

Long-term Implications of Public Investments in Research and Development on Well-being in Sub-Saharan African Countries

Bobo Moussa

bobo_moussa@yahoo.com

University of Ngaoundere

Engmok Bale Hortense

Ministry of Scientific Research and Innovation

Ismaila Amadu

Ministry of Scientific Research and Innovation

Epo Boniface Ngah

University of Yaounde II-Soa

Yacouba Abali

University of Yaounde II-Soa

Research Article

Keywords: Public investments, R&D, Long-term, Well-being, SSA

Posted Date: September 28th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10970152/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Long-term Implications of Public Investments in Research and Development on Well-being in Sub-Saharan African Countries

Authors

Bobo Moussa¹, Engmok Bale Hortense², Ismaila Amadu², Epo Boniface Ngah³, Yacouba Abali³

1. Faculty of Economics and Management, University of Ngaoundere, Cameroon

2. National Centre for Education, Ministry of Scientific Research and Innovation,
Cameroon

3. Faculty of Economics and Management, University of Yaounde II-Soa, Cameroon

Abstract

African countries spend an average of only 0.45% of their Gross Domestic Product on scientific research, which falls well below the global average of 1.7%. Nonetheless, these limited public expenditures in Research and Development (R&D) have an impact on African economies. Thus, this study attempts to evaluate the long-term macroeconomic implications of public R&D investments on well-being in 38 Sub-Saharan African countries over the period 2000-2022. To this end, we employed the Feasible Generalized Least Squares (FGLS), Driscoll-Kraay, Two-Stage Least Squares Instrumental Variables (IV-2SLS), and Lewbel methods, with data retrieved from the 2025 datasets of the World Bank, UNESCO, UNDP, WIPO, and the World Governance Indicators. The findings indicate that a percentage increase in R&D investments improves well-being by 0.09%, triggers a 0.4% increase in technological development, leads to a 0.06% surge in FDI inflows, causes a 0.2% improvement in the quality of governance, and results in a 0.03% rise in GDP. These results imply that public R&D investments are a major catalyst for development in SSA, despite limited government spending on research. As such, it is recommended that R&D investments should be increased and made a strategic priority for their socioeconomic development.

Keywords: Public investments; R&D; Long-term; Well-being; SSA.

1. Introduction

Over the past five decades, scientific research and innovation have been key drivers of economic growth and socioeconomic transformation in various countries across the world (World Bank, 2020). Innovation fosters social welfare. Technological and organisational changes create new terrific opportunities to address societal changes and to improve human life (Fulvio, 2023). This is the fundamental motivation that has traditionally spurred the development of innovation research and policy-making during the last 50 years or so (Martin, 2016; Nelson, 2011). In this regard, Research funding has played an important role in promoting research and innovation.

Nonetheless, each country has different funding systems, funding sources, and funding allocation mechanisms, but at the same time, there are some common practices among countries with well-developed R&D systems that seem to function effectively. Sub-Saharan Africa (SSA), however, is the region with the lowest research capacity and output in the world (World Bank, 2020). In 2018, spending on Research and Development (R&D) reached a record high of almost US\$1.7 trillion, with 10 countries – China, the USA, Japan, Germany, South Korea, India, the UK, Russia, France, and Brazil – accounting for almost 80 per cent of this funding (World Bank, 2020). According to the World Bank (2025), African countries spend an average of only 0.45% of their GDP on R&D, which falls well below the global average of 1.7%. Correspondingly, Africa's share of global patents remains disproportionately low, implying insufficient innovation and technological advancements originating from the continent (World Economic Forum-WEF, 2023; Foresight Africa, 2023; and World Bank, 2025).

Thus, Africa needs to find innovative ways of unlocking government and industry funding. One such example is Grand Challenges, which is a family of initiatives fostering innovation to solve key global health and development problems. This model has been successfully used in Brazil, India, and Canada, among other countries (WEF, 2023). This portrays how the “old paradigm” whereby scientists define research is changing. Scientists used to assign priorities based on their research experience (Science Granting Council Initiative-SGCI, 2023). But now, the goals of large, philanthropic bodies are impacting prioritisation. These bodies often align with multi-stakeholder organisations. These include institutions such as the World Health Organization (WHO). Does this mean that African priorities are being set elsewhere? (SGCI, 2023). This implies that research funding in Africa is characterised by a heavy reliance on international funds (NGOs, foundations, bilateral agencies) despite the

political commitment of African countries to allocate 1% of their GDP to R&D as recommended by the African Union (Holder, 2023).

