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INVESTIGATION OF TELECOMMUNICATION INFRASTRUCTURES-INDUSTRIALISATION-GROWTH NEXUS: EVIDENCE FROM DISAGGREGATED PANEL DATA ANALYSIS*

ABSTRACT

This study examines the telecommunication infrastructures-industrialisation-economic growth nexus in developing countries over the period 2000-2018. A panel data comprising of 99 developing countries were collected and divided into three sub-regions: Latin American & Caribbean (LAMC), Middle East & North Africa (MENA) and Sub-Saharan Africa (SSA). For the analysis, the newly developed panel VAR in generalized method of moment (GMM) estimation approach was applied. Our findings suggest a long-run equilibrium relationship between the three variables. At the same time, strong evidence of two-way causality among the three variables in the entire sample and regions was reported. The panel VAR results suggest that: (i) telecommunication infrastructures have a negative and positive impact on industrialisation and growth, respectively; (ii) industrialisation has a negative impact on growth which imply the inability of the former to drive the latter across the regions. Thus, there is a need to promote realistic policies that will enhance telecommunications infrastructure, levels of industrialisation and economic growth concurrently in the developing countries/regions.

Keywords: Regional Groupings; Panel VAR-Granger Causality; Telecommunication Infrastructures; Industrialisation; Economic Growth
JEL Classification: C33; O30; O14; O47; O55

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RIASSUNTO

Analisi del legame tra infrastrutture di telecomunicazione, industrializzazione e crescita: evidenze da un'analisi di dati panel disaggregati

Questo studio esamina il legame tra infrastrutture di telecomunicazione, industrializzazione e crescita nei paesi in via di sviluppo nel periodo 2000-2018. Sono stati raccolti dati panel relativi a 99 paesi suddivisi in tre sottogruppi: America Latina e Caraibi, Medio Oriente e Nord Africa e Africa Sub-sahariana. In questa analisi è stato applicato il metodo generalizzato dei momenti con tecnica panel VAR recentemente sviluppato. I nostri risultati suggeriscono una relazione di equilibrio di lungo periodo fra le tre variabili e causalità biunivoca fra le tre variabili in tutto il campione. I risultati panel VAR suggeriscono che: (i) le infrastrutture di telecomunicazione hanno un impatto negativo sull'industrializzazione e positivo sulla crescita; (ii) l'industrializzazione ha un impatto negativo sulla crescita il che implica l'inabilità della stessa a guidare la crescita nelle regioni. Pertanto, c'è necessità di promuovere politiche realistiche in grado di potenziare contemporaneamente le infrastrutture di telecomunicazione, i livelli di industrializzazione e la crescita economica nei paesi/regioni in via di sviluppo.

1. INTRODUCTION

The main focus of this article is to study the relationship that exists between the telecommunications infrastructure/development, industrialisation and the economic growth of Latin American & Caribbean (henceforth, LAMC), Middle East & North Africa (hereafter, MENA) and the Sub-Saharan Africa (hereafter, SSA) over the period 2000-2018. It attempts to evaluate the significance of telecommunications infrastructure to SSA, MENA and LAMC's process of industrialisation and economic growth/examining whether the development of the telecommunications sector has contributed to the process of industrialisation and growth and whether the growth of the telecommunications sector is simply a result of improved levels of industrialisation and rapid economic growth. Studies have examined the nexus between economic growth and macroeconomic/none-macroeconomic variables (see, Olabisi and Lau, 2018; Hosein et al., 2019; Laniran and Olakunle, 2019; Ferreira, 2020; Wiafe and Anning, 2021; Makeleni and Sheefeni, 2022; Koukouritakis, 2022 among others), but to the best of our knowledge, empirical researches on the information and communication technology (ICT)/telecommunication infrastructures-industrialisation-growth nexus in the literature for

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SSA, MENA and LAMC are very scanty. However, few studies that are worth mentioning that have examined industrialisation-growth nexus in the literature include that of Wells and Thirlwall (2003) and Opoku & Yan (2019). These studies basically focus on African countries without capturing the impact of telecommunications infrastructure/ICT on industrialisation and economic growth. Filling this gap in the literature is very important because telecommunications infrastructure/digital provide/ICT can further the goals of industrialisation and harness regional's natural and human resources meant to stimulate sustainable growth and development (Prakash, 2019).

Since the 2000s, SSA, MENA and LAMC's telecommunication sectors have experienced rapid expansion (for example, see Fig. 1). This is because, according to the International Telecommunication Union (ITU), the regional governments introduced policies to reform the sector and some of these policies include: new competitors/foreign investment in the sector; public-private partnership; privatization of state-owned enterprises; and market liberalization. Over the last two decades, investment in the telecommunications sector and demand for telecommunication services (such as Internet, mobile phone, fixed-line services etc.) have increased rapidly across the globe (ITU, 2016, 2019). But despite the expansion experienced in the telecommunications sector, the question that remains unanswered in the literature is the role that it has played in contributing to the levels of industrialisation most especially in developing countries, and subsequently in the three regions afore-mentioned. Investigating the questions raised in this study is important because industrial/manufacturing sector is identified in the literature as one of the key engines of economic growth in an economy (Kaldor, 1966, 1967). This assertion has been proven in East Asian countries because the industrial/manufacturing sector placed the region on a high path of economic growth, which earned them the name, that is today popularly called the Asian Tigers. And that is why the need to attain industrialisation for sustainable economic growth for SSA, MENA and LAMC regions has become non-negotiable because industrialisation is an impetus for expanding export, higher productivity, learning and innovation, job creation and accessing capital (Szirmai and Verspagen, 2015; Necmi, 1999; Page, 2011). For example, the need to attain industrial development has become very important that international organisations such as World Bank, United Nations (UN), African Development Bank (ADB), African Union (AU), and New Partnership for Africa's Development (NEPAD) have put policies and initiatives in place to stimulate growth and eliminate poverty through industrialisation in the regions.

The relative growth patterns experienced in the three regions (see Fig. 1(B)) over the years have drawn the attention of both researchers and policymakers to the factors responsible for the growth trajectory. And that is the reason scholars have examined the impact of international trade, tourism, foreign direct investment, transport and financial development on growth, with the studies characterised by mixed findings (*inter alia*: Adams, 2009; Zahonogo, 2016; Gui-Diby, 2014; Akinlo, 2004; Adams and Opoku, 2015; Sakyi *et al.*, 2015). However, the role that telecommunication infrastructures/ICT play in promoting inclusive and sustainable industrialisation or the role that industrialisation plays in stimulating economic growth in SSA, MENA and LAMC have suffered neglect and rigorous empirical investigation. A careful examination of the impact of telecommunication infrastructures/ICT on industrialisation is important because, according to Prakash (2019):

"industrialisation supported by telecommunications infrastructure/ICT could be a chosen pathway for regional growth/development, and the integration into global markets for goods and services".

Hence, to promote industrialisation and economic growth, the role of ICT/telecommunication infrastructures is essential and widely recognised in the economy (Lerner, 2010).

Given that SSA, MENA and LAMC could leverage ICT/telecommunications infrastructure to further their goals of industrialisation, and also considering the fact that industrialisation could serve as augmenter and mediator of both the agricultural and services and as an engine of growth, does the recent growth in the telecommunications infrastructure promote industrialisation and economic growth in the regions? This is a research question that deserves a rigorous empirical investigation for major policy directions in the LAMC, SSA and MENA regions.

Based on the above discussion, this study focuses on addressing crucial research questions, which include: (1) are regions/countries able to make significant progress in their effort to industrialize and increase levels of growth by improving the quality of their ICT, essentially those of telecommunications? (2) can telecommunication infrastructures, industrialisation and economic growth exhibit a causal relationship? (3) does long-run equilibrium relationship exist between telecommunication infrastructures, industrialisation and economic growth in all the regions? To what magnitude can future disparities in industrialisation and economic growth be explained by telecommunication infrastructures? Furthermore, this study contributes to

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existing empirical literature in two ways. First, it estimates the three-way linkages between telecommunication infrastructures, industrialisation and economic growth by employing panel data from 99 developing countries, divided into three sub-regions afore-mentioned. We divide our panel data into three regions for the following reasons: (1) given that we have a relatively rich dataset which include 99 countries, this will allow us to test how well each region is performing; (2) we could explore the element of homogeneity within the context of examining the nexus between telecommunication infrastructures, industrialisation and growth, since countries within the same region sometimes share more similar political, social and economic or socioeconomic features; (3) we could compare the telecommunication infrastructures-industrialisation-growth experiences of the regions and then recommend appropriate policies that best suit each of them. Consequently, we could examine the important issue of whether one size in a region does in fact fit all with regard to the causality between telecommunication infrastructures, industrialisation and growth. Secondly, this study applies the newly proposed panel VAR model in a generalized method of moments (GMM) estimation technique which takes into account endogeneity problems when compared to the traditional panel VAR estimation method (Abrigo and Love 2016).

The remainder of the paper follows this order: section 2 presents a recent overview and patterns in telecommunication infrastructures, industrialisation and growth for the regions; section 3 presents the empirical literature; section 4 presents the study's methodology; section 5 presents the empirical results and discussion; while section 6 presents the conclusion and policy recommendations.

2. Brief overview and patterns in telecommunication infrastructures, industrialisation and economic growth across the regions

This section provides a recent overview and patterns of the average composite index of telecommunication (proxy for telecommunication infrastructures), manufacturing value-added as a percentage share of GDP (proxy for industrialisation), and real GDP (proxy for economic growth) in a visual form by regions. A quick look at the trends of average manufacturing value-added as a percentage share of GDP for the three regions in Fig. 1A below points to the fact that MENA experienced a higher level of industrialisation compared to the two remaining regions (i.e., SSA and LAMC), even though the trend of the graph is shown to be declining. As Figure 2 shows, MENA is gradually and possibly standing out for poor levels of industrial development as measured by manufacturing value-added as a percentage of GDP. In Fig. 1A below, the trend of industrialisation in SSA has shown to be disappointing, given that most of the countries in the region are usually associated with a weak industrial base without the structural change and diversification experienced by other regions. Not unexpectedly, in industrial performance SSA is lagging behind other developing regions. MENA and LAMC had a similar growth trend in Fig. 1B, going by the visual inspection, while growth in SSA remained below the two regions. Similarly, Fig 1C shows the order of composite index of telecommunication for SSA, MENA and LAMC. Taking a careful look at Fig 1C, the three regions had negative trends between 2000 and 2006, and then began to experience a positive trend in early 2006. This point to a possible tremendous growth experienced in the telecommunication sectors of the regions over the period of study. Since investigating the determinants causing fluctuations in the three variables fall outside the scope of this study, these regions still, to some extent, have some things in common which worth mentioning, and they include: poor infrastructure; poor business environment; inadequate science, technology, industrial training etc. (Rodrik, 2014; Noman and Stiglitz, 2015). Given this backdrop, an empirical investigation of the causality between telecommunication infrastructures, industrialisation and growth of these regions requires not only more and further research but also the use of an alternative up-to-date testing methodology which takes endogeneity issues into account, as proposed by Abrigo and Love (2016).

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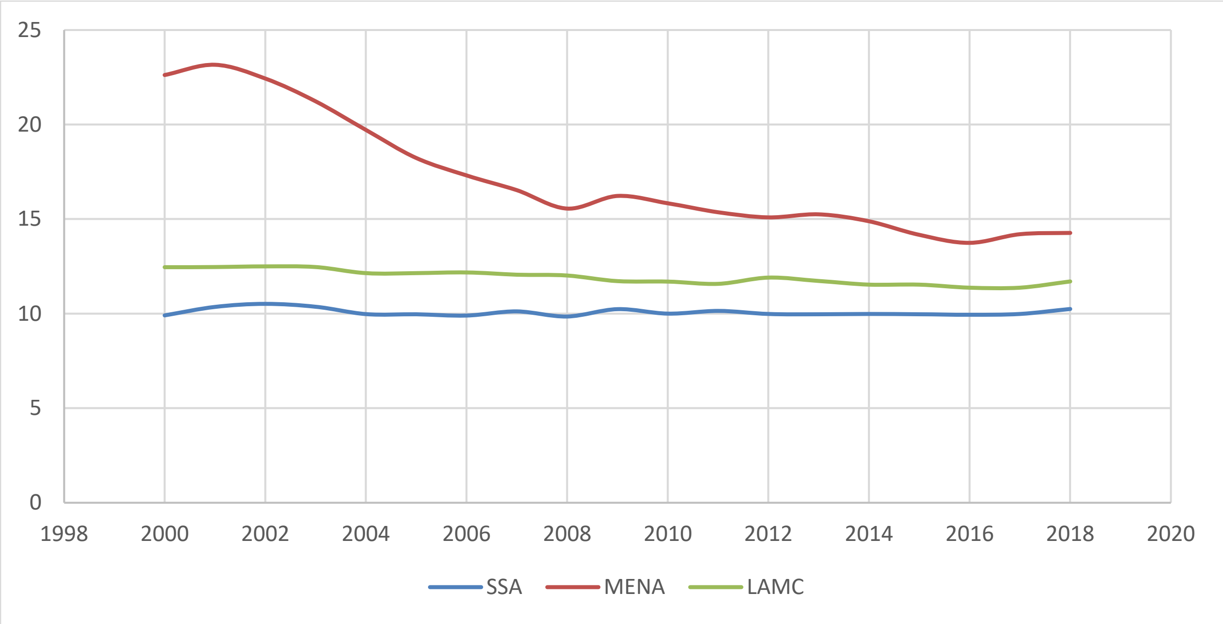
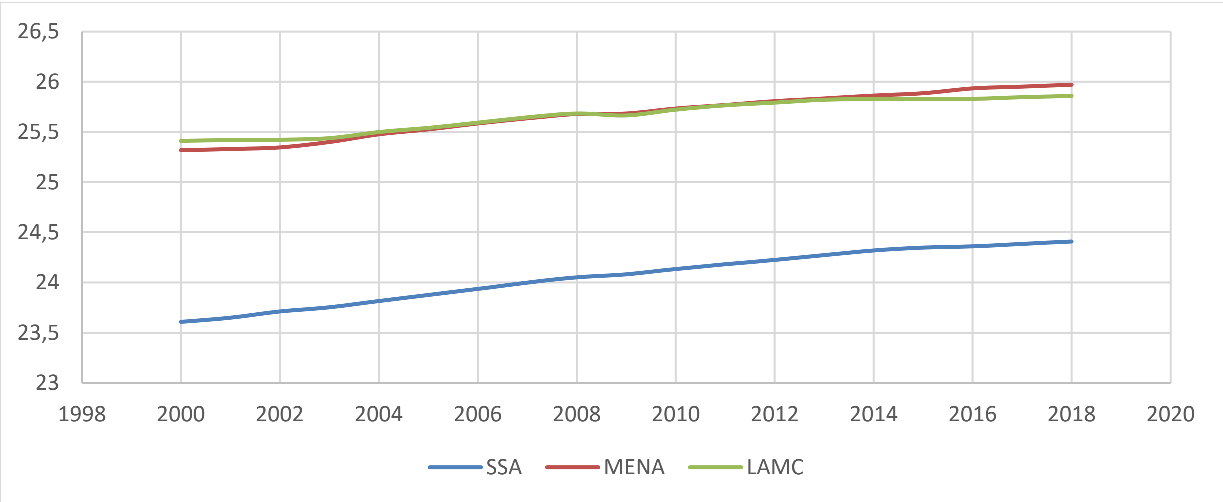
FIGURE 1 - (A) *Manufacturing Value-Added as a Percentage Share of GDP for Selected Regions, 2000-2018*; (B) *Real Gross Domestic Product for Selected Regions, 2000-2018*; (C) *Composite Index of Telecommunication for Selected Regions, 2000-2018*

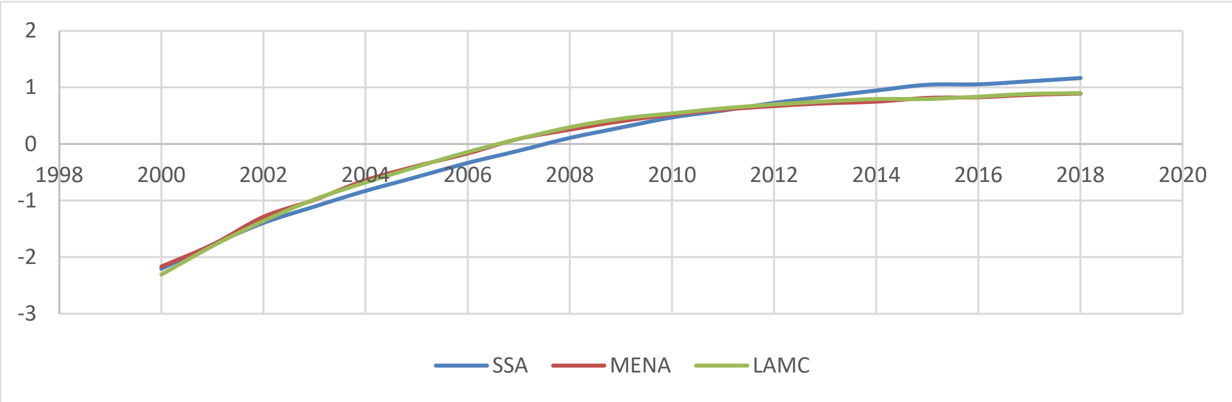
A: Manufacturing value-added as a percentage share of GDP



B: Real gross domestic product



C: Composite index of telecommunication



3. LITERATURE REVIEW

The empirical literature on telecommunications infrastructure/ICT's role in enhancing growth and development has been a growing one for more than three decades. Previous studies that are quantitative in nature that provide insights on the link and nexus that exist between telecommunications infrastructure/ICT, growth and development include David (2019), Maneejuk and Yamaka (2020), Papaioannou and Dimelis (2007), Yousefi (2011) among others. While other studies like Gómez-Barroso and Marbán-Flores (2020a, 2020b) and Vu *et al.* (2020) provide a survey on literature on the nexus existing between the two variables. Overall, they conclude that the role of telecommunications has been conclusively proven over the years as a catalyst for economic growth and development. There are relatively vast empirical studies on telecommunications infrastructure and growth, hence it is difficult for us to provide a detailed comprehensive discussion on all the empirical studies in a precise manner. In order to save space, we, therefore, focused on the methodology, period of the study, geography and main findings of the relevant studies.

