BANK OF INDUSTRY

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Public Debt, Institutional Quality, and Infrastructural Development in Sub-Saharan Africa

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Abstract
This study investigates the complex relationship between public debt, institutional quality, and infrastructural development in sub-Saharan Africa (SSA). Utilizing the System Generalized Method of Moments (GMM) Approach with data from 45 SSA countries spanning 2014 to 2022, it explores how institutional quality moderates the impact of public debt on infrastructure development. Findings reveal that high public debt levels typically suppress infrastructure development by diverting resources to debt-servicing obligations. However, robust institutional frameworks, characterized by transparency, accountability, and effective governance, significantly mitigate these negative effects. Key institutional indicators — voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption —emerge as critical in enhancing infrastructure investment in high debt environments. The study underscores the essential role of strong institutions in leveraging public debt for sustainable development, offering policy insights aimed at enhancing institutional capacity, fostering regional cooperation, and optimizing debt management strategies in SSA.

Keywords: Public Debt, Institutional Quality, Infrastructure, Sub-Saharan Africa
JEL classification: *H54, H63, O40, O55*

I. Introduction

In the vast and diverse landscape of sub-Saharan Africa (SSA), the intricate relationship between public debt, institutional quality, and infrastructural development stands as a critical determinant of the region's economic trajectory. Theoretically, public debt is conceived as a tool to finance economic activities, bridge financial gaps, and stimulate infrastructural development (Chenery & Strout, 1966; Domar, 1946; Harrod, 1939; Keynes, 1936). However, the reality of countries in SSA paints a contrasting picture, marked by the paradoxical scenario of countries accumulating substantial

public debt while grappling with inadequate infrastructural development (Daniel-Adebayo et al. 2022; Lola et al. 2023; Lola & Oni, 2022; Nchofoung et al. 2020; Ndulu, 2021). These countries find themselves in the predicament where the accumulation of public debt has not translated into the anticipated strides in infrastructural development. This incongruity raises questions about the effective management and utilization of public debt in the region.

Previous studies have contributed to the discourse by revealing a negative correlation between public debt and infrastructural development in SSA (Lola et al. 2023; Nchofoung et al. 2020). This suggests a prevailing issue of mismanagement, indicating that the accumulation of public debt has overburdened rather than fostered sustainable development of countries in this region (Said & Sani, 2020; Sani et al. 2019; Sani & Yahaya, 2021). The challenge lies in understanding the underlying factors contributing to this misalignment and seeking viable solutions to recalibrate the relationship between public debt and infrastructural development in SSA.

The literature consistently highlights the pivotal role of institutional quality in ensuring proper management and effective utilization of public debt (Ekouala, 2022; Mehmood et al. 2021; Sani et al. 2019). Institutions characterized by transparent governance, robust legal frameworks, and efficient policy implementation are essential for directing public debt towards meaningful infrastructural projects (Appiah et al. 2022; Ogbaro, 2019). This study examines the mediating role of institutional quality in shaping the relationship between public debt and infrastructural development in SSA.

This paper recognizes the urgency to explore the nuanced dynamics that contribute to the existing disparities between theoretical expectations and practical outcomes in the realm of public debt and infrastructural development in SSA. By focusing on the mediating role of institutional quality, the research seeks to unravel specific mechanisms through which governance structures, legal frameworks, and policy implementation capacities influence the outcomes of public debt-funded projects.

The assumptions underlying this investigation include the theoretical premise that public debt should, in principle, drive infrastructural development. However, the observed accumulation of public debt in SSA countries without commensurate infrastructural growth (Calderón et al. 2018) challenges this assumption. This observation underscores the urgency to address

mismanagement issues and explore the mitigating influence of institutional quality.

This paper aims to contribute to the existing body of knowledge by offering a comprehensive analysis of the interplay between public debt, institutional quality, and infrastructural development in SSA. Through a focused exploration of the mediating role of institutional quality, the research endeavours to provide valuable insights for policymakers, practitioners, and scholars, ultimately fostering sustainable and inclusive development in the region.

Following the introduction, the rest of this paper is organized in the following order. Section 2 reviews the relevant literature; section 3 discusses the dataset and econometric methodology used in conducting this research; section 4 presents the empirical results; and section 5 concludes and suggests appropriate policy recommendations.

2.0 Literature Review

This section provides a backdrop of the intricate interplay between public debt, institutions, and infrastructure development in Sub-Saharan Africa (SSA) with a focus on the theoretical framework and empirical review.

2.1 Public debt in sub-Saharan Africa

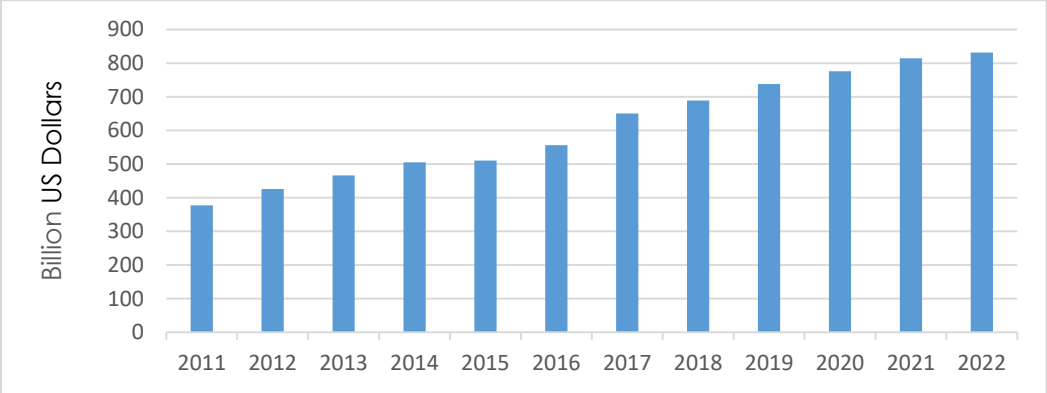
The economic history of sub-Saharan Africa (SSA) is deeply entwined with public debt accumulation shaping the fiscal trajectory of the region through distinct historical phases. The pre-independence era, marked by a colonial legacy, laid the groundwork for subsequent fiscal challenges. After independence, the region initially had high hopes for development, fuelled by external aid and early borrowing. However, this optimism was soon overshadowed by a severe debt crisis in the 1980s, necessitating structural adjustments (Fosu, 1996; Milton, 1999).

In response to the escalating debt crisis, programmes like the Heavily Indebted Poor Countries (HIPC) Initiative were launched in the 1990s, specifically to provide relief for highly-indebted poor countries in SSA (IMF, 2017). The aim was to redirect freed-up resources towards poverty reduction and sustainable development (Olaoye, 2023)). Despite the positive impact of these initiatives, the spectre of indebtedness resurfaced in the region in subsequent years. Moreover, to bolster ongoing efforts, the Multilateral Debt

Relief Initiative (MDRI) was introduced in 2005. By 2015, out of the 36 countries benefiting from these initiatives, an overwhelming 30 were from SSA (Djimeu, 2018). However, challenges related to debt sustainability persist, underscoring the enduring and complex nature of debt dynamics in the region.

The historical overview of public debt accumulation in SSA reflects a cyclical pattern marked by initial aspirations, debt crises, and subsequent relief initiatives. The challenges of managing debt sustainably underscore the need for ongoing vigilance and strategic fiscal management in the region. Figure 1 provides a visual representation of the historical trends in public debt accumulation in SSA.

Figure 1: *Dynamic Trend of Public Debt in SSA*



Source: World Development Indicator, online version 2024.

Figure 1 indicates that from 2011 to 2022, SSA experienced a significant surge in public debt, nearly doubling from around $460 billion in 2013 to over $800 billion by 2022. This period saw a steady increase in debt levels, particularly between 2015 and 2018, when debt rose sharply from about $500 billion to nearly $700 billion. The trend continued upward, reaching $831.536 billion by 2022.

This rapid debt accumulation can be attributed to several factors, including investments in infrastructure, economic stimulus measures, and increased borrowing for development initiatives. Despite efforts like the HIPC initiative and the MDRI, SSA continues to face significant challenges in managing debt sustainably.

The intricate relationship between institutions and public debt is evident, as governance quality and institutional frameworks are crucial in navigating these challenges. The region's economic stability is further complicated by

reliance on international lenders, especially the private sector, making borrowing expensive and refinancing efforts difficult. The persistently high levels of public debt underscore the need for strategic fiscal management and comprehensive reforms to enhance institutional effectiveness and ensure sustainable development in SSA.

2.2 Theoretical framework

In navigating the intricate relationship between public debt and infrastructural development, economic theories offer nuanced perspectives that illuminate the dynamics of this association. Keynesian economics, for instance, posits that active government intervention through increased public debt can serve as a strategic tool for stimulating economic activity(Keynes 1936; Keynes et al. 1971). This perspective underscores the potential of well-managed public debt to initiate a cascade effect, fostering job creation and overall economic development.

Complementary to this, the Endogenous Growth Theory asserts that sustained economic growth is achievable by directing public debt towards investments in human capital and physical infrastructure (Romer, 1990b; 1990a). In light of this, the theory aligns with the notion that strategic allocation of public debt to infrastructural projects can enhance productivity and competitiveness, thereby contributing to a conducive environment for long-term economic growth.

Moreover, fiscal policy theories, specifically the concept of crowding-in, suggest that government spending, financed by public debt, can attract private sector investments (Ahmed et al. 1999; Barro, 1979) When public debt is directed towards infrastructure, it acts as a catalyst not only for government-led development but also for stimulating private-sector involvement. This synergistic relationship creates complementary development, and the combined efforts of public and private investment enhance the overall impact on economic development. This theory is pertinent to the present study as it highlights the interconnectedness of public and private investment in driving infrastructural development.

Debt sustainability frameworks add a layer of prudence to the discussion, emphasizing the careful management of public debt to avoid burdening future generations (IMF, 2019; 2023b). Applied to infrastructural development, these frameworks advocate for maintaining debt levels that ensure fiscal

stability and economic growth, allowing governments to continue financing essential projects without risking over-indebtedness.

Institutional economics, exploring how institutions shape economic behaviour, introduces a crucial perspective. Understanding how institutional quality, encompassing governance structures, the rule of law, and regulatory frameworks, influences the effectiveness of public debt in driving infrastructural development is pivotal (Acemoglu et al., 2005; Acemoglu & Johnson, 2003; North, 1991). This lens provides insights into the mediating role of institutional factors in this complex relationship.

Collectively, these economic theories weave a narrative that enhances our understanding of the multifaceted interactions between public debt, institutional quality, and infrastructural development. Each theory contributes a unique facet, creating a comprehensive framework that illuminates the dynamics at play in the context of the SSA region.

2.3 Empirical review

Public debt and infrastructural development are critical determinants shaping the economic trajectory of nations. Over the years, numerous empirical studies have sought to unravel the intricate relationships between these factors, offering valuable insights into their dynamics. This comprehensive overview delves into various empirical studies conducted across different regions and time frames, shedding light on the complex interplay between public debt and infrastructural development.

In a study by Kapindula and Kaliba, (2019), the impact of public external debt servicing on infrastructure spending in Zambia was investigated. Utilising time series data from 1970 to 2014 and employing the Autoregressive Distributed Lag Model and Bounds Testing Approach, the study revealed a negative correlation. This implies that debt servicing adversely affected infrastructure spending in Zambia, constraining the funds allocated to infrastructure development.

Hameed et al. (2021) explored the impact of public debt on capital accumulation in South Asian countries. Through the use of a Fixed Effect model and various debt indicators, the study analysed 30 years of panel data from 1990 to 2019. The findings identified a negative correlation between

public debt and public debt servicing with capital accumulation, supporting the debt overhang hypothesis.

In a broader African context, Nchofoung et al. (2020) analysed the influence of public external debt on infrastructure development. Using fixed-effects Driscoll and Kraay's estimator and Lewbel's estimator with data spanning 2003 to 2018, the study indicated a predominantly negative impact of external debt on infrastructure levels, emphasising the importance of debt sustainability.

Alaeddine (2022) explored the correlation between public debt and infrastructure in 19 Arab nations. The study, utilising panel data and employing the Generalized Least Squares regression and the Hausman test, revealed a negative impact of debt-to-GDP on the infrastructure index. This emphasized the reliability of the new Human Development Index hypothesis in explaining the infrastructure indicator.

Shifting focus to Nigeria, Lola and Oni (2022) and Lola et al. (2023) investigated the connection between public external debt and sustainable infrastructural development. Using a mixed-methods approach, incorporating structured questionnaires, interviews, and SPSS-based inferential statistics, the study found that external debt did not significantly impact sustainable infrastructural development in Nigeria.

Onwuka (2021) investigated the relationship between external debt burden and infrastructural development in Nigeria. Utilising the Autoregressive Distributed Lag Model (ARDL) and Granger causality test, the research revealed that external debt, domestic debt, and inflation rate negatively impacted infrastructural development in the long run.

Osadume et al. (2022) examined the connection between external debt and infrastructural development in emerging economies, focusing on evidence from Nigeria spanning 1979 to 2019. The study utilized robust least squares regression, Autoregressive Distributed Lag (ARDL), and the Error Correction Model. However, in the long run, external debt did not show a significant correlation with infrastructural development.

Ariyibi et al. (2023) further explored the impact of foreign debts on infrastructure development of Nigeria. Employing the Autoregressive Distributed Lag (ARDL) model with annual time series data from 1983 to 2019,

the study's findings aligned with the dual gap theory, suggesting that external debt can contribute to enhancing economic growth.

Existing studies have provided valuable insights into the direct connection between public debt and infrastructure. However, they often disregard the intermediary impact of institutional quality on this relationship. This gap underscores the necessity for further exploration into how institutional quality may mediate or moderate the effects of public debt on infrastructural development in the SSA region. Institutional quality, encompassing governance structures, the rule of law, and regulatory frameworks, significantly influences the economic landscape. Failure to consider the mediating role of institutional quality may result in an incomplete understanding of the intricate dynamics between public debt and infrastructural development. The present research employs mediation analysis techniques to explicitly scrutinize the mediating role of institutional quality. This entails investigating how institutional factors intervene in the relationship between public debt and infrastructural development. Insights into how institutional quality moderates this relationship can offer guidance to policymakers in creating conditions conducive to sustainable infrastructural development.

3.0 Data and Methodology

3.1 Data source and description of variables

Table 1: *Data Source and Description of Variables*

S/N	Variable	Measurement	Source
1	Infrastructural Development (IDI)	Africa Infrastructure Development Index	AfDB
2	Public Debt (DGR)	Debt to GDP Ratio	IMF
3	Economic Growth (GRA)	GDP Growth Annual	WDI
4	Institutional Qualities (INS)	Six Institutional Quality Index	WDI
5	Debt Service (DSX)	Debt Service to Export Ratio	WDI
6	Government Expenditure (GEX)	Govt. Expenditure as Percentage of GDP	IMF
7	Population Growth (POP)	Population Growth Annual	WDI
8	Urbanization (URB)	Percentage of Urban Population	WDI

Notes: AfDB – African Development Bank, IMF – International Monetary Fund, WDI – World Development Indicators, which is a comprehensive data set compiled by the World Bank.
Source: Author's Compilation, 2024.

3.2 Estimation techniques

The study will employ the System GMM methodology, a dynamic panel data technique that addresses endogeneity concerns in the model. This technique allows for the simultaneous consideration of both levels and differences in the data, enhancing efficiency in estimating parameters. The method is chosen for its adeptness in accommodating complex relationships and dynamic interactions, making it an ideal choice for exploring the nuanced interplay among these variables (Arellano & Bond, 1991). The study employs dynamic panel data models to analyse the time-dependent dynamics, and the System GMM approach, designed explicitly for dynamic panel data, addresses temporal complexity by incorporating lagged values of variables (Arellano & Bover, 1995).

The inclusion of lagged values in the analysis allows for a comprehensive exploration of how changes in institutional quality mediate the impact of public debt on infrastructure development over time (Roodman, 2009b). Challenges related to endogeneity, such as the potential bidirectional relationship between institutional quality and public debt, are effectively handled by System GMM through the use of instrumental variables based on lagged values (Roodman, 2009b). This approach fortifies the reliability of estimates by addressing potential endogeneity issues.

To account for unobserved heterogeneity, the study incorporates country-fixed effects, ensuring that the estimated parameters are robust and unbiased. The System GMM approach enhances the efficiency of handling instrumental variables by utilising moment conditions based on both the differences and levels of variables, contributing to the precision and reliability of parameter estimates (Blundell & Bond, 1998).

The study emphasizes the dynamic nature of the impact of public debt on infrastructure development, and System GMM, reliant on lagged values, enables the exploration of how these effects evolve (Roodman, 2006; 2009a). In conclusion, the System GMM approach is considered methodologically robust and theoretically sound for investigating the intricate relationships between public debt, institutional quality, and infrastructure development in SSA, providing valuable insights into the economic dynamics of this critical region.

3.3 Model specification

Drawing on established economic theories, we consider factors such as economic growth, government investment, urbanization, and population growth as pivotal determinants influencing the interplay between public debt and infrastructure development. Guided by these theoretical foundations, we formulate a comprehensive model as specified below:

$$IDI_{it} = \beta_1 + \lambda IDI_{it-1} + \beta_2 DGR_{it} + \beta_3 INS_{it} + \beta_4 GRA_{it} + \beta_5 DSX_{it} + \beta_6 GEX_{it} + \beta_7 POP_{it} + \beta_8 URB_{it} + \varepsilon_{it} \quad (1)$$

where:

λIDI_{it-1}: Infrastructure Development Index;
λIDI_{it-1}: Lagged Infrastructure Development Index (one period lag)
$\beta_2 DGR_{it}$: Debt to GDP Ratio
$\beta_3 INS_{it}$: Institutional Quality
$\beta_4 GRA_{it}$: GDP Growth Annua
$\beta_5 DSX_{it}$: Debt Service to Export Ratio
$\beta_6 GEX_{it}$: Government Expenditure
$\beta_7 POP_{it}$: Population Growth Annual
$\beta_8 URB_{it}$: Rate of Urbanization
ε_{it} : Error term

This baseline model (1) provides a foundational framework for exploring the relationships between public debt and infrastructure development in SSA. Building upon the insights from Sani et al. (2019), this study extends the investigation to comprehend the moderating impact of institutional quality on the complex relationship between public debt and infrastructure development. To capture this nuanced interaction, an additional term is introduced in the expanded model as $L(INS)it \times L(Deb)it$. Thus:

$$IDI_{it} = \beta_1 + \lambda IDI_{it-1} + \beta_2 DGR_{it} + \beta_3 INS_{it} + \beta_4 GRA_{it} + \beta_5 DSX_{it} + \beta_6 GEX_{it} + \beta_7 POP_{it} + \beta_8 URB_{it} + \beta_9 (DGR * INS)_{it} + \varepsilon_{it} \quad (2)$$

where: β_9 : is the coefficient of the interaction term $(\mathrm{DGR} * \mathrm{INS})_{\mathrm{it}}$.
This augmented model allows for a nuanced exploration of the moderating effect of institutional quality, contributing to a deeper understanding of the interrelationships within the public debt infrastructure development nexus.

4.0 Presentation and Discussion of Results

First, we examine the data used in the model. Panel A of Table 1 reveals significant variability among the variables. Infrastructural Development Index (IDI) and government expenditure (GEX) show the greatest disparities, reflecting diverse economic conditions and institutional frameworks. Population growth (POP) and urbanization (UBN) exhibit moderate variability, while the debt-to-GDP ratio (DGD) and institutional quality (INS) also display wide ranges, indicating varying levels of economic and institutional robustness among the observations. Panel B presents the correlation matrix, which highlights important relationships involving infrastructural development (IDI). A strong positive correlation with institutional quality (INS) at 0.6952 suggests that stronger institutions are associated with higher levels of infrastructural development. Additionally, IDI has a moderate positive correlation with urbanization (UBN) at 0.3661, indicating that more urbanized areas tend to have better infrastructure. Conversely, IDI shows a negative correlation with population growth (POP) at -0.5759, implying that regions with higher population growth may experience lower levels of infrastructural development. The correlation with the debt-to-GDP ratio (DGR) is relatively weak at -0.1283, suggesting a slight negative relationship. Other correlations, such as those with GDP growth (GDP) and government expenditure (GEX), are also weak, indicating less direct influence on infrastructural development. Thus, advanced econometric methodologies like System GMM are necessary to further understand these complex linkages.

Table 2: *Descriptive Statistics and Correlation Matrix*

PANEL A: Descriptive Statistics								
	IDI	DGR	INS	GRA	GEX	DSX	POP	URB
Mean	23.48	56.55	.2114	2.991	3391	7.53	2.38	43.42
Std. Dev.	18.13	30.74	2.073	4.134	6177	6.746	0.827	17.50
Minimum	5.33	11.84	-3.420	-20.80	.995	.3076	-.076	11.77
Maximum	98.88	202.5	5.522	17.11	35852	49.71	4.12	90.73
Observation	405	405	405	405	405	405	405	405
PANEL B: Correlation Matrix								
	IDI	DGR	INS	GRA	GEX	DSX	POP	URB
IDI	1.0000							
DGR	-0.1283	1.0000						
INS	0.6952	0.0155	1.0000					
GRA	0.0593	-0.1588	0.117	1.0000				
GEX	0.1666	-0.2168	-0.026	0.1291	1.0000			
DSX	-0.0410	0.2326	0.1835	0.0230	-0.1883	1.0000		
POP	-0.5759	-0.2923	-0.442	0.0776	0.3050	0.1415	1.0000	
URB	0.3661	0.2001	0.2070	-0.191	0.1003	0.0968	-0.1159	1.0000

Source: Author's compilation.

Table 2 presents the results of the estimated models analysed using the dynamic System Generalized Method of Moments (SGMM). The findings indicate that past levels of infrastructure development strongly influence current levels, as evidenced by the high and significant coefficients for the lagged infrastructure development variable (IDI). This persistence underscores the importance of historical investments and their continuing impact on infrastructure. The coefficient for the debt-to-GDP ratio (*DGR*) is consistently negative and highly significant across all model specifications, suggesting that higher levels of public debt are associated with lower levels of infrastructure development. This inverse relationship implies that increasing public debt may crowd out investments in infrastructure or create economic conditions that hinder infrastructure projects.

