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Does ICT Adoption Moderate the Impact of Entrepreneurship on Economic Growth in Africa?

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Abstract: Many African countries continue to face economic challenges even though the continent has much potential for economic progress. Entrepreneurship and ICT are one of the key forces behind economic change. However, little is known about how entrepreneurship, ICT, and economic growth affect economic resilience and development in Africa at the international level. Designing policies supporting a more resilient and inclusive African economy requires understanding this. This study, therefore, contributes to the existing literature by examining the direct and indirect impacts of entrepreneurship and ICT on economic growth in Africa. The study employs static and dynamic panel analyses to analyze panel data on 29 African countries from 2006 to 2020. The empirical results reveal that entrepreneurship positively influences economic growth in the long-run, but has a negative influence in the short-run, while ICT positively influences economic growth both in the short- and long-run. The moderating effects of ICT on the relationship between entrepreneurship and economic growth reveals that ICT positively strengthens the positive impact of entrepreneurship in Africa both in the short- and long-run. Furthermore, the causality results show that there is bidirectional among economic growth, entrepreneurship, and ICT adoption. Consistent with these findings, policy ramifications are highlighted.

Keywords: Africa; economic growth; entrepreneurship; ICT; panel analysis

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1. Introduction

A major concern in both economic study and economic policymaking is economic growth. Africa has a reliance on traditional sectors, insufficient economic diversification, and consistently high unemployment rates. As a result, interest in economic growth is particularly developing quickly. Africa's real GDP growth has slowed due to the difficult climate, falling from 4.1 percent in 2022 to 3.1 percent in 2023. Population increases have not been sufficiently offset by historical growth rates, resulting in negligible increases in per capita GDP. With nations mostly dependent on conventional low-productivity industries like agriculture or low-skilled services for employment and growth, structural change has been minimal (African Development Bank, 2024). More than 40% of the world's young will be African by 2030, and by 2050, there will be 830 million African young people. Given the potential for young people in the workforce to unleash a demographic dividend that positively improves millions of lives, this growing trend is encouraging. About one in four young people in African economies are unemployed, enrolled in school, or undergoing training. Regretfully, the continent's youth bulge may not propel the anticipated economic growth and wealth creation (International Labor Organization, 2023). Up to 12 million

young people in Africa join the workforce each year, but there are only 3.1 million open positions. As a result, 1.7 million new jobs must be produced each month to meet the demand for employment (Brookings, 2024).

To generate their own revenue and job possibilities, African youths have increasingly resorted to entrepreneurship due to declining public sector opportunities and restricted private sector opportunities during the previous few decades. In addition to becoming more mobile, young people are pursuing careers in fields including technology, music and entertainment, agribusiness, fashion, and renewable energy. With over one in five Africans of working age launching a new company and over three-quarters of young people intending to do so within five years, Africa has the highest rates of entrepreneurship in the world (Winstead & Wells, 2022).

Unlocking the entrepreneurial potential of Africa is no easy feat. Institutions that provide development finance are essential to guaranteeing the success of business endeavors. This goal is actively pursued by several initiatives. For instance, the "Boost Africa" Initiative was introduced in 2019 by the African Development Bank (AfDB) in collaboration with the European Commission and the European Investment Bank (EIB) to encourage youth innovation and entrepreneurship, focusing on start-ups and entrepreneurs. The program aims to enable young Africans to start creative enterprises that can compete locally and internationally. It also seeks to attract foreign and domestic investment while supporting economic growth and job creation. To promote entrepreneurship, a more robust private sector, and the expansion of small- and medium-sized enterprises throughout Africa, the International Finance Corporation (IFC) also established the "Alliance for Entrepreneurship in Africa" in collaboration with African and European partners. Additionally, the IFC started the "She Wins Africa" campaign in early 2023 to assist female entrepreneurs in sub-Saharan Africa. Apart from educating female entrepreneurs, "She Wins Africa" will teach funds, accelerators, and venture capital investors in gender-smart investing to speed up investments in start-ups run by women (Zacharenkova, 2024).

The problem is that self-employment in the informal sector, which is categorized as "vulnerable employment", makes up the majority of entrepreneurship in Africa. Compared to fewer than 50% in the Americas, Europe, and Asia, 95% of working youth in Africa fit this description (International Labor Organization, 2022). The indicators of vulnerable employment include low productivity, low pay, and challenging working conditions. Whether in the formal or informal sector, entrepreneurship in Africa is frequently beset by issues. These include limited access to funding, high operating costs brought on by inadequate infrastructure, unfavorable macroeconomic conditions, and anti-business government policies (Brookings, 2024).

African youth continue to have a strong entrepreneurial spirit. Consequently, entrepreneurship is seen as the answer to Africa's job crisis, despite the numerous obstacles of starting a business on the continent. The African Development Bank (2021) asserts that initiatives to improve Africa's economic prospects must center on entrepreneurship. Changes brought about by the COVID-19 pandemic present opportunities to improve resilience and boost economic expansion. The continent is at a turning point, as its economy is starting to recover from the crisis. Several tendencies are starting to emerge that have the potential to lead to more equitable economic growth. The robust endurance of African economies is demonstrated by the growth rate, which is predicted to rise to 3.7 percent in 2024 and 4.3 percent in 2025.

Africa will continue to expand at the second-fastest rate in the world due to these outturns, with 40 nations expected to reach growth rates higher than those of 2023 (African Development Bank, 2024). The growing impact of digital technologies, which open up new avenues for cross-sector innovation, contributes to this. Some young entrepreneurs use

digital platforms and social media to reach larger consumers. This has been made possible domestically and globally by improvements in information availability and technological advancements. It is commonly known that Africa is ahead of the curve in mini-grids and mobile money. There is a lot of exciting potential for venture capital investors in Africa because of the development of electric vehicles, satellite internet, and artificial intelligence (Brookings, 2024).

Empirical evidence from previous studies has shown that entrepreneurship positively impacts economic growth, particularly in industrial and transition economies (Adusei, 2016; Carree & Thurik, 2010; David et al., 2015; Makwara et al., 2024; Matenda et al., 2023; Urban & Mgwenya, 2024; Yu & Sekiguchi, 2024). However, studies like Huang and Chen (2021) have refuted this. Others have also considered the role of governance in the entrepreneurship-economic growth nexus (Ajide & Dada, 2023; Awwad, 2024; Raimi et al., 2024), but none of these studies have considered how ICT influences entrepreneurship to improve economic growth, particularly in Africa. A curious look at the extant literature reveals that the question of whether ICT influences entrepreneurship to stimulate economic growth seems to have been largely neglected. Does ICT matter in influencing entrepreneurship to stimulate economic growth in Africa? This question stems from the fact that productive or opportunity entrepreneurship in Africa has been an issue of debate, especially in the era of digitalization. ICT and entrepreneurship are commonly recognized as key forces behind economic change, providing avenues for productivity increases, employment creation, and innovation. However, little is known about how ICT, entrepreneurship, and economic growth interact in Africa, and even less is known about how these elements work together to affect economic growth and resilience. Designing policies supporting a more resilient and inclusive African economy requires an understanding of how ICT integration and entrepreneurial activity affect GDP growth, job creation, and income distribution.

In light of this, this study contributes to the existing literature in several ways. Among them is the empirical exploration of the moderating role of ICT in entrepreneurship and economic growth nexus by employing different indicators of ICT. The reason is that ICT influences entrepreneurship in Africa by enhancing efficiency, market access, and innovation, which collectively stimulate economic growth. Digital technologies, like mobile networks and internet connectivity, enable entrepreneurs to reach wider customer bases, streamline operations, and reduce costs through tools like e-commerce platforms and cloud-based solutions. ICT can also foster innovation by providing access to global knowledge and facilitating the development of new products and services tailored to local needs. Additionally, digital financial technologies, such as mobile money and fintech solutions, improve access to capital, empowering small businesses and startups to scale. These advancements not only increase productivity and competitiveness but also create jobs and promote inclusivity, thereby driving sustainable economic growth across the continent. This study provides comprehensive insights into how ICT adoption enhances entrepreneurial activities, particularly in the African context. This addresses gaps in the literature on technology-driven economic growth in developing regions.

