dependent variable = LNGDP (Lon-run)				**Dependent variable = LNGDP (Long-run)**			
Variable	**Coef.**	**Std. Error**	***t*-Stat**	**Variable**	**Coef.**	**Std. Error**	***t*-Stat**
Equation 3				**Equation 4**			
Dependent variable = ΔLNGDP (Short-run) Selected model: ARDL (1,1,1,1,1,1)				Dependent variable = ΔLNGDP (Short-run) Selected model: ARDL (1,1,1,1,1,1)			
Variable	Coef.	Std. error	*t*-Stat	Variable	Coef.	Std. error	*t*-Stat
ΔLNTOP	0.3174	0.115	2.757***	Δ LNTOP	0.273	0.056	4.802***
ΔLNMOB	0.0328	0.012	2.733***	**ΔLNTEL**	0.001	0.008	0.139
ΔLNNET	0.0394	0.009	4.112***	ΔLNNET	0.002	0.011	0.186
ΔLNGFCF	1.2176	0.138	8.794***	ΔLNGFCF	1.006	0.147	6.855***
ΔLNINF	–0.002	0.017	–0.171	ΔLNINF	–0.005	0.003	–1.720*
ECT (–1)	–0.076	0.013	–5.956***	ECT (–1)	–0.160	0.037	–4.282***
Diagnostic tests		**Statistics**		**Diagnostic tests**		**Statistics**	
χ^2 Serial		1.3439(0.2814)		χ^2 Serial		0.249954 (0.7807)	
χ^2ARCH		0.0443(0.8350)		χ^2ARCH		0.209296 (0.6502)	
χ^2Normality		0.7979(0.6710)		χ^2Normality		0.062167 (0.9695)	
χ^2Ramsey RESET		0.4961(0.4898)		χ^2Ramsey RESET		0.297408 (0.7687)	

Note: ***, ** and * signify statistical significance at 1%, 5% and 10%, respectively.
Source: Authors' compilation.

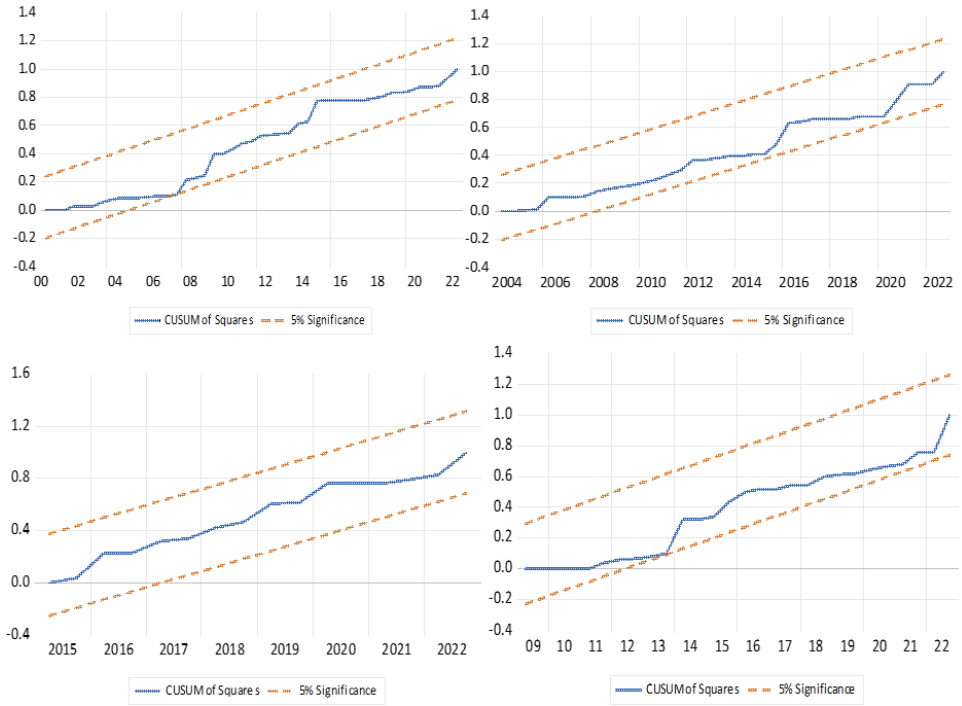

Figure 1. CUSUM of squares tests for Equations (3) and (4) in **Tables 5** and **6**.