For the case of global studies, Yang and Olfman (2006) investigate the effects of international investments in wireline and wireless technologies on growth for 78 countries for the period 1993-1998. The study uses an *ad hoc* regression and finds that the beginning of the adoption of wireless usage has a positive significant impact on economic performance and that there is a nominal or non-significant economic gain from using wireline telecommunication. The findings of the study show that broadband infrastructure and growth have positive causal link, which is made possible with the availability of other critical infrastructures in the economy.

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Koutroumpis (2009) follows the approach of Roller and Waverman (2001) to examine the economic impact of broadband on economic performance for 22 OECD countries for the period 2002-2007. A significant causal positive link between broadband infrastructure and growth was found, especially when a critical mass of infrastructure is present. Thompson and Garbacz (2011) adopt the model developed by Thompson and Garbacz's (2007) study to investigate the impacts of mobile and fixed broadband on GDP for 43 countries. The results of the study show that mobile broadband has a major direct impact on GDP, while fixed broadband has an impact that is no different than zero. And the countries with low income benefit significantly more from mobile broadband.

Lam and Shiu (2010) investigate the causality between telecoms development and growth for 105 countries over the period 1980-2006 within the dynamic panel framework. The study finds that there is a bidirectional causal relationship between real GDP and telecommunications development for high-income countries. The bidirectional causality becomes global when the effect of mobile telecommunications is calculated separately. Pradhan *et al.* (2014) examine the telecommunication infrastructure-growth-development nexus for G-20 countries spanning 1981-2012. The study applied a panel-VAR approach. The findings show a bidirectional causality between telecommunications (internet users plus land lines plus mobile phones) and growth.

For the case of regional studies, Madden and Savage's (1998) study finds a positive nexus between investment in telecoms infrastructure and growth for 27 Central and Eastern European (CEE) countries between 1990 and 1995. Chakraborty and Nandi (2011) examine the growth effect of telecoms infrastructure investment on mainline teledensity and *per capita* growth for 29 Sub-Saharan African countries between 1990 and 2014. The study uses a panel causality test within a panel cointegration framework. The findings of the study suggest that for less developed countries there exists a strong reinforcement between mainline teledensity and *per capita* growth. While bidirectional causality exists between the two variables for more developed countries. David's (2019) study suggests the existence of a bidirectional causality among telecom infrastructures, growth and development for 46 African countries from 2000 to 2015 by applying the panel vector autoregression framework.

For the case of country-specific studies, Cronin *et al.*'s (1991) study for the period from 1958 to 1988 examines the causal link between telecommunications infrastructure and growth for US.

Their results show that US economic activity causes the telecommunications investment at a later time and vice versa. While a recent study of Nadiri *et al.* (2018) investigates the role that modern communication infrastructure plays in the industries, productivity growth, production structure and factor demand for the entire economy of US over the period 1987-2008. The empirical findings indicate that through cost savings, increased use of high-speed broadband networks brings about productivity gains in industries. The social return on investment in communications infrastructure at the aggregate level was also found to be significant. Ward and Zheng (2016) explore the relationship between mobile telecommunications service and economic growth by utilising the Barro-type growth equation for the case of China (province level) for the period 1991 to 2010. The results of the study show that Mobile services contribute much more to growth than fixed telephony but the effect diminishes as the provincial economy develops more. Studies conducted for Nigeria by Posu (2006), Osotimehin *et al.* (2010), and Chiemeke and Longe (2007) conclude that telecommunication infrastructures have contributed positively to growth, increasing investments and economic activities. While a study conducted by Perkins *et al.* (2005) also had a similar conclusion with the one conducted for Nigeria.

Chandra (2003):

"defines industrialisation as the increase of the manufacturing value-added share of GDP". While Echaudemaison (2003) "defines industrialisation as an increasing share of the secondary sector in terms of employment and GDP".

To measure industrialisation, the studies of Nabe (1983), Echaudemaison (2003), Chandra (2003) and United Nations Industrial Development Organization (UNIDO) (2013) used manufacturing sector's share of employment relative to total employment and the manufacturing value-added as a percentage share of GDP as a proxy and this study also follows a similar direction by using just the latter due to data problem. The propensity to stimulate the economy/growth through industrialisation has led some economists to develop theories to further seep up the process of industrialisation. These theories include: Rosenstein-Rodan's (1943) Theory of The Big Push; The Import Substitution Strategy; Leibenstein's (1957) Theory of Critical Minimum Effort; The Export Promotion Strategy; The Doctrine of Balance Growth; Theory of Low Equilibrium Trap and Doctrine of Unbalance Growth of Nelson (1956) and Hausman (1978), respectively. Over time, these theories have led to different significant

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research outcomes and policy choices in the literature. Industrialisation has been seen as a way to achieve economic growth and development for every economy going by the hand-in-hand industrial revolution and growth that took place in the East Asian countries. In history, countries that have been able to achieve growth and development by mainly depending on the agricultural sector remain few and they include Canada, New Zealand and Australia (Thirlwall and Pacheco-López, 2017). While historically, however, the poorest nations have not managed to industrialise (Szirmai and Verspagen, 2015). This section also reviews studies that have investigated the nexus between manufacturing/industrial sector and growth in the empirical literature. At both specific country and cross-country level, different studies have validated the Kaldor's laws by examining the nexus that exists between the manufacturing/industrial sector and growth. Herein are some of these studies. The Kaldor's laws (i.e., Kaldor's *engine of growth hypothesis*) was examined by Hansen and Zhang (1996) using regional data for China that span from 1985 to 1991. The findings of the study validate the hypothesis by establishing a strong nexus between industrial growth and productivity across the 28 regions in China.

Kaldor (1966, 1967) sees the industrial/manufacturing sector as the engine/driver of growth. And his growth hypothesis follows the demand side of the economy as opposed to the supply side of the conventional neoclassical growth hypothesis. His laws of growth hypothesis affirm the positive manufacturing/industrial sector-growth nexus, given that the sector is influenced by dynamic economies of scale. According to Kaldor (1975), (i) improved technical progress, productivity and increase in investment is as a result of increased demand for manufactured goods, (ii) other sectors are boosted by the manufacturing sector as a result of the extra demand it creates for their goods. And it was in this respect that McMillan *et al.* (2017) argued that accumulation of capital and technological adoption meant for productive growth is brought about by an increase in the demand for industrial/manufactured goods. Increase/enhance in/of growth and expansion in export are usually followed by a boom in industrial/manufacturing sector which emanates from its interaction with other economic variables/activities. Kaldor's laws of growth hypothesis is closely related to new theories of endogenous growth in the sense that the industrial/manufacturing sector has the capacity to transfer technological change in an economy (Wong and Yip, 1999; Romer, 1986, 1990; McCausland and Theodossiou, 2012; and Lucas, 1988).

Zhao and Tang's (2018) recent study sort to know what informs China and Russia's economic growth for the period between 1995 and 2008. The results of the study suggest that in the case of China, the manufacturing/industrial sector contributes more to growth when compared to the service sector, while in Russia two sectors dominate, namely, the service sector first and then the primary sector second. McCausland and Theodossiou (2012) use a sample of 11 countries (Australia, Taiwan, Sweden, Germany, France, Korea, Greece and Japan) by applying fixed effect and feasible generalised least squares approaches to affirm the impact of industrialisation on growth. The results suggest that manufacturing output growth plays more crucial role in productivity growth and GDP growth when compared to the service sector. Necmi's (1999) study utilises two-stage least squares for 45 developing and developed countries spanning 1960 to 1994, and to also validate the manufacturing/industry-growth hypothesis. Atesoglu (1993) (study period 1965-1988) and Marconi *et al.* (2016) (study period 1990-2011) using different econometric approaches for the United State and 63 countries respectively, also affirm the hypothesis. Güçlü (2013) explores manufacturing sector-economic growth nexus and finds a positive growth effect of the manufacturing sector for the case of Turkey. The data for the study covers 1990-2000 and it applies OLS and spatial lag and error models. Szirmai and Verspagen (2015) utilise Hausman-Taylor estimator and the fixed effect model to investigate the economic growth effect of the manufacturing sector for 88 developing and developed countries. The data spans from 1950 to 2005. The results of the study suggest a slightly positive economic growth effect of the manufacturing sector. Similar, Haraguchi *et al.*'s (2017) study for developing and developed countries also finds that industrialisation potentially drives economic growth despite the recent assertions of an unstable manufacturing sector, and the reduction in its essence to cause transformation and promote economic growth and development.

On one hand, empirical studies that focus on using macro-level cross-country data especially for regions like Middle East & North Africa (MENA), Latin American & Caribbean (LAMC) and Sub-Saharan Africa (SSA) are few in the literature. While on the other hand for example, the studies of Söderbom *et al.* (2006), Fafchamps *et al.* (2008) among others focus on using micro (firm) level data to examine the issues of the dynamics of the manufacturing sector (for example, what determines manufacturing firm's productivity, obstacles facing Africa's manufacturing firms, export realisation and capacity of manufacturing firms). Few notable studies using macro-level cross-country data for Africa include Wells and Thirlwall (2003), McMillan *et al.* (2017), Diao *et al.* (2017) among others. For example, Wells and Thirlwall's (2003) study finds that there is a

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closer relationship between growth of the industrial/manufacturing sector and the growth of GDP than the service or agricultural sectors from 45 African countries over the period of 1980-1996. While for 53 African countries, Mijiyawa (2017) finds U-shape nexus between *per capita* GDP and manufacturing share of GDP by analysing what drives the manufacturing sector. The study covers the period between 1995 and 2014, and it utilises the system GMM estimation technique.

Before sound policy proposals can be proposed to define industrial/manufacturing activities and promote economic growth using telecommunications infrastructures, robust empirical work is required. This study contributes to the existing literature since previous studies have primarily sought to examine telecommunication infrastructures-growth nexus and industrialisation-growth nexus without analysing/investigating the effect of telecommunications infrastructures. The role of telecommunication infrastructures in boosting industrial/manufacturing sector is obviously important because it could contribute to economic growth going by the Kaldor's laws of growth. Furthermore, this current study is different from the earlier literature in that it amalgamates telecommunication infrastructures, industrialisation and growth in a GMM panel VAR setting. And it proposes policy implications to promote industrial/manufacturing sector by effectively and efficiently utilising telecommunication infrastructures/services for the economy.

4. Methodology and data

4.1 Empirical Strategy

The panel data estimation techniques used in this study consists of a number of processes which include: cross-sectional dependence; a panel unit root test; panel cointegration; panel Granger-causality test; and panel vector autoregression (PVAR) estimations. In order to avoid a spurious regression, we determine whether or not the variables are stationary by applying the first- and second-generation panel unit root tests, and the details of these tests can be found in the next section. To determine the long-run equilibrium relationship between the variables, we also used the first- and second-generation panel cointegration tests, and the details of these tests can be found in the next section. To examine the causal relationship between telecommunication infrastructures, level of industrialisation and growth we utilised Dumitrescu and Hurlin (2012)[1]

[1] For detailed methodological framework for the panel causality test, readers are referred to Dumitrescu and Hurlin (2012) article.

panel causality test because it accounts for the heterogeneous nature of the panel data.

4.2 Brief Theoretical Underpinning

The industrial production function for this study follows the one developed by Holtz-Eakin (1994) and the first law of Kaldor. Holtz-Eakin (1994) utilised a Cobb-Douglas production function, while the first law of Kaldor[2] postulates that there is a positive relationship between manufacturing output and economic growth. According to Brock and German-Soto (2013), the functional form of the production function is assumed to be Cobb-Douglas (CobD) and not in generalized translog. We use the more parsimonious CobD production function following Brock and German-Soto due to the following reasons which were also highlighted in their study: (i) it enforces constant returns as being appropriate considering that returns to scale may not have any significance on an aggregate level; (ii) if partial elasticities of substitution are not significant to the study in relation to output elasticities, translog specification may not be warranted; (iii) it has been discovered that a CobD production function could be used to accurately represent global/regional specifications, which indicate that this level of aggregation is reasonable; and (iv) when a Translog production function is utilized, the use of the CobD production function reduces the multicollinearity that can occasionally be detected with aggregate regional data (see studies that supports these reasons: Boisvert, 1982; Moroney, 1990; Moroney and Lovell, 1997; Sharma *et al.,* 2007; Brock and German-Soto, 2013; Puig-Junoy, 2001). Holtz-Eakin (1994) augmented the first law of Kaldor by including (A) which accounts for and consists of various policy-oriented variables including one which reflects exogenous technical progress. According to Bassanini and Scarpetta (2001) and Saba (2020a), the latter refers to all other unexplained economic growth variables which the model does not explicitly account for. Therefore, to determine the empirical dynamic relationship between economic growth, industrialisation and telecommunication infrastructures, our model can further be augmented to include industrialisation and telecommunication infrastructures in the full sample and the regions via the technical progress parameter (A). The functional form on which our estimated models stand is written as:

$$f(y) = (A)\prod_{i=1}^{n} V_i^{\xi_i}, for\ all\ \xi_i > 0\ and\ i = 1, 2, \ldots, n \quad (1)$$

[2] $Q_i = \varphi_i + X_i M_i$, where Q is total output and M is industrial output.

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where $f(y)$ is the output, V_i represents the inputs and ξ_i are coefficients to be estimated. Due to the availability of panel data and econometric methods, a greater flexibility is achieved which now leads us to the specification of Equation 2. Other variables such as L (labor), K (physical capital) and HK (human capital) which are part of Equation 1 are held constant so that we could estimate our variables of interest.