Despite limited resources, it is incorrect to assume that investments in scientific research and innovation have no impact on Sub-Saharan African economies. Several studies (World Bank, 2020, 2025; WEF, 2023; SGCI, 2023; Jean-Joseph and Faten, 2022; Ayousha and Zoltan, 2025) have examined R&D fund allocation and the impact of innovation on economic growth, yet these works often overlook developing economies. This study fills that gap by evaluating the long-term contribution of public R&D investments to welfare across 38 Sub-Saharan African countries. The remainder of this paper is organized as follows: Section 2 reviews the literature, Section 3 details the methodological framework, Section 4 presents and discusses the results, and Section 5 concludes with public policy implications.

2. Literature review

Public investment in people's welfare is crucial in every country because the people are at the centre of every economic activity ((Lucas, 1988; Senik, 2003; Piketty et al., 2014). A healthy, well-trained, and happy population in a peaceful country are definely going to be productive (Lucas, 1988; Sen, 1999). This therefore implies that income, health, and education are critical for the welfare of people (Meadows et al., 1972; Langlois, 2025). Income, access to healthcare, and the quality of education are essential pillars for measuring a nation's true well-being, a point emphasized by Meadows et al. (1972) and Langlois (2025).

Today, R&D has become a key driver for improving living conditions and the collective standard of living (Herrea, 2005; Rodriguez, 2006). Empirically, this relationship has been extensively studied. To this effect, Jean-Joseph and Faten (2022), for example, analyzed 101 countries to measure the impact of research on growth. Their work shows that R&D spending and exports of technology products stimulate the economy, while highlighting the nonlinear complexity of this relationship.

In addition, Swati et al. (2017) attempted to uncover the relationship between research and development expenditure in 218 countries from 2008 to 2011 using a three-year time lag. They found that R&D expenditure was statistically significant throughout the models tested, and other factors such as gross savings, industry as value added, and services as value added were significant at the one per cent level.

Moreover, Ayousha and Zoltan (2025) analyzed the channels through which research and development (R&D) impacts economic growth in 32 developing countries in the lower-middle-income group for the year 2019. Their results indicated there was no significant

relationship between innovation performance and economic growth. This could mean that while R&D and capital markets may contribute to innovation through entrepreneurship, the contribution is not impactful enough to drive economic growth in developing countries.

It is in this light that Edeme et al. (2017), Razafindrakoto (2006), and Maztruzzi et al. (2006) emphasized that increasing investments in healthcare research and innovation activities has a significant impact on the reduction of mortality, improved life expectancy, as well as the production of goods and services. Therefore, investing adequately in R&D could result in the creation of start-ups, incubators, and technological pools with innovative solutions to improve the livelihoods of people (Romer, 1990; Aghion and Howitt, 1992).

To this effect, Roubaud (2006) and Michineu (2022) argued that investments in health sector research led to the creation of start-ups, which significantly facilitated access to healthcare services and eventually improved the living standards of the masses. To this effect, investing in R&D, particularly in domains like health, education, transportation, and agriculture that have a direct impact on the livelihoods of individuals in a very short time, constitutes a major tool to harness and enhance economic progress and prosperity (Kahneman et al. 2003; World Bank, 2020; Ayousha and Zoltan, 2025). These investments are not solely aimed at financial returns; they transform the economy by modernizing production methods and protecting households from climate-related or health-related shocks, thereby creating cycle between scientific progress and everyday well-being.

Therefore, governance, funding, and institutional framework in particular are key determinants for effective R&D (Acemoglu et al. 2006). This is because the public sector plays a critical role in setting the priorities, putting in place and enforcing regulations, allocating funding, and transforming research findings into consumer goods and services that could have a direct impact on the well-being of the people (Welzl et al., 2005; Razafindrakoto, 2006; Acemoglu et al., 2006). Thus, whilst the importance of research is self-evident in developed countries, it is even more so for less developed nations, for it is hard to imagine development without a certain threshold of self-sufficiency or sovereignty, at least in certain vital sectors such as health, food, education, basic technologies, and the production and processing of raw materials (Foresight Africa, 2023). In this regard, the government plays a key role here, as emphasized by Welzl et al. (2005), Razafindrakoto (2006), and Acemoglu et al. (2006): it must set scientific priorities in line with local needs, manage budgets effectively, and translate discoveries into concrete services for citizens.

3. Methodology

3.1. Data timeframe and choice of countries

This study mobilizes an unbalanced dynamic macroeconomic panel covering 38 Sub-Saharan African (SSA) countries over the period 2000-2022. The choice of this time frame is doubly justified: first, the year 2000 coincides with the launching of the Millennium Development Goals (MDGs), which led to the standardization and structural improvement of socio-economic data collection in SSA. Second, the year 2022 maximizes temporal depth while capturing post-crisis adjustments from the COVID-19 pandemic. To obtain results that reflect the realities on the ground or avoid biased results, countries in a state of statistical fragility, such as Somalia and South Sudan, were not included in the study.