In addition, research at the national level on entrepreneurship and economic growth can still be critiqued, as it is almost exclusively focused on developed and emerging economies. There have also been divergent reports on the actual impact of entrepreneurship on economic growth. Thus, there is a need for further investigations on the actual impact of entrepreneurship on economic progress in the era of digitalization, especially in Africa. Also, this study employs both static (panel-corrected standard error) and dynamic (system GMM) approaches. These provide robust empirical evidence on the causal relationship between ICT adoption and entrepreneurship in driving economic growth in Africa. This addresses endogeneity issues often overlooked in previous studies. Similarly, the direction

of causation among the panel series is also examined using Dumitrescu and Hurlin's (2012) panel causality test, which addresses the problems of cross-sectional dependency and slope heterogeneity across cross-sections. This is crucial for prescribing policies. Finally, this research emphasizes Africa's unique economic and technological landscape. Unlike generalized studies, it provides findings that reflect the continent's challenges and opportunities in leveraging ICT for entrepreneurship.

The remainder of this study includes Section 2, which presents a literature review. Section 3 provides the data and methodology of this study. Section 4 provides the results and a discussion of the empirical results. In Section 5, we present a conclusion of the study and suggest recommendations.

2. Review of the Related Literature

Theoretically, many academics have put up a variety of ideas regarding economic growth, the most well-known of which are endogenous growth and Neoclassical growth theories. These theories all clarify the functional link between inputs and output. Neoclassical growth theory focuses exclusively on how capital and labor contribute to economic growth. The endogenous growth model, on the other hand, gives more weight to the size of the capital stock, the human capital stock, and the technical advancement brought about by investment. This suggests that the position of an active entrepreneur is not explicitly accommodated by the Neoclassicals. In the meantime, fresh theoretical insights into entrepreneurship might be provided by the endogenous growth theory (Wennekers & Thurik, 1999). The rationale is that many endogenous growth models imply that profit-seeking, purposeful knowledge investment determines the long-term growth process (Grossman & Helpman, 1994). Since the results of the investments are unpredictable, the practice of redistributing resources in an attempt to develop technology to make money might be considered entrepreneurial. The problem of entrepreneurship as a catalyst for economic and technical advancement is rarely specifically addressed by endogenous growth models (Carree & Thurik, 2010).

2.1. Studies on Entrepreneurship and Economic Growth

Incorporating entrepreneurship into growth models has been attempted. In his groundbreaking research, Schumpeter (1912) examines the connection between economic growth and entrepreneurship. He concludes that entrepreneurship promotes economic growth by converting innovative ideas into new goods and services that generate employment and gross fixed-capital formation. This conclusion is supported by Porter's (1990) assertion that entrepreneurship is "at the heart of national advantage". It is quite important for implementing innovations. There have been a lot of recent discussions about the role that entrepreneurship plays in promoting economic progress. Economic growth depends on the entrepreneur's ability to implement ideas and foster competition. Economic growth is positively impacted by both the female workplace and entrepreneurship indicators (Chikh-Amnache & Mekhzoumi, 2023). The conclusion that entrepreneurship significantly and favorably affects economic growth in BRICS economies was supported by Tahir and Burki (2023). Economic growth is positively correlated with innovative entrepreneurship (Ordeñana et al., 2024). Gulvira et al. (2024) added that the emergence of women's entrepreneurship indicates unrealized potential for progress and wealth in many nations. Thus, since there is evidence of a positive relationship between entrepreneurship and economic growth, our first hypothesis is stated as follows:

H_1: *Entrepreneurship positively influences economic growth in Africa.*

2.2. Studies on ICT and Economic Growth

The effect of ICT on economic growth at the national, regional, and international levels has also been the subject of numerous studies. Looking into the dynamics of digital provision, public welfare, and poverty management in Nigeria, Noah and David (2013) concluded that the digital divide in Nigeria contributes to the prevalence of poverty by creating a large income gap. It was also reported to improve economic growth and raise living standards. This is also supported by David (2013), who found that real investments in telecommunications, labor, capital stock, and energy supply were statistically significant factors in Nigeria's short-term economic growth. In a study conducted by Adeleye and Eboagu (2019), it was reported that there is a positive correlation between economic growth and ICT development. The performance of ICT, economic growth, and development in Africa are examined by David and Grobler (2020). The findings demonstrated that ICT penetration had a positive effect on economic growth and development and that mobile telecommunication was expanding more quickly than other indicators. Awad and Albaity (2022) also investigated the transmission channels through which ICT contributes to economic growth in Sub-Saharan Africa (SSA). Their findings also support the positive relationship between ICT and economic growth in SSA. This is further supported by David (2024), who assesses the causal relationship between ICT and economic growth in the Southern African Development Community (SADC). ICT diffusion is statistically significant for economic growth, and the DH causality test shows that economic growth and ICT dissemination interact. Considering the positive relationship between economic growth and ICT adoption, our second hypothesis can therefore be stated as follows:

H_2: *ICT adoption and its components positively influence economic growth in Africa.*

2.3. Studies on ICT and Entrepreneurship

Other studies have looked more closely at the connection between ICT and entrepreneurship in addition to those on economic growth and ICT. For example, in the framework of the open innovation dynamic, Gomes and Lopes (2022) investigate the direct impact of ICTs on entrepreneurial activity in OECD nations. They concluded that high ICT levels positively impacted new businesses in OECD nations. With a focus on countries' absorption capacities, Afawubo and Noglo (2022) examined the effect of ICT on overall entrepreneurial activity in developing, emerging, and developed countries. Their findings reveal that entrepreneurship and ICT capital services are positively correlated. Barnett et al. (2019) also supported this by evaluating the effects of ICT use on the likelihood of transitioning to entrepreneurship in rural China. Mkize and David (2021) confirmed that efficient use of ICT is vital for penetrating new target markets. They stated that ICTs are essential for the operations of SMEs and crucial for the survival and growth of economies in general. Entrepreneurship and ICT use are positively correlated and causally related. Sun et al. (2024) used data from the China Family Panel Studies from 2010 to 2020 to investigate how the Internet may help close the gender gap in entrepreneurship. They reported that Internet use is linked to a smaller gender gap in entrepreneurship.

Following the above empirical evidence, the relationships among **ICT adoption**, **entrepreneurship**, and **economic growth** are strongly interlinked through direct and indirect channels. **ICT adoption** catalyzes **entrepreneurship** by providing tools, platforms, and information to foster innovation and reduce barriers to entry for new businesses (Gomes & Lopes, 2022). ICT gives entrepreneurs access to effective communication tools, real-time market data, and affordable ways to reach wider audiences. This encourages entrepreneurship, especially in banking, e-commerce, and tech-driven enterprises. By boosting productivity, encouraging competition, and creating jobs, entrepreneurship, in turn, propels economic growth. Entrepreneurs increase productivity and resource allocation by

bringing innovative products, services, and procedures to the market (Chikh-Amnache & Mekhzoumi, 2023; Ordeñana et al., 2024). Furthermore, by facilitating automation, lowering transaction costs, and boosting productivity through digital tools, ICT adoption may increase the contributions of entrepreneurship to economic growth. Because of greater innovation, better business operations, and easier access to international markets, nations that incorporate ICT into their entrepreneurial ecosystems typically see faster economic development.

Additionally, by enhancing infrastructure, allowing for knowledge exchange, and encouraging a digitally savvy workforce, ICT adoption can directly affect economic growth (Noah & David, 2013; David & Grobler, 2020; David, 2024). Since expanding economies can devote more resources to research and development, education, and technology infrastructure, economic expansion also encourages the adoption of ICT (Noah, 2021; Noah & David, 2024; David, 2024). Adoption of ICT encourages entrepreneurship, which in turn spurs economic growth, and reinvests in ICT, creating a positive feedback cycle. Therefore, there is a cyclical and reciprocal relationship between ICT use, entrepreneurship, and economic growth. The adoption of ICT stimulates entrepreneurs, resulting in creative solutions and economic growth, which also speeds up ICT investments and technological breakthroughs. The third and fourth hypotheses of this study can therefore be stated as follows:

H_3: *ICT adoption positively strengthening the influences of entrepreneurship on economic growth in Africa.*

H_4: *There is a causal relationship between ICT adoption, entrepreneurship, and economic growth in Africa.*

Given the documented evidence on the individual impact of entrepreneurship and ICT on economic growth, as well as the link between entrepreneurship and ICT, there is an observed lacuna in the literature, which, to the best of our knowledge, has not been addressed: Does ICT adoption enhance or distort the impact of entrepreneurship on economic growth? This investigation becomes relevant in understanding the overall effect of entrepreneurship on economic growth. With ICT innovations sprouting across the globe, entrepreneurship activities are now facilitated from several hi-tech channels, making it easy to initiate and execute business activities within and across borders within the comforts of homes and offices. ICT's moderating effects on entrepreneurship's influence on economic growth lie in its ability to enhance the efficiency, innovation, and scalability of entrepreneurial activities. ICT facilitates access to markets, financial resources, and networks, enabling entrepreneurs to overcome traditional barriers such as limited infrastructure and geographic constraints. By streamlining business processes and fostering digital innovation, ICT allows for startups and small businesses to become more competitive and productive. It also reduces the risk of failure through data-driven decision-making and access to real-time information. In this way, ICT strengthens the positive impact of entrepreneurship on economic growth, creating a more robust and inclusive economic environment while reducing the short-term inefficiencies often associated with entrepreneurial ventures.

