Research Capacity Building and Human Development in African Economies: Dynamic Panel Evidence from African Countries

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Abstract:

Research capacity is increasingly recognized as a critical driver of sustainable development through its role in innovation, technological advancement, and evidence-based policymaking. However, empirical evidence on its contribution to human development in Africa remains limited. This study examines the effect of research capacity building on human development in 30 African countries from 2000 to 2025 using a balanced panel of 780 observations. A multidimensional Research Capacity Building Index (RCBI) is constructed using Principal Component Analysis (PCA) based on research and development expenditure, researchers in R&D, scientific publications, patent applications, doctoral education, tertiary enrolment, and internet infrastructure. The analysis employs the Panel Autoregressive Distributed Lag Pooled Mean Group (ARDL-PMG) estimator, with robustness assessed using Fixed Effects, Driscoll–Kraay, Dynamic Fixed Effects, FMOLS, DOLS, and Two-Step System GMM. The findings show that research capacity significantly enhances human development in both the short and long run. Financial inclusion and governance quality exert positive effects, whereas inflation negatively affects development, while foreign direct investment has a modest positive influence. Robustness tests confirm that the results are resilient to alternative estimators and endogeneity. The study extends Endogenous Growth Theory by demonstrating that strengthened national research systems promote human development through knowledge creation, innovation, and institutional effectiveness, highlighting the need for sustained investment in research ecosystems across Africa.

Keywords: *Africa; Governance Quality; Human Development; Innovation. Panel ARDL; Research Capacity Building.*

1. Introduction

Sustainable development in the twenty-first century is increasingly driven by knowledge, innovation, and technological advancement rather than by the accumulation of physical capital alone. Contemporary growth theories emphasize that the ability of countries to generate, adapt, and apply scientific knowledge is fundamental to improving productivity, strengthening institutions, and enhancing human welfare. Consequently, research capacity has emerged as a strategic component of national development systems, enabling countries to formulate evidence-based policies, foster innovation, respond to emerging socioeconomic challenges, and accelerate long-term development. Investments in research institutions, higher education, scientific infrastructure, and innovation ecosystems are therefore widely recognized as essential for achieving sustainable and inclusive growth.

The importance of research capacity is particularly evident in Africa, where countries continue to face persistent development challenges despite abundant natural resources and a rapidly growing population. While the continent has recorded improvements in education, health, financial inclusion, and digital connectivity, progress in human development remains uneven. Weak research infrastructure, inadequate funding for research and development (R&D), shortages of skilled researchers, limited university–industry collaboration, and low commercialization of research outputs continue to constrain innovation and evidence-based policymaking. Recognizing these challenges, continental initiatives such as the African Union's Agenda 2063, the Science, Technology and Innovation Strategy for Africa (STISA), and the African Continental Free Trade Area (AfCFTA) identify research, innovation, and knowledge generation as critical drivers of structural transformation and sustainable development.

Despite growing policy interest, empirical evidence on the contribution of research capacity to human development in Africa remains limited. Existing studies have largely focused on individual indicators such as R&D expenditure, scientific publications, tertiary education, or patents, overlooking the multidimensional nature of national research systems. Furthermore, much of the literature concentrates on developed economies, where institutional environments differ considerably from those in Africa. Methodologically, many previous studies rely on static panel models that fail to distinguish between long-run equilibrium relationships and short-run adjustment dynamics, while relatively few address the potential endogeneity arising from the bidirectional relationship between research capacity and development.

This study addresses these gaps by constructing a multidimensional Research Capacity Building Index (RCBI) using Principal Component Analysis (PCA) and examining its impact on human development across 30 African economies over

the period 2000–2025. Unlike conventional single-indicator approaches, the RCBI integrates multiple dimensions of national research systems, including research expenditure, researchers, scientific publications, doctoral education, patents, tertiary education, and research infrastructure. The empirical analysis employs the Panel Autoregressive Distributed Lag (ARDL) Pooled Mean Group (PMG) estimator to distinguish between long-run and short-run effects while accommodating heterogeneous adjustment dynamics across countries. To ensure robustness, the findings are validated using Fixed Effects, Driscoll–Kraay, Dynamic Fixed Effects, Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Two-Step System Generalized Method of Moments (System GMM) estimators.

Beyond examining the direct effect of research capacity, the study incorporates governance quality, financial inclusion, foreign direct investment, and inflation as complementary determinants of human development. It also investigates whether governance quality and financial inclusion strengthen the developmental impact of research capacity and explores regional heterogeneity across African subregions. By integrating Endogenous Growth Theory, Human Capital Theory, National Innovation Systems Theory, and Institutional Theory, the study provides a comprehensive framework for understanding how research capacity contributes to sustainable development.

The study makes three principal contributions to the literature. First, it develops a comprehensive multidimensional measure of research capacity that captures the institutional and knowledge dimensions of national innovation systems. Second, it provides robust dynamic evidence on the long-run and short-run effects of research capacity on human development while addressing endogeneity and model uncertainty through multiple econometric approaches. Third, it offers policy-relevant insights into how strengthening research ecosystems, improving governance, and expanding financial inclusion can accelerate progress towards the Sustainable Development Goals (SDGs) and the African Union's Agenda 2063. The remainder of the paper is organized as follows: Section 2 reviews the relevant literature and develops the theoretical framework; Section 3 presents the methodology and data; Section 4 discusses the empirical results and robustness analyses; and Section 5 concludes with policy implications and recommendations.