3.2. Variables and sources of data

The central dependent variable, which was used to capture multidimensional well-being, is the Human Development Index HDI calculated by the United Nations Development Programme (UNDP). To test the theoretical robustness of the estimations, we alternatively considered the variable Gross Domestic Product (GDP) per capita in purchasing power parity. R&D efforts and innovation are captured by three key variables: Gross domestic expenditure on R&D as a percentage of GDP (R&D) from UNESCO-UIS; the number of articles published in scientific journals, and the number of patent applications by residents per million inhabitants from the World Intellectual Property Organisation (WIPO). The vector of control variables, extracted from the World Bank's World Development Indicators (WDI), includes: net foreign direct investment inflows as a percentage of GDP (FDI), internet penetration rate (NET), GDP growth rate (GDP), and the Control of Corruption index CC compiled by the Worldwide Governance Indicators (WGI).

The above-mentioned variables were selected because they best reflect the realities of the countries under study and the availability of data for the period under study. The data on the aforementioned variables of interest were retrieved from the 2025 data sets of UNDP, UNESCO, WIPO, WGI, and the World Bank. These sources were preferred because of their credibility and reliability in producing data for scientific purposes.

3.3. Model specification

In alignment with the theoretical framework of endogenous growth (Romer, 1990; Lucas, 1988) and Sen's capabilities approach (1999), we specify three distinct mixed-effects panel models in log-linear form to evaluate the impact of R&D public expenditure on well-

being in SSA. This approach is deemed more suitable for this work as it focuses on economic development proper, triggered and sustained mainly by actions undertaken from within a country, like the endogenous theories outlined:

$$\text{Model 1: } \text{HDI}_{it} = \alpha_0 + \beta_1 \ln \text{R\&D}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

$$\text{Model 2: } \text{HDI}_{it} = \alpha_0 + \beta_1 \ln \text{INN}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

$$\text{Model 3: } \text{HDI}_{it} = \alpha_0 + \beta_1 \ln \text{PAT}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Where $t=2000, \dots, 2022$ denote country and year, respectively. HDI_{it} is the logarithm of the Human Development Index (multidimensional proxy of well-being, in accordance with Ranis et al., 2000; Antonelli and Fassio, 2016). X_{it} represents the vector of control variables (FDI_{it} , NET_{it} , GDP_{it} and CC_{it}). μ_i captures unobserved individual fixed effects (invariant geographical, historical, or cultural characteristics), λ_t represents time fixed effects (global macroeconomic shocks or common world crises), and ε_{it} is the stochastic error term.

To test the theoretical sensitivity of the model against materialist theses, the HDI is replaced by the logarithm of GDP per capita (GDPc), generating the following specification:

$$\text{Model 4: } \ln \text{GDPc}_{it} = \omega_0 + \omega_1 Z_{it} + \gamma X'_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Where Z_{it} represents the primary innovation variables ($\ln \text{R\&D}_{it}$, $\ln \text{INN}_{it}$ and $\ln \text{PAT}_{it}$), and denotes the vector of control variables (FDI_{it} , NET_{it} , GDP_{it} and CC_{it}).

3.4. Estimation techniques

The estimation of macroeconomic panels runs into three classic violations of Ordinary Least Squares (OLS) assumptions: heteroscedasticity, autocorrelation of errors, and cross-sectional dependence (contemporary correlations between countries due to unobserved common shocks).

First, we apply the Feasible Generalized Least Squares (FGLS) estimator for its convergence property in the presence of complex variance structures (Greene, 2012). Second, we mobilize the Driscoll and Kraay (1998) estimator. This technique adjusts the variance-covariance matrix via a non-parametric correction, yielding standard errors that are rigorously robust to cross-sectional dependence, heteroscedasticity, and moving-average autocorrelation.

However, both approaches fail to address the problem of endogeneity. In R&D matters, endogeneity stems from a bidirectional reverse causality: if investment in R&D promotes well-being, raising the level of human development provides states with increased budgetary capacities to fund research. To neutralize this bias, we implement the Two-Stage Least Squares Instrumental Variables (IV-2SLS) method, completed at the end of the chain by Lewbel's (2012) approach to guarantee identification in the presence of potentially imperfect external instruments.

