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The Impact of International Education Aid Project-Type Intervention Costs on Research Output Enhancement in Higher Education Institutions in Sub-Saharan Africa: A Generalized Method of Moments Analysis

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Abstract:- This study investigates the impact of international education aid on research output in higher education institutions across thirty Sub-Saharan African (SSA) countries for a period of fifteen years. The SSA region experiences persistent disparities in research output. The research addresses the problem of uneven distribution and the delayed impact of international aid on research outcomes, which limits the ability of institutions in Africa to contribute effectively to global knowledge production. The specific objective is to examine the role of aid project-type intervention costs on research output while accounting for domestic investments in higher education and R&D. The study employed dynamic panel data models and the Generalized Method of Moments to control for Endogeneity. The study incorporates secondary data from international and government sources to analyze trends. The study findings reveal that while international education aid positively impacts research productivity, its effects are significantly lag, underscoring the need for sustained and long-term funding. The study concludes that international aid alone cannot fully drive research productivity; instead, aid must complement robust domestic investments to create a sustainable impact. Recommendations include promoting sustained and long-term funding models, investing in research infrastructure and capacity development, and enhancing synergies between international education aid and domestic investments. These measures will help optimize the benefits of international education aid, enabling Sub-Saharan African institutions to develop research capacity and contribute meaningfully to regional and global research initiatives.

Keywords:- *International Education Aid; Sub-Saharan Africa; Higher Education; Research Output; Generalized Method of Moments.*

I. INTRODUCTION

International aid is one of the most contentious issues in the academic and policy discourse and plays an important role in the global economy [1]. Higher education (HE) is often underfunded, leading to under-resourced universities as many African governments need more budgets due to competing priorities such as healthcare, primary education, and infrastructure [2], [3]. Public universities rely heavily on government funding, often needing more to meet the growing demand for higher education and support research, staff salaries, and infrastructure. Thus, higher education institutions (HEIs) in Sub-Saharan Africa (SSA) confront several difficulties, such as inadequate facilities, financial, infrastructure, and equipment problems, and the urgent need to strengthen their capacity for research due to weaknesses in scientific and skill competencies to tackle complicated socioeconomic issues in the region [4].

These constraints hinder the ability of HEIs to produce high-quality research, which is crucial for driving economic and social development. International education aid is key to driving research and innovation in the HE sector in SSA [5]. International aid organizations have increasingly directed resources towards enhancing the research capacity of these HEIs. The resources are directed to project-based interventions through funding for academic programs, infrastructure development, and the provision of resources to improve the quality of research output. Additionally, research outputs are a fundamental component of HE as they are a key indicator of an institution's academic excellence and contribution to knowledge creation. Therefore, for SSA countries to thrive in the knowledge economy (KE), they must invest in developing skills, scientific research, innovation, and technology [6]. HEIs are key to achieving these goals and are based on educating the next generation of knowledgeable and high-skilled workers.

The level of education has a significant impact on the economic development of a country [7]. China, Japan, Malaysia, and the Newly Industrialized Economies of Asia are transitioning to 'knowledge-based economies' with Japan setting the pace. Therefore, research outputs are instrumental in informing policy decisions, driving technological advancements, and addressing local and global challenges [8], [9]. In SSA, the production of research outputs is essential for addressing the unique developmental challenges faced by the region. Health, agriculture, education, and environmental sustainability research can potentially generate solutions tailored to the local context. Additionally, high-quality research is important as it enhances the global reputation of HEIs, attracts funding, and fosters collaborations with international partners. However, the capacity to produce impactful research is often constrained by limited resources, inadequate research infrastructure, and insufficient funding [10].

Theoretically, this study expands the scope of international education aid to include research as a critical outcome, offering new perspectives on aid mechanisms, capacity building, and institutions' role while contributing to the broader debate on aid effectiveness. However, there is a pressing need for empirical research that examines the dynamic influence of international education aid. This research seeks to explore the impact of international education aid project-type intervention costs on enhancing research output in higher education institutions across SSA, using the Generalized Method of Moments (GMM) approach. The GMM method handles potential endogeneity issues in the relationship between project funding and research output [11]. The findings of this study will be valuable to policymakers, educational institutions, and international donors in implementing more effective and sustainable aid programs that support the SSA region's higher education and research development.

II. LITERATURE REVIEW

A. Historical Context and Evolution of International Education Aid in the SSA Region

The aid in Sub-Saharan Africa dates back to the post-colonial era when newly independent countries looked to international donors for assistance in developing their educational institutions. Aid was viewed as the only means of encouraging increased investments, resulting in increased economic growth and development, particularly in the 1960s after most African countries gained independence. Initially, aid was driven by economic and political interests, but over time, it evolved to address humanitarian and developmental goals [12]. During the 1960s and 1970s, major global institutions such as the World Bank, UNESCO, and various bilateral aid agencies began to invest heavily in the educational sectors of developing countries, targeting economic development and poverty alleviation. These efforts are driven by the belief that education is a crucial driver of economic growth and social progress [13].

The structural adjustment policies took center stage in the 1980s. The focus then switched to effective governance in the 1990s. The early 2000s saw a renewed emphasis on higher education as an economic growth and innovation driver. More recently, the aid has shifted towards project-type interventions that provide immediate support and build long-term research capacities and institutional resilience. This shift reflects broader educational trends in the SSA region focusing on curriculum [14], student support [15], pedagogy [16], educational technologies [17], and vocational teacher education [18].

