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Innovation and economic growth: An empirical analysis for African countries

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In recent decades, innovation has become recognized as a key driver of economic growth. This study investigated the relationship between innovation and economic growth in 32 African countries from 2006 to 2017. The linear regression panel corrected standard errors (PCSEs) regression estimation was used to analyze the data. PCSE estimation accounted for heteroskedasticity and possible contemporaneous correlation across panels. The findings showed a positive association between the innovation index and economic growth. This result remained true even when research and development (R&D) expenditure (the conventional measure of innovation) was considered for a handful of countries. This finding highlights the significance of innovation in fostering economic growth. The study also found that domestic investment and human capital encouraged economic growth. The study estimated an endogenous growth model with an alternative measure of innovation. Based on the findings, the study recommends that African countries provide financial and material support for R&D in public and private institutions through funding, imparting entrepreneurial research attitudes in academics, and providing an enabling environment for business enterprises.

Keywords: innovation, economic growth, Africa, human capital, R&D expenditure

JEL Classification: O31, O30, O47, O55

Introduction

The contribution of innovation to economic growth has taken centre stage in economic literature for many decades. Economic schools of thought have highlighted that innovation is crucial to sustained economic growth. The neoclassical schools of thought and the endogenous theory are prominent proponents of the role of innovation among the schools of thought. On the one hand, the neoclassical economists Ramsey (1928), Harrod (1939), Domar (1946), Solow (1956) and Swan (1956) posit that capital accumulation and labour are the main drivers of a steady economic growth rate. They asserted that an external injection of technology continuously increases economic growth. Thus, the neoclassical school of thought regards technology as an exogenous variable in the growth process.

On the other hand, the endogenous growth models consider technology as an internal and critical determinant of economic growth. Romer (1990) asserted that internal factors of capital, human capital and innovation drive economic growth in contrast to the neoclassical models. Romer (1990) explained that innovation would generate positive externalities and increase productivity resulting in increasing returns to scale. Grossman and Helpman (1991) and Aghion and Howitt (1992) further asserted that the spillovers from increased innovation and improved human capital spread beyond the knowledge sectors to other sectors of the economy. Thus, public and private investment in technology is crucial for economic growth.

Recently, innovation has been seen as an essential determinant of productivity growth, especially during this age of the Fourth Industrial Revolution. Its significance is reflected in the United Nations Sustainable Development Goal (SDG) number 9, which is hoped to be achieved by 2030. Innovation is a critical factor of goal number 9 and enables all the other SDGs. A significant indicator of innovation is research and development (R&D) expenditure; SDG goal number 9.5, which advocates for countries to significantly increase private and public R&D expenditure (Fendoğlu and Polat 2021). Thus, African countries must design policies promoting R&D, innovation, and infrastructure development to stimulate inclusive economic growth while decreasing poverty and inequality.

More so, the coronavirus pandemic of early 2020 infected millions of people worldwide, emphasizing the significance of R&D innovation in the economy, especially in the health sector. The novel coronavirus, for which there was no cure, rapidly infected people, and many governments opted for long periods of lockdown and limited human interactions. These nationwide lockdowns resulted in a myriad of business issues, from bankruptcy, laying off employees, and remote working, among many others. Akinwale (2020) asserted that only firms with in-built innovation could cope during the lockdown period and survive the turbulent economic period, as was the case for many advanced economies.

Despite the significance of innovation to economic growth, Africa continues to lag behind other continents in economic growth figures. The continent has seen a continued decline in economic growth since the turn of the millennium declining from a high of 6.6% in 2002 to –2% in 2020 (World Bank 2022). The picture is worse when research and innovation figures are considered. Africa contributes merely 2% of world research output, accounts for only 1.3% of research spending, and produces 0.1% of all patents (Simpkin et al. 2019). Against this backdrop, this study aimed to investigate empirically the impact of innovation on economic growth among African countries. Broadly, the study aimed to reflect on whether research and innovation are the missing links in Africa's economic growth.