3. Materials and Methods

The Solow–Swan type of the Neoclassical growth model serves as the theoretical foundation for this investigation. Because of its popularity, this option is frequently found in the empirical literature. The economic growth relationship is established based on an aggregate production function, which can be represented as follows:

$$Y = Af(L.K) \quad (1)$$

where Y = output, K = capital, L = labor and A = total factor productivity (TFP). From Equation (1), output change can be derived as follows:

$$\Delta Y = \frac{\partial Y}{\partial L}.\Delta L + \frac{\partial Y}{\partial K}\Delta K + \frac{\partial A}{\partial A}.F(L,K) \tag{2}$$

$$\text{where : } \frac{\partial Y}{\partial L} = MPL, \frac{\partial Y}{\partial K} = MPK$$

and the MPL and MPK, in turn, represent the Marginal Productivity of Labor and Marginal Productivity of Capital, respectively. Thus, Equation (2) can be rewritten as follows:

$$\Delta Y = MPL.\Delta L + MPK.\Delta K + F(L,K).\frac{\Delta A}{A} \tag{3}$$

Dividing Equation (3) through Y yields:

$$\frac{\Delta Y}{Y} = \left(\frac{MPL}{Y}\right).\Delta L + \left(\frac{MPK}{Y}\right).\Delta K + \frac{\Delta A}{A} \tag{4}$$

Multiplying and dividing the first term on the right side of Equation (4) by L and the second term by K yield:

$$\frac{\Delta Y}{Y} = \left(\frac{MPL}{Y}.L\right).\Delta L + \left(\frac{MPK}{Y}.K\right).\Delta K + \frac{\Delta A}{A} \tag{5}$$

where in a perfectly competitive condition (as a result of which factor inputs are rewarded with their respective marginal products), $\frac{MPL}{Y}.L$ is the share of labor in total output, while $\frac{MPK}{Y}.K$ is the share of capital in total output. Let the share of labor be denoted as $1-\alpha$ and the share capital as α (so that the total output is exactly exhausted by the shares of labor and capital). Then, Equation (5) can be re-written as follows:

$$\frac{\Delta Y}{Y} = (1-\alpha)\frac{\Delta L}{L} + \alpha\frac{\Delta K}{K} + \frac{\Delta A}{A} \tag{6}$$

Equation (6) states that economic growth equals the labor share multiplied by labor growth plus capital share multiplied by capital growth plus total factor productivity growth.

To determine the effect of entrepreneurship on growth, the Neoclassical growth equation adopted in this study is extended through 'A' (level of technology—ICT), which can be construed broadly as embodying productivity and efficiency in all their ramifications. Following the above discussion, the linear productivity growth model can be specified as follows:

$$\left(\frac{\Delta Y}{Y}\right)_{it} = \phi_0 + \phi_1\left(\frac{\Delta L}{L}\right)_{it} + \phi_2\left(\frac{\Delta K}{K}\right)_{it} + \phi_3 EPP_{it} + \phi_4 ICT_{it} + \phi_5 X_{it} + \mu_{it} \tag{7}$$

where $\left(\frac{\Delta Y}{Y}\right)_{it}$ = economic growth, $\left(\frac{\Delta L}{L}\right)_{it}$ = labor force growth, $\left(\frac{\Delta K}{K}\right)_{it}$ = growth of capital stock, EPP = Entrepreneurship, ICT = Information and communication technology, X = Other control variables (financial development, inflation rate, trade openness, population growth, and governance). For notational convenience and measurement of variables, henceforth, the economic growth, labor force growth, and capital stock growth are replaced by the GDP per capita (GDP), labor force participation rate (LFP), and gross fixed capital formation (GFC). With these modifications, the above Equation (7) can be rewritten to examine whether entrepreneurship impact is influenced or hampered by ICT adoption. The ICT–entrepreneurship nexus is represented by the interaction of entrepreneurship with ICT and its components. The model is represented as follows:

$$GDP_{it} = \phi_0 + \phi_1 LFP_{it} + \phi_2 GFC_{it} + \phi_3 EPP_{it} + \phi_4 ICT_{it} + \phi_5 EPP * ICT_{it} + \phi_6 X_{it} + \mu_{it} \quad (8)$$

where *EPP*∗*ICT* is the interacting term between entrepreneurship and ICT adoption, and all other variables remain as defined. Equation (8) represents the empirical growth model to be specified for estimation to achieve the objectives of this study. Based on the theories and related empirical studies, all the coefficients of the variables are expected to be positive except the inflation rate. Also note that the signs of the coefficients of the interaction terms evaluate if the ICT adoption and its components (mobile phones, fixed telephones, and internet access) on entrepreneurship enhances or distorts the impact of entrepreneurship on economic growth. ICT improves entrepreneurship performance on economic growth if the sign is positive and vice versa. Given ICT, the overall impact of entrepreneurship on economic growth is generated as follows:

$$\frac{\partial GDP}{\partial EPP} = \phi_3 + \phi_5 ICT \quad (9)$$

Consequently, if $\phi_5 > 0$, it suggests that ICT boosts entrepreneurship effects on economic growth. However, the overall effects of entrepreneurship on economic growth are contingent upon the degree of the negative if $\phi_5 < 0$. ICT adoption skews the relationship between entrepreneurship and economic growth if the negative sign of ϕ_5 is greater than the positive sign of ϕ_3. Conversely, if the negative sign of ϕ_3 is smaller than the positive sign of ϕ_1, this suggests that the positive impact of entrepreneurship on economic growth cannot be fully impeded by the distortionary effects of ICT. Lastly, if $\phi_3 = 0$, it means that there is no discernible effect of the relationship between ICT use and entrepreneurship on economic growth.

3.1. Data Sources and Measurements

The primary aim of this study is to investigate the extent to which ICT influences the impact of entrepreneurship on economic growth in Africa across a panel of 29 African countries from 2006 to 2020. All the data are sourced from the World Bank Development Indicators, except financial development (sourced from the IMF databases). The dependent variable, economic growth, is measured by the GDP per capita (Constant USD). The two variables of interest earlier justified are ICT adoption and entrepreneurship. ICT is measured by the three major indicators of ICT: mobile phone subscription (MOB), internet connections (INT), and fixed telephone subscription (TEL). This is aggregated by the composite ICT index through principal component analysis (PCA). Entrepreneurship is proxy by the new business entry density metric, which measures the number of registered businesses per 1000 working adults and is used to quantify entrepreneurship. The extensively used measure provides thorough coverage across nations, periods, and variables, in line with earlier studies by Chambers and Munemo (2019) and Ghazy et al. (2022).

The control variables include financial development, inflation rate, labor force participation, trade openness, population growth, gross fixed capital formation, and governance. The financial development measure adopted here is a composite index encompassing various dimensions of financial development, ranging from 0 to 1, where 0 signifies weak financial development and 1 indicates greater financial development. Unlike most previous studies that often use a single indicator or component, this measurement includes dimensions such as financial deepening, stability, and growth, encompassing financial institutions and market development. Specifically, it examines aspects like depth (size and liquidity), access (availability of financial services), and efficiency (cost-effectiveness of

financial services provision and capital market activity). This approach aligns with studies like Munemo (2018, 2022) and Raimi and Haini (2024).

The labor force participation rate is the proportion of the population age 15 and older that is economically active. Skilled labor is required for production and is an essential ingredient for growth. The more the number of skilled labor engaged in the use of machinery for production, the more there is a tendency for the economy to grow, but a high rate of unskilled and untrained can be a drag on growth (Ghazy et al., 2022; Huang & Chen, 2021). Gross fixed capital formation measures the stock of fixed investment, which comprises a net increase in physical assets within the measurement period. According to Romer (1986) and Solow (1956), physical capital accumulation is an important determinant of growth and firms accumulate know-how through capital accumulation, which can produce growing returns and promote economic growth (Ajide et al., 2019; Ngozi et al., 2019).