4.3 Panel VAR Model in a GMM Estimation Framework

In this study, we employed a panel VAR[3] in a GMM estimation framework which is an extension of the traditional panel vector autoregression (VAR) model introduced by Sims (1980) to explore the telecommunication infrastructures-industrialisation-growth nexus. There are several advantages associated with the use of this methodology, which include: (i) all the variables in the model are treated as independent and endogenous without a specific concern about the direction of causality; (ii) each variable in the model is explained by its own lags and by the other variables' lagged values.; (iii) it is not a one-equation model when compared to other models; (iv) it gives room for unobserved individual heterogeneity; and (v) it improves asymptotic results and simplifies the issue of the choice of suitable instrumental variables. Canova and Ciccarelli (2004) simplified the general way of presenting the PVAR model and it is given below as:

$$y_{i,t} = Z_0\psi_{i,t} + V_1 y_{i,t-1} + \cdots + V_\varphi y_{i,t-\varphi} + \mathcal{E}_t \tag{2}$$

where $y_{i,t}$ is a $K \times 1$ vector of a K panel data variables, $i = 1, \ldots, I$, $\psi_{i,t}$ is a vector of deterministic terms, Z_0 is the associated parameter matrix, and the $V's$ are a $K \times K$ parameter matrices attached to the lagged variables $y_{i,t-\varphi}$. The lag order (VAR order) is denoted by φ, while the error term is $\mathcal{E}_t$. Three variables are included in the model: manufacturing value-added as a percentage share of GDP (MGDP), telecommunication infrastructures (TELF), and real GDP (proxy for economic growth (RGDP)). The three variables in a PVAR model are represented as:

$$\begin{bmatrix} 1 \ \psi_{12} \ \psi_{13} \\ \psi_{21} \ 1 \ \psi_{23} \\ \psi_{31} \ \psi_{32} \ 1 \end{bmatrix} \begin{bmatrix} \Delta MGDP_{i,t} \\ \Delta TELF_{i,t} \\ \Delta RGDP_{i,t} \end{bmatrix} = \begin{bmatrix} \psi_{10} \\ \psi_{20} \\ \psi_{30} \end{bmatrix} + \begin{bmatrix} V_{11} \ V_{12} \ V_{13} \\ V_{21} \ V_{22} \ V_{23} \\ V_{31} \ V_{32} \ V_{33} \end{bmatrix} \begin{bmatrix} \Delta MGDP_{i,t-\rho} \\ \Delta TELF_{i,t-\rho} \\ \Delta RGDP_{i,t-\rho} \end{bmatrix} + \begin{bmatrix} \mathcal{E}_1 \\ \mathcal{E}_2 \\ \mathcal{E}_3 \end{bmatrix} \tag{3}$$

[3]The latest STATA pvar programs used for this study was made available by Abrigo and Love (2016) and it has been used by other researchers.

where $y_{i,t}$ is a three-variable vector including 3 endogenous variables which all influence one another: MGDP, TELF and RGDP. The 3×3 matrix W contains the coefficients of contemporaneous relationships between the three variables. The GMM estimator is used to obtain consistent estimates of the parameter in Equation (2). We consider the forward orthogonal deviations or Helmert transformation to the first-difference transformation to remove the panel-specific fixed effects in the panel VAR model. This is because fixed effects are usually correlated with the regressors due to lags of the dependent variables (Arellano and Bond 1991; Blundell and Bond, 1998). Unlike the first-difference transformation, the forward orthogonal deviations would minimize loss of data and allow the panel VAR model to yield efficient estimates due to its capability to overcome weak instrumentation (Abrigo and Love 2016; Arellano and Bover 1995). The presence/absence of causality is deduced from the Wald tests of parameters based on the GMM estimates. To estimate the forecast error variance decomposition (henceforth, FEVD) and impulse response function (henceforth, IRF) models, this paper follows the IRFs and FEVDs framework provided by Abrigo and Love (2016)[4] which was an extension of Hamilton's (1994) and Lütkepohl's (2005) approaches.

4.4 Data

This study used an annual panel data spanning 2000 to 2018 for 99 countries. We further disaggregated our data into regional groups which included the Middle East and North Africa (MENA) (18 countries), the Latin America & Caribbean (LAMC) (39 countries) and Sub-Saharan Africa (SSA) (45 countries). The summary of the dataset can be found in Table 1 below. While Table 2 consists of the list of selected countries used for this study.

[4] Interested readers are referred to Abrigo and Love (2016) for more details. We refer readers to this paper to save space.

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TABLE 1 - *Summary of Dataset*

Variables	Indicators	Variable description	Source of data
MGDP	Industrialisation	Manufacturing value-added as a percentage share of GDP as a proxy for industrialisation. We used this measure by following previous studies such as Gui-Diby and Renard (2015), Marconi *et al.* (2016), (2020a) among others	World Bank's World Development Indicators (WDI) database
RGDP	Real gross domestic product	Real GDP (constant 2010 US$) serves as a proxy for economic growth	World Bank's World Development Indicators (WDI) database
TELF	telecommunication infrastructures	Telecommunications infrastructure is captured by a composite index telecommunication (which comprises of three indicators) by applying principal components method/analysis (PCA). These indicators include: (i) mobile-cellular telephone subscriptions per 100 inhabitants (penetration of connected mobile lines); (ii) fixed-telephone subscriptions per 100 inhabitants (penetration of connected fixed lines); and (iii) percentage of Individuals using the Internet (percentage of population with access to the internet)	International Telecommunication Union database

Note: to compose the composite index telecommunication, we follow the studies conducted by David (2019) and Bera (2019). There were few missing data, and this was taken care of through a projection by linear trend extrapolation of matching known data points by the least squares method and moving the average interpolation procedure for missing data in between two data points. Studies that have used these techniques include David (2019), Saba and David (2022), Saba and Ngepah (2019a, 2019b, 2020a, 2020b, 2020c, 2022a, 2022b, 2022c), Saba (2020b, 2021a, 2021b), Saba *et al.* (2021).

TABLE 2 - *List of Countries Classified into three Different Regional Groups*

Sub-Saharan Africa	Middle East & North Africa	Latin American & Caribbean
Angola, Benin, Botswana, Burkina Faso, Burundi	Algeria, Bahrain, Egypt, Iran (Islamic Republic of)	Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize
Cabo Verde, Cameroon, Central African Rep., Chad	Iraq, Israel, Jordan, Kuwait	Bolivia (Plurinational State of), Brazil, Cayman Islands, Chile, Colombia
Congo (Rep. of the), Côte d'Ivoire	Lebanon, Libya, Malta, Morocco	Costa Rica, Cuba, Dominica, Dominican Rep., Ecuador, El Salvador, Grenada, Guatemala
Dem. Rep. of the Congo, Equatorial Guinea	Oman, Qatar, Saudi Arabia, Tunisia, United Arab Emirates, Yemen	Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua
Eritrea, Eswatini, Ethiopia, Gabon		Panama, Paraguay, Peru, Puerto Rico, Saint Kitts and Nevis, Saint Lucia
Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho		Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
Liberia, Madagascar, Malawi, Mali, Mauritania		
Mauritius, Mozambique, Namibia, Niger		
Nigeria, Rwanda, Sao Tome and Principe, Senegal		
Seychelles, Sierra Leone, South Africa, Sudan		
Tanzania, Togo, Uganda Zambia, Zimbabwe		

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5. EMPIRICAL RESULTS AND DISCUSSION

5.1 Principal Component, Correlation Matrix and Descriptive Statistics Results Analysis

Before starting to report the results for other estimation techniques used in this study, it is very important we first construct telecommunication infrastructures (i.e., composite index of telecommunication) for the entire sample and three regions. We used principal component analysis (PCA) to construct the composite index of telecommunication due to the significant high collinearity between the three indicators of telecommunication in Table 13 at the Appendix. Table 3 presents the results of the PCA for the entire sample and each of the three regions. We retained the component with an eigenvalue >1 and those exceeding 0.40 in absolute value (Saba and David, 2020). The composite index of telecommunication was constructed using the eigenvalue of the first component because it fulfils the condition. Therefore, we ignored the other component 2 and 3 because their eigenvalues were of less significance to the model. Figure 2 at the Appendix which represents the scree plot of eigenvalues after the principal component analysis further supported our choice for the first component.

Table 4 below presents the descriptive statistics results for the entire sample and the three regions. We observed that for the full sample, the mean (or median) values for composite index of telecommunication (proxy for telecommunication infrastructure (TELF)), industrialisation (MGDP) and real GDP (RGDP) are around -1.33E-09, 2.2094 and 23.5461 (or 0.3284, 2.3783, 23.5011), respectively. The maximum and minimum values for the three variables are found to be between 28.5161 and -6.6815, respectively. The standard deviation (SD) is 1.5246, 0.8440 and 1.8815 for TELF, MGDP and RGDP, respectively, which indicates the variation in samples. The skewness has positive value for RGDP, which shows a positively skewed distribution, while the skewness has negative values for TELF and MGDP, which shows a negatively skewed distribution for the two variables. To save space, a similar interpretation holds for the regions. The Jarque-Bera statistics for the full sample and the three regions suggest that the residuals of the variables, at least at the 1% significance level, are not normally distributed.

TABLE 3 - *Principal Component Results*

Entire Sample				
Panel (A): Principal component results				
Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	2.3243	1.7523	0.7748	0.7748
Component 2	0.5719	0.4683	0.1907	0.9654
Component 3	0.1037	-	0.0346	1.0000
Panel (B): Principal components (eigenvectors) results				
Variable	Component 1	Component 2	Component 3	Unexplained
Fixed-telephone	0.5116	0.8203	0.2556	0.3917
Mobile-telephone	0.5830	-0.5500	0.5981	0 .2101
Internet access	0.6312	-0.1569	-0.7596	0.0739
SSA				
Panel (C): Principal component results				
Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	2.1477	1.4073	0.7159	0.7159
Component 2	0.7404	0.6285	0.2468	0.9627
Component 3	0.1119	-	0.0373	1.0000
Panel (D): Principal components (eigenvectors) results				
Variable	Component 1	Component 2	Component 3	Unexplained
Fixed-telephone	0.4374	0.8907	0.1237	0.5891
Mobile-telephone	0.6222	-0.3991	0.6735	0.1687
Internet access	0.6493	-0.2176	-0.7287	0.0945
MENA				
Panel (E): Principal component results				
Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	2.1440	1.4217	0.7147	0.7147
Component 2	0.7224	0.5886	0.2408	0.9555
Component 3	0.1336	-	0.0445	1.0000
Panel (F): Principal components (eigenvectors) results				
Variable	Component 1	Component 2	Component 3	Unexplained
Fixed-telephone	0.4460	0.8901	0.0936	0.5735
Mobile-telephone	0.6228	-0.3838	0.6818	0.1685
Internet access	0.6429	-0.2458	-0.7255	0.114
LAMC				
Panel (G): Principal component results				
Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	2.0320	1.2696	0.6773	0.6773
Component 2	0.7625	0.5569	0.2542	0.9315
Component 3	0.2055	-	0.0685	1.0000
Panel (H): Principal components (eigenvectors) results				
Variable	Component 1	Component 2	Component 3	Unexplained
Fixed-telephone	0.4467	0.8787	0.1684	0.5945
Mobile-telephone	0.6136	-0.4379	0.6571	0.2349
Internet access	0.6511	-0.1902	-0.7348	0.1385

Note: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$, p-value in parentheses.
Source: Author's computation.

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TABLE 4 - *Descriptive Statistics Results*

Entire Sample				Sub-Saharan Africa (SSA)			Middle East & North Africa (MENA)			Latin America & the Caribbean (LAMC)		
Statistics	TELF	MGDP	RGDP	TELF	MGDP	RGDP	TELF	MGDP	RGDP	TELF	MGDP	RGDP
Mean	-1.33E-09	2.2094	23.5461	1.16E-08	2.0672	22.8977	2.34E-09	2.5258	25.1250	-2.92E-09	2.2289	23.5672
Median	0.3284	2.3783	23.5011	0.2545	2.2260	23.0156	0.3925	2.5861	25.1098	0.3663	2.5278	23.6088
Maximum	2.1213	5.0845	28.5161	2.8370	3.5615	26.8745	1.9432	5.0845	27.2767	2.0568	3.8866	28.5161
Minimum	-6.6815	-2.1813	18.6212	-5.6446	-2.1813	18.6212	-6.3357	-0.0963	22.6901	-6.7229	-0.4036	19.7486
Std. Dev.	1.5246	0.8440	1.8815	1.4655	0.8787	1.4742	1.4642	0.7731	1.1274	1.4255	0.7879	2.1487
Skewness	-0.9986	-1.5684	0.11770	-0.5924	-2.4051	0.0895	-1.6198	-0.1575	-0.0878	-1.3358	-0.8975	0.2239
Kurtosis	3.5878	8.8398	2.6539	3.0615	11.6098	3.6370	6.1804	5.1892	2.1383	5.2283	3.6003	2.3381
J-Bera	339.723	3444.01	13.73	50.15	3465.19	15.5986	293.6863	69.7056	11.0209	344.9172	102.0983	18.2043
Prob.	0.0000	0.0000	0.0010	0.0000	0.0000	0.0004	0.0000	0.0000	0.0040	0.0000	0.0000	0.0001
Obs	1881	1881	1881	855	855	855	342	342	342	684	684	684

Source: Author's computation.

5.2 Panel Unit Root Results Analysis

Table 5 presents the panel unit root results for the entire sample and each of the three regions. To explore the stationarity panel unit root properties of the three variables, we chose three and one for the first- and second-generation panel unit root test, respectively. The second-generation panel unit root test was meant for robustness checks. In Table 5, first-generation panel unit root test results, namely Breitung Method (Breitung, 2001; Breitung and Das, 2005), the Im-Pesaran-Shin (IPS) method (Im *et al.*, 2003), and Levine-Lin-Chu (LLC) method (Levin *et al*, 2002). In summary, the results show that all the variables are integrated of order *I*(1) for the first generation panel unit root tests because null hypothesis (H_0) of non-stationarity is rejected given that the p-value is less than 10%. This suggested the need for a panel cointegration test to establish the long-run relationship between the variables.

The LLC, IPS and Breitung tests cannot be fully relied upon given that they do not take into account the presence of cross-sectional dependence in the data. Socially, economically and politically countries within and outside a region are dependent on one another, therefore accounting for this in a data is very important. Hence, our rational for testing for the presence of cross-sectional dependence in our data. This problem is taken care of by utilising: the test statistic proposed by Frees (1995); Friedman's (1937) statistic; and Pesaran's (2004) cross-sectional dependence (CD) test. The results in Table 6 suggest that at 1% significance level, the null hypothesis of cross-sectional independence is rejected for the tests, which shows the presence of cross-sectional dependence on our data. Therefore, to test the robustness of the first-generation panel unit root test results, we apply the Pesaran (2007) panel unit root which considers cross-sectional dependence. In Table 7, at first difference, all the series are found to be stationary. Therefore, the results of the first- and second-generation panel unit root tests concur with each other and this shows the reliability of our unit root analysis. This implies that all the series are stationary/integrated at *I*(1).

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TABLE 5 - *Panel Unit Root Test Results*

Series	Model	LLC	IPS	Breitung
Entire Sample				
TELF	Constant	-23.6612 (0.0000)***	-16.1364 (0.0000)***	
	Constant and trend	-10.6933 (0.0000)***	1.3194 (0.9065)	9.4805 (1.0000)
MGDP	Constant	-4.3329 (0.0000)***	-0.9932 (0.1603)	
	Constant and trend	-1.5822 (0.0568)*	1.1395 (0.8728)	0.4189 (0.6624)
RGDP	Constant	-7.2336 (0.0000)***	3.7127 (0.9999)	
	Constant and trend	-1.4800 (0.0694)*	1.6799 (0.9535)	3.2794 (0.9995)
ΔTELF	Constant	-11.8828 (0.0000)***	-7.9710 (0.0000)***	
	Constant and trend	-10.8920 (0.0000)***	-10.4684 (0.0000)***	-4.6827 (0.0000)***
ΔMGDP	Constant	-14.9594 (0.0000)***	-15.0482 (0.0000)***	
	Constant and trend	-13.0267 (0.0000)***	-11.2063 (0.0000)***	-9.7793 (0.0000)***
ΔRGDP	Constant	-11.6631 (0.0000)***	-11.1994 (0.0000)***	
	Constant and trend	-12.9444 (0.0000)***	-9.4805 (0.0000)***	-9.3368 (0.0000)***
SSA				
TELF	Constant	-15.2569 (0.0000)***	-8.0076 (0.0000)***	
	Constant and trend	-2.8962 (0.0019)***	3.9679 (1.0000)	8.0500 (1.0000)
MGDP	Constant	-2.9409 (0.0016)***	-1.3553 (0.1877)	
	Constant and trend	0.5416 (0.7059)	0.9318 (0.8243)	-0.6635 (0.2535)
RGDP	Constant	-4.0572 (0.0000)***	4.2795 (1.0000)	
	Constant and trend	0.7272 (0.7664)	2.6141 (0.9955)	3.8629 (0.9999)
ΔTELF	Constant	-5.7560 (0.0000)***	-4.8071 (0.0000)***	
	Constant and trend	-4.9182 (0.0000)***	-6.6378 (0.0000)***	-4.4299 (0.0000)***
ΔMGDP	Constant	-11.3736 (0.0000)***	-10.7198 (0.0000)***	
	Constant and trend	-10.8801 (0.0000)***	-8.1166 (0.0000)***	-6.8057 (0.0000)***
ΔRGDP	Constant	-7.2855 (0.0000)***	-7.4796 (0.0000)***	
	Constant and trend	-8.1442 (0.0000)***	-6.3870 (0.0000)***	-6.5258 (0.0000)***

Notes: Null: Unit root (assumes common unit root process): Levin, Lin & Chu (t*) and Breitung (t-stat). Null: Unit root (assumes individual unit root process): and Im, Pesaran and Shin (W-stat).*** p<0.01, ** p<0.05, and * p<0.1 are significance level respectively. *Source*: Author's computations.