B. International Education Aid and Research Output

The role of international education aid in improving research output has been a subject of growing interest, particularly in developing regions such as Sub-Saharan Africa (SSA). According to the OECD Development Assistance Committee (DAC), International aid is aid by the government that targets and promotes the economic development and the welfare of developing countries [19]. Therefore, international education aid is government aid that promotes and targets developing the education sector of developing countries. On the other hand, research output means original, systematic investigation undertaken to gain new knowledge and understanding whose access can be given to scientific publications, patents, data, or other engineered results and processes. HEIs in SSA have long faced challenges related to underfunding, poor infrastructure, and limited access to research resources, affecting their ability to contribute to global research productivity [10].

Donors have been important in funding African higher education post-independence [9]. The aid has been channeled into HE to address challenges faced through targeted project-based interventions to build research capacities. Despite the importance of these interventions, there is limited empirical research directly linking the financial costs of international aid interventions to measurable improvements in research output. The problem is that there needs to be more evidence to show that international education aid improves educational outcomes in recipient countries [20]. Education aid not being able to achieve its goals can be a result of it not being used effectively due to factors like corruption and wastage on inefficient projects [21].

C. Project-Type Interventions and Research Output

International education aid is directed towards addressing the infrastructure deficit many HEIs in Sub-Saharan Africa face. Project-type interventions are targeted initiatives funded by international donors to enhance HEIs' research and educational capacities [19]. These projects may include establishing research centers, providing advanced laboratory equipment, and supporting collaborative research programs. Project-type interventions enhance research output by building sustainable research infrastructure and fostering a culture of innovation and academic excellence by providing institutions with the necessary tools and resources to conduct high-quality research and promote the adoption of best practices in research and education. Whether it is advanced imaging devices, molecular biology equipment, or computing

resources, these investments contribute to the precision and efficiency of research activities [22].

These interventions often include capacity-building components, such as training workshops and mentorship programs, which strengthen research capabilities [23]. Training programs and workshops are common mechanisms through which aid is utilized for faculty development. The programs are conducted by experts from developed countries, exposing faculty members to advanced research methodologies, the latest technological tools, and best practices in their respective fields [24]. The effective utilization of aid goes beyond infrastructure and individual development and extends to cultivating a research-oriented culture within institutions. This cultural shift involves fostering an environment where research is not merely an activity but an integral part of the institutional ethos [25]. Investments in research-oriented culture involves collaborations initiatives and joint research projects that bring together researchers from SSA Institutions and their counterparts in developed regions globally [26]. Thus, institutions in SSA build the capacity to produce outputs that meet international standards regarding quality-enhancing global knowledge [27]). Today's global ranking methodologies used on universities are dominated by research

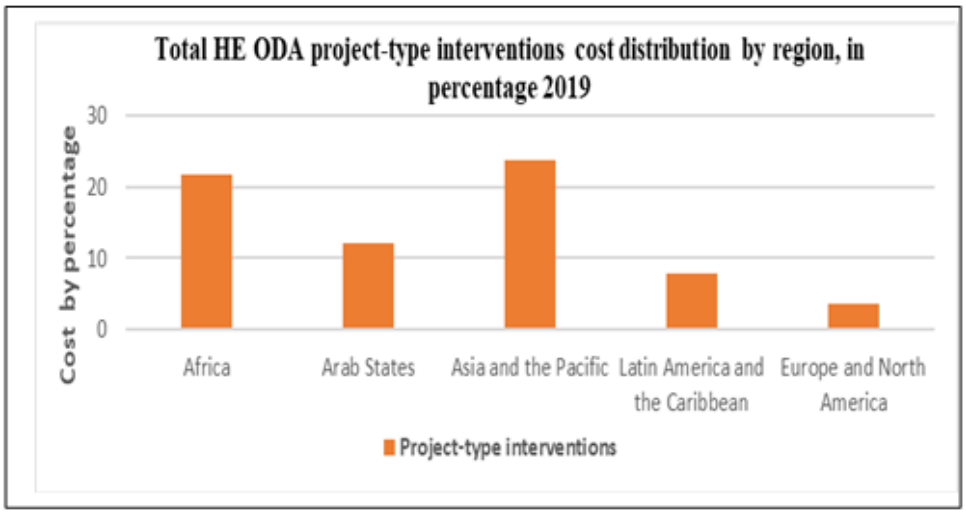

Fig. 1. Percentage Cost Distribution of International Education Aid Project-Type Interventions Cost in HE by Region in 2019
Source: Authors Compilation based on Data from OECD-CRS

Indicators such as several articles and citations [28], making research capacity a crucial factor in the global knowledge economy and obtaining a world-class university status [29]. The GMM approach is a reliable and valuable tool for this study in assessing the causal impact of financial interventions on research output, as it accounts for potential endogeneity and measurement errors [30]. Fig. 1. shows the percentage cost distribution of international education aid project-type interventions in HE by region in 2019.

Fig. 1. shows that only Asia and the Pacific had a larger percentage share of the project-type intervention cost than Africa in 2019. The percentage share of project-type intervention costs was almost a quarter of all HE ODA in 2019 (24%)[19].

D. Higher Education ODA Provided by Type of Donor

HE ODA financial resources are mainly provided by three actors: Development Assistance Committee Countries (DAC), which consist of 30 of the most developed nations worldwide, 26 nations outside the DAC classified as non-DAC countries and multilateral organizations.

Fig. 2. shows that in 2019, almost 80% of HE aids were provided by DAC donors.