To correct for the endogeneity bias inherent in the reverse causality between research and well-being, we adopt the two-stage instrumental variables method (IV-2SLS). In this study, the innovation variables ($\ln R\&D$, $\ln INN$, and $\ln PAT$) are treated as endogenous.

To ensure robust identification of our models, we employ two main external instruments. First, we use innovation variables lagged by one period. ($\ln R\&D_{it-1}$, $\ln INN_{it-1}$, $\ln PAT_{it-1}$) This approach is justified by the fact that research investments depend heavily on the previous year's budgets and infrastructure, which satisfies the relevance condition. Furthermore, past R&D cannot be influenced by the country's current level of well-being, which satisfies the exogeneity condition. Second, we include total public spending on education (as a percentage of GDP). Countries that invest heavily in their education systems create a favorable environment that stimulates research and patent filing, thereby satisfying the relevance condition. This choice also meets the exclusion condition, insofar as the long-term effect on multidimensional well-being is primarily achieved through strengthening the country's technological innovation capabilities. Finally, the economic relevance of these instruments is confirmed by our statistical tests. On the one hand, Hansen's J-test of over-identification confirms the exogeneity of our instruments with p-values above the 10% threshold. On the other hand, the Cragg-Donald and Kleibergen-Paap statistics far exceed the Stock-Yogo critical values, which definitely rule out the risk of weak instruments.

4. Findings and discussions

4.1.Descriptive Analysis of the Data

In accordance with the methodological recommendations, Table 1 below presents the descriptive statistics for the variables selected for our sample, which consists of 38 sub-Saharan African countries over the 2000–2022 period. To this end, the data were preprocessed to exclude outliers, and all indicators were harmonized according to international standards.

Table 1: Descriptive statistics of variables (2000-2022)

Variable	Definition	Unit	Obs	Mean	Std. Dev.	Min	Max	Source
HDI	Human Development Index	Index (0 to 1)	4,348	0.514	0.115	0.312	0.789	UNDP
R&D	Gross domestic expenditure on R&D	% of GDP	829	0.316	0.224	0.005	0.806	UNESCO
PAT	Patent applications by residents	Per million inhabitants.	1,136	2.766	5.044	0.010	29.332	WIPO
INN	Scientific articles published	Number	4,940	549.317	1,859.057	0.000	16,651.1	WIPO
FDI	Net Foreign Direct Investment inflows	% of GDP	4,924	4.118	7.863	-17.292	103.337	World Bank
NET	Internet penetration rate	% of population	871	12.141	15.941	0.006	78.293	World Bank
GDP	Real GDP growth rate	Annual %	874	4.322	4.343	-30.145	33.629	World Bank
GDPc	GDP per capita growth rate	Annual %	874	1.692	4.154	-30.699	27.807	World Bank
CC	Control of Corruption Index	Score (-2.5 to 2.5)	874	-0.584	0.602	-1.688	1.240	WGI

Source: Authors

As a preliminary diagnostic, cross-sectional dependence was assessed using the CD, CDw, CDw+, and CD* tests; the results, reported in Table A (See appendix), provide evidence of cross-sectional dependence for several variables and support the use of estimators robust to cross-sectional dependence.

4.2. Results of the Feasible Generalized Least Squares (FGLS) and Driscoll-Kraay methods

The results of the initial econometric estimations using the FGLS and Driscoll-Kraay methods are displayed in Table 2. They provide a first empirical validation of endogenous growth theories in Sub-Saharan Africa in the case of this study, implying that economic growth and prosperity are triggered from within the country. In this study, the findings show that a percentage increase in R&D public investments in SSA leads to an improvement in well-being by 0.09% captured using the Human Development Index (HDI). The coefficient associated with public R&D expenditure ($\ln R\&D$) stands at 0.0904, and it is highly significant at the 1% threshold (column 1) and 5% threshold (column 4). Considering that the HDI index encompasses the income, health, and education aspects, which are key elements in determining welfare, this result implies that R&D investments have a strong and direct positive impact on the main factors that could harness and enhance the socioeconomic transformation in SSA.

Moreover, this indicates that although R&D investments in Africa are the lowest compared to the rest of the world, they have a significant impact in the long run on the welfare of people. The findings further depict that investing in R&D leads to the accumulation of knowledge and, therefore, could act as a powerful catalyst for technical progress through the establishment of patent rights, attraction of FDI, increased scientific production, and improvement of GDP. Columns (2), (3), (5), and (6) of Table 2 confirm this trend, considering the corresponding coefficients of the variables that are positive, significant, and statistically robust.