TABLE 6 - *Cross-Sectional Dependence Test Results*

Test	Variables	Entire Sample	SSA	MENA	LAMC
Pesaran	TELF	289.132 (0.0000)***	131.957 (0.0000)***	51.101 (0.0000)***	103.465 (0.0000)***
	MGDP	13.724 (0.0000)***	3.095 (0.0020)***	0.243 (0.8077)	5.725 (0.0000)***
	RGDP	237.783 (0.0000)***	116.742 (0.0000)***	38.979 (0.0000)***	81.358 (0.0000)***
Frees	TELF	81.033 (0.0000)***	38.075 (0.0000)***	14.059 (0.0000)***	27.842 (0.0000)***
	MGDP	19.182 (0.0000)***	7.719 (0.0000)***	4.900 (0.0000)***	6.494 (0.0000)***
	RGDP	67.227 (0.0000)***	33.967 (0.0000)***	12.602 (0.0000)***	21.122 (0.0000)***
Friedman	TELF	1659.126 (0.0000)***	767.861 (0.0000)***	297.340 (0.0000)***	585.991 (0.0000)***
	MGDP	96.814 (0.5149)	41.333 (0.5866)	16.140 (0.5139)	47.121 (0.0830)*
	RGDP	1397.085 (0.0000)***	700.797 (0.0000)***	244.272 (0.0000)***	468.028 (0.0000)***

Note:).*** p<0.01, ** p<0.05, and * p<0.1 are significance level respectively at denote rejection of null hypothesis. Notes: 1: Friedman (1937) test for cross-sectional dependence using Friedman's $\chi 2$ distributed statistic, 2: Frees (1995) for cross-sectional dependence by using Frees' Q distribution (T-asymptotically distributed), 3: Pesaran (2004) cross-sectional dependence in panel data models test.
Source: Author's Computations.

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TABLE 7 – *Panel Unit Root Results with Cross-Sectional Dependence*

	Entire Sample		SSA		MENA		LAMC	
Level								
	Constant	Constant and trend	Constant	Constant and trend	Constant	Constant and trend	Constant	Constant and trend
TELF	-2.303**	-2.619	-1.910	-2.441	-2.381**	-2.309	-2.582***	-2.756**
MGDP	-2.033	-2.453	-1.891	-2.357	-1.807	-2.302	-2.118	-2.299
RGDP	-1.830	-2.029	-1.666	-2.086	-1.574	-2.068	-1.732	-1.588
1st Difference								
∆TELF	-3.626 ***	-3.866***	-3.647***	-3.730***	-3.460***	-3.657***	-3.370***	-3.680***
∆MGDP	-3.628***	-3.687***	-3.633***	-3.745***	-3.795***	-3.768***	-3.652***	-3.800***
∆RGDP	-3.329***	-3.606***	-3.520***	-3.807***	-3.031***	-3.359***	-2.963***	-3.266***

Note: ***, ** and * denote statistically significant at the 1%, 5%, and 10% level respectively. The critical values of CIPS test at 10%, 5% and 1% significance levels are: -2.11, -2.2 & -2.36 for intercept, and -2.63, -2.7 and -2.85 for intercept plus trend, respectively.
Source: Author's computations.

5.3 Panel Cointegration Results Analysis

Given that the series of this study are integrated of the same order, this suggests that there is need to carry out a panel cointegration test developed by Johansen-Fisher and Westerlund (2007) to examine the long-run equilibrium relationship between telecommunication infrastructures, industrialisation and economic growth. Before performing the Johansen cointegration tests, this study used the Schwarz Information Criterion (SIC) to determine the optimum lag length for the entire sample and each of the regions. The optimum lag length results are reported in the appendix (see Table 14). Table 8 below presents the Johansen-Fisher test for cointegration results. The results in Table 8 followed the vector autoregression (VAR) process for the combination of the panel series by using the Fisher-Trace and Fisher-Maximum Eigen value tests. Both the trace and maximum Eigen-value test statistics supported the cointegration of 4, 6, 4 and 5 for the entire sample, SSA, MENA and LAMC, respectively. Thus, at least the 4, 6, 4 and 5 vectors of the cointegrating equations had the presence of panel cointegration for the entire sample, SSA, MENA and LAC, respectively. We may conclude that telecommunication infrastructures, industrialisation and economic growth have the long-run equilibrium relationship in the entire sample and each of the three regions.

For robustness check, we apply the Westerlund (2007) cointegration test which is able to account for the presence of cross-sectional dependence in data. Table 9 presents the Westerlund (2007) cointegration test results. We find that the null hypothesis of no cointegration is rejected at 10% significance levels, which confirms the existence of long-run equilibrium relationship between the variables for entire sample, SSA, MENA and LAMC regions. This further confirms that the empirical results are robust and reliable, hence they can be used for drawing inferences.

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TABLE 8 - *Johansen-Fisher Panel Cointegration Test Results*

Variables: Telecommunication infrastructures, industrialisation and Growth

Regions	H_0	H_1	**Trace test** λ-trace statistic	0.05 Critical Value	p-value	H_o	H_1	**Maximum Eigenvalue test** λ-max statistic	0.05 Critical Value	p-value
Entire	$r = 0$	$r \geq 1$	880.5764***	29.7971		$r = 0$	$r \geq 1$	827.2691***	21.1316	0.0000
Sample					0.0000					
	$r \leq 1$	$r \geq 2$	53.3073***	15.4947		$r \leq 1$	$r \geq 2$	50.7781***	14.2646	0.0000
					0.0000					
	$r \leq 2$	$r \geq 3$	2.5292	3.8415	0.1118	$r \leq 2$	$r \geq 3$	2.5291	3.84147	0.1118
SSA	$r = 0$	$r \geq 1$	368.4716***	29.7971		$r = 0$	$r \geq 1$	347.4988***	21.1316	0.0000
					0.0000					
	$r \leq 1$	$r \geq 2$	20.9728**	15.4947	0.0067	$r \leq 1$	$r \geq 2$	17.4432**	14.2646	0.0152
	$r \leq 2$	$r \geq 3$	3.9196*	3.8415	0.0603	$r \leq 2$	$r \geq 3$	3.9596*	3.8415	0.0603
MENA										
	$r = 0$	$r \geq 1$	56.3883***	29.7971		$r = 0$	$r \geq 1$	34.8259***	21.1316	0.0003
					0.0000					
	$r \leq 1$	$r \geq 2$	21.5624**	15.4947	0.0054	$r \leq 1$	$r \geq 2$	21.5045**	14.2646	0.0030
	$r \leq 2$	$r \geq 3$	0.0579	3.8415	0.8098	$r \leq 2$	$r \geq 3$	0.0579	3.8415	0.8098
LAMC										
	$r = 0$	$r \geq 1$	363.4042***	29.7971		$r = 0$	$r \geq 1$	329.9876***	21.1316	0.0000
					0.0000					
	$r \leq 1$	$r \geq 2$	33.4166***	15.4947		$r \leq 1$	$r \geq 2$	29.8639***	14.2646	0.0001
					0.0000					
	$r \leq 2$	$r \geq 3$	3.8527*	3.8415	0.0594	$r \leq 2$	$r \geq 3$	2.5527	2.8415	0.1594

Notes: *Rejection of the null hypothesis of no cointegration at least at the 10% level of significance. Probabilities are computed using asymptotic Chi-square distribution.
Source: Author's computations (2020).

TABLE 9 - *Westerlund Panel Cointegration Test Results*

Statistic	Value	Z-value	P-value	Robust P-value
Entire Sample				
G_t	38.115	433.793	1.000	0.750
G_a	-0.328	13.954***	1.000	0.000
P_t	-12.017	4.869***	1.000	0.000
P_a	-0.290	9.921	1.000	0.500
SSA				
G_t	-3.131	-7.986	0.000	0.400
G_a	-0.407	9.324***	1.000	0.000
P_t	-8.607	2.793***	0.997	0.000
P_a	-0.325	6.647	1.000	0.200
MENA				
G_t	-2.264	-1.055***	0.146	0.000
G_a	-6.152	2.011	0.978	0.750
P_t	-13.899	-6.421***	0.000	0.000
P_a	-9.010	-2.387***	0.009	0.000
LAMC				
G_t	-2.391	-2.319***	0.010	0.000
G_a	-0.517	8.234	1.000	1.000
P_t	-2.907	7.139***	1.000	0.000
P_a	-0.264	6.010	1.000	1.000

Note: *, ** and *** represent significance at the 1%, 5%, and 10% levels respectively; number of replications to obtain bootstrapped p-values is set to 100; bandwidth is selected according to the data depending rule $4(\frac{T}{100})^{2/9} \approx 3$ recommended by Newey and West (1994); Barlett is used as the spectral estimation method.
Source: Author's computations.

5.4 Panel Causality Results Analysis

This study used the Dumitrescu and Hurlin (2012) heterogeneous panel causality test to examine the causal relationship between TELF, MGDP and RGDP and to also reveal the magnitude of the relationship among the series. The study simplified and reduced the panel causality test to the three key panel series of the study: TELF, MGDP and RGDP, for easier tracing of bivariate relationships between them for the entire sample, SSA, MENA and LAMC. In Table 10, the results suggest strong evidence of bidirectional causality between: (i) TELF and MGDP; (ii) TELF and RGDP; and (iii) MGDP and RGDP in entire sample, SSA and LAMC. The

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null hypothesis of no causality was rejected for the entire sample, SSA and LAMC. The individual Wald statistics were statistically significant. These results implied that there was a feedback causal relationship between telecommunication infrastructures, industrialisation and economic growth. In Table 10, the results reveal strong evidence of unidirectional causality running from: TELF to MGDP; TELF to RGDP (and the presence of bidirectional causality between MGDP and RGDP) in MENA. The bidirectional causality result between TELF and RGDP was consistent with the findings of David (2019) and Shiu and Lam (2008). Based on the feedback causality at entire sample, SSA and LAMC (except the causality running from TELF to MGDP, and TELF to RGDP in MENA) among our variables suggested possible endogeneity problem that needs to be accounted for in the next estimated models. This justified the use of a panel causality test based on the GMM estimator, which takes care of endogeneity problems in the panel VAR model through instrumentation (Abrigo and Love, 2016).

5.5 Panel VAR Results Analysis

Table 11 presents the panel-VAR results. Firstly, the entire sample result for the economic growth (RGDP) equation revealed that at 1 percent significance level TELF and MGDP are positively and negatively to RGDP, respectively. This suggests that if composite index of telecommunication increases by 1 percent, economic growth will increase by 0.034 percent. While if the level of industrialisation increases by 1 percent, economic growth will fall by -0.078 percent. The policy implications of these results are: to promote economic growth by 0.034 percent, there is need to increase telecommunication infrastructures performance by 1 percent. This implies that in developing countries, there is need to enate policies that will catalyse the level of industrialisation meant to promote growth. The result of the positive impact of composite index of telecommunication on growth is consistent with the findings of Osotimehin *et al.* (2010), Pradhan *et al.* (2016) and David (2019). The result for industrialisation equation revealed that at 1 percent significance level, composite index of telecommunication is negative to industrialisation. This suggests that if composite index of telecommunication increases by 1 percent, the level of industrialisation will fall by -0.049 percent. This implies that telecommunication infrastructures are still lagging behind in promoting industrial development in developing countries. Secondly, for SSA, MENA and LAMC (except for industrialisation equation) a similar interpretation like that of the entire sample holds, although the magnitude of

TABLE 10 - *Dumitrescu and Hurlin (2012) Panel Causality Test Results*

Model	Null hypothesis	W-statistic	Zbar-statistic	p-value	Direction of relationship observed	Conclusion
Entire Sample						
1	MGDP ↛ TELF	3.8129	4.7826	2.00E-06***	TELF↔MGDP	Bidirectional causality
	TELF ↛ MGDP	4.9652	8.6832	0.0000***		
2	RGDP ↛ TELF	3.9183	5.1395	3.00E-07***	TELF↔RGDP	Bidirectional causality
	TELF ↛ RGDP	6.6856	14.5070	0.0000***		
3	RGDP ↛ MGDP	4.2855	6.3823	2.00E-10***	MGDP↔RGDP	Bidirectional causality
	MGDP ↛RGDP	3.4719	3.6285	0.0003***		
SSA						
1	MGDP ↛ TELF	4.3213	4.3848	1.00E-05***	TELF↔MGDP	Bidirectional causality
	TELF ↛ MGDP	4.5905	4.9990	6.00E-07***		
2	RGDP ↛ TELF	3.9579	3.5554	0.0004***	TELF↔RGDP	Bidirectional causality
	TELF ↛ RGDP	3.7588	3.1010	0.0019***		
3	RGDP ↛ MGDP	4.8253	5.5349	3.00E-08***	MGDP↔RGDP	Bidirectional causality
	MGDP ↛RGDP	3.3614	2.1941	0.0282**		
MENA						
1	MGDP ↛ TELF	2.7789	0.5469	0.5844	TELF→MGDP	Unidirectional causality
	TELF ↛ MGDP	3.7929	2.0105	0.0444**		
2	RGDP ↛ TELF	3.2476	1.2234	0.2212	TELF→RGDP	Unidirectional causality
	TELF ↛ RGDP	5.6127	4.6371	4.00E-06***		
3	RGDP ↛ MGDP	3.8901	2.1509	0.0315**	MGDP↔RGDP	Bidirectional causality
	MGDP ↛RGDP	3.8173	2.0457	0.0408**		
LAMC						
1	MGDP ↛ TELF	3.7801	2.8172	0.0048***	TELF↔MGDP	Bidirectional causality
	TELF ↛ MGDP	6.0243	7.3981	1.00E-13***		
2	RGDP ↛ TELF	4.1225	3.5159	0.0004***	TELF↔RGDP	Bidirectional causality
	TELF ↛ RGDP	10.5016	16.537	0.0000***		
3	RGDP ↛ MGDP	3.8083	2.8747	0.0040***	MGDP↔RGDP	Bidirectional causality
	MGDP ↛RGDP	3.4374	2.1176	0.0342**		

Note: ↔ and → denote bidirectional and unidirectional causality respectively. ↛ denote does not homogeneously cause (i.e H_0). *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Source: Author's Computation.

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TABLE 11 - *Results for the three-Variable PVAR Model*

	RGDP $(t-1)$	TELF $(t-1)$	MGDP $(t-1)$
Entire sample			
TELF (t)	0.0341 (0.0000)***	0.9156 (0.0000)***	-0.0488 (0.0000)***
MGDP (t)	-0.0779 (0.0000)***	0.0576 (0.0000)***	0.9335 (0.0000)***
RGDP (t)	0.8309 (0.0000)***	-0.1179 (0.0000)***	0.1650 (0.0110)***
SSA			
TELF (t)	0.0217 (0.0000)***	0.9483 (0.0000)***	-0.0685 (0.0000)***
MGDP (t)	-0.0754 (0.0000)***	-0.1267 (0.0000)***	0.8436 (0.0000)***
RGDP (t)	0.8879 (0.0000)***	-0.1927 (0.0000)***	0.2395 (0.0000)***
MENA			
TELF (t)	0.0307 (0.0000)***	0.8940 (0.0000)***	-0.0516 (0.0000)***
MGDP (t)	-0.1432 (0.0000)***	-0.1354 (0.0000)***	1.1078 (0.0000)***
RGDP (t)	0.7966 (0.0000)***	-0.2457 (0.0000)***	0.2958 (0.0000)***
LAMC			
TELF (t)	0.0336 (0.0000)***	0.9027 (0.0000)***	-0.0093 (0.4900)
MGDP (t)	-0.0194 (0.0390)**	0.1068 (0.0010)***	0.5090 (0.0000)***
RGDP (t)	0.7627 (0.0000)***	-0.2058 (0.0210)***	-0.0525 (0.5810)

Note: *** p<0.01, ** p<0.05, * p<0.1. *p* values in parenthesis; The error terms include country-specific effect. The optimal lag length used for instrument for the entire sample, SSA, MENA and LAC are 3, 2, 1 and 2 respectively (see Table 14).
Source: Author's Computations.

causation of TELF and MGDP in the economic growth equation, and the magnitude of causation of TELF and RGDP in industrialisation equation differs.