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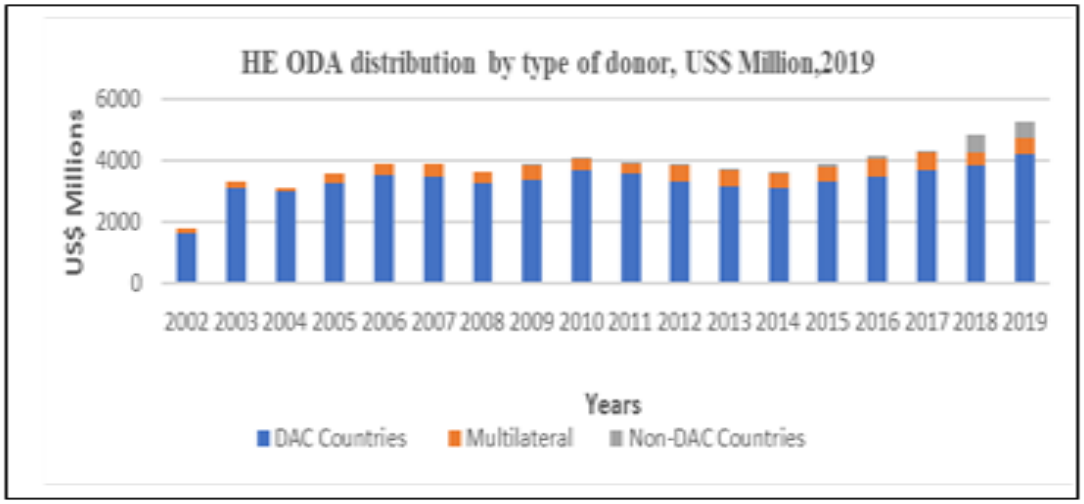

Fig. 2. Total HE ODA Distribution by Type of Donor, in US$ Million, 2019
Source: Authors Compilation based on Data from OECD-CRS

E. Theoretical Framework: Institutional Theory and International Education Aid in Higher Education

Institutional Theory is a powerful explanatory tool for studying many organizational issues, including those in HE, by providing a valuable framework for understanding how education aid interacts with the structures and processes within higher education institutions. Its application in research on HE consists mainly of the concepts of new institutionalism [31]. Institutional Theory examines how institutions comprising formal rules, norms, and practices shape the behavior of individuals and organizations. Additionally, organizations conform to institutional norms and pressures to get stability, legitimacy, and access to resources. Institutional Theory also highlights the role of isomorphism, arising from coercive, mimetic, and normative pressures [32].

HEIs face two institutionalization processes [33]. One is based on the organization itself, comprising commitment and socialization. The other arises from the organizational field or society comprising attribution, habit, or practical action [34]. However, individual actors in HEIs play a key role in adopting or resisting environmental pressures, supporting Performance-Based Funding (PBF) as they believe it improves HE outcomes [35]. PBF states that institutions respond to external stimuli, such as financial incentives, by adapting their behaviors and priorities to align with the prescribed objectives [36].

Therefore, PBF evangelists must define and measure success in research so that the financial incentives drive the intended outcomes [37]. Applied to the context of SSA Higher Education, the PBF highlights that aid allocation should be performance-based, linking financial support to specific research-related milestones [38]. This could include criteria such as the number of research publications and patents.

Project-type interventions funded by international education aid are crucial for institutional development in Sub-Saharan African higher education [23]. Institutional Theory suggests that these interventions help institutions align with international norms and standards, thereby increasing their legitimacy and attractiveness to domestic and international stakeholders. These interventions facilitate the adoption of best practices, enhance research infrastructure, and foster an environment conducive to high-quality research, leading to increased research outputs [32], [39].

Incorporating the principles of Institutional Theory and Performance-Based Funding into global education assistance initiatives can strategically influence SSA higher education institutions to prioritize and enhance their research capacities. Fig. 3. below shows the Institutional Influence and Education Aid-Driven Research Enhancement Framework.