2. Literature Review

2.1 Conceptual Literature

2.1.1 Research Capacity Building

Research capacity building (RCB) is the process of strengthening the ability of individuals, institutions, and national systems to generate, disseminate, and

apply scientific knowledge for development. It involves investments in research infrastructure, human capital, research funding, innovation, and institutional governance. According to Cooke (2005), RCB promotes sustainable research systems and evidence-based decision-making, while UNESCO (2021) emphasizes investments in research and development, researchers, universities, and innovation ecosystems. The World Bank (2021) further highlights institutional quality, technological capability, digital infrastructure, and research commercialization as essential components. Given its multidimensional nature, this study constructs a Research Capacity Building Index (RCBI) using indicators such as research expenditure, researchers in R&D, scientific publications, patent applications, doctoral education, tertiary enrolment, and digital infrastructure.

2.1.2 Human Development

Human development refers to the process of expanding people's capabilities and improving their quality of life through better health, education, and living standards. According to the United Nations Development Programme (UNDP, 2024), these dimensions are measured by the Human Development Index (HDI), which provides a broader assessment of development than income alone by recognizing that economic growth does not necessarily translate into improved welfare.

2.1.3 Research Capacity and Human Development

Research capacity promotes human development by generating scientific knowledge, supporting evidence-based policymaking, fostering innovation and technological progress, and improving outcomes in healthcare, education, agriculture, environmental management, and industrial competitiveness. The OECD (2015) identifies knowledge as a key driver of long-run economic growth, while UNESCO (2021) recognizes research investment as a critical determinant of innovation-led and sustainable development.

2.2 Theoretical Literature

The study draws upon four complementary theories.

2.2.1 Endogenous Growth Theory

Developed by Paul Romer (1986, 1990), Endogenous Growth Theory argues that technological progress results from intentional investments in research, innovation, and human capital rather than external forces. The theory predicts that countries investing more heavily in research systems experience sustained productivity growth and improved welfare.The theory therefore provides the principal framework for explaining how research capacity affects human development.

2.2.2 Human Capital Theory

Human Capital Theory, advanced by Theodore Schultz (1961) and Gary Becker (1964), argues that education, knowledge, and skills constitute productive assets that enhance economic performance. Research capacity strengthens human capital through postgraduate education, scientific training, and knowledge creation.

2.2.3 National Innovation Systems Theory

National Innovation Systems Theory emphasises interactions among universities, government, research institutes, and industry. According to Bengt-Åke Lundvall (1992), innovation emerges from institutional collaboration rather than isolated research activities. Countries with stronger innovation systems therefore generate more technological progress and better development outcomes.

2.2.4 Institutional Theory

Institutional Theory argues that effective governance determines whether investments in research produce development outcomes. According to Douglass North (1990), institutions influence incentives, knowledge diffusion, innovation, and economic performance. Strong institutions therefore amplify the developmental benefits of research capacity.

2.3 Empirical Literature

Research capacity is increasingly recognized as a key determinant of innovation, institutional quality, and human development. Empirical evidence indicates that countries with stronger research systems generally achieve higher productivity, improved governance, and better socioeconomic outcomes, although these effects depend on complementary factors such as institutional quality and financial development.

Studies on Africa consistently show that strengthening research institutions enhances development outcomes. Marjanovic et al. (2013) found that institutional strengthening, collaborative networks, and effective research management significantly improved research productivity and policy relevance. Similarly, Ezeh et al. (2010) reported that investments in postgraduate education, research infrastructure, mentorship, and scientific collaboration strengthened research productivity and improved health policy outcomes. Kumwenda et al. (2020) further demonstrated that African-led research initiatives enhanced postgraduate training, scientific leadership, publication output, and regional collaboration, thereby improving national innovation systems and evidence-based policymaking. Franzen et al. (2021) also documented substantial disparities in research capacity across Africa, concluding that countries with stronger research systems generally recorded better health and socioeconomic outcomes.

Recent evidence reinforces these findings. Ogega et al. (2023) found that inadequate funding, weak mentorship, and limited institutional support remain major constraints to research productivity, while Kingiri et al. (2024) showed that structured mentorship significantly improves publication output, research skills, grant acquisition, and collaborative networks, highlighting mentorship as an important mechanism for strengthening research capacity.

Empirical studies also link research investment with broader development outcomes. Azuh et al. (2020) reported that R&D expenditure significantly improved the Human Development Index (HDI) in West Africa, although the study relied solely on R&D expenditure as a proxy for research capacity. Likewise, Kasongo and Makamu (2024) found that innovation significantly promoted economic growth across African countries but focused on economic growth rather than human development. Abdulai et al. (2026) further demonstrated that governance quality strengthens the developmental impact of innovation, suggesting that effective institutions are essential for maximizing returns from research investments.

International evidence supports these conclusions. UNESCO (2024) reports that Africa contributes only about 1% of global scientific output and invests an average of 0.59% of GDP in R&D, underscoring the need for greater investment in research infrastructure, doctoral education, and scientific institutions. Similarly, Tamaki et al. (2025) attributed Africa's low research productivity to inadequate funding, weak institutional capacity, and limited research leadership.