Interestingly, the composite institutional quality indicators and all subcategories, including voice and accountability (*VAA*), political stability (*PSA*), government effectiveness (*GEF*), regulatory quality (*REQ*), rule of law (*RUL*), and control of corruption (*COC*), have positive and significant effects on infrastructure development. These findings highlight the critical role that strong institutions play in fostering infrastructure growth. Economic growth (GRA) generally supports infrastructure development, as seen from the

positive and significant coefficients in most specifications. Government expenditure (*GEX*) also positively impacts infrastructure, suggesting that higher public spending promotes infrastructure development. Conversely, the debt service to export ratio (*DSX*) has a negative and significant impact, indicating that high debt servicing costs can detract from infrastructure investments. Population growth (*POP*) has a consistently negative effect, suggesting that rapid population growth may strain existing infrastructure. However, urbanization (*URB*) positively influences infrastructure development, reflecting the benefits of urban growth and planning. The constant term in the model is positive and significant in all specifications, indicating a baseline level of infrastructure development independent of the explanatory variables. This baseline effect may be attributed to historical investments and inherent economic conditions that favour infrastructure growth.

The analysis in Table 3 reveals that institutional quality plays a crucial role in transforming the negative impact of public debt on infrastructure development into a positive one. The inclusion of the interaction term between public debt and the composite index of institutional quality is positive and significant, indicating that better institutional frameworks can mitigate and even reverse the adverse effects of high debt levels. Individual institutional indicators further elucidate this effect: higher levels of voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption all significantly reduce the negative impact of debt on infrastructure development. These findings suggest that robust institutions ensure the efficient allocation and utilization of borrowed funds, thereby enhancing infrastructure investment even in the context of high public debt.

Table 3: *Public Debt-Infrastructural Development Relationship in SSA*

Independent Variable	(1) IDI	(2) IDI	(3) IDI	(4) IDI	(5) IDI	(6) IDI	(7) IDI
IDI	0.952***	0.965***	0.938***	0.960***	0.968***	0.961***	0.975***
	(207.02)	(184.36)	(151.19)	(117.67)	(167.88)	(146.59)	(154.67)
DGR	-0.0281***	-0.0348***	-0.0261***	-0.0246***	-0.0146***	-0.0449***	-0.0516***
	(0.009)	(0.0115)	(0.0028)	(0.0051)	(-0.0062)	(-4.16)	(-0.009)
INS	3.799***						
	(0.263)						
VAA		8.047***					
		(0.322)					
PSA			6.195***				
			(0.484)				
GEF				14.74***			
				(0.745)			
REQ					12.19***		
					(0.938)		
ROL						0.0527***	
						(3.71)	
COC							10.74***
							(0.030)
GRA	0.248***	0.139***	0.015***	0.307***	-0.2011***	0.2007***	0.271***
	(0.029)	(0.016)	(0.012)	(0.024)	(0.027)	(0.168)	(0.030)
GEX	0.0001***	0.001***	0.0001***	0.0001***	0.0001***	0.0001***	0.0002***
	(8.82)	(4.81)	(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00001)
DSX	-0.2998**	-0.3449**	-0.1534***	-0.153**	-0.225***	-0.274**	-0.538***
	(0.0268)	(-0.032)	(0.165)	(-0.017)	(0.026)	(0.0269)	(0.032)
POP	-7.698***	-10.47***	-7.741***	-7.741***	-9.049***	-7.836***	-8.452***
	(0.335)	(0.537)	(0.469)	(0.469)	(0.513)	(0.563)	(0.4132)
URB	0.2011***	0.214***	0.214***	0.213***	0.237***	0.247***	0.2694***
	(0.0217)	(0.020)	(0.014)	(0.014)	(0.016)	(0.273)	(0.022)
Constant	31.22***	42.96***	44.94***	44.93***	40.96***	38.62***	39.25***
	(1.453)	(1.832)	(1.368)	(-1.368)	(-1.689)	(-2.806)	(1.980)
Observations	405	405	405	405	405	405	405
Instruments	22	22	22	22	22	22	22
Group	45	45	45	45	45	45	45
AR(1)	0.002	0.001	0.002	0.001	0.002	0.002	0.003
AR(2)	0.058	0.210	0.474	0.474	0.068	0.112	0.400
Hansen	0.938	0.971	0.975	0.975	0.472	0.232	0.245

Note: t statistics in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

IDI= Infrastructure Development Index, DGR = Debt-to-GDP ratio, INS = Institutional Quality, VAA= Voice and Accountability, PSA = Political Stability, GEF= Government Effectiveness, REQ= Regulatory Quality, RUL= Rule of Law, COC = Control of Corruption, GRA = Real GDP Growth Annual, GEX = Government Expenditure as percentage of GDP, DSX= Debt Service to Export Ratio, POP = Population growth annual, URB = Urbanization.

Table 4: *Role of Institutions on Public Debt- Infrastructure Development Relationship in SSA*

Independent Variable	(1) IDI	(2) IDI	(3) IDI	(4) IDI	(5) IDI	(6) IDI	(7) IDI
IDI	0.954***	0.967***	0.940***	0.950***	0.967***	0.9614**	0.976***
	(207.02)	(184.36)	(151.2)	(117.67)	(167.88)	(146.59)	(154.67)
DGR	-0.0102***	-0.0488***	-0.0352***	-0.1131***	-0.1831***	-0.1193***	-0.0203***
	(0.0081)	(0.0124)	(0.0156)	(0.0101)	(0.0101)	(0.0153)	(0.0149)
DGR*INS	0.0494***						
	(0.0032)						
DGR*VAA		0.0990***					
		(0.0031)					
DGR*PSA			0.1172***				
			(0.0115)				
DGR*GEF				0.2008***			
				(0.0119)			
DGR*REQ					0.1715***		
					(0.0047)		
DGR*RUL						0.1790***	
						(0.0122)	
DGR*COC							0.1183***
							(0.0139)
GRA	0.1215***	0.0243***	0.0462***	0.1485***	0.0687***	0.0961***	0.1731***
	(0.0205)	(0.0119)	(0.0172)	(0.0149)	(0.0103)	(0.0151)	(0.0273)
GEX	0.0001***	0.0001***	0.0001***	0.0002***	0.0006***	0.0001***	0.0001***
	(6.730)	(7.530)	(0.0002)	(6.140)	(4.612)	(0.0001)	(04.463)
DSX	-0.2037**	-0.2762**	-0.4121***	-0.0831**	-0.1243***	-0.2099**	-0.3184***
	(0.0235)	(0.027)	(0.0381)	(0.0192)	(0.0226)	(0.0302)	(0.0224)
POP	-9.397***	-11.17***	-9.831***	-8.505***	-9.939***	-9.746***	-9.037***
	(0.4985)	(0.809)	(0.6203)	(0.3110)	(0.5361)	(0.3992)	(0.5556)
URB	0.1972***	0.217***	0.1527***	0.2185***	0.2463***	0.2056***	0.2126***
	(0.0205)	(0.015)	(0.0172)	(0.0190)	(0.0230)	(0.0268)	(0.0230)
Constant	35.55***	38.84***	41.04***	31.88***	32.08***	36.11***	35.02***
	(1.263)	(1.832)	(2.0222)	(1.066)	(2.046)	(1.013)	(1.382)
Observations	405	405	405	405	405	405	405
Instruments	26	22	22	22	22	22	22
Group	45	45	45	45	45	45	45
AR(1)	0.003	0.002	0.001	0.004	0.003	0.002	0.001
AR(2)	0.195	0.210	0.474	0.198	0.101	0.320	0.162
Hansen	0.969	0.971	0.975	0.975	0.472	0.232	0.245

Notes: t statistics in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; IDI= Infrastructure Development, DGR= Debt-to-GDP ratio, INS = Institutional Quality, VAA= Voice and Accountability, PSA = Political Stability, GEF= Government Effectiveness, REQ= Regulatory Quality, RUL= Rule of Law, COC = Control of Corruption, GRA = Real GDP Growth Annual, GEX = Government Expenditure as percentage of GDP, DSX= Debt Service to Export Ratio, POP = Population growth annual, URB = Urbanization.

Table 5: *Robustness Check*

Independent Variable	(1) IDI	(2) IDI	(3) IDI	(4) IDI	(5) IDI	(6) IDI	(7)
IDI	0.954***	0.967***	0.940***	0.950***	0.967***	0.9614**	0.967***
	(207.02)	(184.36)	(151.2)	(117.67)	(167.88)	(146.59)	(167.88)
DGR1	-0.0144***	-0.0474***	-0.0352***	-0.0434***	-0.1831***	-0.0555***	-0.0291***
	(0.0095)	(0.0076)	(0.0075)	(0.0073)	(-0.0101)	(0.0112)	(-0.0104)
DGR1*INS	0.0594***						
	(0.0020)						
DGR1*VAA		0.0933***					
		(0.0027)					
DGR1*PSA			0.0614***				
			(0.070)				
DGR1*GEF				0.1536***			
				(0.0102)			
DGR1*REQ					0.1715***		
					(0.0046)		
DGR1*RUL						0.0836***	
						(0.0071)	
DGR1*COC							0.0995***
							(0.0062)
GRA	0.1730***	0.0043***	0.0149***	0.1711***	0.0687***	0.0243***	0.0687***
	(0.0183)	(0.0133)	(0.0168)	(0.0234)	(0.0104)	(0.0209)	(0.0100)
GEX	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***
	(08.123)	(7.530)	(0.0001)	(8.790)	(4.612)	(7.930)	(8.671)
DSX	-0.1984**	-0.2762**	-0.2788***	-0.2561**	-0.1243***	-0.2210**	-0.2687***
	(0.0i88)	(-0.027)	(0.0415)	(-0.0274)	(0.0225)	(0.0250)	(0.0254)
POP	-8.866***	-11.34***	-11.81***	-10.34***	-10.22***	-10.88***	-10.21***
	(0.3684)	(0.6290)	(0.4762)	(0.4777)	(0.5361)	(0.5426)	(0.5160)
URB	0.2250***	0.2450***	0.2058***	0.2617***	0.2463***	0.2541***	0.2892***
	(0.0106)	(0.0181)	(0.0311)	(0.0137)	(0.230)	(0.0198)	(0.0117)
Constant	32.05**	34.47***	43.26***	39.10***	35.22***	36.49***	34.23***
	(1.867)	(1.641)	(2.236)	(1.645)	(1.813)	(2.057)	(1.813)
Observations	405	405	405	405	405	405	405
Instruments	26	22	22	22	22	22	22
Group	45	45	45	45	45	45	45
AR(1)	0.003	0.002	0.001	0.004	0.003	0.002	0.001
AR(2)	0.166	0.210	0.474	0.198	0.563	0.124	0.162
Hansen	0.866	0.971	0.975	0.975	0.989	0.232	0.245

Note: t statistics in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

IDI= Infrastructure Development, DGR1 = Debt-to-GNI ratio, INS = Institutional Quality, VAA= Voice and Accountability, PSA = Political Stability, GEF= Government Effectiveness, REQ= Regulatory Quality, RUL= Rule of Law, COC = Control of Corruption, GRA = Real GDP Growth Annual, GEX = Government Expenditure as percentage of GDP, DSX= Debt Service to Export Ratio, POP = Population growth annual, URB = Urbanization.

The robustness check in Table 4 confirms the consistency of results when using the debt-to-GNI ratio instead of the debt-to-GDP ratio. The findings emphasize the detrimental impact of debt on infrastructural development. Furthermore, the results underscore the crucial role of institutional quality in mitigating this negative impact, both in composite and individual subcategories of institutional qualities. Stronger institutions, including better voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption, all significantly contribute to mitigating the adverse effects of debt on infrastructure development, as highlighted in the interaction model.

5.0 Summary, Conclusion, and Policy Implication

Extensive research has explored the relationship between public debt and infrastructural development, yet gaps remain regarding the influence of institutional quality in this context. This study addresses this gap by examining how institutional quality moderates the nexus between public debt and infrastructural development in sub-Saharan Africa (SSA). Utilising the System Generalized Method of Moments (GMM) approach with data from 45 SSA countries spanning 2014 to 2022, our study aimed to test the hypothesis that institutional quality plays a crucial role in shaping this relationship.

Our empirical analysis reveals that elevated levels of public debt generally correlate with reduced infrastructure development, highlighting how escalating debt obligations divert resources from productive investments to debt servicing. However, our study identifies a significant mitigating factor: institutional quality. The positive interaction between public debt and the composite index of institutional quality indicates that strong institutional frameworks can alleviate and potentially reverse the adverse impacts of high debt levels. Key indicators such as voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption significantly diminish the negative effects of debt on infrastructure development. To validate our results, we substituted the debt-to-GDP ratio with the five-year average debt-to-GNI ratio, affirming the consistency of findings across various models, and underscoring the robustness of our estimation.

The findings underscore the critical role of institutional quality in moderating the relationship between public debt and infrastructure development. To optimize the benefits of public debt for infrastructural development, SSA

countries should prioritize enhancing institutional frameworks, regulatory quality, and anti-corruption measures. Strong institutions are essential for ensuring the efficient and effective utilization of public debt. Capacity-building initiatives, supported by international organizations and development partners, are crucial for bolstering institutional quality. Policymakers must formulate comprehensive debt management strategies integrating institutional quality considerations, with regular assessments and necessary reforms. Regional cooperation among SSA countries can facilitate the exchange of best practices and resources. At the same time, continuous monitoring and evaluation of public debt projects ensure efficient fund utilization and responsiveness to evolving economic conditions. By focusing on these policy implications, SSA countries can foster sustained economic growth and improved living standards, making institutional quality a practical imperative for achieving long-term development objectives.

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Appendix A

Sub-Saharan African Countries

Angola	Congo, Rep.	Kenya,	Rwanda
Benin	Cote d'Ivoire	Lesotho	Sao Tome and Principe
Botswana	Equatorial Guinea	Liberia	Senegal
Burkina Faso	Eritrea	Madagascar	Seychelles
Burundi	Eswatini	Malawi	Sierra Leone
CaboVerde	Ethiopia	Mali	South Africa
Cameroon	Gabon	Mauritius	Sudan
Central African Republic	The Gambia	Mozambique	Tanzania
Chad	Ghana	Namibia	Togo
Comoros	Guinea	Niger	Uganda
Congo Dem. Rep.	Guinea Bissau	Nigeria	Zambia
Zimbabwe			

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Foreign Direct Investments, Institutional Structure and Economic Growth in Sub-Saharan Africa

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Abstract
Sustainable economic growth is desirable for improved overall macroeconomic performance in sub-Saharan Africa (SSA). However, the balance of payments (BOP) constrains the economic growth potentials of SSA and other developing countries. Hence, international economics and financial literature extol the relevance of financial inflows to sustainable economic growth in developing regions, given their absorptive capacity. Studies on SSA have not reached a consensus yet about the effect of financial inflows on economic growth. In addition, the effects of financial outflows on economic growth in SSA were not considered in previous studies. This study, therefore, using a 27-years (1996 – 2022) time series data across 29 out of the 48 SSA countries, deployed the System Generalized Method of Moments (Sys-GMM) to examine the effect of FDI flows on economic growth in SSA, and the role of institutional structure in the FDI flows-economic growth nexus. Results showed that FDI inflows and outflow promoted economic growth, while deterioration in the institutional structure dampened the economic growth effects of FDI flows. Therefore, the paper emphasized the need for more FDI flows, strengthening the institutions and deepening the financial sector.

Keywords: FDI flows, Institutions, Financial sector, Interaction, System-GMM.
JEL: E02, E22, F21, F33

1.0 Introduction

Sustainable economic growth is desirable for improved overall macroeconomic performance in sub-Saharan Africa (SSA). Perhaps, economic growth potentials as well as internal and external balance of SSA and other developing regions of the world have been constrained mainly by balance of payments (BOP) deficits. The constraint seems to contribute to the wide resource gaps between the developing and the developed regions of the

world. As a result, international economics and finance literature emphasize that the developing regions need inflows of financial resources to reduce the resource gaps and boost its potentials for sustainable economic growth (Chea, 2011). In line with this, conventional economic models predict that financial resources would move from capital-abundant regions to boost investment and output growth in capital-deficient regions (Thirwall-Hussain, 1982; Summer, 2000; Todaro & Smith, 2006). In addition, economic literature explains that inflows of FDI and other financial resources are essential for stimulating economic activities to overcome the problems that SSA and other developing countries face in creating conditions for sustainable growth of their gross domestic product (Yasin, 2005; International Monetary Fund, 2011; World Bank, 2020). Therefore, economic literature suggests a robust link between financial inflows such as FDI and economic growth in SSA and other developing regions.

However, available data (World Bank, 2022) show that the growth rate of gross domestic product (GDP) in SSA remains low relative to the amounts of FDI and other inflows. For instance, GDP growth rates in 1996, 2001, 2006, 2011, 2016 and 2021 were 3.81%, 8.7%, 15.88%, 3.96%, 6.75 and 1.60%, respectively. On the other hand, the region recorded FDI inflow growth rates of 125.69%, -29.55%, 77.31%, 8.35%, -10.46% and -0.03% in the corresponding years. Similarly, FDI outflow growth rates outperformed GDP growth at 3.17%, 40.07% and 19.96% in 1990, 1996, and 2005, respectively. However, the reason for the low GDP growth rate in SSA has not been well researched in the context of FDI flows (Musibau et al. 2017; Ojeleye et al., 2018; Ehigiamusoe & Lean, 2019). The studies failed to properly account for the effects of FDI flows on economic growth in SSA. First, the studies focused on FDI inflow but neglected the fact that FDI outflow has the potential to affect economic growth in the source countries. For instance, some recent studies found that FDI outflow affected economic growth in Brazil and China (Gondim et al. (2018), India (Agnihotri & Arora, 2019) and Romania (Amin *et al*., 2022). Unfortunately, despite the availability of FDI outflow data (World Bank, 2022) and the findings of these non-SSA studies, theoretical and empirical literature has been silent about the economic growth effects of FDI outflow in SSA. Second, the studies downplayed the role of institutional structure (institutional quality and financial sector development) in the FDI inflow-economic growth nexus. Only a few studies considered either the quality of institutions or financial sector development, but not both (Adeniyi et al. 2015; Seyingbo & Adeniyi, 2018; Kouassi, 2019). Therefore, the studies failed to put the economic growth effect of FDI flows in its proper perspective for appropriate financial flows-led economic growth policies.

From the foregoing, the motivation for this paper took its root in the extant theoretical and empirical literature, which suggests a strong connection between financial inflows like FDI and economic growth, especially with the adequate absorptive capacity of a domestic economy. In addressing the gaps, this paper does not only contribute to the empirical literature on the effect of FDI inflow but also the effect of FDI outflow on economic growth in SSA. In addition, this paper evaluates the role of institutional structure in the nexus between FDI flows and economic growth in SSA. Furthermore, this paper has the potential to stimulate further interest and expand the research scope in this and related areas to promote sustainable economic growth in SSA.

2.0 Review of Empirical Studies and Theoretical Framework

2.1 Review of empirical studies

Over the decades, some studies have examined the effects of foreign direct investment on economic growth in countries at various stages of economic development. Some of the studies factored in the relevance of institutional quality or financial sector development in the economic growth process, while others did not. A review of the studies is presented in this sub-section.

For the developed regions, some studies have reported significant positive effects of FDI inflow on economic growth (e.g., Kornecki & Rhoades, 2007; Kornecki et al., 2008). Similarly, Kosztowniak (2016) examined the impact of and causal relationship between FDI inflow and economic growth in Poland and found that FDI inflows promote economic growth and that bi-directional causality exists between them. From the outflow perspective, Ciesiclska and Kiltuniak (2017) evaluated the causality between economic growth and FDI outflow in Poland for 2005Q1 to 2015Q4, and found that causality runs from economic growth to FDI outflow in the short run, which reverses in the long run. Thus, the Polish economy experiences economic growth-led internationalization of productive economic activities, while FDI inflow stock precedes economic growth in the long run.

Recent studies on emerging and non-SSA economies provide evidence that FDI outflow enhances economic growth, while FDI inflow boosts economic growth through institutional quality channel. For instance, Başar and Özkilbaç (2016) found significant positive effect of FDI outflow on economic growth in the short run and significant short- and long-run positive effects on domestic investment in

Turkey. Similarly, Chen (2018) found that China's internationalization strategy boosts its economic growth through FDI outflows. On the other hand, Aziz (2020) showed that, in Arab countries, institutional quality, macroeconomic stability and financial development significantly enhance economic growth via FDI inflows. Similarly, Okwu et al. (2020) and Kang and Martinez-Vazquez (2021) found in cross-continent studies that FDI inflows promote economic growth in 30 leading global economies and in sixty-eight countries with well-developed financial sectors respectively.

In the past decade, studies on developing non-SSA countries reported mixed findings. For instance, Basnet and Pradhan (2014) found that FDI inflow had no significant effect on economic growth in the Southern Asia Association for Regional Cooperation (SAARC). On the other hand, Almfraji, Almfraji and Yao (2014) found negative effect of FDI inflow on economic growth in Qatar. These contradict the studies by Brahim and Rachdi (2014), Nistor (2014) and Govori and Fejzullahu (2020), which found that FDI inflows promoted economic growth in the Middle East and North African (MENA) region, Romania and Kosovo, respectively. Similarly, Agnihotri and Arora (2019) showed that FDI outflows dampened economic growth in India, while Knoerich (2017) and Amin et al. (2022) established that FDI outflows promoted economic growth in less advanced countries and Romania, respectively.

Studies on SSA have similarly differed in their findings about the effect of FDI inflows on economic growth. For instance, Agbloyor et al. (2016) showed that FDI inflow does not promote economic growth in SSA, especially without quality institutions, while Chih et al., (2021) found that FDI inflow promotes economic growth. Recent sub-region and country-specific studies corroborate Chih et al.'s finding. The studies showed that FDI inflow promoted economic growth in Ghana (Antwi & Xhao, 2013), the Economic Community of West African States (Fantessi, 2015), Nigeria (Ojeleye et al., 2018) and South Africa (Maduku & Zerihum, 2021).

From the foregoing, it is obvious that the studies on SSA focused mainly on the FDI inflows-economic growth nexus, with a little consideration of the quality of institutions or financial sector development, but not both. It is also clear that the studies on SSA and specific countries ignored the effects of FDI outflows on economic growth, and the role of institutional quality and financial sector development simultaneously in the nexus. This study contributes to bridging these gaps in the empirical literature.

2.2 Theoretical framework

In economics literature, several theoretical constructs offer explanations for the drivers and dynamics of economic growth. However, Thirlwall-Hussain's (1982) Balance of Payments-Constrained Model of Economic Growth provides a more robust explanation of the dynamics of economic growth, especially in the context of foreign capital inflows, economic openness, and low output growth rates in developing countries. The model explains that foreign capital inflows hold the potential to finance current account deficits and accelerate aggregate output growth rates in developing countries or regions from initial current accounts disequilibrium, despite foreign exchange challenges. For the effect of capital inflows like FDI on economic growth through the balance of payments (BOP) channel, Thirlwall and Hussain explain that countries of developing regions are in initial current account disequilibrium. They express the disequilibrium as:

$$P_{dt}X_t + C_t = P_{ft}M_tE_t \tag{1}$$

where: X is export, P_d depicts domestic price of export, M is import volume, P_f denotes foreign price of import, E is exchange rate, and C denotes volume of capital inflows, while t depicts regular time interval in the inflows.