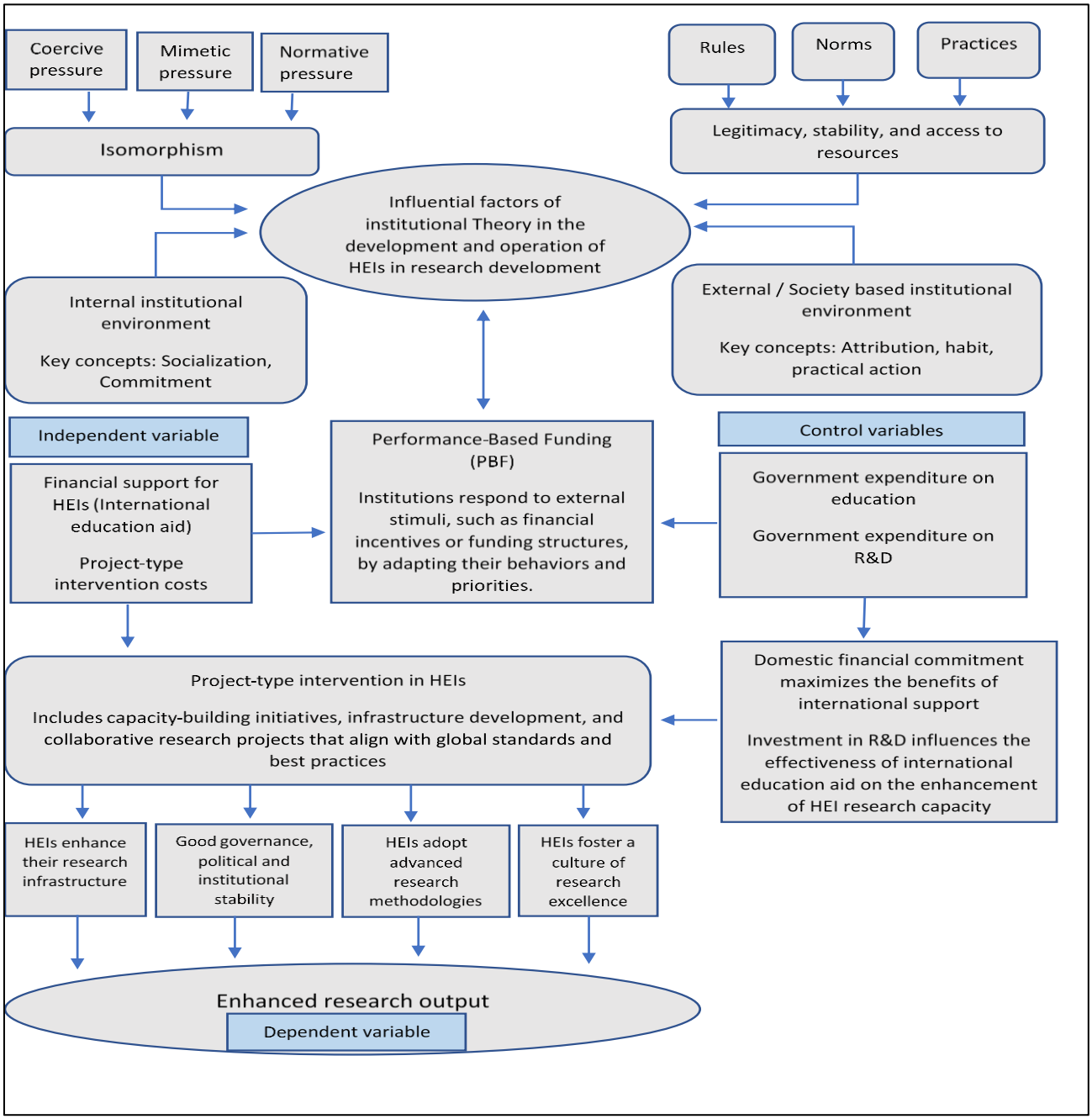

Fig 4. Institutional Influence and Education Aid-Driven Research Enhancement Framework
Source: Authors compilation

F: Empirical Framework; GMM Model Specifications

The choice of the Generalized Method of Moments (GMM) estimation approach was informed by four primary motives, as supported by the scholarly literature [40], [41], which align with the motivation for using a GMM empirical strategy. First, the number of agents or cross-sections had to be more numerically valued than the number of periods to use the estimation technique. Second, correlation coefficients between the levels and first difference series of the aid variables surpassing 0.800 demonstrated persistence in the outcome variables under investigation. The GMM-centric literature generally accepts this threshold as a sign of persistence [42].

Thirdly, cross-country differences were considered during the estimate procedures. Lastly, two basic approaches were taken to resolve endogeneity problems. Internal instruments were used to examine reverse causality in the estimating exercise. Conversely, unobserved heterogeneity was managed over time.

By including options that collapse instruments, limiting instrument proliferation [43], the [44], [45] extension of [11] is acknowledged for providing robust estimates. The basic system GMM estimate approach designed to evaluate the impact of education aid on enhancing research output in SSA higher education is summarized by the following equations in levels (1) and initial differences (2):

$$RO_{i,t} = \beta_0 + \beta_1 PJT_{i,t} + \beta_2 RD_{i,t} + \beta_3 GED_{i,t} + \epsilon i, tE_{\{i,t\}} \quad (1)$$

$$\Delta RO_{i,t} = \gamma_0 + \gamma_1 \Delta PJT_{i,t} + \gamma_2 \Delta RD_{i,t} + \gamma_3 \Delta GED_{i,t} + ui, t \quad (2)$$

Where: At the immediate effect level, equation 1:
RO – Research output index
$PJT_{i,t}$- Project-type interventions costs
$RD_{i,t}$- Expenditure on R&D, Research and Development
$GED_{i,t}$- Government expenditure in higher education of country i in period t
$\epsilon i, tE_{\{i,t\}}$ denotes error terms
$\beta_0, \beta_1\ \beta_2\ \beta_3$ are the coefficients to be estimated

The lagged effect of the model first difference equation 2:
$\Delta RO_{i,t}$ −Research output index at lag of country i in period t
$\Delta PJT_{i,t}$- Project-type interventions costs, at lag of country i in period t
$\Delta RD_{i,t}$- Government expenditure on R&D at lag of country i in period t
$\Delta GED_{i,t}$- Government expenditure on higher education lag of country i in period t
ui, t - denotes error terms
$\gamma_0\ \gamma_1\ \gamma_2\ \gamma_3$ are coefficients to be estimated.

This model framework incorporates dynamic interactions between financial assistance variables and educational outcomes over time to assess how international education aid interventions enhance research outputs within SSA HE.

III. RESEARCH METHODOLOGY

A: Research Design

This study uses quantitative research design because it can provide objective, statistically analyzable, large-scale, replicable, and comparable data. The research employed a panel data approach, utilizing secondary data from 30 Sub-Saharan African countries from 2006 to 2020.

B: Data Collection

Secondary data collection is used in this investigation, which is common in research that seeks a broad, varied understanding of complex issues [46] to guarantee a thorough and varied grasp of the subject. The data for this study were collected from a range of reputable secondary sources such as Peer-reviewed articles from scholarly journal databases like Google Scholar, JSTOR, and PubMed; publications and reports from agencies like the World Bank, OECD, UNESCO, USAID, and the African Development Bank; policy documents and strategic plans from SSA government agencies and educational institutions; and research articles from reliable online databases like ScienceDirect and SpringerLink.