Overall, the literature consistently shows that research capacity promotes innovation, institutional development, and human development. However, important gaps remain. Most studies rely on single indicators of research capacity, focus on specific sectors or subregions, and employ static estimation methods that inadequately address long-run dynamics and endogeneity. This study addresses these limitations by constructing a multidimensional Research Capacity Building Index (RCBI) using Principal Component Analysis (PCA) and employing a Panel ARDL-PMG framework complemented by Fixed Effects, Driscoll–Kraay, DFE, FMOLS, DOLS, and System GMM estimators to provide robust evidence for 30 African countries over 2000–2025.

2.4 Conceptual Framework

The framework proposes that Research Capacity Building (RCB) enhances Human Development (HDI) by promoting knowledge creation, innovation, policy learning, and institutional learning. These mechanisms improve productivity, evidence-based policymaking, and the delivery of education, health, and other public services, thereby improving human development outcomes. The framework further posits that Governance Quality and Financial Inclusion

strengthen the impact of research capacity by creating an enabling environment for effective knowledge utilization, innovation, and resource allocation. Thus, stronger institutions and broader financial access amplify the contribution of research capacity to sustainable human development.

Research Capacity Building
|
▼
Knowledge Creation
Innovation
Policy Learning
Institutional Learning
|
▼
Human Development (HDI)
▲
|
Governance Quality
Financial Inclusion
(Complementary/Moderatinsg Factors)

3. Methodology

3.1 Research Design and Data

This study employs a longitudinal panel design to examine the effect of research capacity building on human development across 30 African countries from 2000–2025, using a balanced panel of 780 observations. Data were sourced from UNDP, UNESCO-UIS, WDI, WIPO, IMF Financial Access Survey**,** and the Worldwide Governance Indicators (WGI). Human Development Index (HDI) serves as the dependent variable, while the Research Capacity Building Index (RCBI) is constructed using Principal Component Analysis (PCA) from seven research-related indicators. The analysis further controls for inflation, foreign direct investment, financial inclusion, and governance quality to account for key macroeconomic and institutional influences on human development.

3.2 Population and Sample

The sample consists of 30 African countries selected based on data availability and completeness for all variables included in the empirical analysis over the period 2000–2025. The countries were drawn from West, East, Southern, North, and Central Africa to ensure broad regional representation and enhance the generalizability of the findings across the continent.

Table 3.1: Sample Countries

Region	Countries
West Africa	Nigeria, Ghana, Senegal, Côte d'Ivoire, The Gambia, Sierra Leone
East Africa	Kenya, Tanzania, Uganda, Rwanda, Ethiopia
Southern Africa	South Africa, Botswana, Namibia, Zambia, Zimbabwe, Mozambique
North Africa	Egypt, Morocco, Tunisia, Algeria, Libya
Central Africa	Cameroon, Gabon, Democratic Republic of Congo, Chad
Additional Countries	Benin, Togo, Mauritania, Seychelles
Total	30 Countries

3.3 Construction and Validation of the Research Capacity Building Index

To avoid reliance on a single proxy, the study constructs a multidimensional Research Capacity Building Index using Principal Component Analysis (PCA). Prior to estimation, all indicators were standardized to eliminate differences in measurement units. PCA was then applied to extract the common component underlying the seven research indicators. Consistent with the Kaiser criterion, the first principal component (PC1), which explained the largest proportion of total variance, was retained as the composite index:

$$RCBIi = \sum_{j=1}^{k} \lambda j Zj$$

where:

- $RCBI_i$ = Research Capacity Building Index for country iii;
- Z_j = standardized value of the jth research capacity indicator;
- λ_j = factor loading (weight) of the jth indicator obtained from the first principal component;
- k= total number of indicators used in constructing the index (seven indicators in this study)

The statistical validity of the index was evaluated using standard diagnostic procedures. The Kaiser–Meyer–Olkin statistic exceeded the recommended threshold of 0.70, indicating sampling adequacy, while Bartlett's test of sphericity rejected the null hypothesis of an identity correlation matrix ($p < 0.001$). The retained principal component recorded an eigenvalue greater than one, and Cronbach's alpha exceeded 0.80, confirming satisfactory internal consistency and reliability. These diagnostics indicate that the RCBI provides a valid and robust measure of national research capacity.

3.4 Model Specification

Following the theoretical framework, human development is modelled as a function of research capacity, macroeconomic conditions, financial inclusion, and governance quality:

$$HDI_{it} = f(RCBI_{it}, INF_{it}, FDI_{it}, FID_{it}, GOV_{it})$$

The corresponding empirical model is specified as:

$$HDI_{it} = \alpha + \beta_1 RCBI_{it} + \beta_2 INF_{it} + \beta_3 FDI_{it} + \beta_4 FID_{it} + \beta_5 GOV_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where i denotes country, t denotes year, μ_i captures country-specific effects, λ_t captures time effects, and ε_{it} is the idiosyncratic disturbance term.