Equation (1) states that the domestic sector ($P_{dt}X_t$) of a developing economy falls short of its external sector ($P_{ft}M_tE_t$), and that the deficit is augmented by capital inflows (C_t). The implication is that countries in developing regions experience current account disequilibrium, which triggers the need for foreign capital inflow (C) to reduce BOP deficits and boost the potential for sustainable growth of their gross domestic product.

For the rate of change of the variables, equation (1) is differentiated partially with respect to P_{dt}, X_t, C_t, P_{ft}, M_t and E_t. Thus,

$$\left(\frac{E}{R}\right)(p_{dt} + x_t) + \left(\frac{C}{R}\right)(c_t) = p_{ft} + m_t + e_t \tag{2}$$

where: $\left(\frac{E}{R}\right)$ and $\left(\frac{C}{R}\right)$ are the proportions of import bill financed by export earnings and capital inflows, respectively. c_t and $(p_{dt} + x_t)$ are the growth rates of capital inflows and export earnings, respectively.

Thirlwall and Hussain assume constant elasticity of demand for imports and exports and, thus, express the import and export functions nominally as follows:

$$M_t = \left(\frac{P_{ft} E_t}{P_{dt}} \right)^{\varphi} Y_{dt}^{\pi} \tag{3}$$

$$X_t = \left(\frac{P_{dt}}{P_{ft} E_t} \right)^{\eta} Y_{ft}^{\varepsilon} \tag{4}$$

where φ and η denote price elasticity of demand for imports (φ < 0) and price elasticity of demand for exports (η < 0), respectively. Y_{dt} depicts aggregate domestic income, π is income elasticity of demand for imports, while Y_{ft} denotes level of income of the rest of the world, and ε is income elasticity of demand for exports. *t* depicts regular time intervals during the trading period. Taking partial derivatives of equations (3) and (4) with respect to P_{dt}, X_t, C_t, P_{ft}, M_t and E_t yield the rates of change of the variables. Hence,

$$m_t = \psi\left(p_{ft} + e_t - p_{dt} \right) + \pi\left(y_{dt} \right) \tag{5}$$

$$x_t = \eta\left(p_{dt} + e_t - p_{ft} \right) + \varepsilon\left(y_{ft} \right) \tag{6}$$

Putting equations (4) and (5) into (2) gives the following BOP-constrained economic growth of the developing countries starting from initial current account disequilibrium:

$$Y_{Bt} = \frac{\left(\frac{E}{R}\eta + \psi \right)\left(p_{dt} - e_t - p_{ft} \right) + \left(p_{dt} - p_{ft} - e_t \right) + \frac{E}{R}\left(\varepsilon\left(y_{ft} \right) \right) + \frac{C}{R}\left(c_t - p_{dt} \right)}{\pi} \tag{7}$$

Equation (7) is disaggregated into component effects on BOP-constrained real GDP growth as follows:

$$Y_{Bt} = \frac{\left(\frac{E}{R}\eta + \psi \right)\left(p_{dt} - e_t - p_{ft} \right)}{\pi} + \frac{\left(p_{dt} - p_{ft} - e_t \right)}{\pi} + \frac{\frac{E}{R}\left(\varepsilon\left(y_{ft} \right) \right)}{\pi} + \frac{\frac{C}{R}\left(c_t - p_{dt} \right)}{\pi} \tag{8}$$

where: $\frac{\left(\frac{E}{R}\eta + \psi \right)\left(p_{dt} - e_t - p_{ft} \right)}{\pi}$ is the volume effect of relative price changes, $\frac{\left(p_{dt} - p_{ft} - e_t \right)}{\pi}$ depicts terms of trade effect, $\frac{\frac{E}{R}\left(\varepsilon\left(y_{ft} \right) \right)}{\pi}$ depicts effect of

exogenous changes in foreign income growth, and $\frac{\frac{C}{R}(c_t - p_{dt})}{\pi}$ denotes the effect of the growth rate of capital inflows.

The focus of this paper is neither the effect of relative prices nor the effect of terms of trade on economic growth. Therefore, we consider them to remain constant. Hence, equation (8) becomes:

$$y^*_{Bt} = \frac{\frac{E}{R}\left(\varepsilon\left(y_{ft}\right)\right) + \frac{C}{R}(c_t - p_{dt})}{\pi} \tag{9}$$

where: y^*_{Bt} depicts the balance of payments-constrained economic growth rate.

With reference to initial current account disequilibrium, equation (9) expresses BOP-constrained economic growth rate as the ratio of weighted sum of real capital flows growth and exports growth induced by the ratio of growth in income of foreigners to the income elasticity of demand for imports. However, information on the income level of the rest of the world $\left(Y_f\right)$ and, by extension, its growth rate $\varepsilon\left(y_{ft}\right)$ is not available to this paper. Again, we assume that $\varepsilon\left(y_{ft}\right) = x_t$. This enables us to incorporate any changes in export volume induced by movements in relative prices. Thus, equation (9) becomes:

$$y^*_{Bt} = \frac{\frac{E}{R}(x_t) + \frac{C}{R}(c_t - p_{dt})}{\pi} \tag{10}$$

Within the framework of the Thirlwarl-Hussain construct, equation (10) is the BOP-constrained economic growth model of developing countries. The model identifies growth rates of exports, capital flows, domestic price of exports and proportion of import bills financed by export earnings and capital flows as the determinants of economic growth. Changes in relative prices affect both exports and imports because they are the two sides of a trade relationship. Therefore, we introduce changes in imports volume resulting from the same movements in relative prices. Thus, we extend equation (10) as follows:

$$y^*_{Bt} = \frac{\frac{E}{R}(x_t) - \frac{E}{R}(m_t) + \frac{C}{R}(c_t - p_{dt})}{\pi} \tag{11}$$

Since capital (FDI) outflow is of interest in this paper, while the domestic price of exports (p_{dt}) is not, we introduce the growth rate of capital (FDI) outflow (C_{ot}) and drop (p_{dt}) from equation (11). Thus, we re-express the equation as follows:

$$y^{*}_{Bt} = \frac{\frac{E}{R}(x_t) - \frac{E}{R}(m_t) + \frac{C}{R}(c_t - c_{ot})}{\pi} \tag{12}$$

Furthermore, we keep the relative shares of the growth rates of exports, imports and capital flows in the growth rate of real GDP constant, as well as the income elasticity of demand for imports and exports. This enables us to linearize equation (12) and render it amenable for estimation. Hence, equation (12) becomes:

$$y_t = x_t - m_t + c_t - c_{ot} \tag{13}$$

Therefore, in the context of the Thirlwall-Hussain economic growth model, with the modifications and extension, equation (13) shows that determinants of growth rate of real GDP (y_t) are growth rates of exports (x_t), imports (m_t), capital (FDI) inflow (c_t) and outflow (c_{ot}). We consider the modification and extension necessary because, in its original form, the Thirlwall-Hussain's model disregards capital outflow and its potential effect on output growth. The modifications and extensions are in tandem with the dictates of data and research needs in our modelled economic growth-FDI nexus for SSA. Hence, this paper contributes to closing this gap in the theoretical literature.

3. Methodology

3.1 Data and sources

The problem variable in this paper is real gross domestic product (RGDP) as the proxy for economic growth, while the solution variables are foreign direct investment (FDI) inflows and outflows. The moderator variables are institutional quality (IQ) and financial sector development (FSD) as the components of institutional structure, while gross capital formation (GCF) and official exchange rate (OEXR) are the control variables. The IQ component of institutional structure comprises six indices, namely control of corruption (CoC), rule of law (RoL), government effectiveness (GE), political stability and absence of violence (PSAV), regulatory quality (RQ) and voice and accountability (VaA), while the FSD component of institutional structure consists of three indices, namely domestic credit to the private sector (DCPS), gross domestic saving (GDS) and broad money supply (BMS). Though financial sector development encompasses money and capital markets, the measures of financial sector development in this paper are limited to these three variables because of data availability and consistency. The time series dimension of the data is 27 years (1996 – 2022), while the cross-sectional dimension is 29 out of 48 countries in SSA. Some recent studies have examined economic growth in relation to FDI inflows and the components of institutional structure (Seyingbo & Adeniyi, 2018; Kouassi, 2019; Glawe & Wagner, 2019; Aziz, 2020). The data were sourced from relevant databases of the World Bank (2022) and were subjected to logarithmic and or one-period lag transformations, where necessary.

The components of institutional structure are multi-dimensional variables and would be cumbersome to incorporate the various dimensions into the analytical models in this paper. Therefore, we used principal component analysis (PCA) to compute a composite index for each of IQ and FSD. Thus, the PCA made it possible to scientifically compress the number of IQ and FSD dimensions, without losing important information about the data set (Smith, 2002; Anton & Rorres, 2010; Abdi & Lynne, 2010). Moreover, excluding any of the dimensions would narrow the concept of institutional quality (Kaufmann et al., 2002) and, by extension, financial sector development. Furthermore, the dimensions of institutional structure were normalized for comparable scales that guaranteed non-biased PCA results.

3.2 Analytical model

The empirical model in this paper emanates from the Thirlwall-Hussain (1982) Balance of Payments (BOP) Constrained Model of economic growth. The choice of the construct is because it provides robust explanations of the drivers and dynamics of economic growth in the contexts of the financial flows and economic openness of developing countries, to which SSA belongs. In addition, the theory recognizes the fact that BOP disequilibrium places some constraints on the economic growth potentials of a developing region like SSA. Based on this, the theory emphasizes the critical role of financial inflows in financing current account deficits and accelerating aggregate output growth rates in developing countries from initial current accounts disequilibrium, despite foreign exchange challenges.

For the analytical models in this paper, we disaggregate capital flow, c_t, in equation (13) into foreign direct investment inflow $(FDII)$ and foreign direct investment outflow $(FDIO)$. Since the focus of this paper is on the effects of FDI inflow and outflow on economic growth in SSA, we drop exports and imports. The literature agrees that the absorptive capacity of a domestic economy boosts the effects of financial flows on economic growth in the recipient as well as the originating economy (Seyingbo & Adeniyi, 2018; Glawe & Wagner, Aziz, 2020; Frajana *et al*., 2020; Kang & Martinez-Vazquez, 2021). Therefore, we use institutional quality and financial sector development as the key indices of institutional structure and absorptive capacity of SSA as the moderator variables in the economic growth-financial flows-nexus. In addition, we introduce gross capital formation (GCF) and official exchange rate (OER) as control variables. Furthermore, some recent studies show that a robust immediate past economic growth rate has the potential to increase the flow of financial resources (Glawe & Wagner, 2019; Neanidis, 2019; Aziz, 2020). Therefore, based on the strength of the theoretical framework and empirical evidence, we specify two models to determine the effects of financial flows on economic growth, and the role of institutional structure. The first is the reference model in which we do not introduce the moderators. The second is the treatment model in which we introduce the moderators, then benchmark the coefficients of the reference and treatment models to establish the role of institutional structure in the nexus between FDI flows and economic growth in SSA. The models are specified below.

Reference Model:

$$rgdp_{i,t} = \alpha_0 + \alpha_1 rgdp_{i,t-1} + \alpha_2\, fdii_{i,t} + \alpha_3\, fdio_{i,t} + \alpha_4 gcf_{i,t} + \alpha_5 oer_{i,t} + \omega_t + \delta_t + \mu_{1,t} \quad (14)$$

where: $rgdp$ represents real gross domestic product, $rgdp_{i,t-1}$ depicts one-period lagged value of real gross domestic product, $fdii_{i,t}$ and $fdio_{i,t}$ stand for foreign direct investment inflow and outflow, respectively. $gcf_{i,t}$ denotes gross capital formation, while $oer_{i,t}$ is the official exchange rate. α_j (j = 1, 2, …, 5) is the vector of coefficients of the explanatory variables in the model. α_0 is the intercept of the model and it denotes the level of SSA's $rgdp$ when there are no FDI inflows and outflows as well as the control variables. Each coefficient connotes the nature and magnitude of the effect of the associated explanatory variable on the explained variable. ω_1 indicates time specific effect, while δ_1 is country specific effect. $\mu_{1,t}$ denotes white noise error term and it embodies the influence of other factors that are not explicitly included in the model. i and t denote the respective cross-sectional and time series dimensions of the data set used for the analysis.

Treatment Model:

$$rgdp_{i,t} = \pi_0 + \pi_1 rgdp_{i,t-1} + \pi_2 iq_{i,t} * fdii_{i,t} + \pi_3 iq_{i,t} * fdio_{ti,} + \pi_4\, fsd_{i,t} * fdii_{i,t} + \pi_5\, fsd_{i,t} * fdio_{i,t} + \pi_6 gcf_{i,t} + \pi_7 oer_{i,t} + \delta_t + \omega_i + \mu_{4,t} \quad (15)$$

where: $iq_{i,t} * fdii_{i,t}$ and $iq_{i,t} * fdio_{ti,}$ are the interactions of institutional quality with FDI inflow and outflow respectively, while $fsd_{i,t} * fdii_{i,t}$ and $fsd_{i,t} * fdio_{i,t}$ represent the interactions of financial sector development with FDI inflow and outflow, respectively. π_k (k = 2, 3, 4, 5) is vector of the coefficients of the interactions of the institutional structure components with foreign direct investment flows. The coefficients as well as δ_1 ω_1, $\mu_{4,t}$, i and t are as defined earlier.

3.3 Estimation and evaluation procedures

Prior to the estimation, we examined the descriptive statistics and other data features of the variables. In addition, we diagnosed the panel data set for cross-sectional dependence among the countries selected from SSA. In addition, we carried out first generation (without cross-sectional dependence) and second-generation (with cross-sectional dependence) panel unit root tests to ensure that none of the variables was integrated at order 2 or higher (Blomquist & Westerlund, 2013). The second-generation unit root tests of Cross-Sectional Augmented IPS (CIPS) account for cross-sectional dependence. The results show that the variables were stationary in their levels, except real GDP, which became stationary in 1st difference. Since the variables were integrated of different orders, and the reference and treatment models had similar underlying data structure, the models were amenable to the same estimation technique. Thus, we considered the system Generalized Method of Moments (sys-GMM) suitable for the analysis (Saddiqui & Ahmed, 2013). Furthermore, the Sys-GMM estimator accommodated the instrument for the equation in the first difference as well as lagged endogenous variables and regressors that were not strictly exogenous in the levels equation and, thus, made it more efficient than the diff-GMM (Saddiqui & Ahmed, 2013; Olubusoye et al., 2016). In addition, the Sys-GMM estimator allowed for fewer instruments (Rao et al., 2020).

Testing for heterogeneity in the slope is a convention of the Generalized Method of Moments (GMM). Therefore, we used the Blomquist and Westerlund (2013) test statistic for the homogeneity test of all the two models in this paper. Based on the Sys-GMM results, we ascertained the appropriateness and robustness of the estimated coefficients through cross-sectional dependence and slope homogeneity tests. In addition, we considered the Arellano-Bond (1991) test of the serial correlation of first autoregressive order AR(1) and the Arellano-Bond (1991) test of the serial correlation test of second autoregressive order AR(2). Furthermore, we carried out the Hansen (1982) test and the Sargan (1958) test to ensure that there were no over-identifying restrictions, that the variables were proper instruments and did not violate the key assumptions of the analytical regression models. Again, as part of the checks for the suitability and robustness of the Sys-GMM-based estimates of the coefficients, we deployed Eberhardt's and Bond's (2009) Augmented Mean Group (AMG) to ascertain that the estimates of the models were reliable and consistent. The AMG accounted for autocorrelation, heteroscedasticity and cross-sectional dependence.

4.0 Results and Discussion

A summary of the descriptive statistics is presented in Table 1. The RGDP of the selected sub-Saharan (SSA) countries averaged US$34,526.96 billion, with a standard deviation of US$83,977.250 billion and maximum and minimum values of US$518,476.8 billion and US$651.346 billion respectively. The standard deviation, which differed greatly from the mean, implies wide fluctuations in RGDP. The highest and smallest values of FDII were US$9,885.001 million and US$833.561 billion respectively, with a US$1,315.272 billion standard deviation. It is evident from the standard deviation that FDII exhibited wide fluctuations during the period. FDIO fluctuated more widely than FDII as shown by the greater standard error relative to the maximum, minimum and mean values of US$7,692.077 billion, US$3,514.733 billion, and US$130.353 billion respectively. The table also reports heterogeneous descriptive statistics values for the institutional quality measures. Within the -2.5 to 2.5 scale, PSAV and CoC had maximum values of 1.282 and 1.230 respectively, while maximum values for GE, RoL, RQ and VaA were 1.057, 1.077, 1.127, and -1.1007 respectively. The negative maximum value for VaA shows that voice and accountability was the worst quality of political, legal and regulatory institutions in the SSA countries. In addition, the institutional quality measures exhibited negative minimum performance measures (-1.559, -1.849, -1.852, -2.452, -2.360 and -1.723, respectively). By implication, the quality of institutions in the SSA countries was still rudimentary. Moreover, the mean values of the measures were negative (-0.616, -0.651, -0.637, -0.522., -0.535 and -0.422, respectively), with standard deviations of 0.622, 0.631, 0.637, 0.870, 0.587 and 0.656 respectively. Obviously, they varied far away from the mean values and thus imply wide fluctuations in the measures. On the other hand, standard deviations of 25.216, 21.661 and 14.452, respectively show that the pace of financial sector development was relative stable. On the contrary, standard deviations for OER and GCF indicate wider fluctuation in the former.

Table 1: *Summary of Descriptive Statistics*

Variable	Mean	Maximum	Minimum	Std. Dev.	Skewness	Obs.
RGDP	34526.960	518476.800	651.346	83977.250	3.870	783
FDII	692.205	9885.001	883.561	1315.272	3.450	783
FDIO	130.353	7692.077	3514.733	686.191	6.720	783
CoC	-0.616	1.230	-1.559	0.622	0.851	783
GE	-0.651	1.057	-1.849	0.631	0.638	783
RoL	-0.637	1.077	-1.852	0.637	0.517	783
PSAV	-0.522	1.282	-2.452	0.870	0.012	783
RQ	-0.535	1.127	-2.236	0.587	0.296	783
VaA	-0.424	-1.007	-1.723	0.656	0.218	783
DCPS	22.246	142.422	0.403	25.216	2.658	783
BMS	31.205	163.650	5.143	21.661	2.214	783
GDS	14.622	64.927	-40.845	14.452	0.902	783
GCF	21.557	79.401	-2.424	9.417	1.507	783
OER	795.513	10439.430	0.164	1476.359	3.930	783

Notes: The economic growth variable (RGDP), and FDI flows are in billions of US dollars. The dimensions of institutional quality (Coc, GE, RoL, PSAV, RQ, and VaA) are in a scale range of -2.5 to 2.5, with -2.5 depicting worst quality and 2.5 indicating best quality. The components of financial sector development (DCPS, GDS and BMS) are percentages of gross domestic product (GDP). The control variable (GCF) is percentage of GDP, while the other control variable (OER) is the ratio of local currency units of the selected SSA countries to one US dollar.
Source: Author's computations (2024)

In Table 2, the result of the partial correlation coefficient shows that RGDP correlates positively with FDII and FDIO (0.640 and 0.497), but negatively with the control variables, GCF and OER (-0.035 and -0.132). Similarly, the relationship between GCF and FDIO and between OER and FDII and FDIO are negative (-0.013, -0.115, -0.082), while GCF relates positively with FDII (0.203). Since the coefficients between the independent variables are less than the 0.80 tolerable limits, there is no evidence of potential multicollinearity problem. Variance inflation factor (VIF) values, which are less than 10, further substantiate the evidence.

Table 2: *Partial Correlation Coefficients*

Variable	RGDP	FDII	FDIO	GCF	OER	VIF
RGDP	1					NA
FDII	0.649	1				2.802
FDIO	0.497	0.363	1			1.514
GCF	-0.035	0.203	-0.013	1		1.487
OER	-0.132	-0.115	-0.082	-0.052	1	1.277

Note: RGDP, FDII and FDIO are in billions of US dollars. GCF is in percentage of gross domestic product, while OER is units of domestic currency for one US dollar.
Source: Researcher's computations (2024).

The results in Table 3 provide statistical evidence (p-values = 0 < 0.01) of cross-sectional dependence among the cross-section of the SSA countries. Thus, economic growth challenges in SSA countries can be traced to their similar macroeconomic conditions and the rudimentary level of their institutional structures.

Table 3: *Cross-Sectional Dependence Test Results*

Foreign Direct Investments and Growth Equation		
Test	**Statistic**	**Prob.**
Breusch-Pagan LM	949.659***	0.000
Pesaran scaled LM	19.079***	0.000
Pesaran CD	9.955***	0.000
Foreign Direct Investments, Institutional Structure and Growth Equation		
Breusch-Pagan LM	4030.590***	0.000
Pesaran scaled LM	127.198***	0.000
Pesaran CD	47.757***	0.000

*Note: *** indicates significance at the 1% level..*
Source: Author's computations (2024)

Table 4 presents the result of the panel unit root tests. It is evident that the series are stationary in their level, *I(0)*, except real GDP, which is stationary in 1st difference, *(1)*. Therefore, the time series values of the variables exhibited a mixed order of integration.

Table 4: *1st and 2nd Generation Panel Unit Root Tests*

Variables	IPS	CIPS	Variables	IPS	CIPS	Remarks
RGDP	-1.369	-1.856	ΔRGDP	-4.029***	-3.756***	*I(1)*
FDIl	-2.348***	-3.885***	ΔFDIl	-6.747***	-5.782***	*I(0)*
FDIO	-3.366***	-3.130***	ΔFDIO	-6.762***	-5.747***	*I(0)*
GCF	-2.151***	-2.645***	ΔGCF	-5.452***	-5.053***	*I(0)*
OER	-1.931**	-2.633***	ΔOER	-3.872***	-4.267***	*I(0)*
IQ	-2.262***	-2.138**	ΔIQ	-5.630***	-4.481***	*I(0)*
FSD	-1.309	-2.415**	ΔFSD	-5.476***	-4.490***	*I(0)*

*Notes: The panel unit root test without cross-sectional dependence is the Im, Pesaran, and Shin, while the panel unit root test with cross-sectional dependence is the CIPS. In addition, *** and ** indicate 1% and 5% respectively and the respective critical values are CIPS - 2.23 and -2.11; and IPS = -2.02 and -1.87.*
Source: Author's computations (2024)

The results in Table 5 show that The null hypothesis of non-homogeneity of the slope coefficients was not valid as indicated by the Blomquist and Westerlund (2013) homogeneity test statistic, which was statistically significant at 1 percent critical level (p-value = 0.000 < 0.01). Thus, there was heterogeneity of slope coefficients in the models.