In addition, the results show that investing in R&D results in an improvement in governance and quality of institutions. The variable control of corruption displays a coefficient of 0.2298, which is very significant at the 1% threshold. This shows that R&D investments have a substantial impact on governance, as indicated by the probabilities and the significant coefficients of the variable CC in all the columns of Table 2. Therefore, research serves as a major tool to improve governance and the quality of institutions in SSA. This might result from the implementation of the research findings and taking into account the policy advice from research institutions by the governments in SSA. This is a strong indication that SSA governments pay a lot more attention to research findings and apply them in the fight against corruption and the improvement in governance.

Table 2: Effect of R&D investment on well-being in SSA using the FGLS and Driscoll-Kraay methods

	(1)	(2)	(3)	(4)	(5)	(6)
	FGLS Method			Driscoll-Kraay Method		
VARIABLES	HDI	HDI	HDI	HDI	HDI	HDI
lnR&D	0.0904*** (0.0204)			0.0904** (0.0362)		
LnINN		0.1291*** (0.0148)			0.1291*** (0.0279)	
lnPAT			0.2998*** (0.0333)			0.2998*** (0.0285)
FDI	0.0528* (0.0272)	0.0678*** (0.0209)	-0.0666 (0.0427)	0.0528** (0.0235)	0.0678*** (0.0179)	-0.0666 (0.0529)
NET	0.0150*** (0.0021)	0.0114*** (0.0018)	0.0015 (0.0031)	0.0150*** (0.0027)	0.0114** (0.0051)	0.0015 (0.0021)
GDP	-0.0018 (0.0092)	0.0042 (0.0063)	0.0240** (0.0119)	-0.0018 (0.0158)	0.0042 (0.0115)	0.0240*** (0.0078)
CC	0.2298*** (0.0632)	0.0846* (0.0453)	0.2251*** (0.0853)	0.2298*** (0.0638)	0.0846* (0.0432)	0.2251** (0.0835)
Constant	0.3765*** (0.0830)	-0.4390*** (0.0745)	0.5078*** (0.1167)	0.3765** (0.1503)	-0.4390*** (0.0562)	0.5078*** (0.0775)
Observations	507	803	194	507	803	194

R-squared				0.2079	0.1946	0.4259
chi2	133.0***	194.0***	143.9***			
Fisher				123.2***	64.66***	41.53***

Source: Authors

Notes: Standard errors are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.3. Results of the Two-Stage Least Squares Instrumental Variables (IV-2SLS) method

To make sure that the findings obtained using the FGLS and Driscoll-Kraay methods are more robust and reliable or void of any bias, the IV-2SLS method was employed to do a second estimation for verification.

After instrumentation, the impact of the research effort strengthens, with the coefficient of (lnR&D) rising to 0.0916, which is significant at 1% (column 1). This amplification of the coefficient post-instrumentation is classic in panel econometrics, and it indicates that baseline OLS or FGLS estimates were biased downward due to measurement errors or a blurring of causalities. Nonetheless, the findings confirm that R&D public investment therefore exerts a direct, net, and structural long-term impact on well-being in Sub-Saharan Africa.

Remarkably, the variable capturing residential patents (PAT) displays the most powerful coefficient of the entire study, reaching 0.4157 (column 3). This result shows that investing in R&D results in the development of local technologies and innovations to address national development challenges. Thus, it can be affirmed based on the results that patents filed by residents reflect the emergence of local technical and technological solutions, calibrated to respond adequately to specific African development problems. On the econometric validity, diagnostic statistics confirm the robustness of the identification. Hansen J overidentification tests display p-values well above the 10% threshold (0.491; 0.443; 0.393), failing to reject the null hypothesis of instrument exogeneity. Concurrently, Cragg-Donald (14,857) and Kleibergen-Paap (9,074) statistics outclass Stock-Yogo critical values, definitively ruling out the risk of weak instruments.

Table 3: Effects of R&D investment on welfare in SSA using the Two-Stage Least Squares

VARIABLES	Instrumental Variables		
	(1)	(2)	(3)
	IV-2SLS Method		
	HDI	HDI	HDI
lnR&D	0.0916*** (0.0244)		
lnINN		0.1349*** (0.0185)	
lnPAT			0.4157*** (0.0365)
FDI	0.0411* (0.0225)	0.0625*** (0.0205)	-0.0427 (0.0368)
NET	0.0156*** (0.0030)	0.0113*** (0.0031)	-0.0028 (0.0043)
GDP	0.0059 (0.0120)	0.0067 (0.0094)	0.0377** (0.0154)
CC	0.2320*** (0.0644)	0.0871* (0.0490)	0.4806*** (0.1233)
Constant	0.3483*** (0.1189)	-0.4692*** (0.0774)	0.7213*** (0.1378)
Observations	461	737	130
R-squared	0.2255	0.1900	0.5635
Region Country FE	Yes	Yes	Yes
Hansen j	0.491	0.443	0.393
Cragg-Donald Wald	14857	13668	150.7
Kleibergen-Paap	9074	5338	118.0
Fisher	27.87***	40.74***	63.91***