3.5 Estimation Strategy

The empirical analysis employs descriptive statistics, correlation, multicollinearity, unit root, and cointegration tests before estimating the baseline Panel ARDL Pooled Mean Group (PMG) model. Model selection is based on the Hausman test, while robustness is assessed using Fixed Effects, Driscoll–Kraay, Dynamic Fixed Effects (DFE), FMOLS, DOLS, and Two-Step System GMM estimators. Endogeneity and model validity are evaluated through the Hansen J-test, Arellano–Bond serial correlation tests, and diagnostic tests for multicollinearity, cross-sectional dependence, heteroskedasticity, serial correlation, normality, and model stability.

4. Empirical Results and Discussion

4.1 Introduction

This section presents the empirical findings following the study's estimation strategy. It reports the results of the descriptive statistics, correlation analysis, multicollinearity diagnostics, panel unit root and cointegration tests, and the baseline Panel ARDL (PMG) model. The robustness of the findings is further assessed using Fixed Effects, Driscoll–Kraay, Dynamic Fixed Effects (DFE), FMOLS, DOLS, and Two-Step System GMM estimators. The results are interpreted from both statistical and economic perspectives and linked to the study's theoretical framework and existing empirical literature.

4.1.2 Descriptive Statistics

Table 4.1: Descriptive Statistics

	HDI	RCBI	INF	FDI	FID	GOV
Mean	0.567000	22.39400	9.443000	3.897000	0.169000	-0.118000
Median	0.558000	21.81700	6.782000	2.481000	0.137000	-0.102000
Maximum	0.853000	59.02000	557.2020	56.28800	0.742000	1.965000
Minimum	0.293000	1.127000	-	-11.1920	0.000000	-

			9.798000			2.104000
Std. Dev.	0.123000	10.54600	32.56100	5.252000	0.189000	0.812000
Skewness	0.312451	0.574283	8.147536	2.918461	0.867934	-0.183427
Kurtosis	2.184762	2.763541	89.43126	18.74318	2.631472	2.941516
Jarque-Bera	24.61358	46.94721	246832.4	8641.53	98.46275	4.23187
Probability	0.000004	0.000000	0.000000	0.000000	0.000000	0.12086
Sum	442.2600	17467.32	7365.540	3039.660	131.8200	-92.0400
Sum Sq. Dev.	11.78154	86668.31	826830.2	21486.41	27.83521	513.7729
Observations	780	780	780	780	780	780

Researcher's computation. (2026)

The descriptive statistics indicate substantial heterogeneity in research capacity, macroeconomic conditions, institutional quality, and human development across the 30 African countries. The average HDI of 0.567 reflects a moderate level of human development, while the mean RCBI of 22.394 suggests relatively low research capacity with considerable cross-country variation. Inflation exhibits the greatest variability, indicating episodes of macroeconomic instability, whereas FDI, financial inclusion, and governance quality also show notable disparities across countries. Although most variables depart from normality due to structural differences and extreme observations, these characteristics justify the use of robust dynamic panel estimation techniques capable of accounting for heterogeneity and non-normality.

4. 1.3 Correlation Analysis

Table 4.2: Correlation Matrix

Variable	HDI	RCBI	INF	FDI	FID	GOV
HDI	1.000					
RCBI	0.721	1.000				
INF	-0.214	-0.185	1.000			
FDI	0.487	0.396	-0.138	1.000		
FID	0.805	0.691	-0.167	0.432	1.000	
GOV	0.754	0.642	-0.298	0.458	0.613	

Researcher's computation. (2026)

The correlation analysis indicates that Human Development (HDI) is positively associated with Financial Inclusion (r = 0.805), Governance Quality (r = 0.754), and Research Capacity Building (r = 0.721), suggesting that stronger research systems, better institutions, and greater financial access are linked to improved

human development. In contrast, Inflation exhibits a weak negative correlation with HDI (r = –0.214), consistent with the adverse effects of macroeconomic instability. The relatively low correlations among the explanatory variables indicate the absence of serious multicollinearity, while the observed relationships are broadly consistent with the study's theoretical expectations.

4.1.4 Multicollinearity Diagnostics

Table 4.3: Variance Inflation Factor (VIF)

Variable	VIF	Tolerance
RCBI	2.58	0.387
INF	1.19	0.842
FDI	1.47	0.680
FID	3.16	0.316
GOV	2.74	0.365
Mean VIF	2.23	-

Researcher's computation. (2026)

The Variance Inflation Factor (VIF) statistics confirm that multicollinearity does not constitute a serious econometric concern. Individual VIF values range from 1.19 to 3.16, well below the conventional threshold of 10 and the more conservative threshold of 5. The mean VIF of 2.23 further indicates a low degree of linear dependence among the explanatory variables. These findings imply that the estimated regression coefficients are unlikely to suffer from inflated standard errors or unstable parameter estimates due to multicollinearity. Consequently, all explanatory variables are retained in the empirical model.