Table 5: *Blomquist and Westerlund Homogeneity Test Results*

Foreign Direct Investments and Growth Equation		
Test	Statistic	Prob
Δ	5.319	0.000
Δ adj	6.222	0.000
Foreign Direct Investments, Institutional Structure and Growth Equation		
Δ	5.685	0.000
Δ adj	7.031	0.000

Note: ***represents significance at the 1% critical level
The null hypothesis is no homogeneous slope coefficient. Alternative hypothesis is homogeneous slope coefficient.
Source: Author's computations (2024).

The effect of FDI flows and institutional structure on economic growth in the SSA region is presented in Table 6.

Table 6: *Estimates of the Effects of FDI Flows and Institutional Structure on Economic Growth in SSA*

Reference Model: Effects of FDI Inflows and Outflows			Treatment Model: Interactive Effects of Institutional Structure and FDI Inflows and Outflows		
Dependent Variable: lnRGDP			Dependent Variable: lnRGDP		
Variable	GMM	AMG	Variable	GMM	AMG
L.lnRGDP	0.8666***		L.lnRGDP	0.9567***	
	(24.407)			(37.203)	
lnFDIl	0.0389***	0.0083	IQ*lnFDIl	0.0023***	0.0064*
	(4.060)	(1.038)		(3.428)	(1.760)
lnFDIO	0.0063**	0.0003	IQ*lnFDIO	-0.0031***	-0.0020
	(2.234)	(0.085)		(-3.252)	(-0.323)
GCF	-0.0016	0.0019	FSD*lnFDIl	-0.0063***	-0.0089
	(-1.153)	(0.913)		(-3.477)	(-1.501)
LOER	-0.0289	0.0326	FSD*lnFDIO	0.0080***	0.0179
	(-1.378)	(0.225)		(2.719)	(1.313)
Constant	1.1409***	8.5374***	GCF	0.0005	0.0018
	(3.386)	(19.676)		(0.515)	(1.008)
Observations	754	783	LOER	-0.0103	0.0024
				(-1.321)	(0.018)
Number of group	29	29	Constant	0.4396*	8.6988***
				(1.843)	(20.773)
Wald chi-square	131280.20		Observations	754	783
	(0.000)				
AR(1) test	-3.76 [0.000]		Number of group	29	29
AR(2) test	1.01 [0.313]		Wald chi-square	215432.92	
				(0.000)	
Sargan test	3.23 [0.318]		AR1 test	-3.31 [0.001]	
Hansen test	4.09 [0.210]		AR2 test	-0.55 [0.584]	
			Sargan test	2.55 [0.563]	
			Hansen test	1.63 [0.432]	

*Notes: *, ** and *** denote significant at 10%, 5% and 1%, respectively.*
The z-statistic values (in brackets) are based on White heteroscedasticity-consistent std. errors. P-values for AR(1), AR(2), Sargan and Hansen (over identification restrictions) statistic values are in parentheses [ ].
Source: Author's computations (2024).

The AR(1), with a -3.76 statistic and p-value of 0.000 was significant at 1 per cent (z-statistic = -3.76, p-value = 0.000 < 0.01), which is the evidence of serial correlation. The sys-GMM requires AR(1) to be significant and that the successive

error terms should be correlated. The AR(2), with a statistic of 1.01 and p-value of 0.313 was not significant and, thus, the null hypothesis of serial correlation is not valid. This is in conformity with Sargan (1958; 1988) and Hansen (1982) that the AR(2) should be serially independent. In addition, the Sargan test statistic of 3.23, with a p-value of 0.318, shows that the variables were proper instruments of the estimated model. Therefore, the post-estimation tests results prove the efficiency of the estimates of the reference model. The Hansen test statistic of 4.09, with p-value of 0.210, was not statistically significant at the 5% level. Thus, the model had valid instrumentation. Furthermore, it is evident from the results that foreign direct investment inflow had significant positive effect on the real GDP of SSA (α_2 = 0.0389, z-test = 4.06, p-value = 0.000 < 0.05). Similarly, foreign direct investment outflow significantly increased real gross domestic product (α_3 = 0.0063, z-stat = 2.23, p-value = 0.026 < 0.05). Therefore, foreign direct investment inflow and outflow promote economic growth in SSA.

The positive effect of FDI inflow is consistent with the works of Adeniyi et al. (2015) for the SSA countries; Fantessi (2015) for the ECOWAS; Uwaoma & Ryan (2015) for a sample of Latin and Caribbean countries; Combes et al. (2017) for selected low- and middle-income countries, Chih et al. (2021) for SSA countries and Okwu et al. (2022) for 30 leading global economies. Similarly, the positive effect of FDI outflow is consistent with the findings for Turkey (Başar & Özkilbaç, 2016), Brazil and China (Gondim et al., 2018), China (Chen, 2018), selected 29 emerging market economies (Nguyen et al., 2018), India (Agnihotri & Arora, 2019; Kumar and Singhal, 2022) and Romania (Amin et al., 2022). However, the positive effect contradicts Agbloyor et al.'s (2016) finding that FDI inflow dampens economic growth in SSA without quality institutions. Perhaps, the contradictory findings could be due to differences in methodological procedures, time series and cross-sectional data scope, but not likely because of peculiarities of the geographical scope of the studies. This position is valid because the finding contradicts Agbloyor et al.'s (2014) but aligns with Adeniyi et al.'s (2015) finding for the same SSA. Furthermore, the results provide evidence that the effects of gross capital formation and official exchange rate on real GDP are negative but not significant (α_4 = -0.0016, Z-test= -1.153, p-value = 0.249 > 0.05; (α_5 = -0.0289, Z-test= -1.378, p-value = 0.160 > 0.05). Thus, the variables do not determine economic growth in SSA. The Wald test statistic value of 131280.20, with p-value of 0.000 indicates that the explanatory variables jointly exert significant effect on economic growth in SSA.

The Arellano-Bond test statistic indicates that the AR(1) is statistically significant at the 1 per cent critical level (z-statistic = -3.31, p-value = 0.001 < 0.01), and thus, provides evidence of serial correlation in the treatment model. Again, this aligns with the sys-GMM, which requires AR(1) to be significant, with correlated successive error terms. On the other hand, like the results of the reference model, the test statistic reveals that the AR(2) is not significant (z-statistic = -0.55, p-value = 0.584 > 0.10) and thus confirms the serial independence of AR(2) (Sargan, 1958; 1988; Hansen, 1982). Similar to the reference model, the Sargan test statistic provides evidence that the independent variables in the treatment model are not subject to overriding instrumentation (chi^2 = 2.55, p-value = 0.563 > 0.10). The variables therefore properly instrument the estimated treatment model. Thus, the post-estimation test results prove the efficiency and suitability of the estimates of the treatment model for informed inferences. Similarly, the statistical insignificance of the Hansen test statistic (chi^2 = 1.63, p-value = 0.432 > 0.10) shows that the model is validly instrumented. Furthermore, it is evident from the results that interactions of FDI inflow and institutional quality as well as financial sector development produce significant positive and negative effects, respectively, on economic growth. (π_2 = 0.0023, z-*stat* = 3.43, p-value = 0.001 < 0.01; π_4 = -0.0063, z-*stat* = -3.48, p-value = 0.001 < 0.01). However, the interaction coefficients are less than the non-interaction coefficients of FDI inflow in the reference model (π_2 = 0.0023 < α_2 = 0.0389; π_4 = -0.0063 < α_2 = 0.0389). These show that the quality of the institutions reduces the positive effect of FDI inflow, while financial sector development erodes the economic growth effect of FDI inflow in SSA. This finding is in line with Yildirim and Gokalp (2016) for a sample of developing countries and Nguyen et al. (2018) for a sample of 29 emerging market economies. The smaller interactive effect of FDI inflow with institutional quality substantiates Seyingbo's and Adeniyi's (2018) finding that the quality of institutions alone exerts a dismal effect on economic growth in sub-Saharan Africa. In addition, the significant negative interactive effect of FDI inflow and financial sector development even at the prevailing level of institutional quality shows that Kutan et al.'s (2017) finding that some aspects of financial development did not promote growth in a sample of 21 Middle East and North African (MENA) countries without institutional quality is not valid for the SSA, Therefore, as Agbloyor et al. (2014) found for SSA, despite the positive interactive coefficient of FDI inflow and institutional quality, the quality of institutions in SSA is weak.

In the treatment model, interactions of FDI outflow with institutional quality and financial sector development exerted significant negative and positive effects,

respectively on economic growth in SSA (π_3 = -0.0031, z-*stats* = -3.25, p-values = 0.001 < 0.01; π_5 = -0.0080, z-*stat* = 2.72, p-value = 0.007 < 0.01). On other hand, the interactive coefficient of FDI outflow and institutional quality in the estimated treatment model was less than the coefficient of FDI outflow alone as seen in the estimated reference model (π_3 = -0.0031 < α_3 = 0.0063). However, the coefficient of FDI outflow and FSD in the estimated treatment model was greater than the coefficient of FDIO alone in the estimated reference model (π_5 = 0.0080 > α_3 = 0.0063). These imply that IQ dampens the economic growth potentials of FDIO, while FSD enhances the effect of FDIO on economic growth in SSA. The Wald Chi-square statistic, with its p-value, provides evidence that the interactions of the indices of institutional structure (institutional quality and financial sector development) with FDI inflow and outflow as well as gross capital formation and exchange rate significantly determine economic growth in SSA (Wald chi-square = 215432.92, p-value = 0.000 < 0.01).

5.0 Conclusion and Recommendations

The results of the reference model show that the effects of FDI inflow and outflow on growth are positive and significant. Therefore, this paper concludes that both FDI inflows and outflows promote economic growth in sub-Saharan Africa. The findings from the results of the treatment model show that institutional quality and financial sector development dampen the economic growth potentials of the region. Therefore, this paper concludes that the institutional structure of SSA is not adequate to harness the economic growth potentials embedded in foreign direct investment flows.

Consequently, this paper emphasizes the need for governments of SSA countries to attract more investment inflows and encourage more investment outflows in order to enhance economic growth. Furthermore, the study recommends that authorities in sub-Saharan African countries should upgrade relevant laws and regulations in order to strengthen the capacity of the institutions to curtail corruption, improve the quality of governance, enhance government stability via reduced violence, instill strict adherence to the rule of law, improve effectiveness of governments in SSA and enhance voice and accountability. In addition, governments of SSA countries should deepen their financial sectors via far-reaching fiscal policy thrusts, like necessary government subsidies and effective economic and social transfers, in order to increase domestic savings. From the angle of monetary policy thrusts, the central banks of the countries should ensure that certain proportions of total domestic credits are channeled into productive

real sectors of the economies of SSA. With these, the institutions and financial sectors of SSA countries would simultaneously stimulate greater positive effects of foreign direct investment inflows and outflows on economic growth.

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Tax Reforms and Innovative Capacity: Implication for Industrial Development in Nigeria

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Abstract
This study investigates the role of tax reforms and innovations in industrial development in Nigeria using time series analysis of data, specifically, the autoregressive distributive lag (ARDL) model to estimate regression coefficients. The findings reveal that innovations boost industrial value added in the short and long terms. Tax rates and the 2005 value-added tax reform were detrimental to industrial performance. Overall, economic growth aids the development of the industrial sector, and trade openness is a vital tool to boost the industrial value added to short-term growth. Furthermore, capital formation, population growth, exchange rate, literacy rate, and natural resource rents do not influence industrial sector development. The study concludes that innovative capacity in the country is vital to boosting industrial development, and hence, should be improved. It further concludes that a higher tax rate is detrimental to industrial development, therefore, it should be curtailed to boost industrial development. Moreover, the 2005 tax reform has not been beneficial to industrial development, thus, a review is needed to offer an alternative pathway to enhance industrial development in Nigeria.

Keywords: Tax reforms, innovation, industrial development, tax rates
JEL classification: O31, O38, L51

1. Introduction

Industrial development is a key driver of economic growth and transformation. It involves the establishment and expansion of industries that produce goods and services, leading to significant changes in a country's economy. Industrial development remains a vital driver of the Nigerian economy (Aderemi et al., 2020) and can significantly contribute to sustainable growth. Industrial growth in developing economies, such as Nigeria, can lead to job creation, technological improvement, and poverty alleviation, similar to Western Europe's industrial revolution in the 19th and early 20th centuries. In recent decades, the Nigerian

government has implemented industrial reforms to boost the country's industrial sector development., but the manufacturing sector has not made significant contributions to the progress of the Nigerian economy.

Statistical data shows a decline in industrial performance from approximately 12% in 1982 to about 7% in 1997, with a further drop between 1998 and 2010 to 6%. In 2011, industrial performance increased marginally but plummeted to about 10% by 2015. The country's industrial performance averaged about 9% from 2016 to 2019 (CBN, 2020). This indicates that the country's industrial performance was inefficient. This coincided with a fluctuating tax rate, which was 24.8% in 1990, 91.2% in 1995, 19.9% in 2000, 10.7% in 2010, 8.22% in 2015, and 11.4% in 2019. However, patent application has been rising over time, reaching 258, 818, and 1,122 in 2010, 2015, and 2019 respectively, indicating that innovative activities have been increasing over the period (WDI , 2022).

In the face of rising innovation and fluctuating tax rates, why has Nigeria's industrial development remained weak over time? An empirical response is urgently needed. Critical variables drive industrial development in any economy, as indicated by both theory and actual research. Barro (200I) highlighted economic institutions and local human capital as key drivers of industrial development. Recent efforts by scholars to identify the key determinants driving industrial development in country-specific and cross-country studies have produced conflicting results. In Nigeria, investigations on this topic have not yielded solid findings (Onodje & Farayibi, 2020; Lawal et al., 2022; Omoyele et al., 2021; Otalu & Anderu, 2015; Aiyedogbon & Anyanwu, 2015). More research is needed to understand better the elements that drive industrial development in Nigeria.

Moreover, factors that may have been responsible for the decline in industrial sector performance, such as the tax rate and the implementation of tax reforms, might have been ignored in previous studies. Higher taxes can be a disincentive to productive activities, which may lead to a decline in the growth and performance of key sectors, including the industrial sector. Similarly, previous investigations may have ignored the critical role of certain factors, such as the country's innovative capacity. A highly innovative country should have a better-performing industrial sector (Lawal et al., 2022).

Given that there is a dearth of studies on the influence of taxes, tax reforms, and innovation on industrial performance in the literature, the present study aims to contribute to existing knowledge by examining how tax reforms and innovative capacity influence the growth of industrial value added in Nigeria.

The remainder of the study is presented as follows: section 2 reviews the literature on industrial sector performance determinants; section 3 documents the method of the study, section 4 presents the results and discussion, and section 5 gives the conclusion and recommendations.

2.0 Literature Review

Several studies on industrial development have investigated the determinants of industrial output and performance. Many focused on the macroeconomic and institutional determinants of the growth of the industrial sector. Otalu and Anderu (2015) examined the factors driving industrial growth in Nigeria using an error correction model. It was observed that capital and labour play a vital role in the industrial sector, while exchange rates have a positive and significant impact.

Aiyedogbon and Anyawu (2015) analysed the impact of macroeconomic factors on Nigeria's industrial productivity from 1981 to 2013 using the ordinary least squares technique. The results indicate a positive correlation between currency rates and industrial production. Interest rates, foreign direct investment, and real GDP positively impact industrial productivity. In contrast, adverse effects result from the consumer price index, wide money supply, and credit to the industrial sector.

Samouel and Aram (2016) used a dynamic panel model to analyse the factors influencing industrialization in 35 African nations between 1970 and 2012. The study identified human capital, labour market conditions, real effective exchange rate, and GDP per capita as factors influencing African industrialization. The study found that the factors driving industrialization in Africa vary by region and evolve with time.

Kumar et al. (2017) used a cross-sectional approach in order to identify factors influencing industrial development in Punjab in 1991, 2001, and 2014. The findings revealed that Infrastructure has a significant impact on industry in Punjab.

Ndiaya and Lv (2018) used the ordinary least squares to evaluate data from 1960-2016 to assess the impact of industrialization on economic growth in Senegal. The study found that increasing industrial output leads to greater economic growth and Industrialization significantly contributes to Senegal's economic growth.

Maroof et al. (2018) conducted a panel auto-regressive distributed lag and Granger causality test to examine the factors influencing industrial development in South Asian nations between 1996 and 2015. Foreign direct investment, equity openness, and inflation were found as the key elements driving industrial development in South Asian countries.

In a study of 50 countries, Zhu et al. (2020) found that the impact of innovation on growth decreases with a developed financial sector and becomes insignificant when credit to the private sector exceeds a threshold of about 60% of GDP.

Jawad et al. (2020) focused on assessing the primary factors of industrial development for a sample of industrialized economies and comparing the European Union (27 countries) to the United Kingdom. Time series data from 1986 to 2017 was used for empirical analysis. Industrial development was measured in terms of industrial value added. Using OLS regression to evaluate the association and percentage variation between the research variables, the results revealed that only capital openness (i.e., the free-flow of internation capital) and trade openness were significant predictors of industry development in the EU. However, in the United Kingdom, equity openness, trade openness, and capital account openness were not major determinants.

Singh and Kumar (2021) analysed the industrial sector in India using linear, log-linear, and nonlinear regression models from 2003-2018. The linear regression revealed positive and statistically significant correlations between gross value added, total persons engaged, gross capital formation, total inputs, labour productivity, per person earnings, capital intensity, credit to industry by scheduled commercial banks, and literacy rate. Log-linear regression results indicated that labour productivity, annual population growth, literacy rate, credit from scheduled commercial banks, total employment, per-person earnings, and gross capital formation positively impact industry gross value added. The study found a linear relationship between gross value added of industries and labour productivity, annual population growth, credit from scheduled commercial banks, total employment, and gross capital formation. Literacy rate, per capita

income, capital intensity, and total inputs all showed a hill-shaped correlation with industrial growth.

The study by Sallam (2021) looked at key factors influencing the Egyptian manufacturing industry from 1970 to 2019. The study used annual time-series data from the World Bank's databases from 1970 to 2019. Autoregressive distributed lag techniques were used to investigate the short- and long-run causation between variables. The empirical results showed a positive and statistically significant connection between industry value-added and each of foreign direct investment, number of workers, and gross fixed capital formation. In contrast, the relationship between industry value-added and GDP and total factor productivity was negative and statistically significant. Other sectors, such as tourism and the Suez Canal, contributed more to domestic product growth, which explains this conclusion.

The study by Udeaja et al. (2021) re-examined the relationship between finance and industrial growth in Nigeria by incorporating aggregate credit to the industrial sector and the financial development index as new variables into the industrial growth model. The study used ARDL bounds testing over four decades to estimate an industrial growth model considering finance-related variables, electricity consumption, and structural breaks. The study found that finance plays a substantial role in driving industrial growth in Nigeria. However, aggregate credit to the private sector may underestimate its long-term impact on industrial performance compared to a sector-specific measure.

Kothakapa et al. (2021) used a dynamic panel model to study the relationship between financial development and industrialization in low- and middle-income countries between 1970 and 2014. The results indicate that the two variables have a nonlinear relationship. The results demonstrate that financial development slows industrial development until it reverses.

Amoah and Jehu-Appiah (2022) analysed the factors influencing industrialization in Africa from 1990-2018 using the two-stage least squares. The research indicates that foreign direct investment, natural resources, and financial development all positively impacted industrialization. Trade openness had a negative impact on industrialization, but human capital and inflation were unimportant.

The study by Aransiola et al. (2022) used annual data from 1990 to 2019 to investigate the impact of market size, agricultural output, GDP growth rate, exchange rate, foreign direct investment inflows, and trade openness on industrial development in Nigeria. Market size, agricultural output, trade openness, GDP growth rate, and exchange rate were not significant factors driving industrial development in Nigeria. However, foreign direct investment (FDI) was a weak driver of industrial development in Nigeria.

An investigation by Saba and Ngepah (2023) used an algorithm created by Phillips and Sul to investigate the convergence club in industrialization. It used data from 183 nations covering the period 2000 to 2018. It also studied the dynamics of the determinants that could influence countries' convergence/divergence clubs. The convergence algorithm results show a divergence in industrialization over the whole sample, implying that less industrialized economies were not catching up with industrialized economies during the sample period. The club merging algorithm results identified six final clubs, with economic, demographic, governance, and geographic criteria all playing a key influence in determining whether a country belongs to a specific final club.

The preceding empirical literature review reveals several industrial growth and development indicators. Although many studies have been conducted on the impact of innovation on economic growth, an investigation of the specific implications of innovation on industrial performance is lacking in the reviewed literature. Given that the growth of the innovative capacity of countries can potentially motivate improvements in the industrial sector by introducing new ideas and products, an investigation of the importance of innovations to the development of the industrial sector in the Nigerian context is a worthwhile research exercise. Moreover, the empirical review also revealed that most studies have ignored the role of tax reforms in the determinants of industrial growth. The present study will, therefore, contribute to existing knowledge on the determinants of industrial sector development.

3.0 Methodology

3.1 Data

This study is based on the time series data obtained from the World Bank's World Development Indicators (WDI) for Nigeria over the 1988-2022 period. The study is focused on Nigeria because of the dire need for industrial growth in the country, which will likely help to ease the numerous economic challenges that are being faced as a result of continuous exchange rate depreciation. Data was obtained for the dependent variable, industrial value added as a ratio of GDP; the main explanatory variables including patent applications, tax rates, and an indicator variable for tax reform in 2005; and the control variables, such as economic growth, gross fixed capital formation, population growth, exchange rates, literacy rate, natural resource rents, and trade openness. Table 1 presents a description of each of these variables to provide a better understanding of their measurement.