The role of innovation in economic growth has been documented in many developed economies. Pradhan et al. (2020) showed that innovation promotes economic growth in OECD countries. However, only a limited number of studies empirically investigated the innovation-growth nexus in African countries. Besides, the few studies focused on Africa only considered a specific region or two or three countries. As a result of the dearth of empirical studies on the African continent, this study investigates the innovation-growth nexus for 32 selected African countries. This paper contributes to the body of literature by using the innovation index of many African countries to provide insight into policymaking, especially in the post-coronavirus era. The innovation index is a composite measure of global innovation that goes beyond the conventional measure of R&D expenditure and patents. Secondly, this study estimates a full endogenous growth model, including human capital, to ascertain its contribution to the growth that Africa desperately needs. Thirdly, this study provides insights into variables required to move out of the post-coronavirus stagnation to achieve the SDGs by 2030. This study's results will provide insights that will benefit African economic planners.

This study is organized as follows. Following the introduction, the next section discusses the theoretical and empirical literature on the innovation-growth nexus. The section thereafter discusses the methodology and data for analyzing the innovation-growth nexus in Africa. This is followed by the section that presents stylized trends and patterns of economic growth and innovation in Africa. The penultimate section presents the empirical results and discussion used in estimating the impact of innovation on economic growth. The last section concludes the study.

Literature review

Theoretical literature review

Over the years, various economic theories have emphasized the significance of technological advancement for economic growth. One such model is the Solow (1956) growth model, which accentuates the role of technological innovation, which leads to sustainable economic growth through increased competition and productivity. The models identified capital accumulation, labour productivity, and population growth as significant determinants of economic growth. However, capital and labour incur diminishing marginal returns in the long run and cannot sustain economic growth. Thus, Solow (1956) concluded that to have sustained growth, it is critical to consider technological growth.

The Solow model, in its essence, predicts that if countries have similar savings rates, population growth, technical progress, and depreciation rates, then regardless of their initial outputs per capita, all countries will converge to a similar balanced growth path. In contrast to the Solow growth model, Romer (1990, 1986) Grossman and Helpman (1991) explained that productivity growth results from intentional innovation by rational, private-sector profit-maximising agents and is endogenously determined (see also Lucas 1988).

The Schumpeterian economic theory of 1939 emphasizes the role of technological innovations in economic growth through competition and skilled labour. These assumptions are supported by empirical studies conducted by Aghion et al. (2009). Nadiri (1993), in the empirical analysis, modelled economic growth by assuming the exogenous growth rate of innovation in a Cobb–Douglas framework. The author showed an association between innovation, productivity growth and output.

Solow (1957), in his early work, concluded that historical growth in industrialized countries could not be attributed to the growing use of physical capital and labour but to new means of production. Romer (1990) argued that having a large population is insufficient for economic growth. Instead, a change in technological innovation was perceived as a driver of economic growth. However, Dao (2013) argued that per capita GDP growth is linearly dependent on access to essential services by the percentage of the urban population. Caballe and Santos (1993) considered human and physical capital technologies in driving economic growth as part of their analysis.

The study examines the endogenous growth model because it considers innovation to be endogenous. In addition, the theory provides other determinants (human capital, labour, capital formation) of economic growth that were used as control variables.

Empirical literature review

Several studies in the global north suggest that economic growth depends on technological innovation, GDP, human capital, financial globalization, and R&D expenditures Wang et al. (2020); Sokolov-Mladenović, Cvetanović, and Mladenović (2016); Wang and Xu (2021); Caesar et al. (2018). A study conducted in 19 European countries using six different innovation indicators found that all the innovation indicators were strongly linked with per capita economic growth (Maradana et al. 2017). However, the results, which depended on the innovation indicators used in the empirical investigation, varied among the 19 European countries. Mensah et al. (2019) used the STIRPAT, IPAT and multiple linear regression (MLR) methods to analyze 28 OECD economies. They found that technological innovation had a positive effect on economic growth. The 28 OECD economies were sub-grouped into Oceania, America, Asia, and Europe.

An empirical study conducted in 184 OECD and non-OECD countries highlighted underlying combinations that drive economic growth (Dellink et al. 2017). The empirical work conducted by Teixeira and Queirós (2016) explains some of the different combinations. The authors found that countries, where structural change contributed to increasing the share of knowledge-intensive activities that required high skills (e.g. Financial Intermediation, Computers, Research, and Development and Education), were perceived to grow faster economically. On the other hand, Doran, McCarthy, and O'Connor (2018) noted that innovation through entrepreneurship was essential in driving economic growth for both developed and developing economies, with some forms of entrepreneurial activity being more important than others.