Trade openness, represented by the ratio of total import and export to GDP, indicates a more developed financial environment, fostering economic growth. A country that opens to international trade requires some level of absorptive capacity to produce, which also affects economic growth (Ngozi et al., 2019; Chikh-Amnache & Mekhzoumi, 2023). The inflation rate is measured by the GDP deflator. Inflation and economic growth are negatively related due to high inflation destabilizing economies (Akinsola & Odhiambo, 2017). This situation suggests that higher inflation reduces growth, even though some evidence has proven otherwise (Khan et al., 2022). Generally, combining the negative impact of ICT on inflation might lead to the dwindling impact of inflation on economic growth.

Governance is measured by the governance index comprising six indicators. It is also identified as a driver of economic growth. The quality and efficacy of a nation's institutional framework exert substantial influence on its economic performance and prospects for growth. Institutional pillars, encompassing the governmental, legal, financial, and sociocultural aspects, hold paramount importance in shaping the business environment and influencing the behaviors of entrepreneurs, investors, and consumers (Raimi et al., 2024). Population growth is expected to positively influence economic growth, as it offers a productive population to contribute to the economic growth and development of the country. However, population growth may also serve as a hindering factor to economic growth due to the increasing demand for economic resources required to cater to the growing population (Raimi & Haini, 2024).

3.2. Analytical Techniques

Descriptive analysis, simple correlation, panel data regression procedures, and the DH panel causality test are all included in the data analysis methodologies. The PCSE is used in the panel data regression analysis to look at the long-term relationship between ICT, entrepreneurship, and economic growth. To confirm the validity of inferences drawn from the results of the estimated regression models, this study also runs pre-estimation tests. Because of its versatility in handling potential issues with serial correlation, heteroscedasticity, and cross-sectional dependency, the PCSE estimate technique is more dependable than panel OLS, fixed, and random effect models. Since there are fewer periods (T) in this study than there are cross-sectional dimensions (N), PCSE is more suited, even if feasible generalized least squares (FGLS) can also be used (Beck & Katz, 1995; Reed & Webb, 2010).

The potential for endogeneity due to the theories and actual data indicating a two-way causal relationship between economic growth and entrepreneurship is an important issue. Thus, in addition to the static panel analysis, the system GMM is used in the study to estimate the model. SGMM offers a reliable estimation for the model's parameters when there is a relationship between the lagged dependent variables and the unobserved panel-level effects. Additionally, it is more effective when autocorrelation, heteroscedasticity, and

endogeneity are present, and it is optimal for panel datasets with a larger nation dimension and a shorter time dimension, such as the one employed in this work. As tools in the estimation process, we use the dependent variable's initial lagged level, which is generated automatically by the over-identifying restriction technique. The number of instruments utilized would affect the over-identifying limits (Roodman, 2009). Therefore, we used the Arellano–Bond and Sargan tests to confirm the reliability of the estimations and the validity of the instruments. Table 1 highlights the details of the variables and the list of countries.

Table 1. Variable descriptions and sources.

Variables	Indicators	Sources
GDP	GDP per capita (Constant USD)	WDI, 2023
EPP	New business entry density (number of registered businesses per 1000 working adults)	WDI, 2023
OFD	Financial development index	IMF, 2023
POG	Population growth (Annual population growth rate)	WDI, 2023
INF	Inflation rate (GDP deflator)	WDI, 2023
MOB	Mobile phone subscribers per 1000 people	WDI, 2023
LFP	Labor force participation rate, total (% of total population ages 15–64) (modeled ILO estimate)	WDI, 2023
TEL	Fixed telephone subscriptions per 1000 people	WDI, 2023
TOP	Trade (% of GDP)	WDI, 2023
INT	Population with access to the Internet (%)	WDI, 2023
GFC	Gross fixed capital formation (% of GDP) proxy for investment	WDI, 2023
ICT	Composite index of telecommunication indicators (Internet, mobile, and fixed telephone)	Authors' computation (based on data collected from the WDI, 2023 database)
GOV	Composite index of governance indicators (control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law, voice and accountability)	Authors' computation (based on data collected from the WGI, 2023 database)

Note: World Development Indicators (WDI); International Monetary Fund (IMF); World Governance Indicators (WGI). List of countries: Algeria, Benin, Botswana, Cabo Verde, Cote d'Ivoire, Egypt Arab Rep., Eswatini, Ethiopia, Gabon, Ghana, Guinea, Lesotho, Liberia, Madagascar, Mali, Mauritius, Morocco, Namibia, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania, Togo, Tunisia, Uganda, and Zambia.

4. Presentation and Discussion of Results

4.1. Descriptive and Correlation Analyses

The upper part of Table 2 presents the results of the descriptive analysis. It indicates that the average GDP per capita among the selected African countries is USD 2319.99, with a median of USD 1277.82, a maximum of USD 10,956.95, a minimum of USD 329.68, and a standard deviation of 1.42. The average number of entrepreneurs per 1000 people is 1.64, with a median of 0.48, a maximum value of 20.09, a minimum value of 0.01, and a standard deviation of 3.09. These suggest that there is a wide differential in the GDP per capita and the number of entrepreneurs among African countries. Except for labor force participation, financial development, and governance urbanization, all other variables exhibit significant variation, with GDP per capita showing the most deviation.

Figure 1 shows the plot of average GDP per capita (GDP) and new business density (NBD) data. This demonstrates that the two variables are moving in the same direction. This suggests that economic growth may be impacted by entrepreneurship. To determine the true causative factors in such a relationship, more research is still necessary.

Table 2. Descriptive statistics and correlation analysis.

	GDP	LFP	GFC	EPP	MOB	TEL	INT	OFD	GOA	TOP	POG	INF
Mean	2319.99	62.93	23.48	1.64	74.11	3.74	18.35	0.18	−0.50	67.31	2.37	7.05
Median	1277.82	62.56	22.58	0.48	74.90	1.07	11.04	0.12	−0.58	64.24	2.56	5.33
Maximum	10,956.95	89.45	52.42	20.09	166.94	36.88	84.12	0.59	0.87	127.06	3.87	100.61
Minimum	329.67	41.64	7.16	0.01	1.09	0.01	0.23	0.03	−1.69	24.01	0.01	−18.07
Std. Dev.	2233.56	11.63	7.14	3.09	39.69	6.11	19.01	0.13	0.54	21.65	0.87	10.11
Skewness	1.42	0.35	0.63	3.05	0.13	3.04	1.24	1.57	0.42	0.45	−0.76	4.55
Kurtosis	4.38	2.47	3.29	12.83	2.09	13.55	3.62	4.54	3.19	2.65	3.01	36.25
Observations	435	435	435	435	435	435	435	435	435	435	435	435
Correlation Analysis												
Variables	GDP	LFP	GFC	EPP	MOB	TEL	INT	OFD	GOA	TOP	INF	POG
GDP	1.00											

LFP	−0.38 ***	1.00										
	(0.00)	-----										
GFC	−0.07	0.17 ***	1.00									
	(0.18)	(0.00)	-----									
EPP	0.68 ***	−0.04	−0.10 **	1.00								
	(0.00)	(0.36)	(0.04)	-----								
MOB	0.65 ***	−0.42 ***	0.04	0.45 ***	1.00							
	(0.00)	(0.00)	(0.36)	(0.00)	-----							
TEL	0.78 ***	−0.25 ***	−0.06	0.52 ***	0.40 ***	1.00						
	(0.00)	(0.00)	(0.23)	(0.00)	(0.00)	-----						
INT	0.61 ***	−0.39 ***	−0.03	0.40 ***	0.79 ***	0.47 ***	1.00					
	(0.00)	(0.00)	(0.56)	(0.00)	(0.00)	(0.00)	-----					
OFD	0.73 ***	−0.21 ***	−0.10 **	0.63 ***	0.55 ***	0.66 ***	0.54 ***	1.00				
	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)	-----				
GOA	0.63 ***	−0.05	−0.01	0.64 ***	0.48 ***	0.58 ***	0.36 ***	0.70 ***	1.00			
	(0.00)	(0.30)	(0.76)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	-----			
TOP	0.51 ***	−0.42 ***	−0.08 *	0.37 ***	0.30 ***	0.45 ***	0.17 ***	0.31 ***	0.34 ***	1.00		
	(0.00)	(0.00)	(0.08)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	-----		
INF	−0.16 ***	0.18 ***	−0.08 *	−0.07	−0.27 ***	−0.10 **	−0.22 ***	−0.08 *	−0.08	−0.06	1.00	
	(0.00)	(0.00)	(0.08)	(0.16)	(0.00)	(0.04)	(0.00)	(0.08)	(0.10)	(0.20)	-----	
POG	−0.69 ***	0.38 ***	0.27 ***	−0.51 ***	−0.48 ***	−0.75 ***	−0.56 ***	−0.67 ***	−0.55 ***	−0.48	0.07	1.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00) ***	(0.13)	-----

Source: authors' computations. Notes: values in parentheses ( ) are the *p*-values of the test statistic; '***', '**', and '*' imply significance at 1, 5, and 10 percent, respectively. GDP is GDP per capita, EPP is entrepreneurship, OFD is financial development, GOA is governance, LFP is labor force participation, INF is the inflation rate, POG is population growth, TOP is trade openness, MOB is mobile phone, TEL is fixed telephone, and INT is internet access.