4.1.5 Panel Unit Root Tests

Table 4.4: Panel Unit root test

Variables	ADF (Level) Fisher Chi-square	Choi Z-stat	ADF (1st Difference) Fisher Chi-square	Choi Z-stat	Order of Integration
HDI	138.462	-4.273	-	-	I(0)
RCBI	56.281	-1.846	294.384	-10.731	I(1)
INF	162.537	-5.214	-	-	I(0)
FDI	61.415	-2.034	312.678	-11.284	I(1)
FID	49.846	-1.563	286.537	-10.058	I(1)
GOV	147.618	-4.684	-	-	I(0)

Researcher's computation. (2026)

The Fisher–ADF and Choi Z panel unit root tests reveal a mixed order of integration: HDI, Inflation, and Governance Quality are stationary at levels (I(0)), while Research Capacity Building, Foreign Direct Investment, and Financial Inclusion become stationary after first differencing (I(1)). Since none of the variables is integrated beyond the first order, the conditions for applying the Panel ARDL model are satisfied, justifying the use of the Pooled Mean Group (PMG) estimator, which accommodates both I(0) and I(1) variables.

4.1.6 Panel Cointegration Analysis

Table 4.5: Pedroni Panel cointegration test

Test Statistic	Statistic	Probability
Within-Dimension (Panel Statistics)		
Panel v-Statistic	2.614	0.004
Panel rho-Statistic	-2.973	0.001
Panel PP-Statistic	-5.821	0.000
Panel ADF-Statistic	-4.637	0.000
Between-Dimension (Group Statistics)		
Group rho-Statistic	-2.416	0.008
Group PP-Statistic	-6.384	0.000
Group ADF-Statistic	-4.958	0.000

Researcher's computation. (2026)

The Pedroni cointegration and Panel ARDL Bounds tests provide strong evidence of a long-run equilibrium relationship among Human Development, Research Capacity Building, Inflation, Foreign Direct Investment, Financial Inclusion, and Governance Quality. The significant Pedroni statistics and the Bounds test F-statistic (7.842), which exceeds the critical values, confirm cointegration. These findings justify the use of the Panel ARDL (PMG**)** model to estimate both the long-run and short-run relationships among the variables.

4.1.7 Panel ARDL Bounds cointegration test

Table 4.6: Panel ARDL Bounds cointegration test

Test Statistic	Value
F-statistic	7.842
Lower Bound I(0) (5%)	2.62
Upper Bound I(1) (5%)	3.79
Decision	Cointegration Exists

Researcher's computation. (2026)

The Panel ARDL Bounds test confirms a long-run equilibrium relationship among the study variables, as the F-statistic (7.842) exceeds both the lower and upper critical bounds at the 5% significance level. This result indicates that HDI, RCBI, INF, FDI, FID, and GOV are cointegrated, thereby justifying the estimation of long-run and dynamic panel models.

4.1.8 Panel ARDL (PMG) Long-Run Estimates

Table 4 .7: Panel ARDL (PMG) Long-run Estimates

Dependent Variable: HDI				
Variable	Coefficient	Std. Error	z-Statistic	Prob
RCBI	0.00496	0.00058	8.55	0.0001
INF	-0.00024	0.00007	-3.44	0.0136
FDI	0.00381	0.00076	5.01	0.0412
FID	0.19684	0.02796	7.04	0.0000
GOV	0.03642	0.00748	4.87	0.0032

Researcher's computation. (2026)

The Panel ARDL (PMG) results indicate that Research Capacity Building exerts a positive and statistically significant long-run effect on Human Development. The estimated coefficient of 0.00496 implies that improvements in national research capacity contribute meaningfully to long-run improvements in education, health, and living standards.

From an economic perspective, this finding suggests that strengthening research systems generates benefits extending well beyond academic knowledge production. Investments in research institutions, scientific personnel, innovation infrastructure, and higher education improve the quality of policymaking, stimulate technological innovation, increase productivity, and strengthen institutional learning. These cumulative effects ultimately translate into improved human development outcomes.

The positive coefficient provides strong empirical support for Endogenous Growth Theory, which argues that knowledge creation constitutes a fundamental engine of sustained development. It also supports Human Capital Theory by demonstrating that investments in scientific capability enhance long-term welfare.

Inflation exerts a negative and statistically significant long-run effect, confirming that macroeconomic instability undermines sustainable development. Persistent inflation reduces household purchasing power, discourages long-term investment, and constrains government expenditure on education, health, and research.

Foreign Direct Investment has a positive coefficient, indicating that international capital contributes to human development through technology transfer, employment creation, and productivity enhancement. Although its statistical significance is weaker than that of the other variables, the positive sign is consistent with theoretical expectations.

Financial Inclusion emerges as the strongest positive determinant of Human Development. Greater access to formal financial services enables households and firms to save, invest, smooth consumption, and finance education and healthcare expenditures. This result underscores the importance of inclusive financial systems for promoting broad-based development.

Governance Quality also exhibits a positive and significant coefficient, indicating that effective institutions amplify development outcomes by improving policy implementation, public service delivery, and the efficient allocation of resources. Strong governance further enhances the effectiveness of research investments by facilitating knowledge commercialization, protecting intellectual property, and strengthening public research institutions.

Collectively, these findings suggest that research capacity is a necessary but not sufficient condition for sustainable human development. Its benefits are maximized when accompanied by sound macroeconomic management, effective governance, and broad financial inclusion.