The study collected data on several variables, including the research output index based on data on scientific and technical journal articles, which combines the number of research publications and patents obtained from World Bank Open Data. The project-type intervention costs (USD) were collected from the OECD databases, and control variables such as the government expenditure in higher education (USD) and the government expenditure on R&D (USD) were collected from World Bank Open Data.

The research output for this study was measured using data on scientific and technical journal articles, providing a reliable indicator of academic productivity and innovation across the countries studied. This approach focuses on formal, peer-reviewed publications widely recognized as key contributors to the global body of knowledge. Using this metric, the study offers a clear and objective means of comparing research outputs, ensuring that the analysis captures the academic contributions that have undergone rigorous evaluation and are accessible through reputable scientific databases.

C: Data Analysis

Data analysis is the systematic process of transforming information into valuable insights [47]. For this research, content analysis was chosen as the primary data analysis technique due to its effectiveness in identifying recurring themes and patterns, enabling the generation of meaningful conclusions from the reviewed literature and previous studies. The analysis focused on panel data from 30 SSA countries over 15 years (2006-2020).

The panel data was rigorously analyzed using Stata 15, a statistical software package that offers advanced tools for panel data analysis. The data analysis process involved several key steps. Initially, the dataset was cleaned and prepared for analysis, ensuring all necessary variables were included, and any missing values were addressed. Descriptive statistics were computed to summarize the key characteristics of the data, providing a foundational understanding of the dataset. Based on the research objective and literature review, the Generalized Method of Moments (GMM) was employed due to its robustness in handling endogenous and dynamic panel data.

The specified models were estimated using Stata 15, which involved running the GMM estimation, checking for instrument validity, and ensuring the models met the necessary statistical assumptions. The estimated coefficients and statistical tests were interpreted in the context of the research question, analyzing the significance and direction of the relationships between the aid project-based interventions and research outputs in HEIs in SSA. Various robustness checks were conducted to confirm the reliability and validity of the findings, including sensitivity analysis and the examination of potential outliers or influential data points.

D: Ethical Considerations

The research adhered to strict ethical guidelines in handling, analyzing, and reporting secondary data, with all sources adequately credited and limitations transparently acknowledged. Confidentiality was maintained where necessary, and any sensitive information was anonymized. Informed consent principles were observed with publicly available data, and care was taken to avoid bias or misrepresentation.

IV. FINDINGS

A. Introduction

This chapter presents the analysis of panel data using STATA version 15. The data from reputable international organizations such as the World Bank Open Data and OECD provided a comprehensive foundation for the study. The Generalized Method of Moments (GMM) estimator was utilized to address potential endogeneity concerns, and Hansen's J-test was performed to validate the instruments used. The results are thoroughly presented and discussed, ensuring reliable, robust and comprehensive conclusions by addressing heteroscedasticity, serial correlation, and Endogeneity issues.

B. Fixed Effects Regression Results and Hypothesis Test

We employ a fixed effects regression model to control for these country-specific factors that might influence the research output index but are not directly included in our Model. This approach allows us to capture unobserved heterogeneity across countries, ensuring that our estimates of the relationships between the independent variables and research output are not biased by omitted country-specific factors. Furthermore, we conduct an F-test for fixed effects to test the hypothesis formally: H_0: No fixed effects (i.e., No significant differences between countries) and H_1: Fixed effects exist (i.e., Significant differences between countries).

Table 1 shows that the within R-squared value of 0.4051, or 40.51%, reflects a moderate fit of the Model, indicating that the independent variables in the Model can explain 40.51% of the variability in research output within individual countries. The Between R-squared value of 0.2772, or 27.72%, measures the variance explained between different groups, revealing that the Model accounts for 27.72% of the differences in research output across countries. This lower percentage indicates that the Model could be more effective at explaining cross-country differences than within-country variance.

The overall R-squared value of 0.2883, or 28.83%, combines both within-group and between-group variances, suggesting that the Model explains approximately 28.83% of the total variation in the research output index. This figure indicates that while the Model has some explanatory power, a significant portion of the variation remains unaccounted for. The F-statistic for the overall Model is F (5, 415) = 56.52 with a probability value of 0.0000. The Prob > F value for the fixed effects test (0.0000) is less than 0.05, which indicates that fixed effects are significant. The null hypothesis **(H_0)** is rejected in favor of the alternative hypothesis **(H_1)**, suggesting that the Model's variables do not capture significant differences between countries. These unobserved factors are likely influencing the research output index. This finding suggests the need for further exploration of country-specific considerations, which may have yet to be explicitly included in the Model but could still substantially impact research output.

Table 1: R-Squared and F-Statistics for Fixed Effects

Statistic	Value	Prob > F
Within R-squared	0.4051	
Between R-squared	0.2772	
Overall R-squared	0.2883	
F-statistic (Model)	F (5, 415) = 56.52	0.0000
F-statistic (fixed effects)	F (29, 415) = 40.50	0.0000

C. Random-Effects GLS Regression Results and Hypothesis Test

We analyze the results of the random-effects Generalized Least Squares (GLS) regression to evaluate how well the independent variables explain the variation in the research output index. These findings offer insights into the factors driving research productivity across different countries, emphasizing the role of random variations in influencing the observed outcomes. The hypothesis tests: H_0: No random effects and H_1: Random effects are present.