3.2 Empirical model

Following the literature on the determinants of industrial development, especially the works of Sallam (2021) and Aransiola et al. (2022), the empirical model for this study was specified to achieve its aims and objectives. These studies provide evidence for the relevance of some macroeconomic and social determinants of industrial performance. This study, therefore, included innovations based on the logical perception that a boost in innovations can help promote industrial growth by developing new ideas and products. Tax rates and tax reforms were included with the perception that increased taxes may deter industrial growth by discouraging new entrants or startups, and reform may help to reverse these detrimental effects by establishing fair tax rates for businesses. The empirical model of this study is, therefore, specified as follows.

$$IND_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i IND_{t-i} + \sum_{j=0}^{q_1} a_j GR_{t-j} + \sum_{j=0}^{q_2} b_j INN_{t-j} + \sum_{j=0}^{q_3} c_j TR_{t-j} + \sum_{j=0}^{q_4} d_j CAP_{t-j} + \sum_{j=0}^{q_5} e_j POP_{t-j} + \sum_{j=0}^{q_6} f_j EXR_{t-j} + \sum_{j=0}^{q_7} g_j LIT_{t-j} + \sum_{j=0}^{q_8} h_j NRR_{t-j} + \sum_{j=0}^{q_9} k_j TO_{t-j} + \sum_{j=0}^{q_{10}} m_j R_{t-j} + \epsilon_t \quad (1)$$

where: *IND* is industrial value added; *GR* is economic growth; *INN* is innovations; *TR* is tax rates; *CAP* is gross fixed capital formation; *POP* is population growth; *EXR* is exchange rate; *LIT* is literacy rate; *NRR* is natural resource rents; *TO* is trade openness; and *R* is tax reforms. subscript *t* is an indicator of time series

data; *i* represents the lag length of the IND, the dependent variable, which ranges from 1 to p lags. On the other hand, j represents the lag length of the independent variables, ranging from 0 to q_n lags, where *n* = 1, 2, …, 10 for the 10 independent variables in the model. Optimal lag length selection was based on Akaike information criterion (AIC). ϵ is the disturbance term. α_0 is the constant term, α_i are the coefficients of the dependent variable and its lags, and $a, b, c, d, e, f, g, h, k, m$ are the coefficients of the independent variables *GR*, *INN*, *TR*, *CAP*, *POP*, *EXR*, *LIT*, *NRR*, *TO*, and *R* respectively.

3.3 Method of analysis

A description of the variables was carried out using the summary statistics (Table 1). The statistics mainly show each variable's mean, standard deviation, and minimum and maximum values. Graphical analysis and the correlation matrix were also used to support the description by providing a time trend and the relationship among variables, verifying that the relationships are not very high among explanatory variables, which might lead to multicollinearity problems. Due to the non-stationarity of some variables leaving the study with combinations of stationary and non-stationary variables, the autoregressive distributive lag (ARDL) model was employed for the empirical analysis. The ARDL technique can handle non-stationary variables and control for the likely endogeneity of some explanatory variables.

Table 1: *Variable Descriptions*

Variable	Definition	Supporting Studies
Industry value-added (IND)	Industry value added (% of GDP).	Jawad et al. (2020)
Economic growth	Annual growth rate of GDP (in %).	Sallam (2021)
Innovations	Total patent applications (residents and non-residents).	Zhu et al. (2020)
Tax rates	Average tax rates (in %).	-
Capital formation	Gross fixed capital formation (% of GDP).	Sallam (2021)
Population growth	Annual growth rate of total population (in %).	Aransiola et al. (2022)
Exchange rate	Official exchange rate (naira per one unit of US dollars).	Udeaja et al. (2021)
Literacy rate	Adult literacy rate (age 15 and above).	Amoah and Jehu-Appiah (2022)

Natural Resource rents	Total natural resource rents (% of GDP).	Saba & Ngepah (2023)
Trade openness	Total trade – Imports and Exports (% of GDP).	Aransiola et al. (2022)
Tax reforms	Indicator variable of 2005 Tax reform, which takes 1 for the reform and post-reform periods and 0 prior to the reform).	-

Source: Author's compilation.

Prior to this ARDL estimation, a unit root test was done to establish whether each variable was stationary. This was conducted through the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) procedures. The main reason for employing both methods was to ensure that the unit root test results are robust to different techniques. Given that the unit root outcomes concluded that some variables are stationary while others are not, it was necessary to conduct a cointegration test to establish a long-run relationship among the stationary and non-stationary variables.

As a result, the ARDL cointegration technique is preferred when dealing with variables integrated with distinct orders, I(0), I(1), or a mix of the two, and robust when there is a single long-run relationship between the underlying variables in a small sample size (Pesaran et al., 2001). The F-statistic (Wald test) detects the long-run link between the underlying variables. In this strategy, the long-run relationship of the series is deemed to be established when the F-statistic surpasses the critical value band. This approach's main advantage is its ability to identify cointegrating vectors when there are several.

4.0 Results and Discussion

A descriptive analysis was conducted to describe the variables. Table 2 shows the statistics. Average industry value added as a ratio of GDP was 28.83%. The highest recorded industrial value added was 37.71% of GDP, and the lowest was 18.17% of GDP. Economic growth measured by the annual growth of GDP was reported to have an average of 4.31%, signifying that the country had steady growth during the period investigated. Although there was negative growth during certain periods, the country experienced a huge growth of 15.33% at a certain point. The total number of patent applications, employed to capture innovations, averaged 445.8, implying that about 446 patent applications are made annually in Nigeria. The least applications made was 235, while 1,122 was

the highest. The average tax rate was reported to be 17.56%. However, 91.27% was the highest reported during the period, and 8.22% was the lowest. Average gross fixed capital formation was reported as 28.96% of GDP, with 3.12% reported as high and 1.17 per cent of GDP as low.

The average annual growth of the population was 2.6%. The highest recorded population growth was 2.76%, and the lowest was 2.38%. The exchange rate measured by the official exchange rate was reported to have an average of 138.5 naira per unit of US dollars. Although the rate was as low as 4.54 naira during a certain period, the country was reported to experience a large depreciation in the naira, making the exchange rate as high as 25.98 naira per US dollar at a certain point. The literacy rate averaged 56.34%, implying that about 56% of adults were literate annually in Nigeria. The lowest literacy rate reported was 51.08%, while 70.2% was reported as the highest in a particular year. Average natural resource rents were reported to be 15.28% of GDP. However, as high as 34.27% of GDP was reported as the country's highest natural resource rents accrued during the period while 4.55 per reported as the lowest. For trade openness 36.33% of GDP was reported as the average, with a large trade openness reported at 53.28% of GDP and a low trade openness reported at 16.9% of GDP.

Table 2: *Descriptive Statistics*

Variable	Mean	Maximum	Minimum	Std. Dev.	Jarque-Bera	Probability
Industry value-added	28.83	37.71	18.17	5.18	0.95	0.623
Economic growth	4.31	15.33	-2.04	3.90	1.42	0.492
Innovations	445.8	1,122	235	308.5	7.52	0.023
Tax rates	17.56	91.27	8.22	14.18	635.0	0.000
Capital formation	28.96	53.12	14.17	11.93	2.59	0.273
Population growth	2.60	2.76	2.38	0.10	1.37	0.503
Exchange rate	138.5	425.98	4.54	117.9	4.45	0.108
Literacy rate	56.34	70.20	51.08	3.97	21.13	0.000
Natural Resource rents	15.28	34.27	4.55	6.72	1.44	0.486
Trade openness	36.33	53.28	16.94	8.65	0.09	0.955
Tax reforms	0.51	1	0	0.51	5.83	0.054

Source: Author's computations.

Tax reform is an indicator variable that takes 1 after the 2005 reforms in the value-added tax (VAT) in Nigeria, which represents a major tax reform, and 0 before the

tax reform in 2005. Its average was 0.51; as expected, its highest was 1, and its lowest was 0.

Jarque-Bera statistics were employed to check for the normality of each of these variables. The result revealed that most variables were normally distributed, with the probability value for their statistics being greater than 0.1 (10% significance level). However, there were some exceptions. Innovations, tax rates, literacy rates and tax reforms had probability values lower than 0.1, signifying a rejection of normality for these variables. Given that these variables were used alongside other normally distributed variables, their use in the estimation may not pose a serious problem. Moreover, a check for the normality of the residual regression model after estimation can help verify this.

To further describe the variables, particularly their movement over time, a time plot of each of them is presented in Figure 1. It reveals that most of the variables exhibit some trend behaviour over time. This suggests that their time series properties, most especially their stationarity, must be examined before the estimation is carried out.

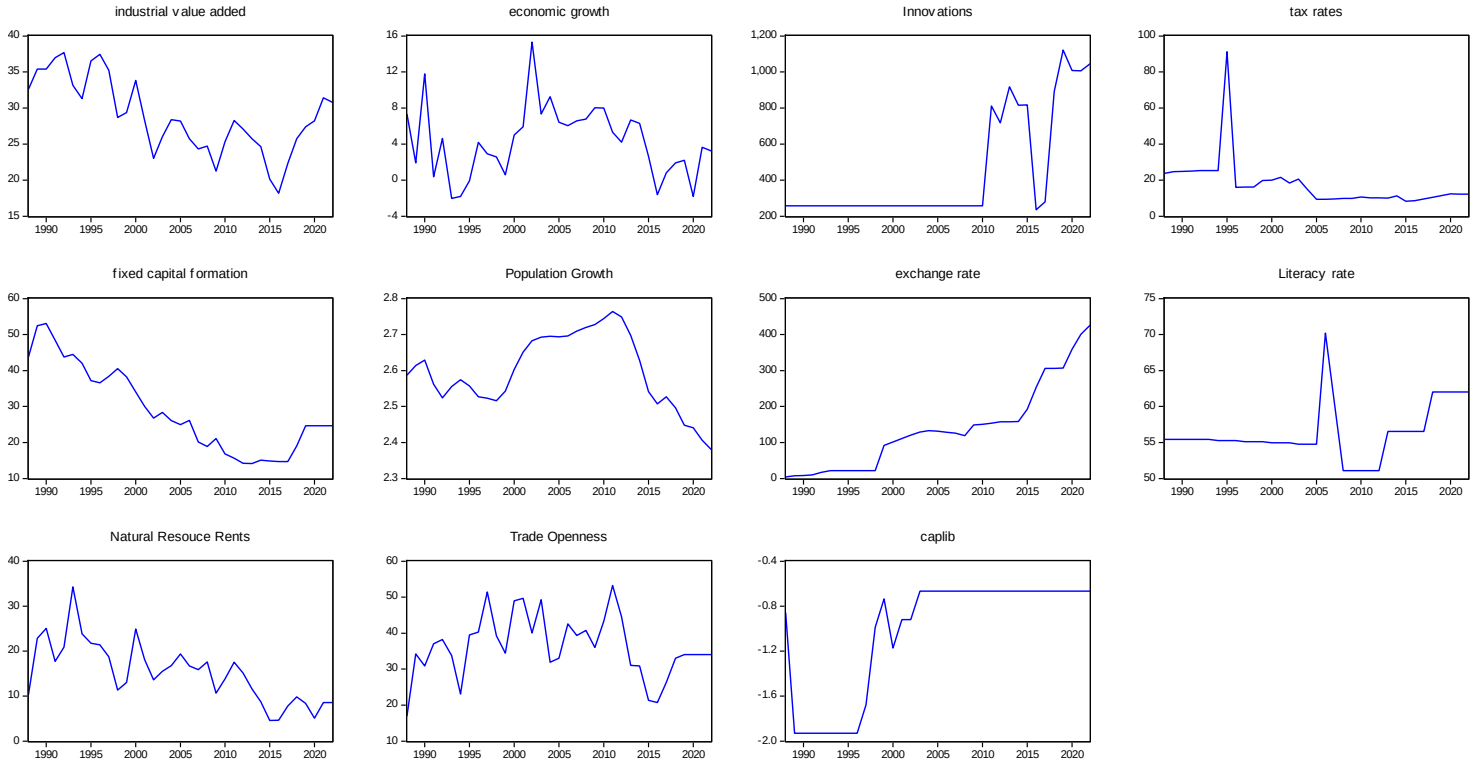
From the unit root test results presented in Table 4, the stationarity of each variable is verified. Before the stationarity test, Table 3 presents the correlation matrix of the relationship among the variables employed. This is primarily relevant to verify that the relationships are not too high to cause multicollinearity problems in the estimation. The correlation matrix is also important in revealing a preliminary relationship that exists among the variables. The results revealed that industrial value added in column (1) is significant and positively related to tax rates, capital formation, and natural resource rents but is significant and negatively related to population growth and exchange rate. However, it does not significantly correlate with economic growth, innovations, literacy rate, and trade openness. In column (2), economic growth is significant and positively correlated with population growth, but its correlation with other variables is insignificant. Innovation in column (3) is significant and positively related to the exchange and literacy rates but negatively correlates significantly with capital formation, population growth, and natural resource rents. Tax rates in column (4) have a significant positive correlation with capital formation and natural resource rents but a negative correlation with exchange rates. It does not significantly correlate with population growth, literacy rate, and trade openness. Capital formation in column 5 is significant and positively correlated with natural resource rents but is

significant and negatively associated with the exchange rate. Population growth in column (6) is also significant and positive in its association with trade openness but is significant and negative in its association with the exchange and literacy rates. The exchange rate in column (7) is positively related to the literacy rate but negatively related to natural resource rents. The literacy rate in column (8) is only negatively related to natural resource rents, and natural resource rents in column (9) are positively related to trade openness.

These correlation results imply a degree of relationship among these variables. Moreover, the correlation coefficients of the relationships among these variables, which are all lower than 0.8 (except for those between industrial value-added and other variables), signify that using them as explanatory variables in the regression model will not cause a problem of severe multicollinearity.

Table 4 presents the unit root test results from the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) procedures. Both procedures were employed to ensure the robustness of stationarity outcomes from the test. The results reveal that some variables are stationary at their level series (without any transformation) while others are not. For instance, economic growth, tax rates, literacy rates, and trade openness are stationary at their level series. This is because their statistics have p-values lower than 0.1 (10% significance level), making them significant. This is verified by both unit root procedures.

Figure 1: *Time Trend of Variables*



Source: Author's Plot using Data from World Development Indicators.

Table 3: *Correlation Matrix of Linear Relationship among Variables*

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Industry value-added	1.0									
2. Economic growth	-0.172	1.0								
	(0.323)									
3. Innovations	-0.191	-0.168	1.0							
	(0.270)	(0.332)								
4. Tax rates	0.533***	-0.198	-0.289*	1.0						
	(0.001)	(0.253)	(0.091)							
5. Capital formation	0.813***	-0.129	-0.475***	0.490***	1.0					
	(0.000)	(0.459)	(0.003)	(0.002)						
6. Population growth	-0.283*	0.602***	-0.378**	-0.114	-0.239	1.0				
	(0.098)	(0.000)	(0.025)	(0.513)	(0.165)					
7. Exchange rate	-0.501***	-0.145	0.737***	-0.428**	-0.672***	-0.394**	1.0			
	(0.002)	(0.404)	(0.000)	(0.010)	(0.000)	(0.019)				
8. Literacy rate	-0.049	-0.203	0.395**	-0.128	-0.063	-0.481***	0.472***	1.0		
	(0.777)	(0.240)	(0.018)	(0.460)	(0.716)	(0.003)	(0.004)			
9. Natural Resource rents	0.646***	0.029	-0.542***	0.420**	0.629***	0.278	-0.704***	-0.287*	1.0	
	(0.000)	(0.867)	(0.000)	(0.012)	(0.000)	(0.104)	(0.000)	(0.094)		
10. Trade openness	0.208	0.244	-0.120	0.060	-0.014	0.360**	-0.161	-0.182	0.352**	1.0
	(0.228)	(0.157)	(0.488)	(0.727)	(0.934)	(0.033)	(0.353)	(0.294)	(0.038)	

Note: ***, **, and * indicate significant relationship at 1%, 5%, and 10%, respectively.
Source: Author's Computations

Table 4: *Unit Root Tests for Stationarity of Variables*

	Augmented Dickey-Fuller (ADF)				Phillips-Perron (PP)			
	Level		First difference		Level		First difference	
	Statistic	p-value	Statistic	p-value	Statistic	p-value	statistic	p-value
Industry value-added	-1.822	0.363	-6.390***	0.000	-1.673	0.435	-6.155***	0.000
Economic growth	-3.832***	0.006			-3.743***	0.007		
Innovations	-1.793	0.375	-1.471	0.532	-0.999	0.742	-8.019***	0.000
Tax rates	-4.353***	0.001			-4.428***	0.001		
Capital formation	-1.227	0.651	-5.350***	0.000	-1.242	0.644	-5.349***	0.000
Population growth	-1.958	0.302	-1.389	0.573	-0.525	0.874	-2.956**	0.049
Exchange rate	2.173	0.999	-3.97***	0.004	2.435	0.999	-3.888***	0.005
Literacy rate	-2.892*	0.056	-6.279***	0.000	-2.980**	0.046		
Natural resource rents	-2.428	0.141	-8.204***	0.000	-2.326	0.169	-15.57***	0.000
Trade openness	-3.892***	0.005			-3.916***	0.004		

Note: ***, **, and * indicate significant and stationary at 1%, 5%, and 10%, respectively.

Source: Author's computations.

On the other hand, industrial value added, innovations, capital formation, population growth, exchange rate and natural resource rents are not stationary at their level series because their statistics have higher p-values. Further investigation revealed that the latter variables are stationary after first differencing. Therefore, the variables used in this study are stationary and non-stationary (but integrated, i.e., stationary after the first difference) variables. This outcome necessitates a cointegration test that is particularly conducted from the bounds test approach from the autoregressive distributive lag (ARDL) procedure. The cointegration test result is presented in Table 5. An F-statistic value of 4.014 is higher than the upper [or I(1)] critical bound at 5% significance level, which is 3.24. This implies that cointegration exists among the variables employed in this study. This result is, therefore, followed by the ARDL regression result in Table 6. The selected lag length results to an ARDL(1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0) model.

Table 5: *Bounds Approach to Cointegration Test*

Test Statistic	Value	k
F-statistic	4.014***	10
	Critical Bounds	
	I(0) Bound	I(1) Bound
At 5%	2.06	3.24

Note: *** signifies significant cointegration.
Source: Author's computations.

As for the main variables, the regression result in Table 6 shows both the short-run and long-run estimates to reveal the short-run and long-run impacts respectively. The result provides evidence for the positive influence of innovations on industrial value added in Nigeria in the short and long run. For instance, innovations have positive coefficients of 0.011 and 0.009 in the short run and long run respectively, with their p-values being 0.0426 and 0.0175, signifying that if an additional application increases the patent application, industrial value added will increase by 0.011 per cent points of GDP in the short run and 0.009 per cent points of GDP in the long run. This finding conforms to the findings of Zhu et al. (2020) and Aransiola et al. (2022) that innovation is vital for industrial development. The economic implication of this finding is that, a rise in innovative activities in the country can help to create more effective methods of production which will boost the overall quality and quantity of outputs. As a result, industrial output and development are improved.

Table 6: *ARDL(1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0) regression of the Impact of Innovations and Tax Reforms on Industrial Growth*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
	Short Run Estimates			
D(Economic growth)	0.670**	0.294	2.280	0.0350
D(Innovations)	0.011**	0.005	2.175	0.0426
D(Tax rates)	-0.167**	0.076	-2.198	0.0412
D(Capital formation)	0.295	0.327	0.903	0.3782
D(Population growth)	-39.58	35.96	-1.100	0.2855
D(Exchange rate)	0.021	0.025	0.877	0.3918
D(Literacy rate)	-0.344	0.216	-1.589	0.1293
D(Natural Resource rents)	-0.005	0.208	-0.024	0.9811
D(Trade openness)	0.356***	0.121	2.928	0.0090
D(Tax Reform)	-8.846**	4.112	-2.151	0.0453
ECT	-0.647***	0.202	-2.855	0.0098
	Long Run Estimates			
Economic growth	0.750**	0.365	2.054	0.0465
Innovations	0.009**	0.003	2.582	0.0175
Tax rates	-0.124**	0.055	-2.220	0.0395
Capital formation	0.141	0.135	1.045	0.3096
Population growth	31.97	18.96	1.685	0.1091
Exchange rate	0.016	0.018	0.877	0.3920
Literacy rate	-0.255	0.167	-1.524	0.1447
Natural Resource rents	-0.003	0.154	-0.024	0.9811
Trade openness	0.049	0.112	0.441	0.6640
Tax Reform (2005)	-6.563**	2.901	-2.261	0.0363
Constant	-73.40	52.54	-1.397	0.1794
R-squared	0.743			
F-statistic	3.476***			0.006
Jarque-Bera Normality test	0.779			0.677
Breusch-Godfrey LM Test	1.886			0.168
Ramsey RESET Test	1.981			0.177

Note: ***, **, and * indicate significant and stationary at 1%, 5%, and 10%, respectively.
Source: Author's computations.

Furthermore, the result provided evidence for the negative impact of tax rate on industrial value added. Its negative coefficients are 0.167 in the short run and and 0.124 in the long run. Its p-values are 0.0412 and 0.0395, signifying that a 1 per cent increase in the tax rate would increase industrial value added by 0.167% points of GDP in the short run and 0.124% in the long run. These findings are in line with expectations as a rise in tax rates discourages productivity in the private sector due to the notion that more is taken away from their productive efforts. This evidently causes disincentives to productive activities and leads to a decline in industrial output. Furthermore, the indicator variable of the tax reform in 2005 has a negative coefficient both in the short (-8.846) and long runs (-6.563). This means the industrial value added was lower during the post-2005 reform than in the pre-reform period. This finding is supported by Oshodi and Muhammed (2022), who documented that the 2005 tax-reform has been detrimental to manufacturing output in Nigeria. The implication of this is that, rather than helping manufacturing and industrial output growth, the reform has largely caused a setback to these sectors and created disincentives for firms.

As for the impact of other variables, economic growth has significant positive coefficients of 0.670 in the short run and 0.750 in the long run, suggesting that overall economic growth benefits industrial value added. The influence of economic growth is supported by previous studies such as Aiyedogbon and Anyawu (2015) and Samouel and Aram (2016), indicating that industrial development is best achieved in the context of a growing economy. There is also evidence of a significant positive impact of trade openness on industrial value added only in the short run but not in the long run. This finding coincides with those of Jawad et al. (2020) and Aransiola et al. (2022), implying that openness to international trade creates a larger market beyond the domestic market, which motivates economic actors and consequently boosts industrial outputs and development. Other factors like capital formation, population growth, exchange rate, literacy rate, and natural resource rents do not significantly influence industrial value added in the short and long terms.The error correction term presented in the short run is another way to reinforce that the variables are cointegrated. Its significant negative coefficient establishes a convergence from short-run disequilibrium to long-run equilibrium. Its coefficient value of -0.647 indicates that about 64.7% of the disequilibrium is corrected in each period for the system to converge back to long-run equilibrium. For further validity of the result, R-squared has a value of 0.743, signifying that the model explains about 74.3% of variations in industrial value added. A significant F-statistic value of 3.476 signifies that the overall model is a good fit. A Jarque-Bera normality test value of

0.779 and its p-value of 0.677 suggest that the model's residual is normally distributed, even though some individual variables are not normally distributed.