Thirdly, the results of the composite index of telecommunication equation (proxy for telecommunication infrastructures) for the entire sample and the three regions revealed that growth is negatively significant to the telecommunication infrastructures at most 5 percent significance level. This suggests that if growth increases by 1 percent, the telecommunication infrastructures will decrease by -0.118, -0.193, -0.246 and -0.206 percent for the entire sample, SSA, MENA and LAMC, respectively. This implies that the gains from growth are not being properly channelled towards the advancement of the telecommunication sector in the three regions. The results for the entire sample and LAMC show that the composite index of telecommunication equation revealed that at 1 percent significance level, MGDP is positive to telecommunication infrastructures. While the composite index of telecommunication equation further revealed that at 1 percent significance level, RGDP is negative to telecommunication infrastructures in SSA and MENA.

The significant and positive impact of telecommunication infrastructures/ICT on economic growth in the full sample and the three regions is interesting because generally, it is believed that telecommunication infrastructures/ICT has the potential: (i) to improve the living standards of countries through generating revenue/income and creating employment opportunities; (ii) it improves productivity of inputs, lowers transaction costs, facilitates the creation of knowledge; (iii) it reduces price dispersions and price fluctuations; and (iv) it makes markets more efficient and promotes investment (*inter alia*: Haftu, 2019; Saba and Ngepah, 2021). All of these roles could have been the reason why telecommunication infrastructures/ICT contributed to economic growth. Telecommunication infrastructures/ICT could not contribute positively to industrialisation/industrial development when compared to its impact on economic growth because the three developing regions are facing a two-pronged challenge in the digital era. Firstly, there is a substantial digital divide in terms of a variety of technologies in the three developing regions and the rest of the regions in the world that are developed – from something as sophisticated as robotics and artificial intelligence to something as basic as having access to internet. For example, the internet penetration in SSA in 2016 was 10% lower than that in South Asia, and in terms of robots, the share of the region in the number of robots sold in the year 2015 was more than 15 times lower than its share in the global GDP of that year (Banga and Velde, 2018). Secondly, even if the region's economy were to have the same access to internet/digital infrastructures as other developed regions they will still not be able to derive similar productivity gains from the internet. This is because previous empirical evidence has suggested that a doubling of internet penetration boosts manufacturing labour productivity in developed regions by roughly 11%, but the impact on less developed regions is only around 3% (UNIDO, 2019).

The inability of the telecommunications/ICT to positively impact industrialisation also points to the fact that the regional governments have not fully taken advantage of the channels and mechanisms through which telecommunications/ICT could affect industrialisation process. For example, the channel of creating new firms which usually involve the use of mobile phones, computers and internet (Zhou *et al.*, 2019). And the telecommunication infrastructures/ICT services could be used to enhance public administration's support, enhance efficiency and productivity of services associated with manufacturing, including customs administration, general logistics, etc (Oulton, 2002). According to literature, the industrial sector in developing regions is faced with infrastructure bottlenecks, insufficient productive capabilities, inadequate

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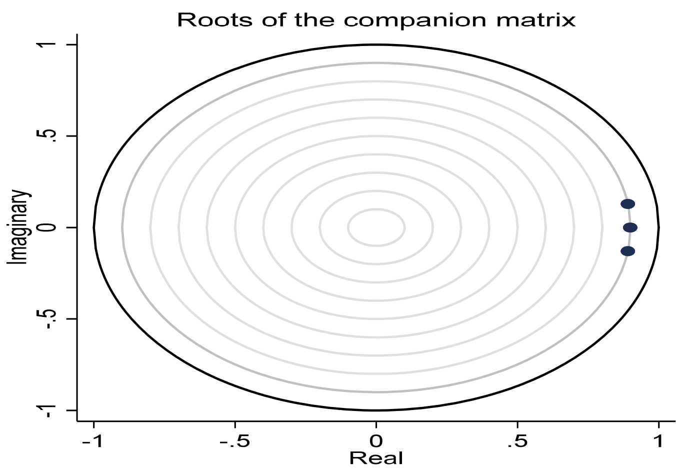
skilled workers, underdeveloped financial markets, high levels of income inequality etc (see Newman *et al.*, 2016; Noman and Stiglitz, 2015). Hence, these factors could hinder the inability of the manufacturing sector to positively contribute to economic growth even though they were not directly investigated by this study.

5.6 Stability Condition Test

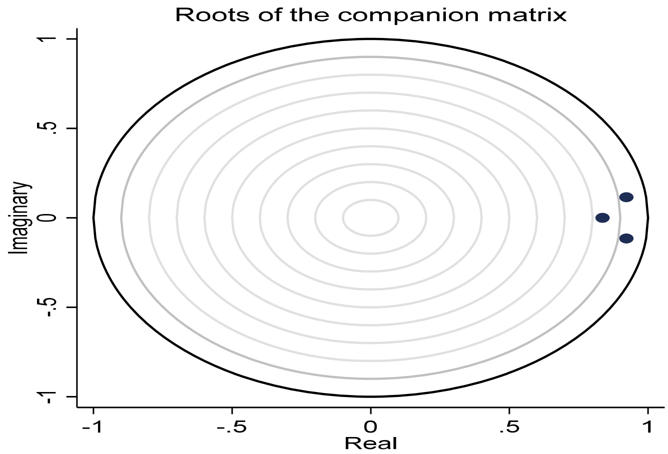
Before we estimate the IRF and FEVD, we perform the stability condition test of the estimated panel VAR in order to ascertain the validity of our model and the reliability of our results. Figure 2 shows the stability condition results for the entire sample, SSA, MENA and LAMC. As a rule of thumb, since the eigenvalues for the entire sample, SSA, MENA and LAMC lie within the unit circle, this implies that all the five estimated panel models have stationary roots (Hamilton, 1994; Lütkepohl, 2005; Abrigo and Love, 2016). Therefore, our estimated models are valid and the results are reliable for interpretation and policy recommendations.

FIGURE 2 - **(D)** *Stability Condition for the Entire Sample;* ***(E)*** *Stability Condition for Sub-Saharan Africa (SSA)*; **(F)** *Stability Condition for the Middle East and North Africa* (MENA); **(G)** *Stability Condition for the Latin America & the Caribbean* (LAMC).

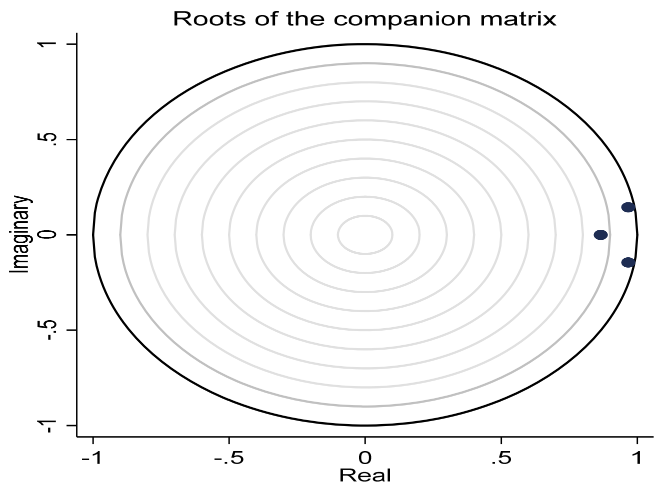
D: Entire Sample



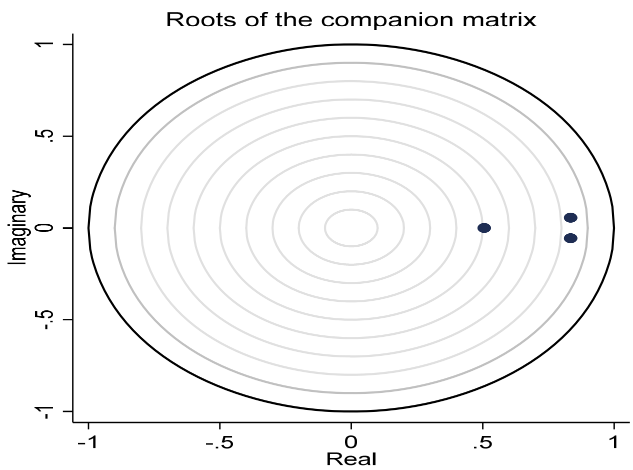
E: Sub-Saharan Africa (SSA)



F: Middle East & North Africa (MENA)



G: Latin American & Caribbean (LAMC)



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5.7 Variance Decomposition and Impulse Response Analysis

In addition to the cointegration, Granger causality and panel VAR tests, this study also utilises forecast error variance decompositions (FEVDs) and impulse response functions (IRFs) analysis of unrestricted VAR estimation process using orthogonalised Cholesky ordering technique. These two methods were used in order to further explain the magnitude of the causation among the variables. By investigating differences in the values of one variable that can be explained by the other variable, FEVD tests/measures the strength of the causal relationship (Shahbaz, 2012), whilst IRF measures the effect of a shock to a predictor variable on the predicted variable (Koop *et al.*, 1996). Table 12 presents the variance decomposition of the variables for 10 periods in which one fourth of the periods (i.e. period 5) is assumed to be the short run and period 10 is the long run. For the entire sample, Panel A, the response of composite index of telecommunication (TELF) to shocks in itself, in the short run will cause 0.941 percent fluctuations but 0.788 percent fluctuations in the long run to TELF. In the short-run, shocks in industrialisation (MGDP) and economic growth (RGDP) causes 0.051 percent and 0.008 percent fluctuations in TELF, respectively. While in the long run, shocks in MGDP and RGDP causes 0.201 percent and 0.011 percent variations in TELF, respectively. While a similar interpretation holds for panel B and C for the entire sample.

For SSA, panel D shows that the response of TELF to shocks in itself reveals that at period 5, in the short run, own shocks will cause 0.919 percent fluctuations, but 0.840 percent fluctuations in the long run to TELF in SSA. In the short run, shocks in MGDP and RGDP causes 0.061 percent and 0.020 percent variations in TELF, respectively. While in the long run, shocks in MGDP and RGDP causes 0.081 percent and 0.079 percent variations in TELF, respectively. In panel E, own shocks of MGDP accounted for 0.952 percent fluctuations in MGDP in the short run but causes 0.881 percent variations in the long run. In the short run, shocks in TELF and RGDP causes 0.026 percent and 0.022 percent variations in MGDP, respectively. While in the long run, shocks in TELF and RGDP causes 0.046 percent and 0.073 percent variations in MGDP, respectively. Panel F shows the response of RGDP to own shocks and shocks in RGDP and TELI in SSA. The empirical results identified that own shocks of RGDP cause 0.549 and 0.279 percent variations in the short run and long run, respectively. In the short run, shocks in TELF and MGDP causes 0.087 percent and 0.365 percent variations in RGDP, respectively.

While in the long run, shocks in TELF and MGDP causes 0.175 percent and 0.545 percent variations in RGDP, respectively.

For MENA, panel G shows that the response of TELF to shocks in itself reveals that at both short run and long run (i.e period 5 and 10), own shocks will cause 0.879 and 0.709 percent fluctuations in TELF, respectively. In panel H, own Innovations of MGDP accounted for 0.850 percent fluctuations in MGDP in the short run but causes 0.685 percent variations in the long run. In the short run, shocks in TELF and RGDP cause 0.049 percent and 0.101 percent fluctuations in MGDP, respectively. While in the long run, shocks in TELF and RGDP cause 0.049 percent and 0.266 percent variations in MGDP, respectively. Panel I empirical results identified that own shocks of RGDP cause 0.481 percent variations in RGDP in the short run but 0.244 percent fluctuations in the long run. In the short run, shocks in TELF and MGDP cause 0.079 percent and 0.441 percent fluctuations in RGDP, respectively. While in the long run, shocks in TELF and MGDP cause 0.106 percent and 0.651 percent variations in RGDP, respectively. While a similar interpretation holds for the LAMC region.

Next, we estimated the IRFs for the entire sample, SSA, MENA and LAMC. The IRFs include their confidence intervals represented by the lower and upper lines on the graphs in Figures 3; the middle lines are the actual response functions, depicting the dynamics of the response of the one variable to shocks of the other variables. The IRFs allow for the time-dependent significance of each response and offer information on the short run dynamics of these impacts. The IRF plots show that a positive shock in composite index of telecommunication leads to: rise in the levels of industrialisation for entire sample, MENA and LAMC; a fall in industrialisation for SSA; decrease in the growth for entire sample, SSA, MENA and LAMC. It is also noteworthy that a shock in industrialisation leads to a small increase in growth for entire sample, SSA, MENA and LAMC. However, these shocks are short-lived, but they can be observed in the entire sample and the three regions. Most shocks have a noticeable influence on one another/the economy only in the first five years, and they are fully absorbed within ten years.

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TABLE 12 - *Variance Decomposition Results*

Entire sample

	Panel A: Variance Decomposition of TELF			Panel B: Variance Decomposition of MGDP:			Panel C: Variance Decomposition of RGDP:		
Period	TELF	MGDP	RGDP	TELF	MGDP	RGDP	TELF	MGDP	RGDP
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	1.0000	0.0000	0.0000	0.0004	0.9996	0.0000	0.0039	0.0281	0.9680
2	0.9949	0.0039	0.0012	0.0003	0.9983	0.0013	0.0115	0.0994	0.8891
3	0.9831	0.0136	0.0032	0.0009	0.9950	0.0041	0.0218	0.1872	0.7910
4	0.9649	0.0296	0.0056	0.0018	0.9903	0.0079	0.0335	0.2739	0.6926
5	0.9411	0.0512	0.0076	0.0029	0.9846	0.0124	0.0458	0.3494	0.6048
6	0.9132	0.0775	0.0093	0.0042	0.9783	0.0175	0.0579	0.4102	0.5319
7	0.8825	0.1071	0.0104	0.0054	0.9718	0.0227	0.0696	0.4564	0.4740
8	0.8505	0.1385	0.0109	0.0065	0.9655	0.0280	0.0807	0.4897	0.4296
9	0.8187	0.1703	0.0110	0.0074	0.9595	0.0331	0.0910	0.5125	0.3964
10	0.7881	0.2011	0.0108	0.0081	0.9541	0.0378	0.1007	0.5270	0.3723

SSA

	Panel D: Variance Decomposition of TELF:			Panel E: Variance Decomposition of MGDP:			Panel F: Variance Decomposition of RGDP:		
Period	TELF	MGDP	RGDP	TELF	MGDP	RGDP	TELF	MGDP	RGDP
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	1.0000	0.0000	0.0000	0.0044	0.9956	0.0000	0.0190	0.0139	0.9670
2	0.9873	0.0110	0.0017	0.0089	0.9890	0.0020	0.0330	0.0909	0.8761
3	0.9659	0.0284	0.0057	0.0145	0.9789	0.0065	0.0497	0.1886	0.7615
4	0.9418	0.0461	0.0120	0.0205	0.9662	0.0133	0.0679	0.2836	0.6485
5	0.9188	0.0609	0.0203	0.0264	0.9516	0.0219	0.0866	0.3645	0.5489
6	0.8979	0.0718	0.0302	0.0321	0.9361	0.0317	0.1054	0.4284	0.4662
7	0.8799	0.0787	0.0414	0.0370	0.9206	0.0423	0.1238	0.4761	0.4000
8	0.8646	0.0820	0.0534	0.0410	0.9058	0.0531	0.1418	0.5099	0.3483
9	0.8514	0.0826	0.0660	0.0441	0.8924	0.0634	0.1591	0.5322	0.3087
10	0.8399	0.0813	0.0788	0.0462	0.8808	0.0729	0.1754	0.5454	0.2791