Table 2. shows the within-group R-squared of 35.25% indicates that 35.25% of the variation in the dependent variable (research output index) is explained by the independent variables within individual groups (countries). The between-group R-squared of 46.95% suggests that 46.95% of the variance between different countries is accounted for by the Model, indicating substantial differences across countries that are also captured by the independent variables. Overall, the combined explanatory power of the Model, measured by the overall R-squared, is 44.26%, which indicates a moderate fit. This reflects the Model's ability to account for almost half of the variance in the research output index. However, a significant portion of unexplained variance might be due to other factors not included in the Model.

The Wald chi-square test was used to test the overall significance of the Model. With a probability value (Prob > chi2) of 0.0000 and a test statistic of 289.70, the test results are highly significant, suggesting that at least one independent variable substantially impacts the research output index. The null hypothesis is rejected, confirming the presence of random effects in the Model. The implication is that unobserved factors specific to each country, which vary randomly across countries influence research output. This supports using a random-effects model, where these group-level differences are accounted for as random variations

rather than being assumed to be fixed. The presence of random effects suggests that there are likely additional, unmeasured factors at play that vary across entities but are not captured by the observed independent variables.

D. Serial Correlation Test Results and Hypothesis Testing: Q(p)-Statistic, P-Value, Serial Correlation

Table 2: R-squared and Wald Chi-Square Test

Statistic Value	Prob > chi2
Within R-squared	0.3525
Between R-squared	0.4695
Overall R-squared	0.4426
Wald chi2 (Model)	Wald chi2(5) = 289.700.0000

Table 3: Q(p)-statistic, p-value, and additional details for each variable:

Variable	Q(p)-stat	p-value	N	Max T	Balanced?
Research_output_index	+ 4.83	0.089	+	30	15
Project-type intervention costs in USD	+ 4.27	0.118	+	30	15

In panel data analysis, ensuring the independence of residuals is crucial for obtaining reliable and unbiased estimates. One common issue is serial correlation, where residuals (error terms) from different periods are correlated.

This violation of independence can lead to efficient parameter estimates and misleading conclusions if not adequately addressed. To detect serial correlation in the error terms of a panel data model, the Bias-corrected Born and Breitung (2016) Q(p)-test was employed in this study[48].

Table 3 above presents the results of the Bias-corrected Born and Breitung (2016) Q(p)-test for serial correlation in a panel data model. The null hypothesis (H_0) for this test suggests that no serial correlation exists, while the alternative hypothesis (H_1) suggests the presence of serial correlation, meaning the residuals are not independent over time.

For project-type intervention costs, the p-value is 0.118 > 0.05. Therefore, the null hypothesis is not rejected for this variable.

E. Endogeneity and Correlation with Error Term

This section investigates the potential for Endogeneity by analyzing the correlation matrix, which displays the strength and direction of relationships between the variables used in the Model. Positive and negative correlations between variables can reveal important patterns, such as whether increased funding for project interventions is associated with higher research output or if certain variables may offset each other.

Table 4. shows a positive correlation which indicates that as one variable increases, the other tends to increase as well. In contrast, a negative correlation suggests an inverse relationship, where an increase in one variable corresponds to a decrease in the other.

The correlation for project-type interventions, expenditure on research and development, and government expenditure on higher education is 0.2332, 0.3661, and 0.5867, respectively, indicating that more significant investments in these areas are associated with higher research output. These positive associations suggest that increased funding, resources, and financial interventions in these areas contribute to higher research productivity.

Table 4: Correlation Matrix and Interpretation

Variable	e	Research output index	Project type intervention	Amount of govt expenditure on R&D	Amount of govt expenditure on higher education
e	1.0000				
Research output index	0.5435*	1.0000			
	(0.0000)				
Project type intervention (USD	-0.1888*	0.2332*	1.0000		
	(0.0001)	(0.0000)			
Amount of govt expenditure on R&D	0.1500*	0.3661*	-0.0029	1.0000	
	(0.0014)	(0.0000)	(0.9507)		
Amount of govt expenditure on higher education	0.0618	0.5867*	0.0649	0.1597*	1.0000
	(0.1908)	(0.0000)	(0.1695)	(0.0007)	

*Significant at the 0.05 level.

Table 5 shows that the lagged research output index—representing the previous period's research output—exhibits a correlation coefficient of 0.5459 with the error term (e). This value indicates a moderate positive correlation between the error term and the lagged research output index, suggesting that the errors in the current Model are somewhat dependent on past research output. This relationship points to potential Endogeneity in the Model, as the error term should ideally be uncorrelated with the independent variables, including the lagged values of the dependent variable. To address this issue, it might be necessary to consider instrumental variables (IV) that can control for the Endogeneity.

F. Model Fit, Multicollinearity, and Model Performance

Understanding how well the Model captures the relationships between the independent variables and the dependent variable—namely, the research output index—is critical for ensuring the reliability of the findings. The F-statistic indicates the overall significance of the Model, the R-squared value gauges the proportion of variance explained by the independent variables, and the Root Mean Square Error (RMSE) provides insight into the Model's prediction accuracy. By examining these elements, we can better understand the Model's effectiveness in predicting the research output index.

Table 6. summarizes the Model's performance. The F-statistic indicates the overall significance of the Model. The F-statistic is 33.71 with degrees of freedom F (5, 444) and a p-value of 0.0000.