Source: Authors

Notes: Robust standard errors are reported in parentheses. Innovation variables are instrumented using one-period lagged values and total public expenditure on education (% of GDP). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.3. Sensitivity and robustness of results

4.3.1. Sensitivity of results by substituting the well-being measure with per capita income

The results presented in Table 4 highlight a divergence in the impact of research effort depending on the development indicator used. Indeed, when well-being is measured by gross domestic product per capita (ln GDPc), the elasticity of R&D spending drops to 0.0185, becoming only marginally significant at the 10% threshold. Conversely, when development is assessed in a multidimensional manner using the Human Development Index (HDI), the effect intensifies significantly. This empirical divergence validates the capabilities approach developed by Amartya Sen (1999). In sub-Saharan Africa, the benefits of scientific research

and technological innovation do not necessarily translate into an immediate increase in monetary wealth. Rather, they manifest through non-monetary externalities that directly contribute to the three fundamental dimensions of human development, namely:

First, there is the public health channel: Public investment in medical R&D helps adapt treatment protocols to local diseases and optimizes the delivery of health services. These factors contribute to a decline in mortality and an increase in life expectancy at birth, a major component of the HDI.

Next, the education and human capital channel: Technological innovation, bolstered by the expansion of digital infrastructure (NET), modernizes access to knowledge platforms and supports technical training. This process creates a positive feedback loop on literacy and enrollment rates.

And finally, the agricultural resilience channel (non-monetary income): A substantial portion of R&D in sub-Saharan Africa is focused on agronomic innovation, particularly through resilient seeds and improved irrigation techniques. These advances strengthen food security and stabilize the subsistence incomes of rural households, without necessarily flowing through the formal channels of market-based GDP. Consequently, limiting the assessment of the returns on scientific research solely to the lens of gross economic growth leads to a systematic underestimation of its actual contribution to social progress and to improving people's quality of life.

Table 4: Sensitivity of results due to changes in the measure of well-being development

	(1)	(2)	(3)
	IV-2SLS Method		
VARIABLES	GDPc	GDPc	GDPc
lnR&D	0.0185* (0.0108)		
lnINN		0.1519*** (0.0516)	
lnPAT			0.3804** (0.1533)
FDI	0.0121 (0.0289)	-0.0063 (0.0222)	-0.0483 (0.0503)
NET	0.0007 (0.0015)	-0.0028 (0.0021)	-0.0028 (0.0026)
GDP	0.9797*** (0.0049)	0.9560*** (0.0079)	0.9813*** (0.0107)
CC	0.1492 (0.0956)	0.2158* (0.1272)	0.2187 (0.2838)
Constant	-1.2955*** (0.0891)	-2.5029*** (0.4193)	-2.2097*** (0.4652)
Observations	462	741	130
R-squared	0.9898	0.9891	0.9917
Region Country FE	Yes	Yes	Yes
Hansen j	0.270	0.761	0.423
Cragg-Donald Wald	8004	713.7	4.918

Kleibergen-Paap	2667	371.6	4.564
Fisher	2666	2002	252.2

Source: Authors

Notes: Robust standard errors are reported in parentheses. The dependent variable is the logarithm of real GDP per capita growth rate (GDPc). ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.3.2. Robustness test by changing the estimation method: Lewbel's (2012) 2SLS

Finally, to counter criticisms related to the choice of external instruments, we implement Lewbel's (2012) method. The results are displayed in Table 5. This approach exploits the heteroscedasticity of the first stage to generate orthogonal internal instruments, guaranteeing a robust estimation even in the absence of perfect traditional instruments.

The results show a high degree of stability of the econometric estimations used. The coefficient associated with R&D expenditure stands at 0.0920 (column 1), a level statistically and economically virtually identical to that obtained using the classic IV-2SLS method (0.0916). This strict convergence across four distinct estimators (FGLS, Driscoll-Kraay, IV-2SLS, and Lewbel) indicates the absolute robustness of the results obtained.