TABLE 12 - *continued*

MENA

Period	Panel G: Variance Decomposition of TELF:			Panel H: Variance Decomposition of MGDP:			Panel I: Variance Decomposition of RGDP:		
	TELF	MGDP	RGDP	TELF	MGDP	RGDP	TELF	MGDP	RGDP
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	1.0000	0.0000	0.0000	0.0276	0.9724	0.0000	0.0091	0.0310	0.9598
2	0.9861	0.0053	0.0086	0.0354	0.9521	0.0125	0.0225	0.1007	0.8768
3	0.9578	0.0150	0.0272	0.0415	0.9220	0.0365	0.0408	0.2048	0.7545
4	0.9206	0.0261	0.0534	0.0460	0.8869	0.0671	0.0608	0.3257	0.6135
5	0.8793	0.0364	0.0843	0.0490	0.8501	0.1008	0.0788	0.4405	0.4807
6	0.8379	0.0446	0.1175	0.0508	0.8135	0.1357	0.0924	0.5323	0.3753
7	0.7991	0.0500	0.1509	0.0515	0.7782	0.1702	0.1010	0.5953	0.3037
8	0.7644	0.0527	0.1829	0.0515	0.7448	0.2037	0.1053	0.6320	0.2626
9	0.7344	0.0531	0.2124	0.0509	0.7135	0.2357	0.1065	0.6485	0.2450
10	0.7094	0.0520	0.2386	0.0498	0.6845	0.2656	0.1055	0.6508	0.2437

LAMC

Period	Panel J: Variance Decomposition of TELF:			Panel K: Variance Decomposition of MGDP:			Panel L: Variance Decomposition of RGDP:		
	TELF	MGDP	RGDP	TELF	MGDP	RGDP	TELF	MGDP	RGDP
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	1.0000	0.0000	0.0000	0.0047	0.9954	0.0000	0.0502	0.0005	0.9494
2	0.9917	0.0073	0.0010	0.0053	0.9946	0.0000	0.0971	0.0043	0.8986
3	0.9804	0. 0167	0.0029	0.0059	0 .9938	0.0002	0.1492	0.0075	0.8433
4	0. 9694	0. 0254	0.0053	0.0064	0.9932	0.0003	0.2009	0.0085	0.7905
5	0. 9597	0. 0325	0.0078	0.0069	0.9928	0.0004	0.2488	0.0082	0.7430
6	0. .9514	0. 0383	0.0103	0.0072	0.9923	0.0004	0.2906	0.0076	0.7019
7	0. 9446	0. 0428	0.0126	0.0075	0.9920	0.0004	0.3256	0.0072	0.6672
8	0. 9389	0. 0464	0.0147	0.0078	0.9918	0.0004	0.3539	0.0073	0.6387
9	0. 9343	0. 0491	0.0166	0.0081	0.9916	0.0004	0.3764	0.0078	0.6158
10	0. 9306	0. 0512	0.0181	0.0081	0.9914	0.0004	0.3938	0.0086	0.5976

Note: Orthogonalised Cholesky ordering used.

Source: Author's computations.

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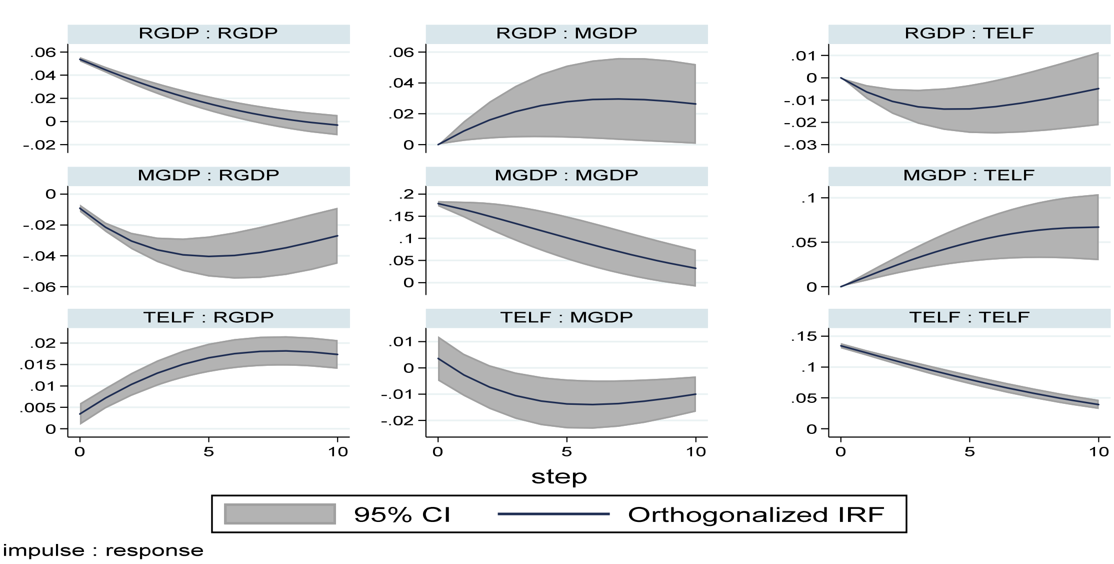
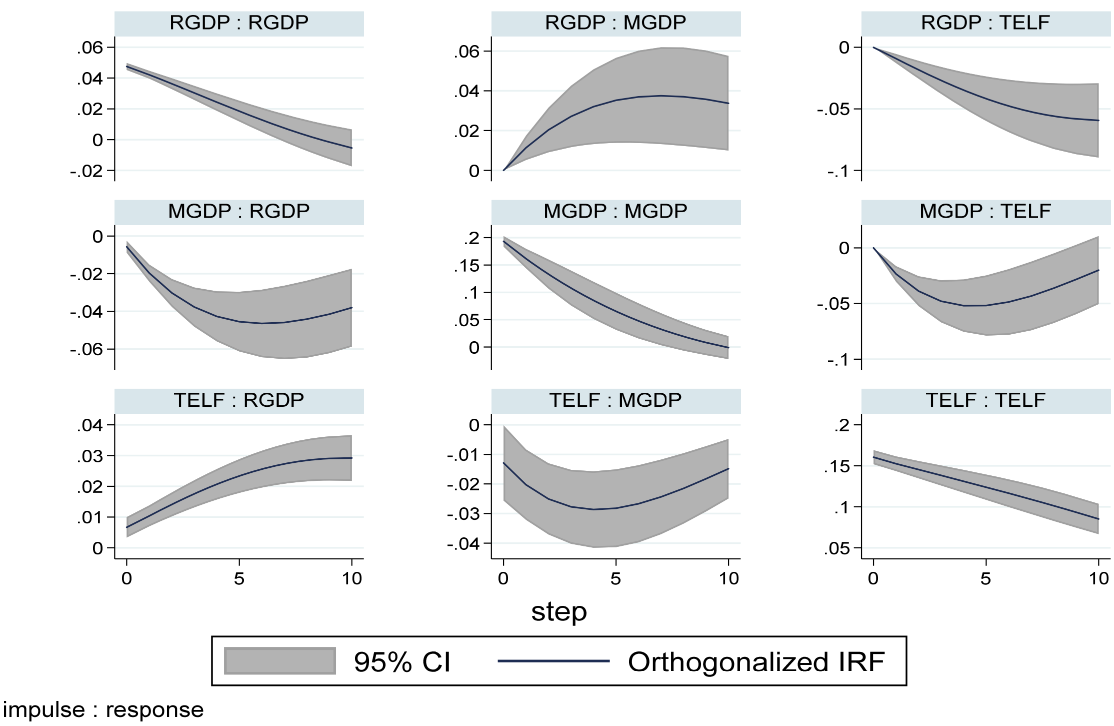
FIGURE 3 - *(H) Full Sample impulse responses; (I) Sub-Saharan Africa impulse responses; (J) Middle East and North Africa impulse responses; (K) Latin America & the Caribbean impulse responses.*

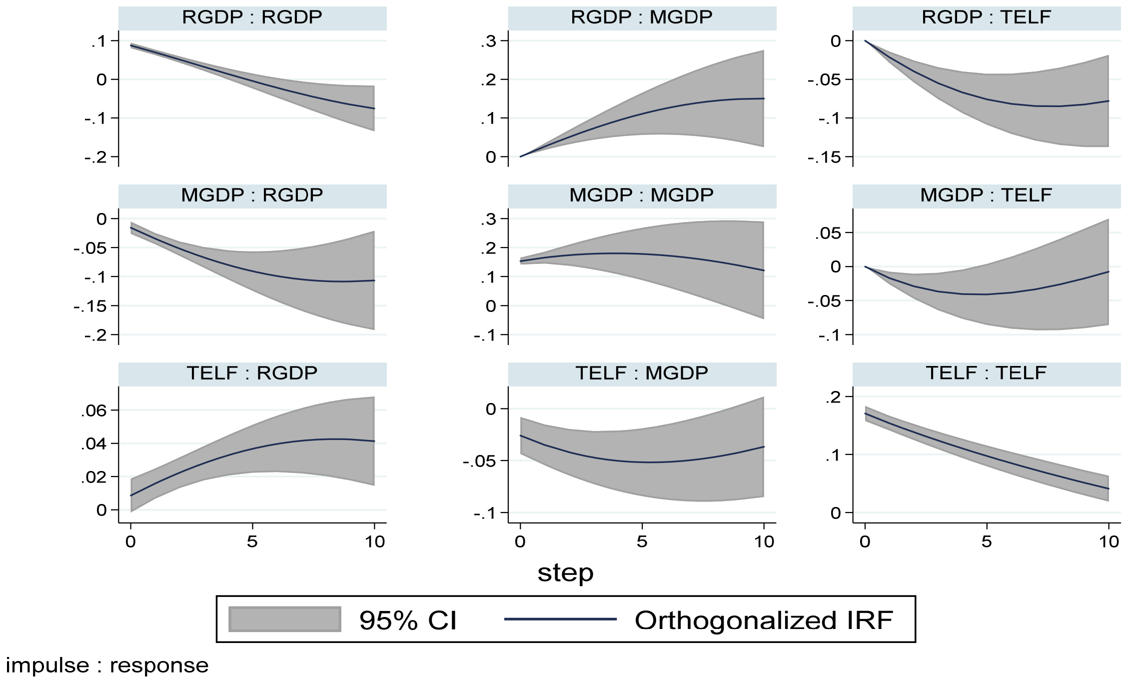
H: Entire sample



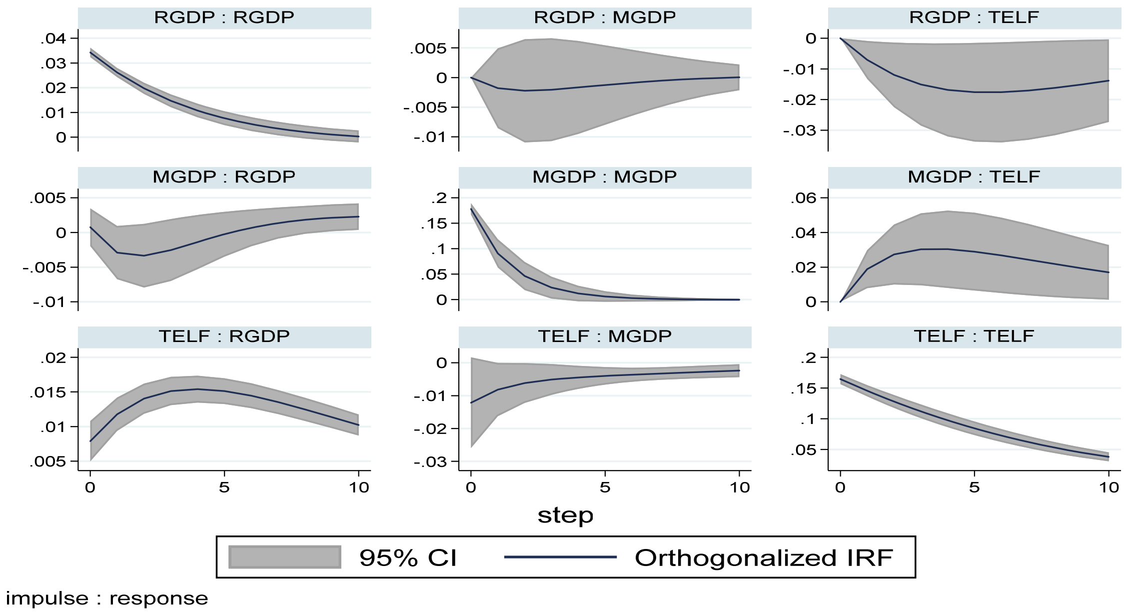
I: Sub-Saharan Africa



J: Middle East and North Africa



K: Latin America & the Caribbean



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6. CONCLUSION AND POLICY RECOMMENDATIONS

This study empirically investigates the nexus between telecommunication infrastructures (TELF), industrialisation (MGDP) and economic growth (RGDP) in a balanced panel of 99 developing countries over the period 2000-2018. These countries were divided into three regions. We focused on this theme because previous researches have mainly paid attention to the relationship between telecommunication infrastructures and economic growth, without finding an innovative measure for telecommunication infrastructures and the dynamic role it might play in promoting industrialisation, and hence, economic growth. Telecommunication infrastructures is measured by a composite index of telecommunication (which comprises of mobile line, fixed line, and internet access penetration) via principal component method. Stationarity, cointegration and causality of the data were examined to gain insight into the degree of relationship that may exist between the three variables. The study used estimation approaches that controlled for endogeneity, cross-section dependence and unobserved heterogeneity problems that may exist in a panel data.

The results from the panel cointegration test suggest a long run equilibrium relationship between the variables. The panel causality test results suggest strong evidence of bidirectional causality between: (i) telecommunication infrastructures and industrialisation; (ii) telecommunication infrastructures and economic growth; and (iii) industrialisation and economic growth in the entire sample, SSA and LAMC. While for MENA, the results reveal strong evidence of unidirectional causality running from: (i) telecommunication infrastructures to industrialisation; (ii) telecommunication infrastructures to economic growth (except for the presence of bidirectional causality between industrialisation and growth). The panel VAR results suggest that: (i) telecommunication infrastructures have a negative and positive impact on industrialisation and growth, respectively; (ii) industrialisation have a negative impact on growth which imply the inability of the former to drive the latter across the regions. The presence of feedback causality results suggest that telecommunication infrastructures, industrialisation and economic growth are interdependent of one another in the entire sample of SSA, MENA and LAMC. The reasons for the interdependence of long run relationships may be due to the mutual reinforcement between telecommunication infrastructures, industrialisation and economic growth, since most of these countries remain underdeveloped. Although factors such as poor infrastructural development, cultural similarity, low economic status, inefficient institutions and high poverty fall outside the scope the study, nonetheless they could have contributed to the interdependence of long run relationships between the variables. These variables are important to the improvement of one another in the long run, as revealed by the panel VAR results.

The policy implications of these results are direct. If policymakers wish to promote long run levels of industrialisation and economic growth, additional attention must be paid to how the regional governments invest and promote the telecommunication sector. From the conclusions, the study first recommends that telecommunication infrastructures, industrialisation and economic growth need overhauling concurrently, since a mutual causality exists between them in the developing regions. With a revamped telecommunication sector, the digital provide for industrialisation attainability and accelerated growth in SSA, MENA and the LAMC regions is possible. Secondly, the empirical results revealed that telecommunication infrastructures are important for industrialisation and economic growth in the regions, therefore all regional governments should enact more policies that will enhance efficient operations of telecommunication sectors/services needed to encourage industrial development and stimulate inclusive economic growth. Thirdly, policies that will enhance the spread of internet access penetration and fixed lines penetration and the affordability of mobile devices should be promoted in the regions, since affordability and accessibility still remain a challenge in the developing regions. Fourthly, due to the degree of backward and forward linkages that telecommunication infrastructures have on their economies, it is recommended that the governments of the regions should formulate, implement, coordinate, monitor, and evaluate telecommunication policies for industrialisation and economic growth aims. There is need to promote inclusive and holistic policies that will enhance the digital provide necessary for industrialisation/industrial development and economic growth concurrently in the developing countries/regions. Telecommunication infrastructures policies should be industrialisation and growth friendly, and also, industrialisation and growth policies should be telecommunication infrastructures friendly, given that a bidirectional causality exists between the variables in the regions.