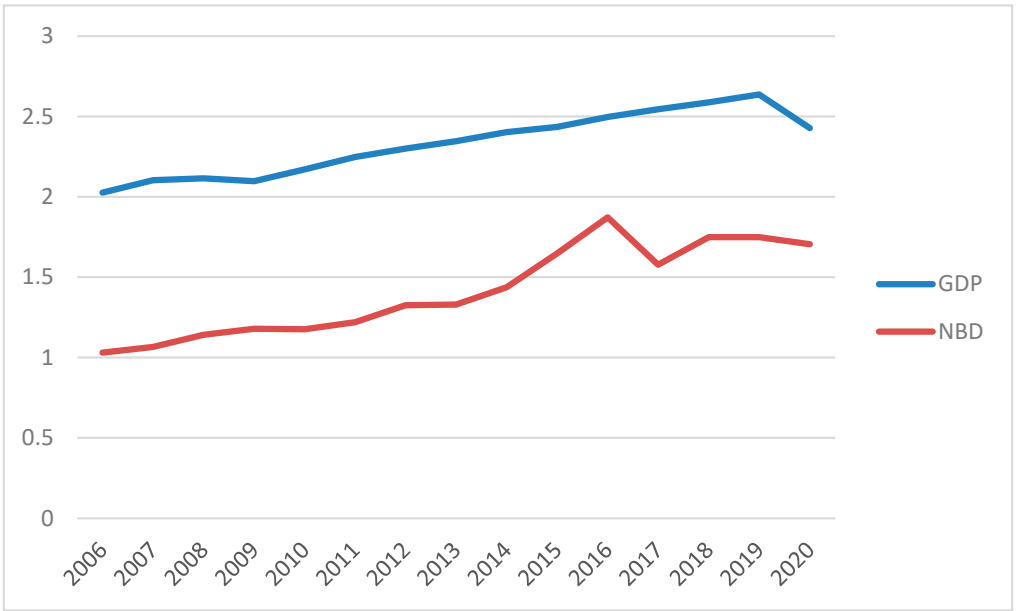

Figure 1. Trend in NBD and GDP. Source: authors' processing.

The lower part of Table 2 shows the correlation analysis. This reveals that GDP per capita has a positive relationship with entrepreneurship, mobile phones, fixed telephone, internet connections, financial development, governance, and trade openness. It is negatively related to labor force participation, inflation rate, and population growth, but does

not correlate with gross fixed capital formation. Furthermore, there is no evidence of a multicollinearity issue in our sample because the correlation coefficients were all less than 0.7. However, as correlation coefficients simply show how strongly the variables are linearly related to one another, a more succinct and detailed examination of the causal effects is required for this intuitive claim. To test this hypothesis further, this study creates multivariate models using the PCSE and system GMM techniques.

A panel series must also be checked for unit-roots and stationarity because discontinuities can significantly affect econometric estimations. A panel series must be examined for stationarity or unit-roots because discontinuities can seriously impair econometric estimates. We conducted panel unit root tests to assess the variables' integration orders. Table 3 displays the results of the PP-Fisher, ADF-Fisher, Levin, Lin, and Chu (LLC), and Im, Pesaran, and Shin (IPS) stationarity tests. The null hypothesis of all the stationarity tests is that the panel series contains a unit root. The results show that GDP per capita (GDP), entrepreneurship (EPP), financial development (OFD), internet connections (INT), governance (GOA), labor force participation (LFP), trade openness (TOP), and fixed telephone (TEL) are integrated of order one or I(1). In contrast, gross fixed capital formation (GFC), inflation rate (INF), population growth (POG), and mobile phones (MOB) are integrated of order zero or I(0). The results of the stationarity tests clearly show that the panel series' integration sequence varies. It is evident from the stationarity tests that there are differences in the integration sequence of the panel series.

Table 3. Panel unit roots test results.

Series	Stationarity	PP-Fisher	ADF-Fisher	LLC	IPS	Decision
GDP	Level	108.09 *** (0.00)	54.33 (0.94)	−2.40 *** (0.01)	1.35 (0.91)	I(1)
	First difference	-	114.65 *** (0.00)	-	−2.34 *** (0.01)	
EPP	Level	72.66 (0.46)	70.38 (0.53)	−0.81 (0.21)	1.21 (0.89)	I(1)
	First difference	227.29 *** (0.00)	144.58 *** (0.00)	−3.30 *** (0.00)	−4.86 *** (0.00)	
GFC	Level	73.18 (0.16)	77.89 * (0.08)	−3.52 *** (0.00)	−1.33 * (0.09)	I(0)
	First difference	194.49 *** (0.00)	-	-	-	
OFD	Level	104.63 *** (0.01)	82.39 (0.19)	−2.71 *** (0.00)	−0.48 (0.31)	I(1)
	First difference	-	188.86 *** (0.00)	-	−7.34 *** (0.00)	
INT	Level	110.70 *** (0.00)	75.26 (0.37)	1.41 (0.92)	0.67 (0.75)	I(1)
	First difference	-	209.46 *** (0.00)	−7.67 (0.00)	−8.65 *** (0.00)	
GOA	Level	97.55 ** (0.02)	86.81 (0.11)	−6.46 *** (0.00)	−1.17 (0.12)	I(1)
	First difference	-	206.95 *** (0.00)	-	−8.61 *** (0.00)	

Table 3. *Cont.*

Series	Stationarity	PP-Fisher	ADF-Fisher	LLC	IPS	Decision
LFP	Level	67.52 (0.56)	37.43 (0.99)	−0.80 (0.21)	6.44 (1.00)	I(1)
	First difference	268.30 *** (0.00)	115.10 *** (0.00)	−11.89 *** (0.00)	−1.32 * (0.09)	
INF	Level	271.68 *** (0.00)	191.76 *** (0.00)	−26.75 *** (0.00)	−10.53 *** (0.00)	I(0)
	First difference	-	-	-	-	
POG	Level	113.11 *** (0.00)	102.25 ** (0.01)	−4.64 *** (0.00)	−1.81 ** (0.04)	I(0)
	First difference	-	-	-	-	
MOB	Level	171.41 *** (0.00)	103.03 *** (0.00)	−8.75 *** (0.00)	−2.62 *** (0.00)	I(0)
	First difference	-	-	-	-	
TOP	Level	87.55 ** (0.03)	76.16 (0.14)	−0.91 (0.18)	−0.70 (0.24)	I(I)
	First difference	-	208.96 *** (0.00)	−11.91 (0.00)	−9.49 (0.00)	
TEL	Level	59.50 (0.85)	92.40 ** (0.05)	−5.85 *** (0.00)	−0.52 (0.30)	I(I)
	First difference	317.28 *** (0.00)	-	-	−9.39 (0.00)	

Source: authors' processing. Notes: values in parentheses ( ) are the *p*-values of the test statistic, '***', '**', and '*' imply significance at 1, 5, and 10 percent significant levels, respectively.

After conducting the unit root tests, the cointegration test is necessary to confirm whether a long-term relationship between the variables exists. This is presented in Table 4 via the Kao Engle–Granger test. This approach is used because it can handle more regressors than the limited Pedroni and Westerlund cointegration tests. The statistic at a one percent significance level confirms the results of the Kao cointegration test, which indicates that each panel series is cointegrated.

Table 4. Kao Engle–Granger panel cointegration results.

Test	Statistic	*p*-Value	Conclusion (H_0)
Augmented Dickey–Fuller	−2.05 **	0.02	Reject

Source: authors' processing. Note: H_0: no cointegration, '**' implies significance at 5 percent and H_0 is rejected.