Table 5: Robustness through the use of an alternative instrumentation method

	(1)	(2)	(3)
	2SLS Lewbel Method		
VARIABLES	HDI	HDI	HDI
lnR&D	0.0920*** (0.0246)		
lnINN		0.1357*** (0.0184)	
lnPAT			0.4098*** (0.0374)
FDI	0.0411* (0.0226)	0.0644*** (0.0205)	-0.0450 (0.0384)
NET	0.0156*** (0.0030)	0.0110*** (0.0030)	-0.0026 (0.0043)
GDP	0.0059 (0.0121)	0.0026 (0.0101)	0.0373** (0.0158)
CC	0.2319*** (0.0648)	0.0876* (0.0491)	0.4837*** (0.1249)
Constant	0.3488*** (0.1198)	-0.4446*** (0.0709)	0.7243*** (0.1410)
Observations	461	737	130
R-squared	0.2255	0.1891	0.5658
Region Country FE	Yes	Yes	Yes
Jp	0.0380	0.00485	0.0253
Cragg-Donald Wald	4953	4563	52.44

Rkf	5589	2949	48.76
Fisher	27.96***	41.59***	57.66***

Source: Authors

Notes: Robust standard errors are reported in parentheses. Instruments are internally generated via Lewbel's (2012) method exploiting first-stage heteroscedasticity. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

5. Conclusion and public policy recommendations

This study evaluated the long-term macroeconomic implications of public investment in Research and Development (R&D) on well-being in 38 Sub-Saharan African countries for the period spanning from 2000 to 2022. By linking the framework of endogenous growth theories with the capabilities approach, empirical estimations (FGLS, Driscoll-Kraay, IV-2SLS, and Lewbel) converge toward a foundational result: national innovation effort is a first-order determinant of human development and improvement in well-being in SSA, with its impact being maximized by the production of patented residential technologies. Conversely, sensitivity analysis proves that limiting the evaluation of research returns to GDP per capita alone leads to a radical underestimation of its contribution to social progress.

In light of these findings, we formulate four concrete, actionable recommendations for Sub-Saharan African decision-makers. First, Ministries of Finance and Scientific Research must collaborate to increase domestic research funding from the current average of 0.32% to the African Union's 1% target, an expansion that should be secured through multi-year budget laws to mitigate dependence on international donors. Furthermore, national industrial property offices must fast-track patent application processes in partnership with regional organizations, while governments provide targeted tax exemptions to local innovators to incentivize domestic creativity.

In addition, policymakers must support scientific funding with comprehensive institutional reforms, as strengthening anti-corruption agencies is essential to ensure that public funds allocated to laboratories and universities are not diverted. Finally, telecommunication regulators should expand national broadband fiber networks, particularly in university hubs and agricultural zones, since access to digital infrastructure remains a fundamental prerequisite to maximizing the returns of modern R&D.

Although our results remain robust, this study presents certain limitations that pave the way for future research; specifically, the use of an unbalanced panel, necessitated by missing data for certain years, limits the precision of country-specific trajectories, while our

macroeconomic framework focuses exclusively on public R&D expenditure due to the scarcity of data regarding private sector funding. Consequently, future research should incorporate microeconomic data to better analyze the contributions of the private sector and NGOs to research. Furthermore, evaluating the specific impact of R&D on the gender gap in education and health would provide deeper insights into the drivers of inclusive well-being.

Appendix

Table A: Cross-Sectional Dependence Tests

	CD	CDw	CDw+	CD*
HDI	-0.410 (0.679)	-0.410 (0.681)	24.150 (0.000)	-1.590 (0.111)
R&D	2.890 (0.004)	-0.270 (0.791)	23.230 (0.000)	-1.540 (0.124)
INN	3.350 (0.001)	-0.420 (0.677)	24.360 (0.000)	-1.180 (0.239)
PAT	0.830 (0.408)	0.510 (0.610)	19.690 (0.000)	-0.730 (0.465)

Notes: p-values are reported in parentheses.

References

- Acemoglu, D., Aghion, P., & Zilibotti, F. (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic Association*, 4(1), 37-74.
- Acemoglu, D., Johnson, S., & Robinson, J. A. (2006). Institutions are a fundamental cause of long-run growth. *Handbook of Economic Growth*, 1, 385-472.
- Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. *Econometrica*, 60(2), 323-351.
- Antonelli, C., & Fassio, C. (2016). Globalization and the knowledge-driven economy. *Structural Change and Economic Dynamics*, 38, 57-69.
- Ayousha, F., & Zoltan, B. (2025). Research and development as a driver of innovation and economic growth: the case of developing economies. *Journal of Social and Economic Development*, <https://doi.org/10.1007/s40847-025-00438->.
- Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics*, 80(4), 549-560.
- Edeme, R. K., Emecheta, C., & Omeje, M. O. (2017). Public health expenditure, health outcomes, and economic growth in Nigeria. *International Journal of Development and Sustainability*, 6(10), 1467-1479.