Breusch-Godfrey's LM test for serial correlation produced a value of 1.886 for the model. Its p-value of 0.168 signifies that the statistic is insignificant, and there is no evidence to reject the notion that the model is free from serial correlation problems. Ramsey's RESET specification test helps establish that the model result is stable and not misspecified as its statistic value of 1.981 has a p-value of 0.177, making the statistic insignificant. By and large, these diagnostic tests point to the validity of the regression result for policy recommendations.

5.0 Conclusion and Recommendations

This study investigated the impact of innovations and tax reforms on industrial value added in Nigeria between 1988 and 2022. The results of its time series analysis revealed that innovation helps promote industrial performance while increasing tax rates is detrimental to improving industrial value added. The findings of this study also provide evidence that the 2005 tax reform has negatively affected industrial value added in Nigeria. Further investigation revealed that overall improvement in the country's economic growth and more openness to international trade could help boost industrial value added.

This study recommends additional steps to boost the country's innovation level through:

- Policies aimed at improving the standard of education, most especially in science and technology.
- Improvement of education standards at the technical schools in the country via policies that provide beneficial and innovation-induced content in their academic curriculum.

These measures will help to boost the innovative capacity of youth in the country and consequently lead to growth in innovations.

It is also recommended that tax rates should be lowered to encourage innovative drive of businesses. Specifically, leniency in tax rates should be directed at small business startups that offer new ideas and products. Openness to international trade should be further promoted to create a bigger market for industrial production beyond the domestic market, to motivate industrial drive

among local businesses. Strategies should also be developed to improve the overall growth of the Nigerian economy to help the industrial sector. Effective investment in the education system and infrastructural projects can help promote ease of business and create a more conducive business environment for economic growth.

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Road Network, Transport-induced Labour Accessibility and Industrial Productivity in the ECOWAS Region

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Abstract
This study examined the effect of road networks and transport-induced labour accessibility on industrial productivity in ECOWAS countries. *The study adapted an endogenous growth model to analyse data set for 15 ECOWAS countries spanning the period 1975 to 2022. Data was retrieved from the World Development Indicators (WDI) to estimate Panel causality and Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) models. Findings showed that total road network and transport-induced labour accessibility had positive and significant effects on industrial sector productivity in both the short and long run. Also,* a unidirectional causality was recorded running from road network to industrial sector productivity*, and a feedback causal relationship between transport-induced labour accessibility and industrial sector productivity. Consequently, governments and business moguls should collaborate to mitigate transport*-induced labour accessibility challenges *by subsiding public transport for workers and* upgrading the existing road networks to improve industrial sector productivity across ECOWAS member countries.

Keywords: *Road network, Labour Accessibility, Industrial sector Productivity, Cross-sectional Autoregressive Distributed Lag (CS-ARDL)*
JEL classification: L9

1.0 Introduction

One of the critical factors influencing industrial productivity in the Economic Community of West African States (ECOWAS) region is the quality of road networks and their impact on transport-induced labour accessibility. Road networks are essential for the efficient movement of people, goods, and services, and their quality directly affects workers' ability to access job

opportunities. This, in turn, influences labour market dynamics and industrial productivity. A well-industrialized nation is expected to have robust infrastructure, which positively impacts the industrial sector and drives economic growth. Adequate and efficient infrastructure not only enhances the quality of life but also promotes rapid industrialization. Infrastructure development in Africa is vital for fostering economic growth, improving living standards, contributing to human development, reducing poverty, and achieving the Sustainable Development Goals (African Development Bank, AfDB, 2018).

The expansion of transport infrastructure alters road network routes because lower travel costs affect the transport network matrix. This expansion leads to the construction of new routes and improvements to existing infrastructure, including adjustments in industrial locations and changes in land use. For instance, developing new road transit can change the network's centrality, making some areas more important due to their proximity to resources. Firms aiming to remain competitive may relocate their operations to reduce production costs or expand business opportunities. Similarly, people are more likely to move to areas with better career prospects and a variety of amenities (Fujita et al., 2001).

The quality of road infrastructure in the ECOWAS region varies widely, with many countries facing significant challenges in building and maintaining efficient road networks (Uduak, 2014), especially in rural areas. These variances impact workers' ability to access industrial zones and urban employment centres, influencing overall productivity and economic development. Existing roads often suffer rapid deterioration due to insufficient financial resources allocated to road maintenance. The resulting potholes, erosion, and general disrepair make commuting challenging and time-consuming, affecting the reliability and efficiency of transport systems and further hindering labour mobility and accessibility (Alinaitwe & Muhammad 2024). Additionally, limited road connectivity within and between ECOWAS member countries restricts the free movement of labour and goods, vital for regional economic integration and industrial productivity. Addressing these challenges is essential for fostering regional growth and improving the livelihoods of millions in the ECOWAS region.

Poor road conditions and inadequate transport infrastructure lead to higher transportation costs, burdening workers with increased commuting expenses (Venables et al., 2014). This reduces their disposable income and limits their ability

to access distant job opportunities. Travelling on poor-quality roads significantly extend commute times, decreasing productivity and negatively impacting workers' quality of life and job satisfaction. Additionally, poor road conditions result in higher traffic accident rates, posing significant safety risks and discouraging longer commutes. Unsafe and unreliable transport options contribute to stress and health issues, further reducing workers' productivity and well-being (World Health Organization, 2022). The disparity between urban and rural road networks is stark, with urban areas typically enjoying better infrastructure. In contrast, rural areas remain underdeveloped, limiting labour mobility and access to industrial jobs for rural populations. This imbalance contributes to economic disparities, as urban areas attract more investment and development while rural areas lag, perpetuating cycles of poverty and limited economic opportunities.

Improved transport infrastructure can drive economic gains by lowering travel expenses and influencing the spatial distribution of businesses and households (Venables et al., 2014). Enhanced transport networks allow households to live closer to workplaces, saving on travel costs and enabling workers to be more productive by increasing mobility and resource access. Businesses can more easily find suitable workers, enhancing overall labour market efficiency. In the ECOWAS region, road network density is significantly lower compared to transit-developing countries and global averages (United Nations Office of the High Representative for Least Developed Countries (UN-OHRLLS), 2021). Since the inception of the ECOWAS union in 1975, the region's road network has deteriorated, decreasing from 9,500 km in 1985 to 4,000 km in 2020 (World Bank, 2021). This decline has severely impacted the industrial sector and overall economic growth in the region.

2.0 Literature Review

Theoretical argument on this study is linked to the work of Stephen et al. (2019) on the impact of newly-built highways on employment and transport-induced labour productivity in Britain, which was analysed using data from industrial firms. Road network was employed in the study as a proxy for exposure to transportation improvements to estimate changes in the minimum time required for labour to go from home to work. The study discovered a strong positive relationship between

freshly-built roadways, employment, and neighbourhood businesses. According to the findings, newly-built highways draw transportation-intensive firms to the area and lead some already-established companies to restructure their production processes. Na et al. (2011) investigated how roads affected labour market activity in 19 OECD nations. The study used several models that included dependent, independent, and control variables over a 17-year period, from 1990 to 2006. The study found a correlation between highway use and employment activity; the network effect of highways enhanced labour productivity per worker.

Some studies in the literature also link the performance of the industrial sector and total road infrastructural development. The effect of road infrastructure and labour accessibility on manufacturing sectors in Mexico was examined by Castañeda and Shemesh (2000). The study, which covered the 25-year period from 1993 to 2018, used an autoregressive distributed lag (ARDL). It found that a 10% increase in road transport infrastructure increased manufacturing productivity by 0.62% to 0.96%; the immediate effect may be small, but the long-term impact will be greater. Sun (2018) examined the impact of transport infrastructure on industrial structure in China from 2005 to 2018. Panel data from 31 Chinese provinces and cities was used; a benchmark panel regression model was established and a dynamic panel model with hysteresis effects was introduced. The results show that roads have a clear driving effect on secondary industry, but railways have a stronger driving effect. In terms of the control factors, the degree of economic development, the level of human capital, and the pace of urbanization considerably favour the tertiary industry while significantly harming the primary sector. Andreas (2003) investigated how road infrastructure affects growth and productivity. Cross-sectional time series data from the manufacturing sector between 1970 and 1993 was used in the analysis. The results show how crucial road infrastructure is to industrial production. Antle (2003) found a strong and positive relationship between infrastructure quality and total production when the Cobb Douglas production function was applied for 19 developed and 47 developing countries. The quantity of infrastructure per square kilometre of land was used to define the gross national product (GNP) from the transportation and communication sectors.

Some studies on the effect/impact of road network and infrastructure development on industrial sector productivity have yielded a variety of findings.

Ogwo and Agu (2016) discovered that total road network has a negative effect on industrial sector productivity. Nadabo (2023) used autoregressive distributed lag (ARDL) to examine the impact of institutional quality on the connection between infrastructure development and manufacturing sector performance in Nigeria from 2002 to 2021. The results show that institutional quality on infrastructure development has a negative impact on the manufacturing sector's performance over the long and short term. Similarly, Chukwuebuka and Jisike (2020) studied the relationship between industrial sector productivity and infrastructure development in sub-Saharan Africa using a panel data collection of 17 nations from 2003 to 2018. The panel least squares estimation method was used to analyse the relationships between the variables. The results revealed that the key determinants affecting industrial sector productivity in sub-Saharan Africa are the quantity and quality of road network and telecommunications infrastructure. The findings indicate that sub-Saharan Africa's relatively poor industrial sector productivity is mostly due to the region's subpar energy and transport infrastructure, as well as its underutilization of its water supply and sanitation facilities.

Azolibe and Okonkwo (2020) studied the relationship between industrial sector productivity and infrastructure development in sub-Saharan Africa using a panel data from 17 nations for the period 2003 to 2018.. The panel least squares estimation method was used to analyse the relationships between the variables. The results reveal that the key determinants affecting industrial sector productivity in sub-Saharan Africa are the quantity and quality of telecommunications infrastructure. The transport infrastructure effect is insignificantly related to industrial sector growth because the region recorded the least transport infrastructure development in terms of road and railroad densities compared to other developing nations in the world. Similarly, Akekere et al. (2017) analysed Nigeria's governmental infrastructure spending and growth in industrial output. The findings revealed that, on the one hand, there are several correlations between the growth of the industrial sector and public capital infrastructure as measured by the infrastructure development index, the human development index, and the inflation rate. The wide money supply and exchange rate, on the other hand, were found to have a positive correlation with the growth of the industrial sector. Thus, it can be concluded that Nigeria's infrastructure has a negative impact on the development of the industrial sector. This finding

demonstrates that infrastructure accessibility or quality had little impact on industrial expansion.

Similarly, Stephen (2017) examined the impact of industrial sector productivity on public infrastructure capital in Nigeria. Co-integration was used in the study to support the existence of linkages, and the results showed that, on the one hand, the expansion of the industrial sector is negatively correlated with public capital infrastructure as measured by the infrastructure development index, the human development index, and the inflation rate. The outcome demonstrates that infrastructural accessibility or quality had no bearing on industrial expansion.

Ogwo and Agu (2016) studied the impact of the availability of transport infrastructure on Nigeria's manufacturing enterprises performance. Both primary and secondary data were used in the study, with the primary data coming from certain manufacturing enterprises that operate in the nation and how their performance status influences the GDP of the nation. According to the result, Nigeria's sub-standard road infrastructure negatively affects the marketing performance of the manufacturing industry, including sales and profitability. Nigeria's quality of road infrastructure has great effect on the use of industrial capacity but has insignificant effect on the manufacturing production index.

Furthermore, how much the industrial and transportation sectors contribute to the development of the nation depends greatly on the annual budgetary allocation to the transportation sector. Mesagan and Ezeji (2016) studied how Nigeria's manufacturing industry performed in relation to its social and economic infrastructure applying the autoregressive distributed lag (ARDL) model. The result shows that while ICT and the Toda-Yamamoto causality test had a positive impact on manufacturing performance, electricity and road had a minimal negative impact on manufacturing value added.

The present study used cross-sectional augmented autoregressive distributed lag (CS-ARDL) models to underscore the effect of road networks and transport-induced labour accessibility on industrial productivity in the ECOWAS region. The use of this method is a novelty as previous panel studies ignored cross-sectional dependencies among their chosen variables. Based on this method, this study examined the relationship between total road network and industrial sector productivity and the relationship between transport-induced labour accessibility

and industrial productivity in the ECOWAS region. It also identified the direction of causality among total road network, transport-induced labour accessibility, and industrial productivity in the region

3.0 Methodology

In examining the role of investment in transport infrastructure on industrial productivity in the ECOWAS region, this study relies on the endogenous growth theory. This theory posits that improvements in innovation, knowledge, and human capital drive increased productivity, thereby positively influencing economic growth. Following the framework established by Mankiw et al. (1992), the analysis is specified as follows:

$$Y(t) = K(t)^{\alpha} A(t) L(t))^{1-\alpha} \quad (1)$$

where:

Y_i = output
K_i = capital
L_i = labour
A = level of technological progress

$$K(t)^{*} = \left(\frac{S}{\delta}\right)^{\frac{1}{1-\alpha}} A(t)L(t) \quad (2)$$

Note that K, A and L are functions of time, and $S, \delta \; and \; \alpha$ are all constants, $L(t)$ is the labour force with growth at rate n and $A(t)$ is the technology growth at rate g.

$$y(t)^{*} = \left(\frac{S}{\delta}\right)^{\frac{\alpha}{1-\alpha}} A(t)L(t) \quad (3)$$

Equation 4 is the output per labour, which is replaced with the growth of the economic sector (GES) and this serves as the foundation for the theoretical framework underpinning this study.

$$gy = g + n \quad (4)$$

Expanding the theoretical framework to encompass the dynamic relationship between transportation infrastructure and industrial productivity in ECOWAS, this study adapts the model used by Chukwuebuka and Jisike (2020). In their model, transportation infrastructure serves as the independent variable, while industrial

value added is the dependent variable. The functional form of the model is as follows:

$$INDV_{it} = f(TRN_{it}; TILA_{it}; V_{it}) \quad (5)$$

In this study, industrial productivity was measured with data on industry value added, as in Chen and Golley (2014), Chenery (1960), and Sveikauskas et al. (2018). Total road network was measured by the entire road network in kilometres (per square kilometre of arable land), while transport-induced labour accessibility was calculated using the labour force divided by total investment in transport infrastructure which is a vector of control variables such as gross capital formation, labour force participation rate, credit to the private sector, and defence budget, as used in Chukwuebuka and Jisike (2020). These variables were used for three objectives in this study. The first objective is the relationship between total road network and industrial sector productivity in the ECOWAS region, and the model is specified below:

$$INDV_{it} = f(TRN_{it};\ GCF_{it}; LAB_{it}; CRED_{it}; DB_{it}) \quad (6)$$

The semi-log-linear form of the model is specified as;

$$InINDV_{it} = \beta_0 + \beta_1 InTRN_{it} + \beta_2 InGCF_{it} + \beta_3 LAB_{it} + \beta_4 CRED_{it} + \beta_5 DB_{it} + \mu_{it} \quad (7)$$

In this model, InINDVit represents the log of industrial value added for country i in period t. InTRNit is the log of the total road network, measured by the total length of roads per square kilometre of arable land for country i over period t. InGCFit denotes the log of gross capital formation for country i in period t. LABit represents the labour force, a critical component for producing goods and services in country i over period t. The labour force participation rate (percentage of the total population aged 15+) will be used as a proxy for the labour force. CREDit is the credit to the private sector as a percentage of GDP for country i over period t. According to Olowofeso et al. (2015), credit to the private sector includes financial resources provided to the private sector, such as loans, advances, purchases of non-equity securities, trade credits, and other accounts receivable, which establish a claim for repayment. Adequate credit to the industrial sector will enhance investment and productivity. For this study, the ratio of credit to the private sector to GDP was used as a measure of credit to the

private sector. DBit represents the defence budget as a percentage of GDP for country i over period t. This refers to government expenditure on defence, which is crucial for creating a conducive environment free from internal and external aggression, thereby ensuring the safety of investments and boosting industrial productivity. The ratio of government expenditure on defence to GDP was used as a proxy for the defence budget.

The second objective investigates the relationship between transport-induced labour accessibility and industrial productivity in the ECOWAS region with the specified model in Equation (8).

$$INDV_{it} = f(TILA_{it};\ CRED_{it}; GCF_{it}; DB_{it}) \quad (8)$$

The semi- log-linear form of the model is specified as:

$$InINDV_{it} = \beta_0 + \beta_1 TILA_{it} + \beta_2 lnGCF_{it} + \beta_3 CRED_{it} + \beta_4 DB_{it} + \mu_{it} \quad (9)$$

In this model, INDVit represents the log of industrial productivity, measured using the industry value-added of country i over period t. TILAit denotes transport-induced labour accessibility, which is measured by calculating the transport-induced labour accessibility indicator of the integral index. This integral indicator reflects the total transport costs and is calculated using the following:

$$Transport - induced\ Labour\ accessibility_{it} = \sum_k LF_{it} / InTITI_{it} \quad (10)$$

where: $Transport - induced\ Labour\ accessibility_{it,}$ defined as $LAB_{it,}$ is the total labour force of country *i* over period *t*; $InTITI_{it}$ is log of total investment in transport infrastructure (Lee, 2019 and Lavrinenko et al., 2019).

The third objective is to identify the direction of causality among the total road network, transport-induced labour accessibility, and industrial productivity in the ECOWAS region. The Granger causality test was utilized to achieve this objective.

Hurlin's (2005) panel causality test also necessitates covariance-stationary variables for the variables being examined. Granger (1969) permits testing of the causal links between variables after the stationarity of the variables has been established. The Panel Granger causality test, which integrates cross-sectional and time-series data, is a better technique for determining causality than the well-developed Granger causality test for time-series data. Compared to using solely time-series data, it is more efficient (Hurlin & Venet, 2001). In 1988, Holtz-

Eakin, Newey, and Rosen created the Panel Granger test taking into account the subsequent fixed-effect model:

$$y_{it} = \omega_i + \sum_{k=1}^{k} y^{(k)}\, y_{it-k} + \sum_{k=1}^{k} \beta^{(k)} x_{it-k} + \varepsilon_{it} \qquad (11)$$
$$i = 1, \ldots\ldots\ldots\ldots . N, t = 1, \ldots\ldots . T$$

where ω_i represents the constant influence of the individual and coefficients $y^{(k)}$and $\beta^{(k)}$ are expected to be constant throughout the board. The hypothesis for the suggested Granger test is:

$$H_0 : \beta^{(1)} = \beta^{(2)} = \beta^{(k)} = 0 \qquad (12)$$

In this study, attempts were made to determine whether total road network and transport-induced labour accessibility determine or influence industrial productivity in ECOWAS. Thus, the model is specified as:

$$lnINDV_{it} = \beta_{1i} + \sum_{k=1}^{k} \partial_{11i}\, lnINDV_{it-1} + \sum_{k=1}^{k} \partial_{12i}\, InTRN_{it-1} + \sum_{k=1}^{k} \partial_{13i} TILA_{it-1} + \varepsilon_{1t} \qquad (13)$$

$$InTRN_{It} = \beta_{2i} + \sum_{k=1}^{k} \partial_{21i}\, InTRN_{it-1} + \sum_{k=1}^{k} \partial_{22i}\, TILA_{it-1} + \sum_{k=1}^{k} \partial_{23i}\, InINDV_{it-\,1} + \varepsilon_{2t} \qquad (14)$$

$$TILA_{it} = \beta_{3i} + \sum_{k=1}^{k} \partial_{31i}\, TILA_{it-1} + \sum_{k=1}^{k} \partial_{32i}\, InTRN_{it-1} + \sum_{k=1}^{k} \partial_{33i} InINDV_{it-\,1} + \varepsilon_{3t} \qquad (15)$$

For a given country (*i*) at a given time (*t*), the variables stand for industrial productivity, the entire road network, and labour accessibility induced by transportation. The error term, denoted by ε, has a zero mean and is serially uncorrelated. The speed of adjustment is also ∅. To illustrate the constant drifting, use β_{1i}. More significantly, the panel causality test for the chosen sample nations in this study is determined using simultaneous equations (13), (14), and (15).

3.1 Data description

All the 15 ECOWAS members (Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo) were represented in this study's panel data. The ECOWAS region was chosen because the countries are classified as low and middle-income due to the pervasive lack of infrastructure and diminishing industrial productivity.

The measured variables included industrial sector productivity (*INDV*), assessed using industry value-added data; total road network (TRN_{it}) measured in per square kilometre of arable land; and transport-induced labour accessibility (*TILA*), evaluated by calculating the transport-induced labour accessibility indicator of the integral index. Furthermore, V_i is a vector of control variables, containing the following: the stock of private capital employed in production, expressed as an annual percentage growth rate known as gross capital formation (*GCF*); total labour force participation rate, represented as a percentage of the population over the age of 15, and which defines labour force participation (*LAB*). Credit to the private sector (*CRED*), calculated as the GDP (gross domestic product) divided by the credit to the private sector; and defence budget (*DB*), the amount allotted by the government to defence spending as a percentage of GDP. The data used for the analyses was sorted from the World Development Indicators (WDI) published in 2024.

3.2 Estimation technique

This study used three techniques to analyse the impact of transport infrastructure on industrial productivity in ECOWAS countries. First, we examined the data using descriptive statistics. This involved calculating averages and using tests like Jarque-Bera to check if the data followed normal distribution (Gujarati & Dawn, 2009). Also, we performed correlation analyses to avoid issues with multicollinearity (when variables are highly correlated). The study then employed panel unit root tests to see if the data had a time trend (was increasing or decreasing over time). These tests considered two scenarios: one where all countries behaved independently (first-generation tests), and another where they might influence each other (second-generation tests). Among the second-

generation tests, the factor-based approach was used because it can handle situations where countries' economies are interconnected. Finally, we applied the Cross-sectional Augmented Autoregressive Distributed Lag (CS-ARDL) model. This model was used to predict how changes in transport infrastructure would affect industrial productivity across the 15 ECOWAS countries. To assess the accuracy of the model's predictions, the root mean square error (RMSE) was estimated. A low RMSE indicates a more effective model.