The results of the cross-sectional dependency tests using the Breusch–Pagan LM and Pesaran tests are shown in Table 5. At the one percent significance level, the findings confirm that there are cross-sectionally dependent components among the variables. This problem is made worse by the high degree of economic interdependence among African nations. Ignoring this could lead to skewed and inconsistent study results. The results validate the presence of cross-sectionally dependent factors among the variables at the one percent significant level. This is exacerbated by the increasing economic interconnectedness among African countries. Ignoring this could cause the study's results to be distorted and inconsistent. As was previously noted, this is one of the reasons why the PCSE technique was used in this work, which is appropriate for handling these and related problems.

Table 5. Cross-sectional dependence test.

Test	Statistic	Prob.
Breusch-Pagan LM	2959.43 ***	0.00
Pesaran scaled LM	88.59 ***	0.00
Pesaran CD	31.37 ***	0.00

Source: authors' processing. Note: '***' implies significance at 1 percent.

4.2. Presentation and Discussion of Empirical Results

The findings from the PCSE regarding the long-run effects of ICT, entrepreneurship, and the control variables on economic growth are presented in columns (1) to (8) of Table 6, respectively. Columns (1), (3), (5), and (7) showcase findings on whether entrepreneurship, ICT, and their components individually promote economic growth, and columns (2), (4), (6), and (8) showcase the findings of whether the interactions of entrepreneurship with ICT adoption and its components enhance or alters its impact on growth significantly. As part of a robustness analysis aimed at verifying the potential effects of ICT, entrepreneurship, and the control variables on economic growth, we further employed the dynamic analysis (system GMM-SGMM) method. This is used to examine the short-run effects, as indicated in columns (1) to (8) of Table 8. Importantly, post-estimation tests confirm the robustness of the estimates derived from the PCSE and SGMM models. The variance inflation factors (VIF) for economic growth models are relatively low, with values ranging from 1.81 to 2.04, indicating no significant multicollinearity among the explanatory variables. The correlation analysis supports this finding. Additionally, the Wald Chi-square (X^2) statistics, all significant at the 1 percent level, and the R-square (R^2) statistics, ranging from 0.72 to 0.78 percent, suggest that the model estimations are reliable and valid for decision-making. Furthermore, results from the SGMM indicate no first-order serial correlation, and the Sargan test confirms the validity of the instruments used for estimation, thus passing diagnostic tests.

Table 6. PCSE estimations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPP	1.88 ***		2.09 ***		1.93 ***		1.91 ***	
	(9.786)		(12.97)		(9.380)		(11.21)	
OFD	3.78 ***	4.47 ***	3.42 ***	5.69 ***	3.94 ***	4.85 ***	4.04 ***	4.57 ***
	(11.34)	(10.37)	(12.62)	(23.27)	(12.68)	(15.14)	(12.97)	(14.64)
INF	−5.12	−7.74	−7.63 *	−6.07	−4.78	−7.62	−3.15	−8.48 *
	(−1.07)	(−1.61)	(−1.91)	(−1.45)	(−1.02)	(−1.60)	(−0.64)	(−1.77)
LFP	−3.17 ***	−3.43 ***	−4.00 ***	−4.94 ***	−2.69 ***	−3.40 ***	−2.41 ***	−3.49 ***
	(−7.75)	(−15.42)	(−20.93)	(−27.22)	(−5.95)	(−13.89)	(−6.232)	(−14.44)
TOP	16.19 ***	16.62 ***	6.54 ***	6.37 **	16.13 ***	14.73 ***	12.87 ***	12.40 ***
	(5.63)	(5.37)	(2.68)	(2.36)	(6.18)	(5.04)	(4.52)	(4.21)
POG	−3.70 ***	−5.05 ***	5.79	−1.88 ***	−2.88 ***	−4.87 ***	−4.39 ***	−5.47 ***
	(−4.99)	(−6.32)	(0.96)	(−2.83)	(−3.41)	(−5.68)	(−4.60)	(−6.35)
ICT	3.63 ***							
	(4.48)							
GFC	1.23 ***	1.41 ***	5.85 ***	1.09 ***	9.10 ***	1.27 ***	8.47 ***	1.25 ***
	(4.34)	(4.31)	(2.60)	(4.07)	(3.40)	(4.14)	(3.09)	(4.04)
GOA	4.86 ***	7.34 ***	2.57 ***	3.48 ***	4.67 ***	6.35 ***	2.69 ***	4.90 ***
	(7.38)	(9.64)	(4.46)	(5.56)	(6.70)	(7.70)	(2.69)	(6.59)
EPPICT		6.01 ***						
		(5.16)						
TEL			1.43 ***					
			(12.05)					
EPPTEL				1.82 ***				
				(15.05)				
INT					2.27 ***			
					(4.56)			

Table 6. *Cont.*

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EPPINT						3.65 ***		
						(5.55)		
MOB							1.11 ***	
							(5.23)	
EPPMOB								1.46 ***
								(8.39)
Constant	1.46 **	2.13 ***	2.18 ***	2.90 ***	1.23 *	2.24 ***	1.18	2.53 ***
	(2.04)	(3.14)	(4.35)	(5.10)	(1.80)	(3.46)	(1.43)	(3.89)
Observations	435	435	435	435	435	435	435	435
R-squared	0.75	0.72	0.78	0.76	0.75	0.72	0.75	0.73
Multicollinearity (VIF)	1.94	1.82	2.04	1.87	1.97	1.87	2.00	1.81
Wald Chi-square (X^2)	10,904.80	8234.64	6939.04	4246.94	10,028.96	5462.19	14,746.75	8034.88
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Source: authors' processing. Notes: '***', '**', and '*' denotes significance @ 1, 5, and 10 percent, respectively.

4.2.1. The Entrepreneurship Positively Influences Economic Growth over the Long Run

Based on the empirical findings derived from the PCSE analysis, the coefficient associated with entrepreneurship demonstrates a positive and statistically significant relationship at the 1 percent level. This indicates that the direct impacts of entrepreneurship positively influence economic growth over the long run. This implies that a 1-unit increase in entrepreneurship corresponds to a 1.88-unit rise in economic growth. This finding corroborates the first hypothesis of this study. This is also consistent with Huang and Chen (2021) and Munyo and Veiga (2022), who stated that entrepreneurship is an important contributor to economic growth, as well as Ajide and Dada (2023) and Ning (2021), who concluded that entrepreneurship has a significant impact on economic growth in Africa. The fact that entrepreneurship encourages innovation, generates jobs, and diversifies economies may be the reason for its beneficial effects in Africa. Entrepreneurs drive efficiency and value development in undeveloped areas by introducing new goods, services, and business models that tackle regional issues. Furthermore, entrepreneurship improves household incomes and addresses serious unemployment concerns by creating job opportunities, especially for young people. Entrepreneurial endeavors diversify economic activity by decreasing dependence on established industries, increasing African economies' resilience to external shocks and changes in the global market. In addition to increasing productivity and stimulating GDP growth, this dynamic activity lays the groundwork for sustainable development.

4.2.2. ICT Adoption Is Associated with Economic Growth

Considering the impact of aggregate ICT adoption on economic growth, the coefficient of ICT adoption is positive and statistically significantly associated with economic growth at the 1 percent level. This indicates that the direct impacts of ICT adoption positively influence economic growth over the long run. A 1-unit increase in ICT adoption corresponds to a 3.63-unit rise in economic growth. This is consistent with Adeleye et al. (2021), Awad and Albaity (2022) that ICT contributed directly to growth in Africa. Specifically, we also discuss the disaggregated effects of ICT components to look at their heterogeneous effects. Since different ICT components may have different effects on economic growth. It is possible to understand these diverse contributions by breaking down ICT adoption. The results show that economic growth is positively impacted by the three components of ICT (mobile phone, fixed telephone, and internet connections) at the 1 percent level. This indicates that the direct impacts of mobile phones, fixed telephones, and internet connections positively influence economic growth over the long run. That is, a 1-unit increase in mobile phones, fixed telephones, and internet connections corresponds to 1.11, 1.43, and 2.27 units increase in economic growth, respectively. This is consistent with the studies by David and Grobler

(2020), David (2024), and, Gomes and Lopes (2022). These findings corroborate the second hypothesis of this study.