Table 6. Long-run and short-run analysis of interactive models.

Equation 1				**Equation 2**			
Dependent variable = LNGDP (Long run)				Dependent variable = LNGDP (Long run)			
Variable	Coef.	Std. Error	*t*-Stat	Variable	Coef.	Std. Error	*t*-Stat
C	6.773	1.824	3.71	C	0.802	0.58	1.37
LNMOB	3.805	0.763	4.98***	**LNTEL**	0.77	0.14	5.5***
LNTOP	1.618	0.345	4.68***	LNTOP	0.64	0.20	3.2***
LNTOPLNMOB	–0.855	0.184	−4.65***	LNTOPLNTEL	−0.34	0.10	–3.4***
LNGFCF	1.127	0.140	7.99***	LNGFCF	1.173	0.13	8.76***
LNINF	−0.003	0.010	−0.31	LNINF	−0.004	0.01	−0.37
Adj. *R*-squared	0.72			Adj. *R*-squared	0.69		
DW-statistic	0.955			*DW*-statistic	1.234		
Equation 3				**Equation 4**			
Dependent variable = ΔLNGDP (Short run) Selected model: ARDL (1,1,1,1,1,1)				Dependent variable = ΔLNGDP (Short run) Selected model: ARDL (1,1,1,1,1,1)			
Variable	Coef.	Std. error	*t*-Stat	Variable	Coef.	Std. error	*t*-Stat
C	0.012	0.0107	1.18	C	0.005	0.014	0.36
ΔLNMOB	0.199	0.0500	3.98***	**ΔLNTEL**	0.384	0.189	2.03*
ΔLNTOP	0.331	0.0825	4.01***	ΔLNTOP	0.837	0.372	2.25**
Δ LNTOPLNMOB	−0.025	0.0079	−3.2***	ΔLNTOPLNTEL	−0.041	0.020	−1.99*
ΔLNGFCF	0.295	0.04358	6.77***	ΔLNGFCF	0.254	0.051	4.97***
ΔLNINF	−0.426	0.1231	–3.5***	ΔLNINF	−0.350	0.157	−2.27**
ECT (–1)	−0.840	0.2473	–3.4***	ECT (–1)	−0.265	0.134	−1.96*
Diagnostic tests	**Statistics**			**Diagnostic tests**	**Statistics**		
χ^2 Serial	1.8882(0.1836)			χ^2 Serial	0.3185(0.7309)		
χ^2ARCH	1.2274(0.2794)			χ^2ARCH	0.1949(0.6623)		
χ^2Normality	0.4128(0.8135)			χ^2Normality	1.2680(0.5304)		
χ^2Ramsey RESET	1.8212(0.0844)			χ^2Ramsey RESET	0.1262(0.7259)		

Note: ***, ** and * signify statistical significance at 1%, 5% and 10%, respectively
Source: Authors' compilation.

4. Discussion and conclusions

4.1. Discussion of Long-run and Short-run ARDL

The estimation of the long and short-run ARDL models was undertaken to determine the direct impacts of telecommunications development and foreign trade on economic growth in South Africa. Both models' positive coefficients for LNTOP (trade openness) underscore the advantageous effects of global economic integration on growth. This observation supports the theory that increased trade openness can improve economic efficiency and facilitate access to broader markets. These findings are in harmony with those of Ijirshar (2019), Fetahi-Vehapi et al. (2016), Salahuddin and Gow (2016), Hye et al. (2016), Jouini (2015), Eriş and Ulaşan (2013), Brueckner and Lederman (2015), and Chang et al. (2009), who all observed positive impacts of trade openness on economic growth. Conversely, these results contrast with the

research of Jawaid and Waheed (2017) and Melitz (2003), who noted potential adverse effects of foreign trade on the economy. Additionally, our findings diverge from those of Malefane and Odhiambo (2021), who reported that trade openness does not significantly impact economic growth in Lesotho in the short or long term, irrespective of the trade openness proxy employed.

Interestingly, the role of technology, as indicated by LNMOB (mobile subscriptions) and LNNET (internet usage), also emerges as a critical factor. While LNMOB positively influences growth in Equation 1, LNTEL (telephone subscriptions) plays a similar role in Equation 2, reflecting the growing importance of telecommunications development in South Africa. This finding supports the findings by Behera et al. (2023), Soylu et al. (2023), Adeleye and Eboagu (2019), Salahuddin and Gow (2016), and Lee et al. (2012), who noted that ICT use significantly boosts economic growth.