4.0 Results

Table 1 summarizes the data used in the study and provides key descriptive statistics for the variables – mean (average) standard deviation, skewness and kurtosis, and Jarque-Bera statistics. The table presents the main outcome variable of the study, the dependent variable and the independent variables the control variables, factors potentially affecting industrial productivity. It includes values across the entire range, from the minimum to the maximum, indicating a tendency towards a normal distribution. Skewness values are positive for all variables except total road network, while kurtosis values exceeding 3 suggest leptokurtic distributions for all variables except for road network and labour force, which exhibit platykurtic distributions (kurtosis values below 3). Jarque-Bera statistics indicate that all series are not normally distributed, with statistically significant p-values at the 5% level, rejecting the normality assumption. Therefore, the variables did not follow a normal distribution over the period studied.

Table 1: *Descriptive Statistics*

Variables	INDVA	TRN	TILA	LF	GCF	CRED	DB
Mean	38.0143	4.2061	0.0191	49.6165	54.5874	14.6325	1.7411
Maximum	253.7166	5.2887	0.1285	79.2900	515.6162	73.1921	29.7277
Minimum	3.4067	3.0414	0.0017	23.8550	5.3539	0.0000	0.0087
Std. Dev.	36.4500	0.5645	0.0184	13.5441	83.8012	11.3264	2.8718
Skewness	2.6316	-0.0932	2.6414	0.0649	3.4774	1.8238	6.6188
Kurtosis	11.4404	2.5769	11.5187	2.0884	15.8314	7.8719	50.9641
Jarque-Bera	**2906.4070**	**6.2792**	**2951.4890**	**24.9038**	**6256.8470**	**1088.0510**	**72726.3100**
Probability	(0.0000)	(0.0000)	(0.0433)	(0.0112)	(0.0013)	(0.0002)	(0.0000)
Obs	705	705	705	705	705	705	705

Notes: Std. Dev. = Standard Deviation; Obs = Number of Observations; INDVA – industrial sector productivity; TRN – total road network; TILA – transport-induced labour accessibility; GCF – gross capital formation; LAB – labour force participation rate; CRED – credit to the private sector; DB – defence budget. The bolded values imply significance at 5%.
Source: Author's computation.

Table 2 displays the correlation matrix coefficients for industrial productivity (INDVA) as the dependent variable and independent variables including total road network (TRN) and transport-induced labour accessibility (TILA), alongside control variables: gross capital formation (GCF), labour force participation rate (LAB), credit to the private sector (CRED), and defence spending (DB). The correlation analysis revealed that the covariate regressors exhibit varying degrees of correlation, as indicated by the coefficients ranging from -0.7100 to 0.8259. None of the correlation coefficients reach 0.90, indicating the absence of perfect multicollinearity among the regressors. This suggests that the variables were sufficiently independent from each other in the regression analysis.

A cross-sectional dependence test presented in Table 3 was estimated before estimating the model for the link between total investment in transport infrastructure, the transport road network, transport-induced labour accessibility, and industrial sector productivity in the ECOWAS region. Cross-sectional dependence is a common statistical attribute of panel datasets, often driven by unified economic policies and financial and economic integration among countries, particularly within regions like ECOWAS. Therefore, testing for cross-sectional dependence in the variables is essential to determining the appropriate techniques for examining their relationships.

The study employed four different tests to check for cross-sectional dependence – Breusch-Pagan LM, Pesaran Scaled LM, Bias-corrected Scaled LM, and Pesaran Cross-sectional Dependence (PCD) tests. The results indicate that all the variables significantly depend on each other at the 1% level. This means the economies of the countries in the study are interconnected and should be considered as a group when analysing their industrial productivity.

Table 2: *Correlation Matrix Coefficients*

	INDVA	TRN	TILA	GCF	LF	CRED	DB
INDVA	1.0000						
TRN	0.3236	1.0000					
TILA	0.2165	0.8259	1.0000				
GCF	0.1469	-0.0923	-0.0231	1.0000			
LF	0.0723	0.1085	-0.0597	-0.0440	1.0000		
CRED	-0.0609	-0.2365	-0.1005	-0.2947	-0.2453	1.0000	
DB	-0.1116	-0.0216	-0.0644	0.1337	0.1205	-0.1395	1.0000

Source: Author's computation.

Table 3: *Cross-sectional Dependence Tests*

Variables	Bruesch-Pagan LM	Pesaran Scaled LM	Bias-corrected Scaled LM	Pesaran CD
$INDV$	2150.1640***	141.1297***	140.9667***	31.7376***
TRN	1782.9150***	115.7871***	115.6241***	-0.0389
TILA	2534.5840***	167.6573***	167.4942***	26.1733***
GCF	1378.7750***	87.8988***	87.7358***	28.9727***
LAB	2391.1200***	157.7573***	157.5942***	17.0657***
$CRED$	1386.2230***	88.4128***	88.2497***	22.2571***
DB	1058.5840***	65.8035***	65.6405***	0.1571

Note: *** represents statistical significance at 1%. Lagrange Multiplier (LM), CD; Cross-sectional dependence
Source: Author's computation.

Further pre-test analysis was conducted to identify each variable's order of integration (see Table 4). It is imperative to evaluate the stationarity of the time series prior to conducting the main analysis. To verify that the series used in the analysis were stationary, a unit root test was conducted. In particular, it used robust second-generation unit root tests against cross-sectional dependence in panel data, such as the cross-sectional augmented Dickey-Fuller (CADF) test and

the cross-sectional augmented Im, Pesaran, and Shin (CIPS) test. The results of the second-generation unit root tests show that the variables have a mixed order of integration. Thus, the model that is most suitable for this study is the Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) model, which is strong enough to handle mixed order of integration and robust to cross-sectional dependence in panel data.

Table 4: *Panel Unit Root Tests*

	CIPS			CADF		
Variables	Level	1st Difference	Integration Order	Level	1st Difference	Integration order
INDVA	-2.5230***	-6.0360***	*I*(0)	-1.9850	-2.6800***	*I*(1)
TRN	-2.7680***	-4.3640***	*I*(0)	-1.5430	-2.2420**	*I*(1)
TILA	-1.6320	-5.8790***	*I*(1)	-0.7470	-2.4490***	*I*(1)
GCF	-2.9000***	-5.6370***	*I*(0)	-1.8130	-2.8900***	*I*(1)
LF	-1.5480	-2.5050***	*I*(1)	-0.5740	-3.4280***	*I*(1)
CRED	-1.6740	-5.8090***	*I*(1)	-1.4250	-2.9410***	*I*(1)
DB	-2.2650***	-5.6640***	*I*(0)	-1.2940	-2.2380**	*I*(1)

Note: ***p < 0.01 and **p< 0.05; Critical values: -2.03, -2.11, -2.26 for 10%, 5%, and 1% significance level respectively. *Footnote:* CIPS Cross-sectional augmented Im, Pesaran, and Shin and CADF Cross-sectional Augmented Dickey-Fuller
Source: Author's computation.

This study used both first-generation (Pedroni and Kao residual) and second-generation (Westerlund) cointegration tests to evaluate the possibility of cointegration among variables with varied orders of integration. Taking into account any potential cross-sectional dependence among the variables, these tests were selected to look into the existence of a cointegrating relationship. Four indicators were used as statistical significance at the 1% level to confirm cointegrating variables. The Pedroni residual cointegration test results show significant cointegration estimates across seven statistics from the panel and group strands. This validates the study's conclusion that the variables are cointegrated. A statistically significant t-statistic of -6.3217 was also obtained at the 1% level using the Kao residual cointegration test, which further supported the existence of a cointegrating relationship between the variables. In addition to the first-generation tests, the Westerlund cointegration test results show that all four statistics are statistically significant, indicating robust evidence of cointegration among the variables. This comprehensive analysis supports the examination of

relationships involving transport road networks, transport-induced labour accessibility, and industrial productivity across ECOWAS nations. The findings are detailed in Table 5, providing robust evidence of cointegration among the variables examined.

Table 5: *Panel Cointegration Tests*

Panel A: Pedroni Residual Cointegration Test			
Panel Statistics		Group Statistics	
Panel v-Statistics	0.9557(0.1696)		
Panel rho-Statistic	-0.7408(0.2294)	Group rho-Statistic	-0.0336(0.4866)
Panel PP-Statistic	-2.5362***(0.0056)	Group PP-Statistic	-2.3569***(0.0092)
Panel ADF-Statistic	-2.0608**(0.0197)	Group ADF-Statistic	-1.5867*(0.0563)
Panel B: Kao Residual Cointegration Test			
t-Statistic	-6.3217***(0.0000)		
Residual Variance	69.1233		
HAC Variance	84.5658		
Panel C: Westerlund Cointegration test			
G_t	-2.8780**(0.0400)	P_t	-13.3480***(0.0000)
G_a	-13.6870**(0.0300)	P_a	-14.7300***(0. 0000)

Notes: Values in the parentheses denote probability values. ***, **, and * represents statistical significance at 1%, 5%, and 10%, respectively.
Source: Author's computation.

Table 6 presents the findings from the Cross-sectional Augmented Autoregressive Distributed Lag (CS-ARDL) technique. The pre-test analyses necessitate the choice of technique used for this study. Panel A of the table indicates significant findings regarding the effects of various factors on industrial productivity in the long run. Transport road networks and gross capital formation exhibit positive impacts on industrial productivity. Specifically, they both demonstrated a statistically significant effect (lnTRN = 0.7879, t = 2.31, $p < 0.05$; lnGCF = 0.1645, t = 1.68, $p < 0.10$), suggesting that these factors are significant drivers of changes in industrial sector productivity in the ECOWAS region.

Table 6: *Effects of Transport Road Networks on Industrial Productivity in the ECOWAS Region*

Dependent variable: $INDVA$				
Panel A: Long-run Estimates				
Variable	Coefficient	Std. Error	t-Stat	Probability
TRN	0.7879**	0.3407	2.31	0.021
GCF	0.1645*	0.0978	1.68	0.093
LF	1.0743	0.8030	1.34	0.181
$CRED$	-0.1080	0.2467	-0.44	0.661
DB	3.4651	3.4276	1.01	0.312
Panel B: Short-run Estimates				
$\Delta INDVA(-)$	0.4396 ***	0.0569	7.73	0.000
ΔTRN	0.4508***	0.1767	2.55	0.011
ΔGCF	0.1326*	0.0814	1.63	0.103
ΔLF	0.6682	0.4670	1.43	0.152
$\Delta CRED$	-0.0504	0.1187	-0.42	0.671
ΔDB	1.6653	1.5996	1.04	0.298
ECM_{t-1}	-0.5604***	0.0569	-9.85	0.000
Panel C: Diagnostic test		**Statistic**	**Prob**	
RMSE		5.08	0.0000	

Note: ***, **, and * represents statistical significance at 1%, 5%, and 10%, respectively.
Source: Author's computation.

In contrast, credit to the private sector demonstrated negative and insignificant effects on industrial productivity in the ECOWAS region in the long run (CRED = -0.1080, t = -0.44, p > 0.05). This implies that while this factor is included in the model, it does not significantly contribute to changes in industrial productivity in the long run. This could be as a result of inadequate credit assessment mechanisms or a lack of access to credit for small and medium-sized enterprises (SMEs) in ECOWAS countries, which can limit the benefits of credit. Firms might struggle to access the necessary funds or face stringent borrowing conditions. If credit is not efficiently allocated, it may not reach the most productive or innovative firms. Poor credit allocation can result in funds being used for less productive purposes, thereby hindering overall industrial productivity. Moreover, the estimated coefficients reveal the magnitudes of these effects: a 1% increase

in transport road network and gross capital formation corresponds to a positive change of 0.7879% and 0.1645% increase in industrial productivity respectively. Also, a unit increase in labour force participation rate and defence spending led to about 107.43% and 346.5% increase in industrial productivity respectively. Thus a higher labour force participation rate means more individuals are working or actively seeking employment. This enlarges the pool of labour available for industrial activities, potentially leading to higher production levels and productivity. If the increase in labour force participation involves skilled workers, productivity could increase dramatically due to better utilization of human capital. Skilled workers can operate machinery more efficiently, innovate processes, and contribute to higher output and defence spending often leading to advancements in technology and infrastructure, which can spill over into the civilian industrial sector. Innovations in materials, electronics, and manufacturing processes developed for defence purposes can be applied to industrial production, significantly boosting productivity. Conversely, a unit increase in credit to the private sector leads to a decrease of 10.8% in industrial productivity in the long run.

As displayed in Panel B, it is evident that total road network, gross capital formation, labour force, and defence spending show a positive impact on industrial productivity, while only total road network and gross capital formation have significant effects on industrial productivity (lnTRN = 0.4508, t = 2.55, p < 0.05; lnGCF = 0.1326, t-stat = 1.63, p < 0.10). Conversely, credit to the private sector has negative but insignificant effects on industrial productivity in the short run (CRED = -0.0504, t = -0.42, p > 0.05). This suggests that the relationships observed between these variables are consistent across both short-run and long-run periods. The ECT, denoted as ECM_{t-1}, indicates how quickly variables adjust to shocks and return to their equilibrium levels. Typically, a negative coefficient of ECM_{t-1}, with an absolute value less than one and statistically significant at a chosen significance level, is expected. The coefficient of the error correction term (ECM_{t-1}= −0.5604, t= −9.85, p < 0.05) was estimated to be negative and statistically significant at the 1% level. This suggests that by the next year, deviations from the industrial productivity equilibrium trend will adjust by roughly 56%. In summary, from 1975 to 2022, the industrial productivity adjustment process moved quickly. Moreover, the results of the cointegration tests presented in Table 5 are supported by the importance of the error correction term coefficient, which validates the existence

of a long-run equilibrium relationship in the model estimated for transport road networks and industrial productivity.

A residual test was carried out to guarantee the accuracy and dependability of the parameter estimates and to make solid inferences from the findings. The results showed that the estimated model's root mean square error (RMSE) was 5.08. This low RMSE score indicates that the model's ability to explain how transport road networks affect industrial productivity in the ECOWAS region is very effective. This suggests that the model fits the data well and the estimated correlations are statistically significant, which strengthens the validity of the study's findings about how transit infrastructure affects industrial production in the area.
The pre-test analyses necessitated the choice of technique used for this study. Panel A of Table 6 indicates significant findings regarding the effects of various factors on industrial productivity in the long run. Transport road networks and gross capital formation exhibited positive impacts on industrial productivity. Specifically, they both demonstrated a statistically significant effect (lnTRN = 0.7879, t = 2.31, $p < 0.05$; lnGCF = 0.1645, t = 1.68, $p < 0.10$), suggesting that these factors are significant drivers of changes in industrial sector productivity in the ECOWAS region.

The result of the second objective is presented in Table 7. It is evident that transport-induced labour accessibility, gross capital formation, and defence spending exhibited positive impacts on industrial sector productivity, while only transport-induced labour accessibility had a significant effect on industrial productivity in the long run (TILA = 1997.468, t = 1279.16, $p < 0.05$). This suggests transport-induced labour accessibility is a significant factor influencing changes in industrial sector productivity in the long term.

In contrast, credit to the private sector demonstrated negative and insignificant effects on industrial productivity among ECOWAS countries in the long run. (CRED = -0.0003, t = -0.36, $p > 0.05$). Also, gross capital formation and defence budgets demonstrated insignificant effects on industrial sector productivity. This implies that while these factors are included in the model, they do not significantly contribute to changes in industrial productivity in the long term. Moreover, the estimated coefficients reveal the magnitudes of these effects: A unit increase in transport-induced labour accessibility and defence spending will lead to an

increase of about 199.75% and 0.4% increases respectively in industrial productivity. However, a percentage increase in gross capital formation corresponds to a positive change of 119.86% increase in industrial productivity. Conversely, a unit increase in credit to the private sector leads to a decrease of 0.03% in industrial productivity in the long run.

Table 7: *Effects of Transport-induced Labour Accessibility on Industrial Sector Productivity in the ECOWAS Region*

Dependent variable: $INDVA$				
Panel A: Long-run Estimates				
Variable	Coefficient	Std. Error	t-Stat	Probability
$TILA$	1997.46***	1.5616	1279.16	0.000
GCF	119.86	107.887	1.11	0.267
$CRED$	-0.0003	0.0009	-0.36	0.720
DB	0.0040	0.0058	0.70	0.482
Panel B: Short-run Estimates				
$\Delta INDVA$	0.0007**	0.0003	2. 09	0.037
$\Delta TILA$	1996.13***	1.5310	1303.78	0.000
ΔGCF	119.87	107.81	1.11	0.266
$\Delta CRED$	-0.0003	0.0009	-0.36	0.719
ΔDB	0.0041	0.0058	0.71	0.480
ECM_{t-1}	-0.9993 ***	0.0003	-3123.78	0.000
Panel C: Diagnostic test		**Statistic**	**Prob**	
RMSE		0.02	0.0000	

Note: ***, **, and * represents statistical significance at 1%, 5%, and 10%, respectively.
Source: Author's computation.

From the short-run estimates, gross capital formation and defence spending continued to exhibit a positive impact but an insignificant effect on industrial productivity, while transport-induced labour accessibility had a positive and significant effect on industrial sector productivity in the ECOWAS region (TILA = 1996.132, t = 1303.78, $p < 0.05$). Conversely, credit to the private sector had a negative and insignificant effect on industrial sector productivity in the short run (CRED = -0.0003, t = -0.36, $p > 0.05$). This consistency in relationships across both short-run and long-run periods suggests robustness in the model's findings.

In addition, the estimated coefficient of the error correction term (ECM_{t-1}) was negative and statistically significant at the 1% level (ECM_{t-1} = -0.9993, t = -3123.78, p < 0.01). This indicates that deviations from the equilibrium path of industrial sector productivity were corrected by approximately 99% within the following year. Hence, the adjustment process for industrial sector productivity in ECOWAS was rapid during the period from 1975 to 2022. Furthermore, the statistical significance of the error correction term coefficient affirms the presence of a long-run equilibrium relationship in the model estimated for transport-induced labour accessibility and industrial sector productivity, aligning with the findings from the cointegration tests reported in Table 5.

The estimated model's root mean square error (RMSE) was 0.02. This low RMSE score suggests that the estimated model fits the data precisely, supporting the validity of its conclusions on how labour accessibility caused by transportation affects productivity in the region's industrial sector.

The result for the third objective is presented in Table 8. The causal relationship analysis between total road network, transport-induced labour accessibility, and industrial sector productivity in ECOWAS utilized the Dumitrescu and Hurlin (2012) panel causality test.

Table 8: *Direction of Causality among Total Road Network, Transport-induced Labour Accessibility, and Industrial Sector Productivity in the ECOWAS Region*

	W-stat	Prob	Remarks
A: Transport Road Network and Industrial Sector Productivity			
$TRN \nRightarrow INDVA$	3.7902***	0.0033	
$INDVA \nRightarrow TRN$	3.1464	0.0692	Uni-directional causality
B: Transport-Induced Labour Accessibility and Industrial Sector Productivity			
$TILA \nRightarrow INDVA$	4.3697***	0.0000	
$INDVA \nRightarrow TILA$	5.2398***	0.0000	Bidirectional causality
C: Transport-Induced Labour Accessibility and Transport Road Networks			
$TILA \nRightarrow TRN$	9.9286***	0.0000	
$TRN \nRightarrow TILA$	1.4797	0.2749	Uni-directional causality

Notes: *** and ** represents statistical significance at 1% and 5%, respectively.
$\nRightarrow$ represents homogenously Granger causes
Source: Author's computation.

The findings indicate several significant causal relationships: a bidirectional causation between transport-induced labour accessibility and industrial sector productivity; a unidirectional causality from total road network to industrial sector productivity; and Transport-induced labour accessibility unidirectional causality towards total road network in the ECOWAS region. These results underscore complex interrelationships among total road network, labour accessibility, and industrial sector productivity within the ECOWAS region, providing insights into the dynamic interactions shaping economic development in the region.

5.0 Discussion of Results

Based on the results, the productivity of the industrial sector was positively impacted and significantly affected by the entire road network and gross capital formation, while credit to the private sector exhibited negative and insignificant effects on industrial productivity in the ECOWAS region. The results imply that while transportation road network, gross capital formation, defence budget and labour force participation rate are determinants of positive changes in industrial sector productivity, credit to the private sector undermined the productivity of the industrial sector in the region in the short-run and long-run periods.

This is in line with studies conducted by Sun (2018), Antile (2003), Chukwuebuka and Jisike (2020), and Andreas (2003) which found that road transport infrastructure has demonstrated beneficial and significant effects on industrial productivity in several developed and developing countries. Other studies, on the other hand, admitted that road network and infrastructure development have contributed insignificantly to the expansion of the industrial sectors in developing countries (Nadabo, 2023; Azolibe and Okonkwo, 2020; Akekere et al., 2017; Stephen, 2017; Ogwo and Agu, 2016; and Mesagan and Ezeji, 2016).

Both short- and long-term assessments revealed favourable and significant effects of worker accessibility caused by transportation on industrial sector productivity. On the other hand, in both the short and long terms, credit to the private sector had negative and insignificant effects on industrial sector productivity. The results imply that while transport-induced labour accessibility is a significant determinant of positive changes in industrial sector productivity, credit to the private sector caused a decline in the productivity of the sector in ECOWAS countries in the short-run and long-run periods. These findings suggest

that labour accessibility serves as one of the significant tools that determine the productivity of the industrial sector in ECOWAS. This result is in line with the findings from Jae (2019), Castañeda and Shemesh (2000), Stephen et al. (2019), and Na et al. (2011).

Notably, this study is unique in its comprehensive examination of the relationship between total road networks, transport-induced labour accessibility, and industrial sector productivity from the establishment of ECOWAS in 1975 to 2022, potentially contributing to the divergence in findings compared to existing literature.

6.0 Conclusion and Recommendations

Based on the empirical results of this investigation, some conclusions were drawn regarding the state of transport infrastructure and its impact on industrial sector productivity in ECOWAS countries. It was observed that transport-induced labour accessibility is poor, which implies that there is limited road connectivity within and between ECOWAS countries. This restricts the free movement of labour and goods in the region. Poor-quality roads significantly extend commute times, decreasing productivity and negatively impacting workers' quality of life and job satisfaction. However, the study also concluded that transport-induced labour accessibility can undermine the potential growth capacity of the industrial sector because of inaccessibility of skilled labour to industrial sector productivity.

Since total road network and transport-induced labour accessibility are contributing factors to industrial sector productivity, the study proposes the following recommendations. ECOWAS leaders should:

- Upgrade the existing road networks to meet international standards, focusing on durability and capacity to handle increased traffic.
- Develop and modernize border posts with advanced facilities to improve efficiency in customs and immigration processes.
- Establish logistics hubs near borders to facilitate the efficient movement of goods and people across borders.
- Standardize customs procedures and harmonize tariffs across ECOWAS member states to simplify cross-border trade.