Empirical evidence from a study conducted in G-7 countries found that R&D, labour, globalization, financial development, and GDP were essential factors in explaining technological innovation (Wang et al. 2020). Diebolt and Hippe (2019) also emphasized that human capital was the most significant historical factor related to current patent applications per capita and current GDP per capita in the European regions under study.

The empirical findings of studies conducted in Asia found that a lack of innovation activities had a negative impact on the overall innovation capacity of Asian countries in the long run (Law, Sarmidi, and Goh 2020). The authors suggest that sustainable economic growth should be supported by a complementarity between policies that foster growth and the quality of labour, capital, and fracture in the respective countries. Shukla (2017) showed a positive association between innovation and economic growth in the global north. The study noted the unavailability of data as a significant limitation.

Szirmai and Verspagen (2015) re-examined the role of innovation in manufacturing as a driver of growth in industrialized and developing countries from 1950–2005 and found a moderate positive impact on economic growth. Sesay, Yulin, and Wang (2018), in their empirical study conducted in Brazil, Russia, India, China, and South Africa (BRICS) economies, found that developing the national innovation system (NIS) was a potential opportunity to speed up economic growth. It is pertinent to note that empirical literature focusing on developed and emerging economies highlighted a challenge with the lack of data available for emerging economies to account for the innovation index.

Using the Pooled Mean Group estimation technique in Sub-Saharan Africa (SSA), Zahonogo (2016) found that it was critical to consider human capital in innovation studies, as it enhanced labour productivity and boosted growth. Otekunrin, Chinoda, and Matowanyika (2021) showed a causal relationship between economic growth, capital formation, and financial innovation in Africa. Haftu (2019) further argued that human capital and information communication technology could impact the per capita income of the people in the region positively.

Recently, Anakpo and Oyenubi (2022), in their analysis of a panel of SADC countries, showed that skilled labour (graduates, post-graduates, and researchers) working in R&D, ICT, Patents, and STEM have a positive association with per capita income. In addition, Akinwale and Surujlal (2021) argued that R&D and innovation could help drive growth in South Africa as they have an established association with economic growth. The authors further argued that the country could achieve economic growth in the short run by increasing spending on R&D.

Olaoye et al. (2021) investigated the impact of R&D expenditure and governance on economic growth for selected African countries. Constrained by the availability of R&D data, the study focused on four African countries (South Africa, Egypt, Tunisia, and Uganda). These four countries were the only countries with the most data points recorded for R&D expenditure. The study used linear regression and correlated panels corrected standard errors to analyze the data between 2000 and 2016. The results revealed that R&D and governance were significant determinants of economic growth. One limitation of the study was that it did not estimate a full economic growth model; thus, variables such as investment and human capital were not accounted for in the study.

Empirical studies in developing countries have reported a lack of innovation data in their analyses. Several studies (Coccia 2013; Falk 2007; Olaoye et al. 2021; Savrul and Incekara 2015) used R&D expenditure as a percentage of GDP (R&D intensity) to denote innovation. However, R&D expenditure data is unavailable in many African countries. Thus, this paper addressed this gap using the innovation index data compiled by the World Economic Forum. The innovation index is part of the computation for the Global Competitiveness index. The innovation index is a more comprehensive proxy of a country's innovation activity, accounting for different components of innovations such as multi-stakeholder collaboration, scientific publication, patent applications, R&D expenditure, and research prominence index. Furthermore, this study estimated full endogenous growth models for a panel of 32 African countries, providing more depth to the results.

Methodology

Model specification

This study used the endogenous growth model to estimate the relationship between innovation and growth. In contrast to the classical economics of Solow, who treats technology innovation as exogenous to the growth equation, the new growth model of Romer, and Grossman and Helpman posits that technology innovation is endogenously determined by innovation and human capital through knowledge acquisition. Thus, a profit-maximising firm will use the Cobb–Douglas equation determined by Lucas (1988):

$$Y = AK^{\alpha}L^{\beta}C^{\gamma} \tag{1}$$

where Y is output, A is the technology that improves labour productivity, K is the stock of physical capital, L represents labour, and C denotes the human capital regarding knowledge accumulation and α, β, *and* γ denote the output elasticities for capital, labour and human capital. Taking the logarithms, Equation 1 is transformed into a linear equation:

$$lnY = lnA + \ \alpha lnK + \ \beta lnL + \ \gamma lnC + \ \mu \tag{2}$$

Essentially, endogenous growth is based on three main assumptions: (1) technological change drives economic growth, (2) economic agents drive technological changes by intentionally inventing products to respond to market incentives, and (3) the created technologies are non-rivalry.