In both equations, gross fixed capital formation (LNGFCF) shows a strong positive association with economic growth, emphasising the pivotal role of investment in physical assets for sustained economic development. This result is supported by Keho (2017) and Fetahi-Vehapi et al. (2015), who found that gross fixed capital formation positively and significantly affects economic growth. Inflation (LNINF) impacts LNGDP negatively in both equations. Whilst it has a negligible effect in Equation 1, it demonstrates a negative and significant impact in Equation 2.

In equations 3 and 4, the immediate effects of changes in the explanatory variables on economic growth are observed. Here, the responsiveness of the economy to short-term fluctuations in trade openness, mobile subscriptions, internet usage, and investment is evident. The significant positive coefficients of ΔLNTOP (change in trade openness) and ΔLNGFCF (change in gross fixed capital formation) in both equations suggest that these factors are crucial for short-term economic stimulation. Notably, these results confirm the importance of trade openness and telecommunications development in South Africa in the short and long run. These findings support the empirical literature for the long-run equations described above.

The negative and significant error correction terms in Equations 3 and 4 in **Table 5** indicate a long-run economic relationship between the independent variables in these models and the dependent variable. This suggests an adjustment mechanism where the economy reverts to its long-term growth trajectory after experiencing short-term deviations. This finding is crucial for policymakers, as it indicates the resilience of the economic system to short-term shocks.

4.2. Discussion of results of the interactive ARDL models

This section examines whether telecommunications development enhances or hinders trade in the trade-growth nexus. The analysis begins by examining models incorporating MOB and TEL (the telecommunications development indicators) and their interactions with trade openness (TOP), as depicted in **Table 6**.

Firstly, the long-run Equations 1 and 2 in **Table 6** show that the significant negative effects of the interactive terms between trade openness and the telecommunications development indicators are smaller in magnitude than the coefficients for trade openness, implying that the positive impact of trade openness on

GDP is not entirely counteracted by the negative interaction effects in the two equations over the long run. For instance, when accounting for the negative interaction effects, the net effects of trade openness remain positive across both equations in the long run, as demonstrated in the quantifications below:

$$\text{Equation (1)} = 1.618 - 0.855 = 0.763$$
$$\text{Equation (2)} = 0.640 - 0.340 = 0.300$$

Secondly, Equations 3 and 4 in **Table 6** indicate that the interaction of telecommunications development and trade openness negatively and significantly impacts economic growth. These interaction terms enable us to assess whether telecommunications advancements enhance or distort trade openness's effect on economic growth. Moreover, the magnitudes of these negative coefficients are critical for evaluating the impact of telecommunications development on trade in the trade-growth nexus. For example, subtracting 0.025 (coefficient of ΔLNTOPLNMOB) from 0.331 (coefficient of ΔLNTOP) yields 0.306, representing the positive total impact of trade openness on economic growth when considering mobile subscriptions (MOB). Importantly, this finding suggests that the negative interaction effect is insufficient to diminish the positive impact of trade openness on economic growth in South Africa. This result aligns with the findings of Adeleye et al. (2021).

Finally, the difference between the coefficient of ΔLNTOP (0.837) and the coefficient of ΔLNTOPLNTEL (0.041) is 0.796. This further reinforces the idea that the negative interaction between trade openness and fixed telephone subscriptions does not undermine the positive impact of trade openness on economic growth. These results concur with the findings of Singh and Siddiqui (2023), who found that ICT penetration plays a less significant role in influencing economic growth. These findings also agree with Adeleye et al. (2021) on MOB and TEL, who found that the negative interaction of these variables with trade does not significantly hinder the positive impact of trade openness on economic growth. However, these results are at variance with Adeleye et al. (2021) (who argued that ICT adoption enhances the impact of trade on growth in different regions of the African continent), Xing (2018) (who found that the efficient use of ICT, equipped with high-speed internet and secure servers, was vital for unlocking e-trade potentials in developing and least-developed countries) and Yushkova (2014) (who found that telecommunications infrastructure substantially impacts intra-African trade, suggesting that improved ICT infrastructure could enhance trade). This finding is notably significant and enriches the existing literature by unequivocally confirming the positive influence of trade openness on economic growth in South Africa despite the negative impact of telecommunication development on trade. Remarkably, few studies have employed interactive variables to investigate the impact of telecommunications development indicators on the trade-economic growth relationship.