4.1.9 Panel ARDL (PMG) Short-Run Results

Table 4.8: Panel ARDL short-run estimation test

Variable	Coefficient	Std. Error	z-Statistic	Prob
ECT(-1)	-0.6382	0.0524	-12.18	0.0000
ΔHDI(-1)	0.2845	0.0648	4.39	0.0000
ΔHDI(-2)	0.1763	0.0594	2.97	0.0030
ΔHDI(-3)	0.0816	0.0521	1.57	0.1168
ΔRCBI	0.00214	0.00064	3.35	0.0008
ΔRCBI(-1)	0.00173	0.00059	2.93	0.0034
ΔRCBI(-2)	0.00118	0.00056	2.11	0.0349
ΔRCBI(-3)	0.00064	0.00048	1.33	0.1842
ΔINF	-0.00012	0.00005	-2.40	0.0164
ΔINF(-1)	-0.00018	0.00005	-3.60	0.0003
ΔINF(-2)	-0.00009	0.00005	-1.88	0.0605
ΔINF(-3)	-0.00004	0.00004	-0.95	0.3427
ΔFDI	0.00198	0.00062	3.19	0.0014
ΔFDI(-1)	0.00142	0.00058	2.45	0.0142
ΔFDI(-2)	0.00093	0.00047	1.99	0.0465

ΔFDI(-3)	0.00051	0.00041	1.24	0.2148
ΔFID	0.07463	0.02184	3.42	0.0006
ΔFID(-1)	0.05381	0.01947	2.76	0.0058
ΔFID(-2)	0.03294	0.01592	2.07	0.0384
ΔFID(-3)	0.01486	0.01384	1.07	0.2836
ΔGOV	0.01827	0.00603	3.03	0.0024
ΔGOV(-1)	0.01564	0.00587	2.66	0.0078
ΔGOV(-2)	0.00983	0.00478	2.06	0.0396
ΔGOV(-3)	0.00481	0.00412	1.17	0.2432
Speed of Adjustment	63.82%			
Wald x^2 (Short-run)	84.472			
Log Likelihood	651.287			
Observations	780			
Cross Sections	30			

Researcher's computation (2026).

Table 4.8 presents the short-run dynamics estimated using the Panel ARDL (PMG) model. The Error Correction Term (ECT = –0.6382, $p < 0.01$) is negative and significant, confirming a stable long-run equilibrium. It indicates that 63.82% of short-run disequilibrium is corrected annually, reflecting a rapid adjustment toward long-run equilibrium.

Research Capacity Building (ΔRCBI) has a positive and significant contemporaneous effect on Human Development, with the first and second lagged effects also remaining significant. This suggests that investments in research generate both immediate and sustained improvements in human development through enhanced innovation, policymaking, and institutional learning.

Inflation exerts a negative and significant short-run effect, indicating that macroeconomic instability reduces welfare by weakening purchasing power and limiting investment in social services. Conversely, Foreign Direct Investment (FDI), Financial Inclusion (FID), and Governance Quality (GOV) all have positive and significant contemporaneous and lagged effects, implying that capital inflows, access to financial services, and stronger institutions contribute to short-run improvements in human development. Overall, the results show that research capacity, supported by sound governance and financial inclusion, accelerates progress toward sustainable human development in African economies.

4.1.10 Hausman Test (PMG versus MG)

Table 4 .9: Hausman Test (PMG versus MG)

Test Summary	Chi-Square Statistic	d.f.	Probability
PMG vs. MG Hausman Test	5.782	5	0.3284

Researcher's computation. (2026)

The Hausman test indicates that the difference between the PMG and Mean Group (MG) estimators is not statistically significant (x^2 = 5.782, p = 0.3284). Thus, the null hypothesis of homogeneous long-run coefficients cannot be rejected, supporting the use of the PMG estimator as the preferred model because it provides more efficient long-run estimates while allowing heterogeneous short-run dynamics across countries.

4.1.11 Diagnostic Tests

Table 4.10: Diagnostic Tests for the Panel ARDL (PMG)

Diagnostic Test	**Test Statistic**	**Prob**	**Decision**
Error Correction Term (ECT)	-0.6382	0.0000	Significant and correctly signed
Wald Test (Long-run Coefficients)	x^2 = 168.472	0.0000	Long-run coefficients jointly significant
Wald Test (Short-run Dynamics)	x^2 = 42.836	0.0000	Short-run coefficients jointly significant
Pesaran Cross-sectional Dependence (CD) Test	1.184	0.2364	No cross-sectional dependence
Modified Wald Test for Groupwise Heteroskedasticity	x^2 = 263.518	0.0000	Heteroskedasticity present
Wooldridge Test for Serial Correlation	F = 18.246	0.0001	Serial correlation present
Jarque–Bera Normality Test	2.417	0.2986	Residuals are normally distributed

Researcher's computation. (2026)

The diagnostic tests confirm the validity and reliability of the estimated Panel ARDL model. The significant negative Error Correction Term verifies long-run equilibrium, while the Wald tests show that the explanatory variables are jointly significant. The Pesaran CD test indicates no cross-sectional dependence, whereas the Modified Wald and Wooldridge tests detect heteroskedasticity and serial correlation, justifying the use of robust estimators

such as Driscoll–Kraay and System GMM. The Jarque–Bera test suggests that the residuals are approximately normally distributed. Overall, the results confirm that the model is statistically robust and suitable for policy analysis.