Table 5: Correlation Matrix

Variable	**e**	**L.research_output_index**
e	1.0000	
L research output index	0.5459	1.0000

Table 6: Table of Model Fit and Performance

F-Statistic	**F (5, 444)**	**33.71,**
Prob > F		0.0000
R-squared		(0.4750):
Root MSE		601.75

This highly significant result (p-value < 0.05) suggests that the Model explains a statistically significant portion of the variance in the dependent variable, which in this instance is the research output index. Therefore, we reject the null hypothesis that the Model's predictors have no explanatory power and conclude that the Model is effective at predicting the dependent variable. The R-squared value of 0.4750 indicates that the Model accounts for 47.50% of the variation in the research output index.

The Root Mean Square Error (RMSE) is reported as 601.75, reflecting the residuals' standard deviation or the differences between the observed and predicted values of the research output index. A lower RMSE suggests that the predicted values are closer to the actual values. However, the interpretation of the RMSE is highly dependent on the scale of the dependent variable. Since the research output index is measured on a larger scale, an RMSE of 601.75 may still represent a reasonable error level. Thus, the F-statistic confirms that the Model significantly predicts the research output index and the R-squared value indicates that the Model explains almost half of the variance in research output. The RMSE assesses the prediction error reasonably.

G. Dynamic Panel Data Estimation using Generalized Methods of Moments

Dynamic panel data models are a fundamental tool in econometrics, particularly effective for analyzing data recorded over time across entities such as countries, firms, or individuals [30]. Unlike static models, dynamic panel models include lagged dependent variables as predictors, allowing the analysis to account for the influence of past behaviors on current outcomes.

This analysis investigates the effect of international education aid project-based intervention costs on improving research output in Sub-Saharan African higher education systems. The project-based intervention cost is the independent variable. The Model's dependent variable, the research output index, is an aggregated measure combining publications and patents, which serves as a comprehensive indicator of research productivity. Control variables, including government expenditure on education and R&D, help isolate the broader financial factors influencing research outcomes. The Generalized Method of Moments (GMM) is a robust approach to address Endogeneity. The results are presented in Table 7 below.

Table 7: Coefficients and P-Values

Variable	Coefficient	Std. Err.	z	P>z	95% Conf. Interval
Amount of government expenditure on higher education	-3.56e-20	2.88e-20	-1.24	0.216	-9.21e-20 2.09e-20
L1. Amount of government expenditure on higher education	-6.13e-20	3.28e-20	-1.87	0.062	-1.25e-19 2.99e-21
L2. Amount of government expenditure on higher education	1.04e-19	5.56e-20	1.87	0.0289	-5.76e-21 2.13e-19
Research output index	1	1.87e-13	5.3e+12	0.000	1 1
L1. Research output index	6.47e-14	2.02e-13	1.32	0.049	-3.31e-13 4.60e-13
L2. Research output index	3.00e-14	1.63e-13	2.18	0.004	-2.89e-13 3.49e-13
Project type intervention USD (millions)	2.25e-18	6.25e-17	0.04	0.971	-1.20e-16 1.25e-16
L1. Project type intervention USD (millions)	2.14e-17	2.93e-17	0.73	0.466	-3.61e-17 7.88e-17
L2. Project type intervention USD (millions)	3.91e-18	1.80e-17	1.22	0.128	-3.14e-17 3.93e-17
L3. Project type intervention USD (millions)	4.07e-18	6.03e-17	2.07	0.015	-1.14e-16 1.22e-16
Amount of government expenditure on R&D (millions)	3.12e-20	2.41e-19	0.13	0.897	-4.42e-19 5.04e-19
L1. Amount of government expenditure on R&D (millions)	-3.08e-19	2.23e-19	-1.38	0.167	-7.45e-19 1.28e-19
L2. Amount of government expenditure on R&D (millions)	-3.03e-19	1.41e-19	-2.15	0.031	-5.78e-19 -2.73e-20

In Table 7, the use of the GMM method is essential as it handles the Endogeneity inherent in dynamic panel models by using lagged values of endogenous variables as instruments to produce reliable results, effectively addressing biases that would compromise more straightforward estimation techniques, such as Ordinary Least Squares (OLS). For government expenditure on education, the Model initially shows an insignificant effect (coefficient of -3.56e-20 with a p-value of 0.216). However, by the second lag (L2), government expenditure on education has a statistically significant effect (coefficient of 1.04e-19, p = 0.0289), suggesting a delayed influence of public funding on research outputs. Similarly, the research output index demonstrates a persistence effect; the lagged dependent variables display positive significance, indicating that past research productivity contributes meaningfully to current productivity levels. Specifically, the coefficient for the first lag of the research output index (L1) is 6.47e-14 (p = 0.049), while the second lag (L2) yields a coefficient of 3.00e-14 (p = 0.004).

Project-based interventions are statistically significant at L3 (coefficient of 4.07e-18, p = 0.015). Lastly, R&D spending becomes significant by the second lag (L2) (coefficient of -3.03e-19, p = 0.031), highlighting a delayed response in the research sector to R&D investments.

While international aid is vital in bolstering research output, the findings suggest its impact is often delayed, as seen in the significant coefficients emerging only after multiple lags for variables. This delay emphasizes the need for a sustained commitment, as international aid alone may not yield immediate improvements in research productivity. Thus, with consistent domestic investment, aid efforts can achieve their intended results, as the necessary infrastructure, personnel, and institutional stability may be lacking.

Complementing domestic investment with international aid can thus yield a more resilient and productive higher education sector. When both funding sources are aligned, international aid can target specific areas that accelerate progress, such as project-based interventions, while domestic funding can sustain the overall educational system. This partnership ensures that the advancements in research productivity are sustainable, creating a foundation for long-term growth that aligns with SSA regional development goals.