ICT adoption has a transformative positive impact on economic growth in Africa through increasing productivity, improving connection, and stimulating innovation, which may account for the observed positive association between ICT adoption and economic growth. It increases overall economic production by streamlining business procedures, allowing for companies to function more effectively and grow more quickly. ICT makes it easier for people and companies to connect globally and take advantage of new opportunities by facilitating access to markets and information. For example, internet connectivity and mobile technologies have transformed industries like education, banking, and agriculture, allowing for improved resource management and service provision. By offering resources for creating new goods and services, particularly in underprivileged areas, ICT also promotes innovation. ICT speeds up the creation of jobs, revenue, and eventually sustains economic growth throughout the continent by promoting entrepreneurship through e-commerce platforms and expanding financial inclusion through digital payment systems.

4.2.3. ICT Adoption Strengthens the Positive Effects of Entrepreneurship on Economic Growth

The primary focus of this study centers on examining whether ICT adoption augments or dampens the positive effect entrepreneurship has on economic growth. To ascertain this, we evaluate the overall impact of leveraging ICT adoption to influence entrepreneurship in driving economic growth in Africa. The results presented in column (2) of Table 6 reveal that the coefficient of the interactive variable representing ICT adoption and entrepreneurship is positive and statistically significant at the 1% significance level. This indicates that 1-unit increase in entrepreneurship resulting from improvements in ICT adoption leads to a corresponding increase of 6.01 units in economic growth in Africa. Essentially, ICT adoption serves to reinforce the entrepreneurship–growth nexus in the region. This finding suggests that a symbiotic relationship between entrepreneurship and ICT adoption cultivates an environment conducive to economic growth in Africa. In addition, the results presented in columns (4), (6), and (8) of Table 6 reveal that the coefficients of the interactive variables representing ICT components (landlines, internet access, and mobile phones) and entrepreneurship are positive and statistically significant at the 1% significance level. This implies that a unit increase in entrepreneurship resulting from improvements in landlines, internet access, and mobile phones leads to a corresponding increase of 1.82, 3.65, and 1.46 units in economic growth in Africa. Thus, all the ICT components (landlines, internet access, and mobile phones) also reinforce the entrepreneurship–growth nexus in the region. These findings corroborate the third hypothesis of this study.

This outcome, which is a significant finding and contribution to the literature, implies that ICT adoption enhances the impact of entrepreneurship on economic growth in Africa. ICT adoption significantly enhances the effects of entrepreneurship on economic growth in Africa by improving efficiency, market access, and innovation capacity for businesses. It fosters innovation by connecting entrepreneurs to global knowledge networks, facilitating the creation of locally relevant products and services. ICT also enhances access to financing through digital payment systems and crowdfunding platforms, empowering entrepreneurs to fund and expand their ventures. By addressing traditional constraints and amplifying entrepreneurial contributions, ICT adoption transforms entrepreneurship into a powerful driver of inclusive economic growth across Africa.

Moreover, to evaluate whether ICT adoption amplifies the entrepreneurship–growth nexus and determines whether ICT adoption and entrepreneurship are substitutive or complementary, this study investigates the marginal impacts of ICT adoption and entrepreneurship using Equation (9). The findings presented in Table 7 demonstrate that, on average, a 1-unit rise in entrepreneurship, conditioned on the average level of ICT adoption, results in a 53.22-unit increase in economic growth. This indicates that, in nations with widespread and robust ICT adoption, improvements in entrepreneurship activities lead to a significant enhancement in economic growth by 53.22 units. Specifically, a 1-unit rise in entrepreneurship, conditioned on the average level of landlines, internet connections, and mobile phones results in a 10.99-, 70.84-, and 111.22-unit increase in economic growth. This indicates that, in nations with widespread and robust landlines, internet connections, and mobile phones, entrepreneurship activities improve economic growth by 10.99, 70.84, and 111.22 units. Thus, ICT adoption acts as an accelerator in the entrepreneurship–growth nexus, suggesting that both ICT adoption and entrepreneurship complement each other in fostering economic growth in Africa. As a result, measures targeted at enhancing ICT and entrepreneurship ought to take precedence over one another, since they both support economic growth in Africa. This suggests that bolstering ICT and entrepreneurship can significantly increase economic growth and promote economic development throughout the continent. Hence, ICT adoption plays a pivotal role in maximizing the positive impact of entrepreneurship activity on economic growth in Africa.

Table 7. Marginal effects of entrepreneurship and ICT adoption.

Entrepreneurship (EPP)			
ICT and its components	Direct Impact	Indirect Impact	Marginal Impact
ICT Adoption (8.23)	1.88 ***	51.34 ***	53.22 ***
Telephone Average Value (3.74)	2.09 ***	8.90 ***	10.99 ***
Internet (18.35)	1.93 ***	68.91 ***	70.84 ***
Mobile Value (74.11)	1.11 ***	110.11 ***	111.22 ***

Source: authors' processing. Notes: '***' denotes significance @ 1 percent.

Considering the coefficients of the control variables, the results reveal that financial development, trade openness, gross fixed capital formation, and governance positively influence economic growth in Africa, and that labor force participation and population growth negatively impact economic growth. The positive impacts of financial development, trade openness, gross fixed capital formation, and governance are in line with the theories and some of the previous studies like Awwad (2024), Hamdan et al. (2020), and Raimi et al. (2024). The negative impacts of labor force and population growth contradict these theories, but are in line with studies such as Adeleye et al. (2021) and Raimi and Haini (2024).

Results from the SGMM estimations represented in columns (3) and (4) of Table 8 show that growth is persistent in the data in the two models. A percentage increase in the previous year's economic growth contributes between 0.89 and 0.90 units to current growths, on average, ceteris paribus. The coefficients of all the explanatory variables are consistent with the results obtained in the PSCE estimations except entrepreneurship and labor force participation. The negative effect of entrepreneurship is in line with the conclusions of studies like Matenda et al. (2023).

Table 8. SGMM estimations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.GDP	0.89 ***	0.90 ***	0.94 ***	0.91 ***	0.93 ***	0.93 ***	0.89 ***	0.93 ***
	(49.59)	(15.93)	(11.82)	(16.26)	(39.94)	(12.67)	(8.90)	(13.37)
EPP	−2.97 ***		−3.04 ***		−1.67 ***		−3.01 ***	
	(−4.77)		(13.37)		(−5.11)		(−5.06)	
OFD	1.12 ***	8.36 ***	1.10 ***	8.95 ***	9.69 ***	1.13 ***	1.09 ***	1.10 ***
	(5.99)	(12.53)	(10.57)	(12.00)	(5.16)	(7.66)	(4.72)	(12.81)
INF	−1.03 ***	−0.81 *	−0.65	−0.95 **	−1.27 ***	−1.30 **	−0.28	−0.98 *
	(−2.96)	(−1.93)	(−1.19)	(−225)	(−2.86)	(−2.50)	(−0.27)	(−1.84)
LFP	23.60 ***	13.76 ***	2.69 ***	14.43 ***	18.42 ***	23.16 ***	2.54 ***	2.11 ***
	(4.76)	(8.81)	(16.26)	(6.76)	(4.08)	(7.56)	(9.76)	(11.09)
TOP	6.83 ***	5.08 ***	4.73 ***	4.83 **	5.37 ***	4.77 ***	5.31 ***	4.70 ***
	(19.11)	(14.54)	(7.68)	(14.09)	(17.92)	(12.85)	(8.65)	(10.04)
POG	7.94 ***	3.79 ***	−2.42	3.78 ***	8.48 ***	5.41 ***	7.71 ***	8.46 ***
	(3.04)	(3.46)	(−1.30)	(2.85)	(5.23)	(3.49)	(3.30)	(5.25)
ICT	2.40 **							
	(2.53)							
GFC	−21.04	1.12 ***	8.81	13.25 *	6.71	8.19	−13.28	−4.35
	(−0.98)	(1.47)	(0.16)	(1.88)	(0.62)	(1.27)	(−0.95)	(−0.09)
GOA	4.45 ***	3.21 ***	4.76 ***	2.62 ***	2.91 ***	2.07 ***	4.62 ***	2.96 ***
	(5.58)	(12.14)	(11.35)	(9.21)	(3.03)	(4.03)	(5.89)	(12.05)
EPPICT		0.15 ***						
		(2.39)						
TEL			−2.29 ***					
			(−10.07)					
EPPTEL				−0.05				
				(−0.34)				
INT					−4.30 ***			
					(−4.68)			
EPPINT						−0.22 ***		
						(−6.48)		
MOB							1.10 ***	
							(4.78)	
EPPMOB								−0.10 ***
								(−9.53)
Constant	−1.54 **	−1.20 ***	−1.63 ***	−1.31 ***	−1.62 ***	1.94 ***	−1.68 ***	−1.68 ***
	(−6.38)	(−8.58)	(4.347)	(−8.44)	(−9.56)	(−10.29)	(−11.88)	(−14.06)
AR1	−1.12	−1.07	−1.09	−1.07	−1.08	−1.07	−1.08	−1.06
	(0.26)	(0.28)	(0.28)	(0.28)	(0.28)	(0.29)	(0.28)	(0.29)
Observations	406	406	406	406	406	406	406	406
R-squared	92,836.98	269,414.44	86,344.77	88,197.83	53,031.89	1,444,479.67	200,820.48	71,629.48
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Wald $\chi 2$ –statistic	19.06	20.05	20.50	19.17	20.70	18.99	17.12	19.03
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)

Source: authors' processing. Notes: '***', '**', and '*' denotes significance @ 1, 5, and 10 percent, respectively.