The study estimates a Cobb–Douglas production function as depicted in Equation 2 (Akoum 2016; Inekwe

2015). Equation 2 estimates the determinants of economic growth based on the theoretical production function of capital, population, human capital, and innovation. These variables are selected in accordance with the endogenous growth theory predictions. Thus, the empirical Cobb–Douglas production equation is specified as follows:

$$lnGDP_{i,t} = \alpha_i + \beta_1 lnINN_{i,t} + \beta_2 lnRCF_{i,t} + \beta_3 lnEMP_{i,t} + \beta_4 lnHC_{i,t} + \mu_{i,t} \quad (3)$$

where i and t represent the cross-sectional units (country) and time dimensions (year) of panel data. GDP is real GDP per capita/in constant US $2015 prices used to proxy economic growth in the model. INN represents the Innovation Index, which captures the essence of technological change. In the robustness estimation, the Research and development (R&D) is used to measure innovation. RCF is real gross fixed capital formation as a percentage of GDP used to measure physical capital. HC is the Human capital index representing human capital that captures the knowledge aspect of the Cobb–Douglas production function. EMP is the employment rate to measure the labour force as an additional control variable based on the empirical literature.

Equation 3 essentially estimates the growth model, in which GDP per capita is dependent on innovation, real gross fixed capital formation, the proportion of the labour force that is active and working, and human capital.

Data sources

The study used data for six variables: GDP per capita, innovation index, R&D expenditure, capital formation, employment rate and human capital index. The GDP per capita, R&D expenditure, capital formation and employment rate were downloaded from the World Development Indicators of the World Bank. The Human capital index was sourced from the Penn World Tables (PWT 2021) (10.0). The data were collected from 2006 to 2017 from 32 African countries.[1]

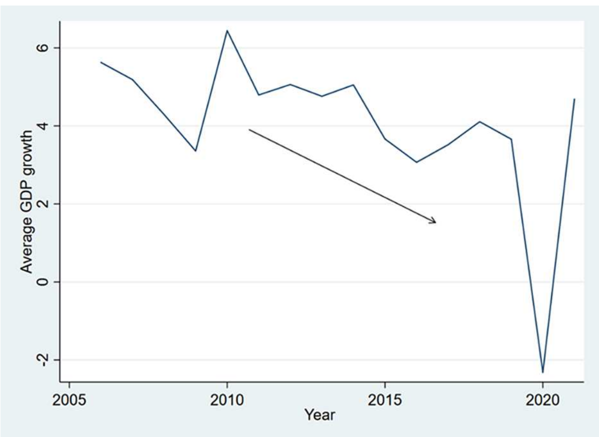

Figure 1: Average annual GDP growth rate.
***Source*:** Authors' computation.

The availability of data determined the inclusion criteria for countries in the sample. Many empirical studies used R&D expenditure as a percentage of GDP (R&D intensity) to denote innovation. This study deviated from this trend due to the unavailability of data on R&D intensity in many African countries. Only a handful, not more than five African countries, have R&D intensity data for five consecutive years. Therefore, this study used the innovation index compiled by the World Economic Forum as part of the computation for the Global Competitiveness index. The innovation index is a more comprehensive proxy of a country's innovation activity as it goes beyond R&D expenditure. The index indicators included the diversity of the workforce, state of cluster development, international co-inventions, multi-stakeholder collaboration, scientific publication, patent applications, R&D expenditure, research prominence index, buyer sophistication, and trademark applications. The weighted score is between one (less innovative) and seven (ideal innovation score). Table A2 provides a detailed description of the index's components and how each component was collected and scored. For example, the H-index, which measures the number of peer-reviewed published articles and how many have been cited at least once, was collected for all the countries to provide a score. The score was collected from SCImago and normalized using the log to a scale of 0–100 (see Schwab 2019).