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REFERENCES

Abrigo, M.R. and I. Love (2016), “Estimation of Panel Vector Autoregression in Stata”, *The Stata Journal*, 16(3), 778-804.

Adams, S. (2009), “Foreign Direct Investment, Domestic Investment, and Economic Growth in Sub-Saharan Africa”, *Journal of Policy Modeling*, 31(6), 939-949.

Adams, S. and E.E.O. Opoku (2015), “Foreign Direct Investment, Regulations and Growth in Sub-Saharan Africa”, *Economic Analysis and Policy*, 47, 48-56.

Akinlo, A.E. (2004), “Foreign Direct Investment and Growth in Nigeria: An Empirical Investigation”, *Journal of Policy Modeling*, 26(5), 627-639.

Arellano, M. and S. Bond (1991), “Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations”, *The Review of Economic Studies*, 58(2), 277-297.

Arellano, M. and O. Bover (1995), “Another Look at the Instrumental Variable Estimation of Error-Components Models”, *Journal of Econometrics*, 68(1), 29-51.

Atesoglu, H.S. (1993), “Manufacturing and Economic Growth in the United States”, *Applied Economics*, 25(1), 67-69.

Banga, K. and D.W. te Velde (2018), “Digitalisation and the Future of Manufacturing in Africa,” London; Available at: <https://odi.org/en/publications/digitalisation-and-the-future-of-manufacturing-in-africa/>, accessed on 07th July 2022.

Bassanini, A. and S. Scarpetta (2001), “The Driving Forces of Economic Growth: Panel Data Evidence for the OECD Countries,” *OECD Economic Studies*, 33(2), 9-56.

Bera, S. (2019), “Club Convergence and Drivers of Digitalization across Indian States”, *Telecommunications Policy*, 43(8), 101822.

Blundell, R. and S. Bond (1998), “Initial Conditions and Moment Restrictions in Dynamic Panel Data Models”, *Journal of Econometrics*, 87(1), 115-143.

Boisvert, R. (1982), “The Translog Production Function: Its Properties, its Several Interpretations and Estimation Problems,” Agricultural Economics Research Report, No. 82-28, Department of Agricultural Economics, Cornell University, New York.

Breitung, J. (2001), *The Local Power of some Unit Root Tests for Panel Data*, in: B.H. Baltagi, T.B. Fomby, R. Carter Hill (Eds), “Nonstationary Panels, Panel Cointegration, and Dynamic Panels” (pp. 161-177) , Emerald Group Publishing Limited: Bingley.

Breitung, J. and S. Das, (2005), "Panel Unit Root Tests under Cross-Sectional Dependence", *Statistica Neerlandica*, 59(4), 414-433.

Brock, G. and V. German-Soto, (2013), "Regional Industrial Growth in Mexico: Do Human Capital and Infrastructure Matter?", *Journal of Policy Modeling*, 35(2), 228-242.

Canova, F. and M. Ciccarelli (2004), "Forecasting and Turning Point Predictions in a Bayesian Panel VAR Model", *Journal of Econometrics*, 120(2), 327-359.

Chakraborty, C. and B. Nandi (2011), "'Mainline' Telecommunications Infrastructure, Levels of Development and Economic Growth: Evidence from a Panel of Developing Countries," *Telecommunications Policy*, 35(5), 441-449.

Chandra, R. (2003), "Industrialization and Development in the Third World", Routledge: London.

Chiemeke, S.C. and O.B. Longe (2007), "Information and Communication Technology Penetration in Nigeria: Prospects, Challenges and Metrics," *Asian Journal of Information Technology*, 6(3), 280-287.

Cronin, F.J., E.B. Parker, E.K. Colleran and M.A. Gold (1991), "Telecommunications Infrastructure and Economic-Growth: An Analysis of Causality", *Telecommunications Policy*, 15(6), 529-535.

David, O.O. (2019), "Nexus between Telecommunication Infrastructures, Economic Growth and Development in Africa: Panel Vector Autoregression (P-VAR) Analysis", *Telecommunications Policy*, 43(8), 101816.

Diao, X., M. McMillan and D. Rodrik (2017), "The Recent Growth Boom in Developing Economies: A Structural Change Perspective", NBER Working Paper No. 23132.

Dumitrescu, E-I. and C. Hurlin (2012), "Testing for Granger Non-Causality in Heterogeneous Panels", *Economic modelling*, 29(4), 1450-1460.

Echaudemaison, C-D. (2003), "Dictionnaire d'économieet de sciences sociales (SES)", 6e ed., Nathan: Paris.

Fafchamps, M., S. El Hamine and A. Zeufack (2008), "Learning to Export: Evidence from Moroccan Manufacturing", *Journal of African Economies*, 17(2), 305-355.

Ferreira, C. (2020), "Globalisation and Economic Growth: A Panel Data Approach", *Economia Internazionale/International Economics*, 73(2), 187-236.

Frees, E.W. (1995), "Assessing Cross-Sectional Correlation in Panel Data", *Journal of Econometrics*, 69(2), 393-414.

 © 2022. Camera di Commercio di Genova

Friedman, M. (1937), "The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance", *Journal of the American Statistical Association*, 32(200), 675-701.

Garbacz, C. and H.G. Thompson Jr. (2007), "Demand for Telecommunication Services in Developing Countries," *Telecommunications Policy*, 31(5), 276-289.

Gómez-Barroso, J.L. and R. Marbán-Flores (2020a), "Telecommunications and Economic Development – The 20th Century: The Building of an Evidence Base", *Telecommunications Policy*, 44(2), 101904.

Gómez-Barroso, J.L. and R. Marbán-Flores (2020b), "Telecommunications and Economic Development – The 21st Century: Making the Evidence Stronger", *Telecommunications Policy*, 44(2), 101905.

Güçlü, M. (2013), "Manufacturing and Regional Economic Growth in Turkey: A Spatial Econometric View of Kaldor's Laws", *European Planning Studies*, 21(6), 854-866.

Gui-Diby, S.L. (2014), "Impact of Foreign Direct Investments on Economic Growth in Africa: Evidence from Three Decades of Panel Data Analyses", *Research in Economics*, 68(3), 248-256.

Gui-Diby, S.L. and M-F. Renard (2015), "Foreign Direct Investment Inflows and the Industrialization of African Countries", *World Development*, 74, 43–57, <https://doi.org/10.1016/j.worlddev.2015.04.005>.

Haftu, G.G. (2019), "Information Communications Technology and Economic Growth in Sub-Saharan Africa: A Panel Data Approach," *Telecommunications Policy*, 43(1), 88-99.

Hamilton, J. (1994), "Time Series Econometrics", Cambridge University Press, Cambridge, UK.

Hansen, J.D. and J. Zhang (1996), "A Kaldorian Approach to Regional Economic Growth in China," *Applied Economics*, 28(6), 679-685.

Haraguchi, N., C.F.C. Cheng and E. Smeets (2017), "The Importance of Manufacturing in Economic Development: Has this Changed?", *World Development*, 93, 293-315.

Hausman, J.A. (1978), "Specification Tests in Econometrics", *Econometrica*, 46(6), 1251-1271.

Holtz-Eakin, D. (1994), "Public-Sector Capital and the Productivity Puzzle," *The Review of Economics and Statistics*, 76(1), 12-21.

Hosein, R,. R. Deonanan and K. Evans (2019), "Foreign Direct Investment, Exports and Economic Growth in SIDS: Evidence from Saint Lucia", *Economia Internazionale/International Economics*, 72(1), 47-76.

Im, K.S., M.H. Pesaran and Y. Shin (2003), "Testing for Unit Roots in Heterogeneous Panels," *Journal of Econometrics*, 115(1), 53-74.

ITU (2016), World Telecommunication/ICT Indicators Database Online, International Telecommunication Union, available at: <https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx>.

ITU (2019), ICT Data for the World, by Geographic Regions and by Level of Development, International Telecommunication Union, available at: <https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ITU_regional_global_Key_ICT_indicator_aggregates_rev1_Jan_2022.xlsx>.

Kaldor, N. (1966), Causes of the Slow Rate of Growth of the United Kingdom, Cambridge University Press: Cambridge, UK.

Kaldor, N. (1967), Strategic Factors in Economic Development, New York State School of Industrial and Labor Relations, Cornell University: Ithaca.

Kaldor, N. (1975), "Economic Growth and the Verdoorn Law – A Comment on Mr Rowthorn's Article", *The Economic Journal*, 85(340), 891-896.

Koop, G., M.H. Pesaran and S.M. Potter (1996), "Impulse Response Analysis in Nonlinear Multivariate Models", *Journal of Econometrics*, 74(1), 119-147.

Koukouritakis, M. (2022), "Environmental Performance and GDP Growth: A Non-linear Approach for the G20 Countries," *Economia Internazionale/International Economics*, 75(1), 101-130.

Koutroumpis, P. (2009), "The Economic Impact of Broadband on Growth: A Simultaneous Approach", *Telecommunications Policy*, 33(9), 471-485.

Lam, P-L. and A. Shiu (2010), "Economic Growth, Telecommunications Development and Productivity Growth of the Telecommunications Sector: Evidence around the World", *Telecommunications Policy*, 34(4), 185-199.

Laniran, T.J. and V.A. Olakunle (2019), "Remittances and Foreign Aid: Substitutes or Complements in the Economic Growth of Developing Countries?", *Economia Internazionale/International Economics*, 72(1), 23-46.

Leibenstein, H. (1957), Economic Backwardness and Economic Growth, Wiley: New York.

Lerner, J. (2010), "The Future of Public Efforts to Boost Entrepreneurship and Venture Capital", *Small Business Economics*, 35(3), 255-264.

 © 2022. Camera di Commercio di Genova

Levin, A., C-F. Lin and C-S. J. Chu (2002), "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties", *Journal of Econometrics*, 108(1), 1-24.

Lucas Jr., R.E. (1988), "On the Mechanics of Economic Development", *Journal of Monetary Economics*, 22(1), 3-42.

Lütkepohl, H. (2005), New Introduction to Multiple Time Series Analysis, Springer: New York.

Madden, G. and S.J. Savage (1998), "CEE Telecommunications Investment and Economic Growth", *Information Economics and Policy*, 10(2), 173-195.

Makeleni, M. and J.P. Sheefeni (2022), "Life Insurance and Economic Growth in South Africa," *Economia Internazionale/International Economics*, 75(2), 213-240.

Maneejuk, P. and W. Yamaka (2020), "An Analysis of the Impacts of Telecommunications Technology and Innovation on Economic Growth", *Telecommunications Policy*, 44(10), 102038.

Marconi, N., C.F. de Borja Reis and E.C. de Araújo (2016), "Manufacturing and Economic Development: The Actuality of Kaldor's First and Second Laws", *Structural Change and Economic Dynamics*, 37, 75-89, <https://doi.org/10.1016/j.strueco.2015.12.002>.

McCausland, W.D. and I. Theodossiou (2012), "Is Manufacturing still the Engine of Growth?", *Journal of Post Keynesian Economics*, 35(1), 79-92.

McMillan, M., D. Rodrik and C. Sepulveda (2017), "Structural Change, Fundamentals and Growth: A Framework and Case Studies", NBER Working Paper No. 23378.

Mijiyawa, A.G. (2017), "Drivers of Structural Transformation: The Case of the Manufacturing Sector in Africa", *World Development*, 99, 141-159. <https://doi.org/10.1016/j.worlddev.2017.07.007>.

Moroney, J.R. (1990), "Energy Consumption, Capital, and Real Output: A Comparison of Market and Planned Economies," *Journal of Comparative Economics*, 14(2), 199-220.

Moroney, J.R. and C.A.K. Lovell (1997), "The Relative Efficiencies of Market and Planned Economies," *Southern Economic Journal*, 63(4), 1084-1093.

Nabe, O. (1983), "Military Expenditures and Industrialisation in Africa", *Journal of Economic Issues*, 17(2), 575-587.

Nadiri, M.I., B. Nandi and K.K. Akoz (2018), "Impact of Modern Communication Infrastructure on Productivity, Production Structure and Factor Demands of US Industries: Impact Revisited", *Telecommunications Policy*, 42(6), 433-451.

Necmi, S. (1999), "Kaldor's Growth Analysis Revisited", *Applied Economics*, 31(5), 653-660.

Nelson, R.R. (1956), "A Theory of the Low-Level Equilibrium Trap in Underdeveloped Economies", *The American Economic Review*, 46(5), 894-908.

Newman, C., J. Page, J. Rand, A. Shimeles, M. Söderbom and F. Tarp (2016), Made in Africa: Learning to Compete in Industry, Brookings Institution Press: Washington, DC.

Noman, A. and J.E. Stiglitz (2015), Industrial Policy and Economic Transformation in Africa, Columbia University Press: New York.

Olabisi, O.E and E. Lau (2018), "Causality Testing between Trade Openness, Foreign Direct Investment and Economic Growth: Fresh Evidence from Sub-Saharan African Countries", *Economia Internazionale/International Economics*, 71(4), 437-464.

Opoku, E.E.O. and I.K.M. Yan (2019), "Industrialization as Driver of Sustainable Economic Growth in Africa", *The Journal of International Trade and Economic Development*, 28(1), 30-56.

Osotimehin, K.O., E.Y. Akinkoye and O.O. Olasanmi (2010), "The Effects of Investment in Telecommunication Infrastructure on Economic Growth in Nigeria (1992-2007)", Oxford Business and Economics Conference Program, St. Hugh's College, Oxford University: Oxford, UK.

Oulton, N. (2002), "ICT and Productivity Growth in the United Kingdom", *Oxford Review of Economic Policy*, 18(3), 363-379.

Page, J. (2011), "Should Africa Industrialize?", UNU-WIDER Working Paper No. 47.

Papaioannou, S.K. and S.P. Dimelis (2007), "Information Technology as a Factor of Economic Development: Evidence from Developed and Developing Countries", *Economics of Innovation and New Technology*, 16(3), 179-194.

Perkins, P., J. Fedderke and J. Luiz (2005), "An Analysis of Economic Infrastructure Investment in South Africa", *South African Journal of Economics*, 73(2), 211-228.

Pesaran, M.H. (2021), "General Diagnostic Tests for Cross-Sectional Dependence in Panels", *Empirical Economics*, 60(1), 13-50, <https://doi.org/10.1007/s00181-020-01875-7>.

Pesaran, M.H. (2007), "A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence", *Journal of Applied Econometrics*, 22(2), 265-312.

Posu, S.M.A. (2006), "Information and Communication Technologies in the Nigerian Economy", International Conference on Human and Economic Resources, Izmir.

 © 2022. Camera di Commercio di Genova

Pradhan, R.P., M.B. Arvin and J.H. Hall (2016), "Economic Growth, Development of Telecommunications Infrastructure, and Financial Development in Asia, 1991-2012," *The Quarterly Review of Economics and Finance*, 59, 25-38.

Pradhan, R.P., M.B. Arvin, N.R. Norman and S.K. Bele (2014), "Economic Growth and the Development of Telecommunications Infrastructure in the G-20 Countries: A Panel-VAR Approach", *Telecommunications Policy*, 38(7), 634-649.

Prakash, A. (2019), "The Role of Industrialisation and ICT in Africa's Growth and Integration into Global Value Chains", Economic Research Institute for ASEAN and East Asia, <http://hdl.handle.net/11540/10871>.

Puig-Junoy, J. (2001), "Technical Inefficiency and Public Capital in U.S. States: A Stochastic Frontier Approach," *Journal of Regional Science*, 41(1), 75-96.

Rodrik, D. (2014), "The Past, Present, and Future of Economic Growth," *Challenge*, 57(3), 5-39.

Roller, L-H. and L. Waverman (2001), "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach," *American Economic Review*, 91(4), 909-923.

Romer, P.M. (1986), "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, 94(5), 1002-1037.

Romer, P.M. (1990), "Endogenous Technological Change", *Journal of Political Economy*, 98(5, Part 2), S71-S102.

Rosenstein-Rodan, P.N. (1943), "Problems of Industrialisation of Eastern and South-Eastern Europe", *The Economic Journal*, 53(210-211), 202-211.

Saba, C.S. (2020a), "Security as an Outcome for Promoting Economic Prosperity in the Regional Economic Communities of Africa: Evidence from a Panel Data Analysis," *African Security Review*, 29(4), 376-400.