Foresight Africa. (2023a). *Africa's economic sovereignty and technological self-sufficiency*. Brookings Institution.

Foresight Africa (2023b). Top Priorities for the Continent in 2023. Africa Growth Initiative, Brookings Institution.

Fulvio, C. (2023). Innovation and social welfare: A new research agenda. *Journal of Economic Surveys*, 37(4), 1156-1191.

Greene, W. H. (2012). *Econometric Analysis* (7th ed.). Prentice Hall.

Herrea, M. (2005). Research and development as a driver of modern well-being. *World Development Review*, 33(4), 512-529.

Jean-Joseph, M., & Faten, B. B. (2022). The impact of research and development (R&D) on economic growth: new evidence from kernel-based regularized least squares. *The Journal of Risk Finance*, 23(5), 583-604.

Kahneman, D., Diener, E., & Schwarz, N. (Eds.). (2003). *Well-being: Foundations of hedonic psychology*. Russell Sage Foundation.

Kahneman, D., Krueger, A. B., Schkade, D. A., Schwarz, N., & Stone, A. A. (2004). Toward national well-being accounts. *American Economic Review*, 94(2), 429-434.

Langlois, M. (2025). *Indicateurs critiques du bien-être des populations*. Éditions Économiques Modernes.

Lewbel, A. (2012). Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models. *Journal of Business & Economic Statistics*, 30(1), 67-80.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1), 3-42.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The limits to growth*. Earth Island.

Martin, B. R. (2016). Twenty challenges for innovation studies. *Science and Public Policy*, 43(3), 432-450.

Maztruzzi, M., Kaufmann, D., & Kraay, A. (2006). Governance indicators for 1996-2005. *World Bank Policy Research Working Paper*, (4012).

- Michineu, K. (2022). Health sector research, entrepreneurship, and standards of living in developing nations. *Health Economics and Policy*, 19(3), 301-318.
- Nelson, R. (2011). The Moon and the Ghetto revisited. *Science and Public Policy*, 38(9), 681–690.
- Piketty, T. (2014). *Capital in the Twenty-First Century*. Harvard University Press.
- Piketty, T., Saez, E., & Zucman, G. (2014). Distributional national accounts: Methods and estimates for the United States. *The Quarterly Journal of Economics*, 133(2), 553-609.
- Ranis, G., Stewart, F., & Ramirez, A. (2000). Economic growth and human development. *World Development*, 28(2), 197-219.
- Razafindrakoto, M. (2006). Gouvernance, institutions et efficacité des politiques publiques en Afrique subsaharienne. *Revue d'Économie du Développement*, 20(2), 85-114.
- Rodriguez, J. (2006). Shaping lives: The impact of technological pool creation on livelihoods. *Technology and Society*, 28(2), 204-221.
- Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, 98(5, Part 2), S71-S102.
- Roubaud, F. (2006a). Les déterminants du bien-être en Afrique : une approche comparative. *Revue d'Économie du Développement*, 14(2), 65-98.
- Roubaud, F. (2006b). Impact de la recherche médicale sur l'accès aux soins et le niveau de vie en milieu urbain. *Santé Publique et Développement*, 12(1), 47-65.
- Sen, A. (1999). *Development as Freedom*. Oxford University Press.
- Senik, C. (2003). Is man doomed to progress? Long-term income, relative income, and happiness. *Journal of Economic Behavior & Organization*, 54(4), 495-515.
- Science Granting Council Initiative-SGCI (2023). Research funding in Africa: highlights from the SGCI Masterclass Working Paper. Retrieved from www.sgci africa.org.
- Swati, S., Kumar, A., & Mishra, P. (2017). Uncovering the time-lagged relationship between R&D expenditure and economic parameters: A global perspective. *Research Policy*, 46(8), 1432-1445.
- Swati, M., Will, G., Sana, S. (2017). The Economic Impact of Research and Development. *Econometrics*, 3161.

Welzl, H., Müller, M., & Fischer, R. (2005). The role of the public sector in transforming research into consumer goods. *Innovation: The European Journal of Social Science Research*, 18(3), 289-305.

World Bank. (2020). The Importance of Sectoral Investments for Human Development in Africa. World Bank Group.

World Bank (2020). Comparative study of research funds. Retrieved from www.worldbank.org.

World Bank (2025). Research and development expenditure (% of GDP). Retrieved from www.worldbank.org.

World Economic Forum (2023). Africa needs to find innovative ways of unlocking government and industry. Retrieved from www.worldeconomicforum.org.