4.2.4. Bidirectional Causality Between ICT, Entrepreneurship and Economic Growth

Table 9 displays the causality results among the three key variables (economic growth, entrepreneurship, and ICT). This is further explained in Figure 2 to show the connections and the direction of causality between the variables. The results show a bidirectional relationship between all of the variables. These suggest that the variables have two-way causal relationships. This is evident in the way these variables interact to reinforce each other. By increasing productivity, encouraging innovation, and facilitating worldwide connectivity, ICT stimulates economic growth, while economic growth generates the resources and demand for additional ICT development. Similarly, innovation and job creation are two ways entrepreneurship propels economic growth, and a booming economy provides an ideal setting for entrepreneurial endeavors. Entrepreneurial activity also encourages ICT adoption by generating a need for technology solutions, while ICT empowers entrepreneurs by offering tools for invention, market access, and operational efficiency. These interactions work together to produce a self-reinforcing loop that propels general technological advancements and the economy.

Table 9. Causality test.

Null Hypothesis:	W-Stat.	Z bar-Stat.	Prob. Value	Remark
EPP does not homogeneously cause GDP	5.73 ***	4.87	0.00	↔
GDP does not homogeneously cause EPP	5.90 ***	5.14	0.00	
ICT does not homogeneously cause GDP	5.39 ***	4.32	0.00	↔
GDP does not homogeneously cause ICT	6.56 ***	6.20	0.00	
ICT does not homogeneously cause EPP	5.67 ***	4.78	0.00	↔
EPP does not homogeneously cause ICT	7.33 ***	7.42	0.00	

Source: authors' processing. Notes: '***' denotes significance @ 1 percent and ↔ indicates unidirectional causality.

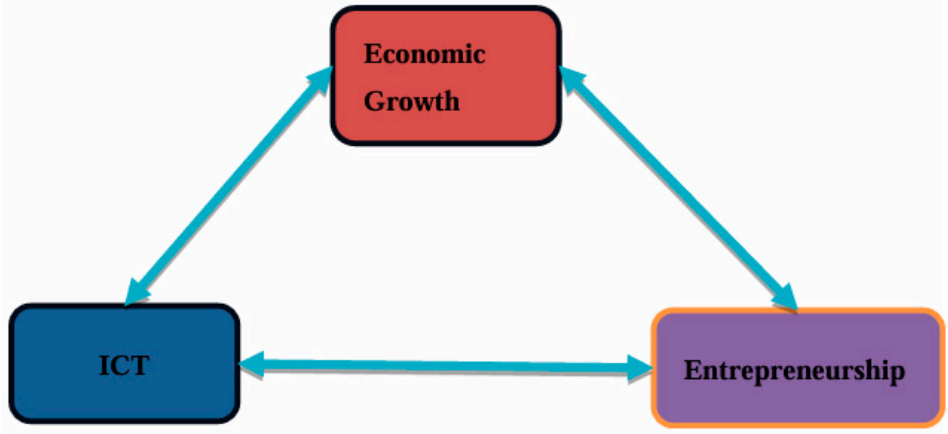

Figure 2. Causal relation flow.

5. Conclusions

This study confirms the effect of ICT-driven entrepreneurship on economic growth in 29 African economies between 2006 and 2020. It adds to the body of literature by investigating the relationship between ICT adoption and the nexus between entrepreneurship and growth by using PCSE and SGMM estimations for robustness checks. This study also examines how ICT adoption, entrepreneurship, and other control variables affect economic growth over different periods, both directly and indirectly. This study further examines the direction of causality among ICT, entrepreneurship, and economic growth. According to the findings from this study, entrepreneurship has a short-term detrimental impact on economic growth, but a long-term positive influence. This implies that the two African periods have a contradictory relationship, with notable differences in consequences. The findings also demonstrate that ICT adoption and its components have a beneficial long-term impact on economic growth. ICT adoption's moderating effects on the relationship between economic growth and entrepreneurship show that it enhanced the benefits of entrepreneurship in Africa over the long and short terms. In addition, this study shows that ICT adoption acts as an accelerator in the entrepreneurship–growth nexus, suggesting that both ICT adoption and entrepreneurship complement each other in fostering economic growth in Africa. The causality results reveal bi-directional causality among the variables. Furthermore, the results of the control variables show that while labor force participation and population increase have a negative impact on economic growth in Africa, financial development, trade openness, gross fixed capital formation, and governance all have favorable effects.

Based on these empirical results, suggestions are made to improve Africa's economic growth. First, policymakers should concentrate on expanding ICT adoption to mitigate the short-term detrimental effects of entrepreneurship on economic growth and enhance its long-term advantages. This entails investing in digital infrastructure, such as growing

broadband networks, ensuring that internet access is reasonably priced, and assisting with the adoption of mobile technology. Governments and the private sector should work together to lower costs and increase the accessibility of ICT tools for entrepreneurs. Initiatives to promote digital literacy should also be given top priority to guarantee that business owners can use these tools to increase operational effectiveness and reach new markets.

Ensuring the creation of a supportive environment that helps new companies get past their initial operational obstacles to handle the short-term difficulties related to entrepreneurship. Targeted financial incentives, such as tax exemptions, startup grants, and subsidized access to necessary resources like training programs and ICT tools can help achieve this. To mentor entrepreneurs, facilitate networking, and improve their company resilience, business incubation hubs and accelerators ought to be set up. These initiatives will lessen the short-term distortionary effects of entrepreneurship and lower the failure rates.

Each country's policies should incorporate ICT solutions into entrepreneurship development initiatives because of the moderating impact of ICT on entrepreneurship. For instance, mobile banking apps, digital payment systems, and e-commerce platforms can help business owners expand their operations and tap into international markets. To develop specialized digital solutions that address the unique requirements of African entrepreneurs, governments should collaborate with IT firms. Promoting the use of automation, data analytics tools, and cloud-based services can improve company performance and guarantee long-term financial gains.

Policies should highlight entrepreneurship as a catalyst for long-term economic transformation while reducing short-term negative effects. Governments ought to support educational and training initiatives that foster the development of technology and entrepreneurial skills. Policies that promote innovation and research and development (R&D) can also help create high-value goods and services that eventually boost economic growth. The contribution of entrepreneurship policies to sustainable economic growth will be maximized if they are in line with national development goals.

To capitalize on the complementary relationship between ICT adoption and entrepreneurship, efforts should be geared towards prioritizing the development of digital infrastructure. Investments in broadband connectivity, mobile networks, and affordable ICT services are critical to creating an environment where entrepreneurs can thrive. By addressing ICT and entrepreneurship simultaneously, governments can amplify their impact on economic growth, leveraging the bi-directional causality to create a self-reinforcing cycle of innovation and development.

This empirical study provides pertinent information regarding ICT development, entrepreneurship, and economic growth in African economies. However, it is crucial to be aware of its limitations. First, as a micro-panel analysis, the study is based on data that are currently available from African countries. This limits the scope of the study, the variables chosen, and the analytical methods used. All of these may influence the findings. The exclusion of pertinent factors influencing economic growth or methods could raise concerns about potential problems like omitted variables and analytical bias. Future research can improve this by performing a macro-panel analysis alongside pertinent techniques to increase the scope and depth of the current literature. Second, informal entrepreneurship is overlooked by this study's focus on formal entrepreneurship. This might limit how widely our findings can be applied. Additionally, this study focuses on the moderating effect of ICT development on entrepreneurship–growth nexus across African countries, possibly omitting sub-regional differences. Lastly, sector-specific differences in entrepreneurship are not taken into consideration. To gain a deeper understanding of the subject matter, future studies should take sectoral, sub-regional, and informal entrepreneurship analyses into account.

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