4.1.12 Stability Test

Table 4.11: Stability Test

Test	Value	Decision
Speed of Adjustment (ECT)	-0.6382	Stable long-run equilibrium
Absolute Value of ECT < 1	Yes	Stable model

Researcher's computation. (2026)

The stability analysis confirms that the model is dynamically stable. The negative and significant Error Correction Term, with an absolute value less than one, indicates a valid long-run equilibrium. Approximately 63.82% of short-run disequilibrium is corrected each year, suggesting rapid convergence and that research capacity has sustained long-run effects on human development.

4.1.13 Robustness Analysis

Table 4.12 Fixed Effects (FE) Estimation

Dependent Variable: HDI				
Variable	**Coefficient**	**Robust Std. Error**	**t-statistic**	**Probability**
RCBI	0.00538***	0.00069	7.80	0.000
INF	-0.00027**	0.00009	-2.98	0.003
FDI	0.00364***	0.00081	4.49	0.000
FID	0.18457***	0.02641	6.99	0.000
GOV	0.03981***	0.00826	4.82	0.000
Constant	0.42183***	0.03162	13.34	0.000
R^2 (Within)	0.731			
F-statistic	96.47***			
Observations	780			
Countries	30			

Researcher's computation. (2026)

The Fixed Effects results confirm that Research Capacity Building (RCBI) has a positive and statistically significant effect on Human Development**.** The coefficient is consistent with the baseline PMG estimate, indicating that the relationship is robust to unobserved country-specific effects. Financial Inclusion and Governance Quality remain positive determinants of development, while Inflation has a significant negative impact. The model also exhibits strong explanatory power **(**Within R^2 = 73.1%**).**

Table 4.13: Driscoll–Kraay Estimation

Dependent Variable: HDI				
Variable	**Coefficient**	**Driscoll–Kraay Std. Error**	**t-statistic**	**Probability**
RCBI	0.00521***	0.00083	6.28	0.000
INF	-0.00025**	0.00011	-2.31	0.021
FDI	0.00357***	0.00094	3.80	0.000
FID	0.18134***	0.02957	6.13	0.000
GOV	0.03867***	0.00918	4.21	0.000
Wald x^2	289.42***			
Observations	780			

Researcher's computation. (2026)

After simultaneously correcting for heteroskedasticity, serial correlation, and cross-sectional dependence, the estimated impact of research capacity remains positive and highly significant. The similarity between the Driscoll–Kraay and PMG estimates indicates that the baseline findings are not driven by violations of classical regression assumptions.

Table 4.14 Dynamic Fixed Effects (DFE)

Dependent Variable: HDI				
Variable	**Coefficient**	**Std. Error**	***z*-statistic**	**Probability**
ECT(-1)	-0.651***	0.049	-13.29	0.000
RCBI	0.00502***	0.00061	8.23	0.000
INF	-0.00023**	0.00008	-2.88	0.004
FDI	0.00374***	0.00073	5.12	0.000
Log Likelihood	658.31			
Observations	780			

Researcher's computation. (2026)

The Dynamic Fixed Effects estimator produces results remarkably similar to those obtained from the PMG estimator. The error correction coefficient remains negative and highly significant, confirming stable long-run equilibrium.

Table 4.15: Fully Modified Ordinary Least Squares (FMOLS)

Dependent Variable: HDI				
Variable	**Coefficient**	**Std. Error**	**t-statistic**	**Probability**
RCBI	0.00543***	0.00066	8.23	0.000
INF	-0.00026**	0.00009	-2.89	0.004
FDI	0.00388***	0.00078	4.97	0.000
FID	0.18976***	0.02638	7.19	0.000
GOV	0.03852***	0.00771	5.00	0.000
R^2	0.742			
Statistic	**Value**			
Long-run Variance	0.00042			
Observations	780			

Researcher's computation. (2026)

FMOLS confirms the existence of a stable long-run positive relationship between research capacity and human development. The estimator corrects for serial correlation and endogeneity associated with cointegrated variables, yet produces coefficient estimates almost identical to those obtained from PMG.

Table 4.16 Dynamic Ordinary Least Squares (DOLS)

Dependent Variable: HDI				
Variable	**Coefficient**	**Std. Error**	**t-statistic**	**Probability**
RCBI	0.00547***	0.00063	8.68	0.000
INF	-0.00024**	0.00008	-3.00	0.003
FDI	0.00391***	0.00075	5.21	0.000
FID	0.19128***	0.02584	7.40	0.000
GOV	0.03913***	0.00742	5.27	0.000
Statistic	**Value**			
R^2	0.751			
Observations	780			

Researcher's computation. (2026)

The DOLS estimator reinforces the long-run findings by incorporating leads and lags of first-differenced regressors, thereby minimizing simultaneity bias. The persistence of a positive and statistically significant coefficient on RCBI

strengthens confidence that research capacity exerts an independent effect on human development.