Stylized trends and patterns of growth and innovation in Africa

In the last decades, African countries' economic growth has shown an overall decline. Between 2006 and 2010, the average annual growth rate was highest for the period under investigation, even after drastically falling in 2008 due to the global financial crisis. The annual growth rate peaked in 2010 at 6.4%, which can be attributed to the increase in economic activity as a result of the World Cup, the increase in tourism, and the increase in foreign direct investment (World Bank 2022).

From 2011 to 2021, the average annual growth was 3.6%, showing a declining trend. This rate is carried by the handful of upper-middle-income economies within the sample that have developed tourism, a rich oil market, and received immigrant remittances. However, the majority of the countries in the sample have experienced political instability, conflicts, poor governance, and poor infrastructure (Omar 2019). Thus, Africa's economic growth remains below its full potential (Figure 1).

Moreover, GDP per capita is different across countries on the African continent, even though Sub-Sahara Africa is classified as a low-income region. From the sample of 32 countries, five are classified as upper middle income with a per capita GDP of above US$5000; sixteen are lower middle-income countries with per capita GDP between US$1000 and US$4500; lastly, eleven countries are low-income countries with less than US$1000 per capita, according to the World Bank 2022 economies classifications.

Turning to innovation, the trends in the innovation index, ranging from one (1 = least innovative) to seven (7 = highly innovative), are depicted in Figure 2. The data show that only four countries have an index above the average of 3.0 for four consecutive years. South Africa recorded a consistent innovation index (between 3.5 and 3.8) above the mean throughout the period under investigation. Tunisia recorded the highest innovation index of 4.02 in 2007. Moreover, Kenya and Rwanda respectively have shown an increase in innovation post-2013 and 2015. The remaining countries' innovations fall below the average, with Ghana, Ethiopia and Zambia showing significant improvements.

Figure 3 shows the scatterplot of the trends in the innovation index vis-à-vis GDP per capita, which is the variable of interest. Generally, the figure shows a positive association between the two variables, as shown by most studies in the empirical literature review. It shows that relatively high per capita income is associated with higher levels of innovation. Interestingly, Figure 3 also shows that countries are clustered at a per capita income below US$2000. This is typical for most African countries as the continent is plagued with low economic growth and high poverty rates.

This study further tested the robustness of the innovation index variable against conventional methods of measuring innovation, such as R&D expenditure. Figure 4 shows a comparison of the trends of the innovation index and R&D expenditure as a percentage of GDP in logarithmic terms. The logs of the variables are used to standardize the values. R&D expenditure data is unavailable for many African countries, and those countries that reported it have a number of missing data points. Only three countries have a comprehensive continuous data point for R&D expenditures. Figure 4 shows the innovation index and R&D expenditure flow, showing upward trends. It is important to note that the

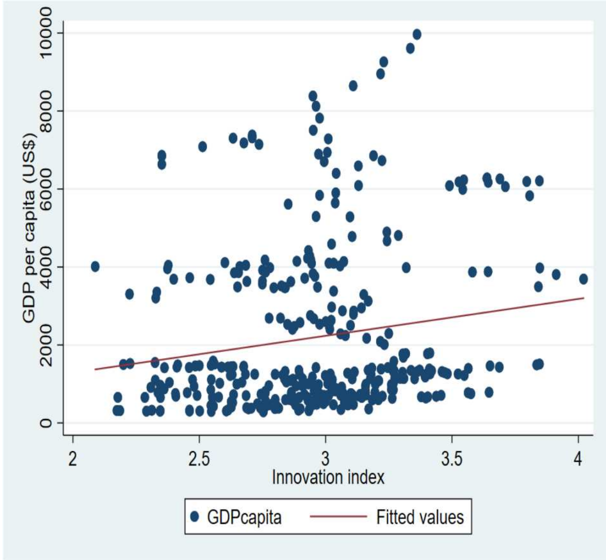

Figure 3: Trends in innovation index and GDP per capita.
Source: Authors' computation.

Figure 2: Innovation index by country.
Source: Author' computation.