Saba, C.S. (2020b), "Convergence or Divergence Patterns in Global Defence Spending: Further Evidence from a Nonlinear Single Factor Model", *Peace Economics, Peace Science and Public Policy*, 27(1), 51-90, <doi:10.1515/peps-2020-0012>.

Saba, C.S. (2021a), "Defence Spending and Economic Growth in South Africa: Evidence from Cointegration and Co-Feature Analysis. Peace Economics", *Peace Science and Public Policy*, 28(1), 51-100, <https://doi.org/10.1515/peps-2021-0017>.

Saba C.S. (2021b), "Convergence and Transition Paths in Transportation: Fresh Insights from a Club Clustering Algorithm", *Transport Policy*, 112, 80-93, <10.1016/j.tranpol.2021.08.008>.

Saba, C.S. and O.O. David (2020), "Convergence Patterns in Global ICT: Fresh Insights from a Club Clustering Algorithm", *Telecommunications Policy*, 44(10), 102010.

Saba, C.S. and O.O. David (2022), "Identifying Convergence in Telecommunication Infrastructures and the Dynamics of their Influencing Factors Across Countries," *Journal of the Knowledge Economy*, 1-54, <https://doi.org/10.1007/s13132-022-00967-2>.

Saba, C.S. and N. Ngepah (2019a), "A Cross-Regional Analysis of Military Expenditure, State Fragility and Economic Growth in Africa", *Quality and Quantity*, 53(6), 2885-2915.

Saba, C.S. and N. Ngepah (2019b), "Military Expenditure and Economic Growth: Evidence from a Heterogeneous Panel of African Countries", *Economic Research-Ekonomska Istraživanja*, 32(1), 3586-3606.

Saba C.S. and N. Ngepah (2020a), "Empirical Analysis of Military Expenditure and Industrialisation Nexus: A Regional Approach for Africa", *International Economic Journal*, 34(1), 58-84.

Saba, C.S. and N. Ngepah (2020b), "Nexus between Defence Spending, Economic Growth and Development: Evidence from a Disaggregated Panel Data Analysis," *Economic Change and Restructuring*, 1-43, <https://doi.org/10.1007/s10644-020-09311-7>.

Saba, C.S. and N. Ngepah (2020c), "Convergence in Military Expenditure and Economic Growth in Africa and its Regional Economic Communities: Evidence from a Club Clustering Algorithm," *Cogent Economics & Finance*, 8(1), 1832344.

Saba, C.S. and N. Ngepah (2021), "ICT Diffusion, Industrialisation and Economic Growth Nexus: An International Cross-Country Analysis," *Journal of the Knowledge Economy*, 1-40, <https://doi.org/10.1007/s13132-021-00795-w>.

Saba, C.S. and N. Ngepah (2022a), "Convergence in Renewable Energy Sources and the Dynamics of their Determinants: An Insight from a Club Clustering Algorithm", *Energy Reports*, 8, 3483-3506.

Saba, C.S. and N. Ngepah (2022b), "Convergence in Renewable Energy Consumption and their Influencing Factors across Regions: Evidence from Convergence Algorithm Approach", *Environmental Science and Pollution Research*, 1-34, <https://doi.org/10.1007/s11356-022-19731-9>.

Saba, C.S. and N. Ngepah (2022c), "Nexus between Telecommunication Infrastructures, Defence and Economic Growth: A Global Evidence", NETNOMICS: Economic Research

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and Electronic Networking, <https://doi.org/10.1007/s11066-022-09151-9> (forthcoming).

Saba, C.S, N. Ngepah and N.M. Odhiambo (2021), "Analysis of Convergence in Transport Infrastructure: A Global Evidence", *European Journal of Transport and Infrastructure Research*, 21(2),137-160.

Sakyi, D., R. Commodore and E.E.O. Opoku (2015), "Foreign Direct Investment, Trade Openness and Economic Growth in Ghana: An Empirical Investigation," *Journal of African Business*, 16(1-2), 1-15.

Shahbaz, M. (2012), "Does Trade Openness Affect Long Run Growth? Cointegration, Causality and Forecast Error Variance Decomposition Tests for Pakistan," *Economic Modelling*, 29(6), 2325-2339.

Sharma, S.C., K. Sylwester and H. Margono (2007), "Decomposition of Total Factor Productivity Growth in US States", *The Quarterly Review of Economics and Finance*, 47(2), 215-241.

Shiu, A. and P-L. Lam (2008), "Causal Relationship between Telecommunications and Economic Growth in China and its Regions," *Regional Studies*, 42(5), 705-718.

Sims, C.A. (1980), "Macroeconomics and Reality", *Econometrica*, 48(1), 1-48.

Söderbom, M., F. Teal and A. Harding (2006), "The Determinants of Survival among African Manufacturing Firms", *Economic Development and Cultural Change*, 54(3), 533-555.

Szirmai, A. and B. Verspagen (2015), "Manufacturing and Economic Growth in Developing Countries, 1950–2005", *Structural Change and Economic Dynamics*, 34, 46-59.

Thirlwall, A.P. and P. Pacheco-López (2017), Economics of Development: Theory and Evidence, 10th ed., Red Globe Press: London.

Thompson, H.G. and C. Garbacz (2011), "Economic Impacts of Mobile versus Fixed Broadband," *Telecommunications Policy*, 35(11), 999-1009.

UNIDO (2013), Industrial Development Report 2013. Sustaining Employment Growth: The Role of Manufacturing and Structural Change, United Nations Industrial Development Organisation: Vienna.

UNIDO (2019), G20 Initiative on "Supporting Industrialization in Africa and LDCs", Review of Progress, United Nations Industrial Development Organization, Available at: <https://www.unido.org/sites/default/files/files/2019-11/The_G20_Initiative_on_Supporting_Industrialization_in_Africa_and_LDCs.pdf>, accessed on 07th July 2022.

Vu, K., P. Hanafizadeh and E. Bohlin (2020), "ICT as a Driver of Economic Growth: A Survey of the Literature and Directions for Future Research", *Telecommunications Policy*, 44(2), 101922.

Ward, M.R. and S. Zheng (2016), "Mobile Telecommunications Service and Economic Growth: Evidence from China", *Telecommunications Policy*, 40(2-3), 89-101.

Wells, H. and A.P. Thirlwall (2003), "Testing Kaldor's Growth Laws across the Countries of Africa", *African Development Review*, 15(2-3), 89-105.

Westerlund, J. (2007), "Testing for Error Correction in Panel Data", *Oxford Bulletin of Economics and Statistics*, 69(6), 709-748.

Wiafe, E.A. and L. Anning (2021), "Effects of SINO FDI on the Growth of Sub-Saharan Africa", *Economia Internazionale/International Economics*, 74(1), 1-24.

Wong, K-Y. and C.K. Yip (1999), "Industrialization, Economic Growth, and International Trade", *Review of International Economics*, 7(3), 522-540.

Yang, S.C. and L. Olfman (2006), "The Effects of International Telecommunication Investment: Wireline and Wireless Technologies, 1993-1998", *Telecommunications Policy*, 30(5-6), 278-296.

Yousefi, A. (2011), "The Impact of Information and Communication Technology on Economic Growth: Evidence from Developed and Developing Countries", *Economics of Innovation and New Technology*, 20(6), 581-596.

Zahonogo, P. (2016), "Trade and Economic Growth in Developing Countries: Evidence from Sub-Saharan Africa," *Journal of African Trade*, 3(1-2), 41-56.

Zhao, J. and J. Tang (2018), "Industrial Structure Change and Economic Growth: A China-Russia Comparison", *China Economic Review*, 47, 219-233, <https://doi.org/10.1016/j.chieco.2017.08.008>.

Zhou, Q., P. Gao and A. Chimhowu (2019), "ICTs in the Transformation of Rural Enterprises in China: A Multilayer Perspective", *Technological Forecasting and Social Change*, 145, 12-23.

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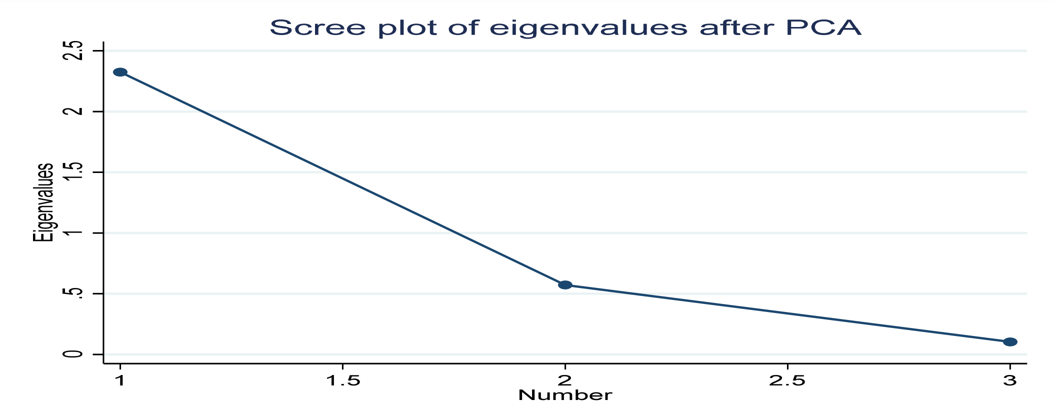
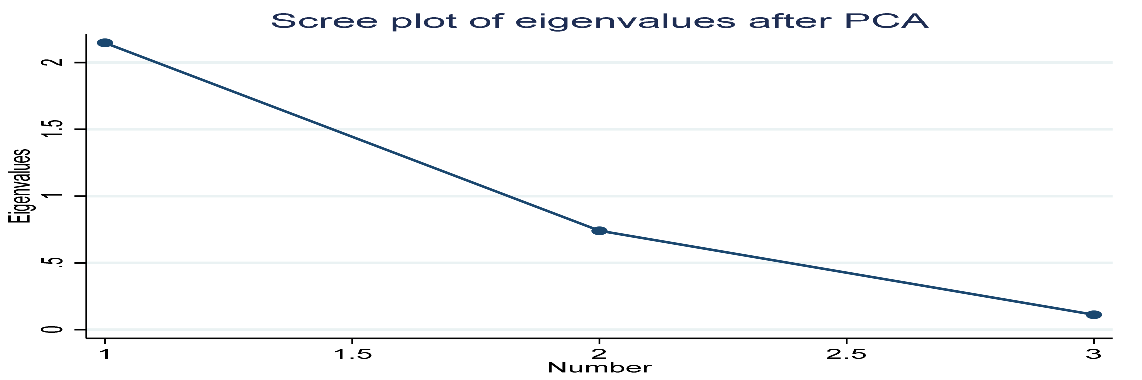
APPENDIX

FIGURE 4 - ***(L)*** *Entire Sample scree plot;* ***(M)*** *Sub-Saharan Africa (SSA) scree plot;* ***(N)*** *Middle East and North Africa (MENA) scree plot;* ***(O)*** *Latin America & the Caribbean (LAMC) scree plot*

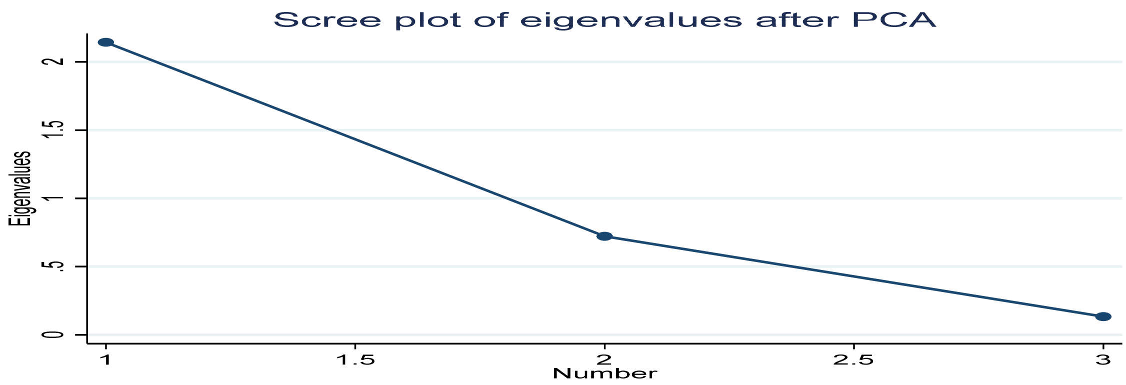
L: Entire Sample



M: Sub-Saharan Africa



N: Middle East and North Africa



O: Latin America & the Caribbean

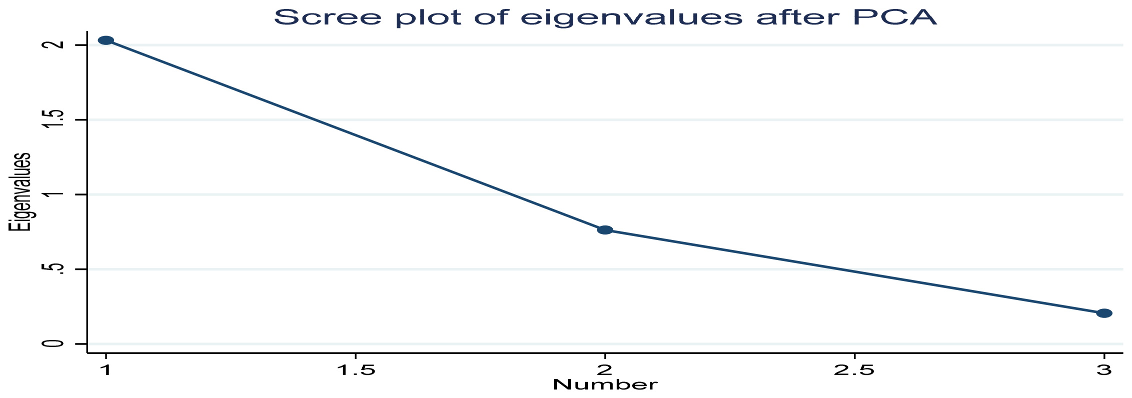


TABLE 13 - *Correlation Matrix Results*

Panel (A): Entire Sample			
Variables	Fixed-telephone	Mobile-telephone	Internet access
Fixed-telephone	1.0000		
Mobile-telephone	0.4510*** (0.0000)	1.0000	
Internet access	0.6568*** (0.0000)	0.8575*** (0.0000)	1.0000
Panel (B): SSA			
Fixed-telephone	1.0000		
Mobile-telephone	0.3306*** (0.0000)	1.0000	
Internet access	0.4564*** (0.0000)	0.8770*** (0.0000)	1.0000
Panel (C): MENA			
Fixed-telephone	1.0000		
Mobile-telephone	0.3573*** (0.0000)	1.0000	
Internet access	0.4476*** (0.0000)	0.8604*** (0.0000)	1.0000
Panel (D): LAMC			
Fixed-telephone	1.0000		
Mobile-telephone	0.2864*** (0.0000)	1.0000	
Internet access	0.4382*** (0.0000)	0.7761*** (0.0000)	1.0000

Note: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$, p-value in parentheses.
Source: Author's computations.

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TABLE 14 - Optimum Lag Length Selection Results

Variables: telecommunication infrastructures, Industrialisation and Growth			
Entire Sample			
Lag	**AIC**	**SIC**	**HQIC**
0	9.571	9.582	9.575
1	-4.695	-4.649	-4.678
2	-4.780	-4.700	-4.750
3	-4.821	-4.708*	-4.778*
4	-4.822*	-4.675	-4.767
5	-4.822	-4.640	-4.754
Sub-Saharan Africa			
0	9.110	9.131	9.118
1	-4.714	-4.629	-4.681
2	-4.866	-4.718*	-4.809*
3	-4.880*	-4.668	-4.798
4	-4.868	-4.592	-4.761
5	-4.857	-4.518	-4.725
Middle East & North Africa			
0	7.719	7.761	7.736
1	-4.503	-4.335*	-4.435
2	-4.578	-4.284	-4.460
3	-4.668*	-4.248	-4.499*
4	-4.633	-4.087	-4.413
5	-4.650	-3.978	-4.380
Latin America & the Caribbean			
0	8.970	8.995	8.980
1	-5.073	-4.973	-5.034
2	-5.367	-5.191*	-5.298*
3	-5.392*	-5.141	-5.293
4	-5.380	-5.053	-5.252
5	-5.355	-4.953	-5.197

Note: * indicates lag order selected by the criterion. AIC is Akaike information criterion; SIC is Schwarz information criterion;Hannan-Quinn information criterion.