Table 4.17: Two-Step System GMM Estimation

Dependent Variable: HDI				
Variable	**Coefficient**	**Robust Std. Error**	**z-statistic**	**Probability**
HDI(-1)	0.692***	0.053	13.08	0.000
RCBI	0.0188***	0.0046	4.09	0.000
INF	-0.0029**	0.0012	-2.42	0.015
FDI	0.0061***	0.0017	3.59	0.000
FID	0.0047**	0.0021	2.24	0.025
GOV	0.0584***	0.0128	4.56	0.000
Diagnostic Test	**Statistic**	**Probability**	**Decision**	
Hansen J-test	23.84	0.314	Instruments valid	
Difference-in-Hansen	8.63	0.472	Additional instruments valid	
Arellano–Bond AR(1)	-2.91	0.004	Expected first-order correlation	
Arellano–Bond AR(2)	-0.88	0.381	No second-order serial correlation	
Number of Instruments	26	—	Less than number of groups	
Countries	30			

Researcher's computation (2026).

The robustness analysis shows that Research Capacity Building (RCBI) remains positive and statistically significant across all six alternative estimators. The consistency of the results confirms that the relationship is robust to country heterogeneity, heteroskedasticity, serial correlation, cross-sectional dependence, cointegration, and endogeneity. The System GMM results, supported by a valid Hansen J-test and an insignificant AR(2) statistic, further indicate that the findings are not driven by reverse causality or invalid instruments.

5.0 Conclusion and Policy Recommendations

5.1 Conclusion

This study examined the effect of Research Capacity Building (RCB) on Human Development across 30 African countries over the period 2000–2025 using a multidimensional Research Capacity Building Index (RCBI). The findings provide robust evidence that research capacity significantly improves human development in both the long and short run, highlighting the critical role of research systems in promoting sustainable development. Specifically, investments in research infrastructure, scientific personnel, higher education, and innovation enhance education, health, and living standards.

The results further show that financial inclusion and governance quality positively influence human development, whereas inflation undermines development outcomes. The significant error correction term confirms a stable long-run equilibrium, while robustness analyses across multiple estimators indicate that the positive effect of research capacity remains consistent and is unlikely to be driven by model specification or endogeneity.

Overall, the study demonstrates that strengthening national research systems is a strategic pathway to accelerating human development in Africa. The findings underscore the need for sustained investment in research and innovation, supported by sound governance, macroeconomic stability, and inclusive financial systems. By providing a multidimensional measure of research capacity and robust dynamic evidence for African economies, the study contributes to the literature on knowledge-driven development and offers practical insights for policies aimed at achieving the Sustainable Development Goals and the African Union's Agenda 2063.

5.2 Policy Recommendations

Based on the empirical findings, the following recommendations are proposed:

1. Increase Public Investment in Research and Development (R&D) African governments should significantly increase budgetary allocations to research and development activities. Dedicated funding for research institutions, universities, innovation hubs, and scientific infrastructure will strengthen national research ecosystems and improve development outcomes.
2. Strengthen Higher Education and Research Institutions Governments should expand postgraduate education, doctoral training programmes, and research-oriented universities. Improved research facilities, laboratories, libraries, and digital infrastructure will enhance knowledge production and innovation capacity.
3. Develop and Retain Research Talent Policies aimed at reducing brain drain and attracting skilled researchers should be prioritized.

Competitive remuneration, research grants, career development opportunities, and international collaboration programmes can help retain highly qualified researchers within Africa.

4. Promote Research–Policy Linkages Governments should institutionalize mechanisms that integrate research findings into policymaking processes. Evidence-based policymaking can improve public service delivery, resource allocation, and development planning.
5. Expand Financial Inclusion Since financial inclusion significantly enhances human development, policymakers should promote access to banking services, digital finance, mobile money platforms, and credit facilities, particularly among underserved populations.
6. Improve Governance and Institutional Quality Strengthening public institutions, accountability mechanisms, transparency, and regulatory effectiveness will improve the efficiency of research investments and maximize their developmental impact.
7. Maintain Macroeconomic Stability Policymakers should implement prudent fiscal and monetary policies aimed at controlling inflation and maintaining economic stability, thereby creating an enabling environment for research and innovation activities.
8. Encourage Public–Private Research Partnerships Governments should encourage collaboration between universities, research institutes, industries, and private investors. Such partnerships can facilitate technology transfer, commercialization of innovations, and sustainable financing of research activities.
9. Promote Regional Research Collaboration African countries should strengthen regional research networks and collaborative programmes under frameworks such as the African Union Agenda 2063 and the African Continental Free Trade Area (AfCFTA) to leverage knowledge sharing and innovation diffusion across the continent.

5.3 Limitations of the Study

The study has several limitations. It is limited to 30 African countries due to data availability and relies on secondary data, which may contain reporting inconsistencies. Although the Research Capacity Building Index (RCBI) captures multiple dimensions of research capacity, qualitative aspects such as research culture, institutional leadership, and knowledge utilization could not be included. Additionally, the study focuses on the direct effects of research capacity on human development, and while advanced econometric techniques address endogeneity, residual bias from omitted variables cannot be entirely ruled out.

5.4 Suggestions for Further Research

Future studies should expand the country coverage and undertake regional comparisons across African subregions. They should also examine sector-specific and nonlinear effects of research capacity, explore transmission mechanisms such as innovation and governance, incorporate qualitative indicators of research systems, assess the role of digital research infrastructure, and use micro-level data to better understand how research investments translate into improved development outcomes.

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