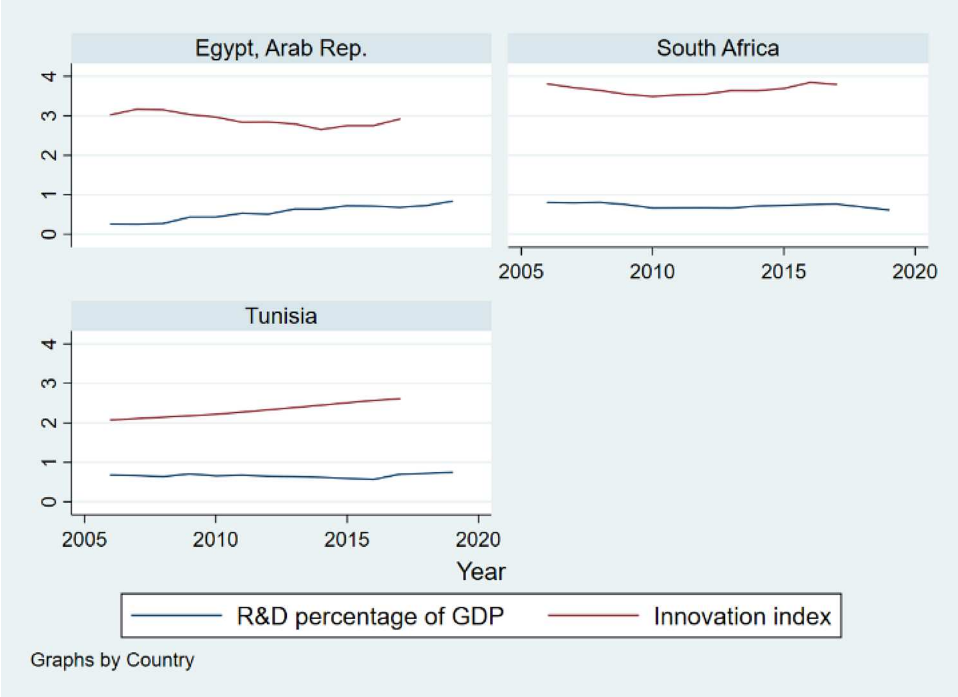

Figure 4: Comparison of the logs of innovation index and R&D intensity.
***Source*:** Authors' computation.

innovation index is relatively higher than the R&D intensity, in logarithmic terms, because it is a comprehensive measure. The innovation index is a composite measure that takes into account ten subcomponents as described in Table A1.

Low levels of innovation on the African continent stem from three major factors: a lack of skilled human capital, labour market rigidities, and reliance on the primary sector (Inekwe 2015). Most African countries rely on a mono-economy of the primary sector, such as agriculture and natural resources. The economies that are slightly more advanced in manufacturing are more innovative. An economy's innovation potential depends on the level of diversification within the economy.

Results and discussion

Table 1 shows the summary of the data variables used for the estimation. The table shows that the average per capita income for African countries is US$2206 as shown in Figure 3, with a minimum of US$286 for the small country of Burundi in 2017, and the highest per capita income was Mauritius with US$9966 in 2017. Due to the variety of the countries included in the sample, the standard deviation is considerably large. The average innovation index is relatively low, 3 out of an ideal of 7. The highest innovation index was 4.02 in Tunisia in 2007. Domestic investment (gross fixed capital formation) averaged 23% of GDP, with the highest ratio at 57% in Ghana in 2007. The average employment rate and human capital was 60% and 1.9, respectively.

Further, this study tested for autocorrelation and heteroskedasticity to determine the estimation technique. This is because the OLS are unbiased but inefficient in the presence of autocorrelation and heteroskedasticity. Table 2 shows the presence of autocorrelation and heteroskedasticity in the data with the rejection of the null

Table 1: Source and description variables.

Variable	Name	Description	Source
INN	Innovation index	The innovation index is part of the Global competition index	World Economic Forum
R&D	R&D intensity	Gross domestic expenditures on research and development (R&D), expressed as a percentage of GDP	World Development Indicators
RGDP	Real GDP	Constant GDP at 2015 US dollar Prices	World Development Indicators
GDP capita	GDP per capita	GDP per capita is gross domestic product divided by midyear population.	World Development Indicators
GDI	Gross Domestic Investment	Gross fixed capital formation as a percentage of GDP	World Development Indicators
Emp	Employment rate	Employment to population ratio is the proportion of a country's population that is employed.	World Development Indicators
HC	Human Capital	Human capital index, based on years of schooling and returns to education	Penn World Table 10.0

***Source*:** Authors' estimation.

Table 2: Descriptive statistics.