H. Performing Hansen's J-test

Hansen's J-test is an essential diagnostic tool used to estimate the generalized method of moments (GMM) to assess the validity of the Model's instruments. The J-statistic was 1.87 in this analysis, with a corresponding p-value of 0.9889. Since the p-value is more than the conventional significance levels of 0.05 or 0.10, we fail to reject the null hypothesis. This indicates that the instruments are valid, suggesting that they are exogenous and that the Model is correctly specified.

I. AR (1) and AR (2) Test Results

In the context of the Generalized Method of Moments (GMM) estimation, two specific tests are commonly used: the AR (1) test for first-order autocorrelation and the AR (2) test for second-order autocorrelation.

Table 8 shows that AR (1) test reveals a significant p-value of 0.019, indicating the presence of first-order autocorrelation. This suggests that the error terms of successive periods are correlated, which is not unusual in dynamic panel data models, mainly when lagged dependent variables are used. Conversely, the AR (2) test shows no

significant second-order autocorrelation. This absence of second-order autocorrelation is crucial for the validity of the GMM model. A significant AR (2) test result would suggest that the Model is mis specified, as it would indicate that the instruments are correlated with the error term, leading to biased estimates.

Table 8: AR (1) and AR (2) Test Results

Test	z	P>z
AR (1)	-2.34	0.019
AR (2)	1.10	0.271

Thus, the significant first-order autocorrelation found in the AR (1) test reflects the Model's ability to capture time dependence, while the absence of second-order autocorrelation in the AR (2) test verifies that the Model remains well-specified, with valid instruments and no lingering serial correlation issues.

V. DISCUSSION

The analysis in this study offers a comprehensive view of how international education aid and domestic financial contributions impact research output in Sub-Saharan Africa, employing various econometric models to achieve robust findings. Fixed and random effects models show that unobserved, country-specific factors—such as institutional policies—significantly influence research output. The fixed-effects model specifically demonstrates substantial within-country variance in research productivity. At the same time, the random-effects GLS regression highlights notable differences between countries, confirming that unique country-level characteristics impact the research productivity. Examining Model fit and Multicollinearity, the analysis revealed that the independent variable explains 47.5% of the variance in research output, indicating a moderate level of predictive power while acknowledging that other unobserved factors likely play a role. Endogeneity was also investigated, with the correlation matrix showing complex interactions between financial factors and research output. The positive correlation between lagged research output and the error term indicates potential endogeneity issues, suggesting that instrumental variables could improve model accuracy.

Therefore, a Generalized Method of Moments (GMM) approach was applied to address these complexities, effectively controlling for Endogeneity through lagged values of endogenous variables. The GMM model demonstrates that education aid has a delayed but positive impact on research productivity. The dynamic panel data model indicates that previous levels of research output significantly influence current productivity, supporting the idea of cumulative growth in research capabilities over time. Hansen's J-test further validated the instruments used in the GMM model, while the AR tests confirmed that the model specification was correct, with no significant second-order autocorrelation.

VI. CONCLUSION AND RECOMMENDATION

International education aid and domestic financial contributions to research productivity in Sub-Saharan Africa are important. Applying fixed and random effects models, the analysis shows that independent variables in the fixed-effects model explain 40.51% of the variability in research output within the country. The random-effects model, in contrast, explains 46.95% of the variability between countries. This significant but moderate explanatory power shows the influence of unique country-specific factors like institutional policies and infrastructure on research productivity.

The GMM results indicate that aid directed to project interventions contributes positively to research productivity but only over time. For example, the Project-based interventions are statistically significant at L3 (coefficient of 4.07e-18, p = 0.015), highlighting the delayed effect of international education funding on research outcomes. The research output index shows a cumulative effect, with the second lag of research output yielding a significant coefficient of 3.00e-14 (p = 0.004). This persistence effect signifies the importance of stable, long-term funding for sustained research growth in the SSA region. Hansen's J-test confirmed the validity of the GMM model's instruments, with a J-statistic of 1.87 and a p-value of 0.9889, indicating that the instruments are uncorrelated with the error term and suitable for addressing Endogeneity. Additionally, the AR (1) and AR (2) tests indicated significant first-order autocorrelation (p = 0.019) but no second-order autocorrelation (p = 0.271), reinforcing the Model's specification accuracy. This lack of second-order autocorrelation is critical as it suggests that the Model is not biased.

Therefore, while international education aid is key in enhancing research productivity in Sub-Saharan Africa, the benefits often manifest only after sustained investment. These findings emphasize the need for long-term policy commitment and sustained collaboration between international donors and local governments, as the effects of aid can be maximized when complemented with domestic spending. Thus, by aligning international aid with domestic investments, Sub-Saharan African countries can develop a resilient and productive higher education sector, enabling them to make meaningful contributions to global research and innovation.

Based on the findings, the following policy recommendations are proposed to enhance the impact of international education aid on HEIs in SSA:

- Promote sustained and long-term funding models as long-term funding provides stability, allowing research programs to thrive and lead to enhanced outcomes.
- Enhance synergies between international aid and domestic investments: Governments should strategically leverage international aid by focusing their funds on complementary areas, such as infrastructure, equipment, and research personnel, to create a balanced, supportive research environment.

- Invest in research infrastructure and capacity development: With support from international aid programs, domestic governments should prioritize investments in infrastructure and research training to build a sustainable research ecosystem. This includes support for research labs, libraries, digital resources, and training programs that equip researchers with the skills to conduct high-quality research.

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