The negative and significant error correction terms in Equations (3) and (4) of **Table 6** signify a long-term economic relationship between the independent variables and GDP in these models. This implies the presence of an adjustment mechanism whereby, following short-term deviations, the economy gradually returns to its long-term growth path.

The potential contributions of our results are twofold. Firstly, the study offers robust empirical evidence that trade openness positively affects economic growth, reinforcing the argument for policymakers to reduce trade barriers and integrate economies into the global market. This contribution is crucial for policymakers and economic strategists leveraging global economic integration to stimulate growth. Secondly, by highlighting the significant positive impact of telecommunications development, particularly mobile subscriptions and internet usage, on economic growth, the findings of this study underline the importance of investing in ICT infrastructure. This contributes to the growing body of literature recognising ICT as a cornerstone of modern economic development strategies.

4.3 Conclusions and Recommendations

The primary aim of this study was to analyse the direct impacts of telecommunications development and trade openness on economic growth in South Africa, assessing whether telecommunications development enhances or hinders trade openness in the trade-growth nexus. We addressed three key questions: (a) the impacts of telecommunications development and foreign trade on South Africa's economic growth, (b) the existence of a long-term economic relationship between telecommunications development, foreign trade, and economic growth in South Africa, and (c) the influence of telecommunications development on trade within the foreign trade-growth nexus in South Africa.

The findings reveal that both telecommunications development and trade openness positively and significantly impact South Africa's short- and long-term GDP, underscoring their beneficial effects on economic growth. Control variables, including internet usage and gross fixed capital formation (investment), also positively and significantly influence GDP, whereas inflation exhibits a consistent negative effect.

The negative and significant error correction terms across all estimated models indicate a long-term economic relationship between the independent variables and GDP. This suggests an adjustment mechanism where the economy reverts to its long-term growth trajectory following short-term deviations. This is crucial for policymakers regarding the economic system's resilience to short-term shocks.

The findings from the ARDL models underline the significant impact of telecommunications development and foreign trade on South Africa's economic growth, offering broader practical implications for the African continent. The positive coefficients associated with trade openness and the pivotal role of technology, demonstrated through mobile subscriptions and internet usage, present numerous practical applications and policy implications for Africa. Firstly, enhancing trade openness emerges as a critical strategy, with its positive influence on economic growth highlighting the necessity for African economies to integrate more fully into the global market. This could involve reducing trade barriers, simplifying customs procedures, and engaging in regional trade agreements to boost economic efficiency and access to larger markets. By adopting such measures, African nations could replicate South Africa's success, as shown by the results, and leverage global economic integration to foster growth across the continent. Secondly, investment in ICT infrastructure is equally crucial, as the significant role of telecommunications in economic

development indicates. African governments are urged to prioritise expanding mobile networks and internet access, especially in rural and underserved areas, to spur economic growth. Such investments would enhance education, healthcare, and innovation and pave the way for a digitally inclusive society. Thirdly, the strong positive correlation between gross fixed capital formation and economic growth emphasises the importance of fostering an environment conducive to investment. Ensuring political stability, implementing favourable tax policies, and developing robust legal frameworks would encourage domestic and foreign investment. This, in turn, would support infrastructural development and technological advancement, essential for economic growth. Fourthly, the ARDL models reveal negative error correction terms, suggesting an economy's resilience to short-term shocks and tendency to revert to long-term growth paths. Policymakers should, therefore, employ a mixed-methods approach to policymaking, blending short-term actions with long-term strategic planning to ensure sustained economic development. Lastly, the relationship between telecommunications development and trade openness necessitates tailored telecommunications policies. Considering various countries' specific economic needs and contexts, policymakers should design these policies to support trade. This may involve focusing on technologies that most effectively bolster trade and economic activities within their respective countries, moving away from a one-size-fits-all approach to a more tailored policy framework.

In addition, the study recommends that South African policymakers focus on enhancing local goods' competitiveness in global market value chains and reducing trade barriers. It also advocates for capitalising on the Africa Continental Free Trade Agreement (AfCFTA) to increase potential future trade across Africa and potentially foster economic growth. Future research could include more variables, subject to data availability, explore the relationships using nonlinear ARDL models, and potentially incorporate a mixed-methods approach with primary data collection.

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