Variable	Obs	Mean	Std Dev.	Min	Max
GDP per capita	384	2 206,3	2 148,5	286,4	9 966,8
Innovation	371	3,0	0,4	2,1	4,02
Capital formation	375	23,1	8,7	8,8	57,3
Employment	382	60,4	15,9	36,2	86,0
Human capital	384	1,9	0,5	1,1	2,9

Source: Authors' computation.

Table 3: Autocorrelation and heteroskedasticity tests.

Wooldridge test	H0: No autocorrelation
F	3.302 (0.0489)**
Wald test	H0: No heteroskedasticity
Chi2 (Prob > Chi2)	472.69 (0.0000)***

Source: Authors' computation.
Note: (*), (**), (***) 10, 5, and 1% significance levels, respectively.

hypothesis. Thus, this study used the linear regression panel corrected standard errors (PCSE) because the method accounts for these factors.

The PSCE estimation results show that the independent variables explain approximately 83% of the variation in the dependent variable. The model is stable and significant. Moreover, the results show that innovation has a positive impact on economic growth such that a 10% change in innovation will lead to a 5.7% increase in economic growth. This result is in line with previous empirical studies by Olaoye et al. (2021), Omar (2019), and Inekwe (2015). The positive association between the innovation index and GDP per capita is in line with the predicted association in Figure 3. The positive result also reaffirms the innovation index variable as a robust measure of innovation. This provides a basis for more studies on the African continent. In addition, economic growth increases with investment in African countries. The results further show that a 10% increase in investment will increase GDP per capita by 0.6%.

Human capital positively and significantly impacts economic growth. The results show that economic growth is proportionately sensitive to the level of human capital. This is in line with the theoretical underpinning that human capital plays a crucial role in fostering growth. Risso and Carrera (2019) also find a highly significant response of economic growth to human capital in developing countries. Thus, African countries must bridge the skills deficiency gap in science, technology, and innovation to unlock the continent's potential and foster economic growth.

Lastly, the coefficient of employment rate is negative and insignificant, as is the trend for least developing countries. Inekwe (2015) also found a negative and insignificant relationship between the labour force participation rate and economic growth.

As a robustness check, this study estimated Equation 3, with R&D expenditure as a measure of innovation. A full set of R&D expenditure data for the period under investigation was available for only three countries

Table 4: PCSE estimation results.

	Coefficient
lninn	0,57***
	(0,14)
lninvest	0,06***
	(0,0027)
lnemp	−1,73
	(0,01625)
lnhc	1,78***
	(0,069)
_cons	11,38***
	(0,134)
Group variable: Country1	Number of obs = 360
Time variable: Year	Number of groups = 32
Panels: correlated (unbalanced)	Obs per group:
Autocorrelation: no autocorrelation	min = 7
Sigma computed by pairwise selection	Avg = 11.25
	max = 12
Estimated covariances = 528	Rsquared = 0,8267
Estimated correlation = 0	Wald chi2 (4) = 31547,70
Estimated coefficients = 5	Prob > chi2 = 0,00

Source: Authors' computation.
Notes: (*), (**), (***) 10, 5, and 1% significance levels, respectively. Standard errors in parentheses.

(Egypt, Tunisia, and South Africa). The results in Table A2 in the appendix are similar to those in Table 3. The results show a positive relationship between R&D expenditure and per capita GDP. It implies that a 10% increase in R&D expenditure is predicted to increase economic growth by 3.6%. Whereas the direction of association is the same for both measures of innovation, the magnitude is different. The difference can be attributed to differences in the measurement of the two variables. Moreover, Figure 4 shows that the innovation index is relatively higher in logarithmic terms than the R&D expenditure. This difference translates to the estimation results. The other variables are consistent with the results in Table 3.

The findings of this study show that both measures of innovation produce similar results. Therefore, the index provides a basis for a more in-depth analysis of the role of innovation in African countries.

Conclusion

This study analyzed the impact of innovation on economic growth for 32 African countries over the period 2006–2017 using the panel-corrected standard error approach. The results align with the endogenous growth model, showing empirical evidence that innovation positively and significantly impacts economic growth among African countries. Nonetheless, African countries need to improve the reporting of measures of innovation, such as R&D surveys or patent registration records, to provide more vigorous evidence for research-relevant policy decision-making. The success of this initiative will ensure that African countries catch up with the fourth industrial revolution and advanced countries.

Notwithstanding the amount of work that still needs to be done on the African continent, a few countries have started implementing innovation policy initiatives over the last decade. Countries such as South Africa, Rwanda, Kenya, Nigeria, and Morocco have specific policy initiatives to grow the economy through innovation. For example, the Rwandese government introduced the National Commission for Science and Technology, developed R&D centres and provided incentive schemes for R&D and innovation. Kenya has continued to build strategic Science, Technology, and Innovation efforts by creating institutions that foster innovation policy in the country. One such initiative is the innovation policy framework that outlines the country's innovation vision. A focus issue outlined in the innovation policy framework is the focus on the generation and management of intellectual property rights, technological transfers, development, and diffusion.

This study further recommends, firstly, that African governments provide financial and material support for R&D in public and private institutions through funding, imparting entrepreneurial research attitudes in academics, and providing an enabling environment for business enterprises to conduct research and innovate. Secondly, this study recommends that African countries reinforce support for their national innovation systems and cultivate strong collaboration among academics in research institutions, experts in the business sector, financial institutions, and policymakers. This kind of collaboration would build local innovation capabilities, which are strong enough to survive economic turbulence. The results of this paper provide some policy implications that can encourage innovation in Africa.

Disclosure statement

No potential conflict of interest was reported by the authors.

Note

1. Algeria, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Chad, Egypt, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe.

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Appendix A

Tables A1: Description subcomponent of innovation index.

Indicator	Description of data collected	scale
Diversity of the workforce	In your country, to what extent do companies have a diverse workforce (e.g. in terms of ethnicity, religion, sexual orientation, gender)?	1 = not at all; 7 = to a great extent
State of cluster development	In your country, how widespread are well-developed and deep clusters (geographic concentrations of firms, suppliers, producers of related products and services, and specialized institutions in a particular field)?	1 = non-existent; 7 = widespread in many fields
International co-inventions	Number of patent family applications with co-inventors located abroad per million population.	Year average
Multi-stakeholder collaboration	In your country, to what extent do people collaborate and share ideas within a company? In your country, to what extent do companies collaborate in sharing ideas and innovating? In your country, to what extent do business and universities collaborate on research and development (R&D)?	1 = not at all; 7 = to a great extent 1 = not at all; 7 = to a great extent 1 = do not collaborate at all; 7 = collaborate extensively
Scientific publication	Score on an index measuring the number of publications and their citations, expressed at the country level	A log transformation is applied to the raw score before it is normalized to a 0–100 scale.
Patent applications	Total number of patent family applications per million population	A log transformation is applied to the raw score before it is normalized to a 0–100 scale.
R&D expenditure	Expenditures on research and development (R&D), expressed as a percentage of GDP	0–100
Research prominence index	Score on an index that measures the prominence and standing of private and public research institutions.	0–100
Buyer sophistication	In your country, on what basis do buyers make purchasing decisions?	1 = based solely on the lowest price; 7 = based on sophisticated performance attributes
Trademark applications	Number of trademark applications per million population	2 year moving average

***Source*:** Global Competitiveness Index Report (2019).

Table A2: shows the PCSE estimation results (R&D expenditure).

Variable name	Coefficient
lnR&D	0,36**
Lninvest	0,18***
Lnemp	−2,55
Lnhc	0,01*
_cons	13,74
Group variable: Country1	Number of obs = 36
Time variable: Year	Number of groups = 3
Panels: correlated (unbalanced)	Obs per group:
Autocorrelation: no autocorrelation	min = 12
Sigma computed by pairwise selection	Avg = 11
	max = 12
Estimated covariances = 6	Rsquared = 0,65
Estimated correlation = 0	Wald chi2 (4) = 131,03
Estimated coefficients = 5	Prob > chi2 = 0,00

***Source*:** Authors computation
Notes: (*), (**), (***) 10, 5, and 1% significance levels, respectively. Standard errors in parentheses