- Implement uniform transport policies and regulations to ensure smooth transit of vehicles across borders.

Furthermore, to mitigate transport-induced labour accessibility challenges, the governments of ECOWAS countries should:

- Provide subsidies for public transport to enhance affordability and accessibility for workers, enabling them to commute to job locations despite poor road conditions.
- Prioritize quick-fix road improvements on critical sections of the network, especially routes leading to major employment centres.
- Collaborate with private sector entities to develop transportation infrastructure and services, such as company-run shuttle services for employees.

In addition, to promote bi-directional causality between industrial sector productivity and road network development, governments of ECOWAS member nations should: facilitate access to funds through monetary institutions to encourage investment in productive activities within the industrial sector, thereby fostering beneficial outcomes for the transport industry.

These recommendations are aimed at addressing the identified challenges and capitalising on opportunities to enhance the transport road network and improve industrial sector productivity across the ECOWAS region. By implementing these measures, policymakers can foster economic activities with a view to enhancing the transport road network and raising industrial sector productivity throughout ECOWAS member nations.

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Impact of Electricity Consumption and Renewable Energy on Digital Economy in Nigeria

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Abstract
The world's progress is overwhelmingly dependent on digital economy because it is critical to economic development. This study is therefore motivated by the need to advance digital economy, instead of economic growth that has been extensively researched. It specifically investigated the long-run and dynamic interaction between electricity consumption and the digital economy, as well as the impact of renewable energy on the digital economy in Nigeria. It employed the Johansen co-integration approach for the period 1990 to 2022. The main findings revealed that there are long-run positive and significant connections between the explanatory variables – electricity consumption, renewable energy consumption, and per capita income – and the digital economy in Nigeria. It also found that 23.6% deviation from the long-run equilibrium in digital economy is corrected for annually. Therefore, for Nigeria's government to promote digital economy, there is urgent need to encourage renewable energy and electricity consumption through effective fiscal policies tools.

Keywords: Digital economy, Electricity demand, Renewable energy, Regression
JEL classification: O33, Q30, Q40, C13

1.0 Introduction

The inefficiency of the energy sector and weak technological advancement after the pandemic years have attracted enormous interest, especially in a number of emerging economies. Both energy and the digital economy are not only critical for the smooth functioning of the economy, but also crucial to technological development. Perhaps this is the reason why many countries of the world are now emphasizing non-renewable (electricity) energy efficiency and renewable energy consumption (Cozzi et al. 2024), as these energies can aid the achievement of economic development (Nkansa et al. 2022).

In the same vein, digital economy plays a big role in bringing about enormous opportunities for innovation and job creation. In fact, no nation can achieve economic development where digitalization of businesses and economic processes is weak. Digital economy has also been identified as an important enabler of connectivity, access to economic activities and public services (Dong et al., 2024; Zhang et al., 2024). However, the percentage of individuals using the internet in Nigeria merely increased from 51.4% in 2020 to about 55.4% in 2021; while the proportion of Ghanaians with access to internet service rose from 56.6% to 68.2% during the same period (World Bank, 2024). For South Africa, it increased from 70.3% in 2020 to 72.3% in 2021. This further suggests that Nigeria's digital inclusion is unimpressive.

Several studies have observed that economic development will decline without electricity and renewable energies, as they are an indispensable source of advancement in terms of real consumption and production (Peprah, 2022; Phillippi et al., 2022). Electricity is fundamental to powering devices such as production tools, equipment and technologies (Babatunde et al., 2023). These not only safeguard human health and welfare, but also boost economic productivity. Yet only 59.5% of Nigerians have access to electricity and Nigeria's total renewable energy capacity was 2.16 megawatts in 2022 (World Bank, 2024). These are low compared to South Africa where 89% had access to efficient electricity and also produced 10,623 megawatts renewable energy in the same period.

Wang, Wang and Li (2023) propose that energy reform could improve economic progress especially in emerging nations. This is important because energy is consumed for commercial, industrial, and economic purposes. This could also have far-reaching implications for digital economy in Nigeria. Therefore, for appropriate policies, the research questions that arise based on the experience of Nigeria are:

1. What is the impact of electricity consumption and renewable energy on digital economy in Nigeria?
2. Are there long-run relationships among the variables?

This study thus estimated the long-run interaction between electricity consumption, renewable energy and digital economy in Nigeria.

The research is structured as follows: section 1 focuses on a general introduction, then section 2 provides a review of the literature. The research methodology is

presented in section 3. Section 4 focuses on the estimations, and section 5 concludes with recommendations.

2.0 Literature Review

Electricity consumption is the amount of electricity required by economic agents – consumers, producers, and government – over the course of a year (Inglesi, 2010). This is measured in watt-hours (Wh). It is also the total amount of electrical energy used by firms and households over a specific period. It therefor implies that electricity is consumed for industrial, residential, and commercial purposes. However, the concept of renewable energy is energy derived from a natural source with the potential to be replenished at a higher rate than it is consumed (Puertas & Marti, 2022). It includes solar power, wind power, bioenergy, and hydroelectric power.

On the other hand, digital economy refers to economic activities that emerge from connecting individuals, enterprises, devices, data and operations through digital tools. It means leaving the traditional economic system that is more prevalent in developing nations. This transition should be in favour of efficient internet access and connectivity (Lange, Pohl & Santarius, 2020). It is also described as a group of commercial and economic endeavours that make use of electronic and digital technologies. Thus, its activities include: e-digital marketing, commerce, digital financial services, and software.

Theoretically, the energy ladder theory explains how economic progress is linked to access to clean energy (Paunio, 2018). The theory emerged with the fuel-wood crisis experienced in the 1970s and 1980s, and maintained that changes in energy-use and the consumption patterns of households in accordance with their variations in economic status can predict advancement. It further argued that as the income of households rise, they will consume different types of energy sources and use digital technologies. It claimed that to guarantee digitalization of the economy, there would be a need to implement projects in the area of renewable energy, such as solar and wind, as well as to take regulatory measures to improve electricity energy consumption (IEA, 2020; Puertas & Marti, 2022). The basic premise of the theory is that, as nations have better access to electricity and renewable energies, people will move away from biomass into cleaner technologies. This way, the digital economy will improve (Paunio, 2018; Wang et al., 2023).

However, numerous empirical studies have been carried out with focus on the impact of energy on economic growth. For example, Rahman et al., (2022)

examined whether energy consumption and human capital play important roles in economic growth. The findings from the panel regression showed that all the variables contribute positively to economic growth. In Nigeria, Salisu and Moronkeji (2022) estimated the impact of electricity consumption on manufacturing output from 1980 and 2021. The ARDL result of the study revealed that in the long-run, labour, capital and electricity consumption are the only variables that determine manufacturing output in Nigeria. Liu and Feng (2023) studied the effects of energy laws that stimulate renewable energy-based electricity generation in 129 nations. The results from panel estimations show that renewable energy technologies contribute to economic growth and job creation.

Candra et al. (2023) utilized structural vector autoregressive (SVAR) to compare the effects of renewable energy on economic growth in middle- and high-income nations. The findings show that renewable energy has positive economic effects. Mostefaoui et al. (2024) assessed the effects of greenhouse gas emissions and found a significant negative impact on economic growth. Cozzi et al. (2024) sought in their analyses to establish whether clean energy boosts economic growth. They found that clean energy accounted for 10% of global GDP growth in 2023.

Another group of studies explored the effects of digital economy on energy. Chao et al. (2023) found that digital technologies made the energy market smarter and more efficient in China. Zhang and Wong (2024) assessed the impact of digital economy on renewable energy also in China. Based on the panel data of 31 provinces, the study found a positive association between digital economy and renewable energy. Dong et al. (2024) explored the links between digital economy and energy vulnerability for 110 economies using the generalized method of moments (GMM) model. Their findings show that digital economy effectively reduces energy vulnerability.

The third set of empirical evidence considered progress in ICT to drive digital economy by energy. Kim and Tang (2020) investigated whether renewable energy policy promotes technological designs in the United States. The study utilized panel data from 50 states between 1997 and 2016, and found that renewable energy did not have a statistically significant impact on digital technologies. However, Hillie et al. (2020) with policy and patent data for 194 countries assessed how renewable energy affects innovation in technologies. The

study covered the period 1990 to 2016; and also found that renewable energy increases digital technologies.

Chen, Cui and Jiang (2022) assessed the effect of electricity generation mix and wholesale price on social welfare from five Southern Chinese provinces. The study found that the Chinese's welfare and technologies improved as electricity wholesale prices reduced. Chen and Yue (2023) estimated the impact of urban energy saving construction on green innovation in Chinese cities. The findings from quasi-natural research showed that renewable energy improves innovation efficiency. Lee and Wang (2024), who applied panel techniques on 280 Chinese cities from 2003 to 2019, found that renewable energy policy is positively related to energy transition and technology significantly.

However, the foregoing review of literature indicates that the true effect of energies on digital economy has not been sufficiently estimated. In fact, evidences from developing nations are completely missing. Furthermore, the combined impact of electricity consumption and renewable energy on digital economy has apparently not been examined. These are key literature gaps from existing studies that motivated this study.

3.0 Research Methodology

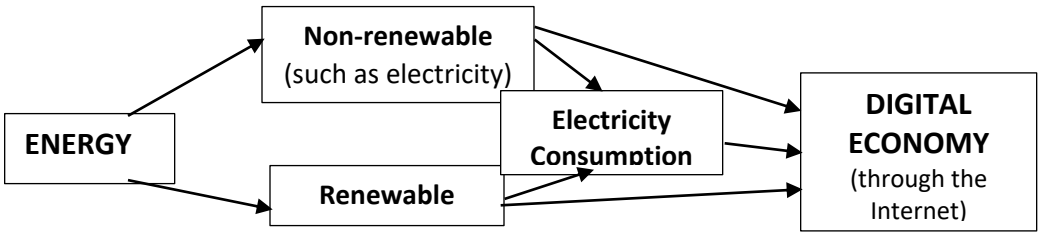
3.1 Theoretical construct

No clear-cut generalizations can be made from the existing knowledge about the impact of energy (electricity and renewable) on digital economy. Some affirm that energy is a precondition for internet connectivity and proficient digital output (Gao et al., 2023) whereas Fridstron (2023) is of the view that technologies and digital economy require a huge amount of energy, particularly electricity, in order to function.

However, others attest to negative effects of energy on digital economy, for example, energy emissions, particularly from non-renewable energy, trap radiation from solar and warm the earth's surface. The warmer temperatures over time, also spur heat to increase, which greatly affects digital functionality, as well as causes aerial cables to soften reducing internet speed. This implies that intense solar radiation and sunlight interfere with satellite signals which cause service disruptions and reduce the efficiency of digital consumption and production activities.

Within this context, this study constructed the analytical model. Figure 1 illustrates the implications of energy on the digital economy. That is, both non-renewable and renewable energies could possibly predict digital economic activities. In fact, renewable energy has the potential to cause equipment, tools and devices to experience overheating, and then intermittent connectivity issues or total hardware failure. Thus, renewable energy can affect the consistency of wireless signals and reduce digital efficiency as indicated in Figure 1.

Figure 1. *Energy-Digital Economy Implications*



Source: Author's initiative 2024.

The flow of pointer impact from electricity to digital economy is also demonstrated in Figure 1. This indicates that to achieve digital progress, the Internet needs to function properly, and must be connected to power supply or the electricity source (Yu et al., 2023). Power failure will cause electronic devices (routers and optical network terminals) to reboot or totally shut down. By implication, this will lead to connectivity loss, and amassed frustration during online economic activities which affects economic productivity adversely (Gao et al., 2023). Thus, without reliable electricity access, digital economy will fail or underperform.

The flow path of directional impact from renewable energy to digital economy as Figure 1 also indicates advocates that this energy is vital to achieving digital economy through internet sustainability. This is because internet servers and devices require huge amounts of energy to operate optimally. Ideally, however, positive connections are expected from both renewable and non-renewable energies on digital economy.

3.2 Model and description of data

The model for this study is adapted from the energy ladder theory that posits that electricity and renewable energy consumption mimic the orthodox neoclassical theory of consumer behaviour. It was also specified based on the depiction of

Zhang and Wong (2024). However, this model differs from the aforesaid in that it accounts for the long-run impact of both as major determining factors of digital economy. Insight from the energy ladder theory suggests that people will consume cleaner energy as their income increases, and this will improve economic progress. This implies that to enhance digital economy, access to energy is key and specified as:

$$DE_t = f(E_t) \quad (1)$$

where: DE_t represents digital economy, E_t denotes access to energy for consumption and production activities, and t is the time period.

Equation (1) is also informed by Sustainable Development Goal 7 (SDG 7) that emphasizes affordable, reliable, sustainable and modern energy for all by 2030 globally. Since energy can be non-renewable (electricity) or renewable, equation (1) is modified as:

$$DE_t = f(ENC_t, REC_t, CV_t) \quad (2)$$

where: ENC_t is electricity net consumption, REC_t denotes renewable energy consumption, and CV_t is the control variable.

This study considered per capita income (PCI) for CV_t because it represents a stable and efficient macroeconomic environment and development policies that predict the welfare of individuals and the digital economy. In terms of econometric forms, equation (2) is further modified as:

$$DE_t = \alpha + \beta_1 ENC_t + \beta_2 REC_t + \beta_3 PCI_t + \varepsilon_t \quad (3)$$

By converting all variables in equation (3) into the natural logarithm, the model is:

$$InDE_t = \alpha + \beta_1 InENC_t + \beta_2 InREC_t + \beta_3 InPCI_t + \varepsilon_t \quad (4)$$

The description of the variables is presented in Table 1.

Table 1. *Variables and Their Characteristics*

Variables	Definition	Source
DE	Digital economy (DE) is the economy in which technologies are used in economic activities. In this study, DE was proxied by % of Nigerians using the internet. This study adopted this proxy because it is the % of individuals who have used the internet for economic and non-economic activities from any location in Nigeria in the last 12 months via mobile devices, computer,	International Telecommunication Union (ITU) World Telecommunication/ICT indicators Database

	personal digital assistants, etc. Several empirical studies, such as Song & Yuxin (2020), Wang & Li (2024) similarly proxied people with access to internet for digital economy in their studies.	
ENC	Electricity net consumption.	United States Energy Information Administration (EIA)
REC	Renewable energy consumption (% of total final energy consumption). It is the share of renewable energy in total final energy consumption. It is also a proxy for renewable energy.	World Bank database (World Bank, 2024)
PCI	Per capita GDP. This represents a stable and efficient macroeconomic environment and development policies that promote digital economy.	World Bank database (World Bank, 2024)

Source: Author's compilation (2024).

3.3 Estimation methods

The study used the Johansen and Juselius co-integration approach. The uniqueness of the procedure is that the order of integration must be I(1). Based on the importance of DE for developing economies, the approach would allow the study to measure the short- and long-run impact of explanatory variables on DE. Another merit of the approach is that its operations are better compared to the single-equation and alternative multivariate methods.

The short- and long-run dynamics from explanatory variables to DE are captured through the vector error correction model (VECM) which is expressed as:

$$\Delta InDE_{1t} = \beta_o + \sum_{i=1}^{p} \beta_{1i} \Delta InDE_{1,t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta InENC_{2,t-i} + \sum_{i=1}^{p} \beta_{3i} \Delta InREC_{3,t-i} + \sum_{i=1}^{p} \beta_{4i} \Delta InPCI_{4,t-1} + \theta ECT_{t-1} + \varepsilon_{it} \quad (5)$$

where: β_o denotes draft component, Δ is the first difference, ECT_{t-1} denotes the lagged residual term, ε_t is the white noise, and θ is the coefficients of ECT for short-run dynamics.

The study covered the period 1990 to 2022. In terms of *apriori* expectations, the study's explanatory and control variables are expected to expand digital economy in Nigeria.

4.0 Empirical Evidence (Results)

The summary statistics of the variables are presented in Table 2. The mean of Nigerians with access to internet (the proxy of digital economy) is merely 13.6%. This suggests that digital economy conditions are weak and as a result, investments and production in the economy will not be optimal. The highest percentage in the sample is 55%, which was recorded in 2021. This perhaps was as a result of the lockdown of traditional economic activities in Nigeria so as to curb the spread of the coronavirus (COVID-19) in 2020 and 2021. The average electricity net consumption was also low (US$18.13 billion). It also confirms that a larger proportion of Nigerians use electricity for both consumption and production activities.

Table 2. *Summary Statistics of Variables*

	DE	ENC	REC	PCI
Mean	13.631	18.130	84.771	1630.076
Median	5.545	19.000	84.630	1871.756
Maximum	55.36	32.000	88.680	3200.953
Minimum	0.000	0.000	80.640	494.129
Std. Dev.	18.017	8.926	2.383	810.791
Observations	33.000	33.000	33.000	33.000

Source: Author's computations (2024).

The mean of renewable energy demand (% of total final energy consumption) was 84.8%, and the average per capita income was US$1,630.08.

Table 3 shows the correlation matrix for the variables. A positive and high correlation was observed between electricity net consumption and digital economy in Nigeria. The same link was also seen from renewable energy consumption to digital economy. The findings suggest that as more Nigerians consume electricity and renewable energies, the digital economy expands.

Table 3. *Correlation Matrix (1990-2022)*

	DE	ENC	REC	PCI
DE	1.0000	0.8471	0.7258	0.5880
ENC	0.8471	1.0000	0.7749	0.7352
REC	0.7258	0.7749	1.0000	0.5013
PCI	0.5880	0.7352	0.5013	1.0000

Source: Author's computations (2024).

The results of the stationarity tests are shown in Table 4. With respect to the Phillips-Perron (PP) and the Augmented Dickey-Fuller (ADF) tests, the results for digital economy are -2.8143 and -3.2140 for ADF and PP respectively. These are less than the critical limit of 10%. All the variables exhibited stationarity at their first differences as shown in Table 4. The study therefore applied the Johansen-Juselius co-integration approach to estimate the long-run impacts.

Table 4. *Results of Stationarity Tests*

Variables	ADF		Phillips-Peron		Remark
	Level	1st Diff.	Level	1st Diff.	
ENC	-0.3722	-8.2663***	-0.8610	-9.4842***	I(1)
REC	-1.7006	-5.6212***	-1.7379	-5.6441***	I(1)
PCI	-1.5231	-4.6259**	-1.6685	-4.5447**	I(1)
DE	1.7796	-2.8143*	2.9522	-3.2140*	I(1)
Critical values	ADF test: 1% = -3.6616 5% = -2.9604 10% = -2.6191		Phillips-Peron: 1% = -3.6616 5% = -2.9604 10% = -2.6191		

Note: (***), (**) and (*) means significant at 1%, 5% level, and 10% level, respectively
Source: Author's computations (2024).

The findings of the co-integration test are presented in Table 5. Both the trace and maximum eigenvalue tests indicated that there is one co-integrating equation in the model at 0.05 level. The finding thus provides evidence of co-integration.

Table 5: *Johansen Co-integration Tests*

Unrestricted Co-integration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.7860	81.6482	69.8188	0.0042
At most 1	0.6206	47.7256	47.8561	0.0514
At most 2	0.4854	26.4005	29.7970	0.1172
At most 3	0.3582	11.7826	15.4947	0.1676
At most 4	0.0879	2.0251	3.8414	0.1547
Trace test indicates 1 co-integrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level				
Unrestricted Co-integration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.786033	33.92259	33.87687	0.0494
At most 1	0.62066	21.32512	27.58434	0.2571
At most 2	0.485443	14.61788	21.13162	0.3166
At most 3	0.358228	9.757492	14.2646	0.2283
At most 4	0.087944	2.025174	3.841466	0.1547
Max-Eigen test indicates 1 co-integrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level				

Source: Author's computations (2024).

The findings of the estimated long-run digital economy function are reported as:

$$InDE_t = -107.20 + 6.71ENC_t + 18.35REC_t + 0.95PCI_t \quad (6)$$

S.E.:	(23.32)	(0.36)	(5.11)	(0.95)
t-statistics:	(-4.59)	(18.33)	(3.58)	(4.21)
P-value:	(0.0001)	(0.0000)	(0.0016)	(0.0004)

Equation 6 is the result for long-run estimates. The findings show that electricity net consumption and renewable energy consumption have positive significant impact on digital economy at 1% level. Moreover, per capita income also has positive significant impact on digital economy in the long-run at 1% level. The result confirmed that Nigeria's digital economy relies on electricity consumption,

renewable energy, and per capita income in the long-run. These connections mean that government can enhance and promote digital economy by increasing access to electricity, encouraging both renewable and non-renewable energies consumption. These are in line with the findings of Lee and Wang (2024) who found a positive and significant impact of renewable energy policy for stimulating energy transition and technologies in China.

Table 6. *Short-run Results Estimates*

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
D(LDE(-1))	*0.4994****	*0.1454*	*3.4340*	*0.0032*
D(LENC)	*2.1536****	*0.5100*	*4.2231*	*0.0006*
D(LREC)	*6.0181**	*3.4236*	*1.7579*	*0.0968*
D(LPCI)	*0.4315***	*0.1763*	*2.4474*	*0.0255*
ECM(-1)	*-0.2360***	*0.1437*	*-1.6424*	*0.0189*
Intercept	*0.0425*	*0.0679*	*0.6258*	*0.5397*

R-squared = 0.6916
Adj. R-squared = 0.6009
F-statistics = 7.625
Durbin-Watson stat. = 2.0105
Prob. = 0.0006

Note: (***), (**) and (*) means significant at 1%, 5% level, and 10% level, respectively
Source: Author's computations (2024).

The short-run results are also shown in Table 6 where all the exogenous estimates have positive and significant impact on digital economy in Nigeria. The lagged DE has impact of current DE at 1% level. It provides strong support that achievements in previous digitalization of the economy will enhance the digital economy. The positive signs obtained for the coefficients of LENC, LREC and LPCI suggest that in the short-run, the digital economy would be efficient as expected, as these variables are increasing. The results are statistically significant. This implies that energies are preconditioned for proficient digital output. It also submits that digital economy requires a huge amount of energy in order to function effectively. These are in line with the findings of Chen and Yue (2023) who found a significant positive link between renewable energy and innovation efficiency in China.

It is expected that the error correction model (ECM) term should be negative and statistically significant to affirm the long-run and short-run links. The result shows that the ECM term of -0.236 is significant at 5% level. It means that the adjustment speed converging towards the long-run equilibrium is -0.236. Thus, 23.6% deviation from the long-run equilibrium in digital economy is corrected for annually.

The study also applied the diagnostics tests and the results are presented in Table 7. The tests are important to confirm the model's stability, serial and normality correlation, and heteroskedasticity. For this study, Godfrey serial correlation LM test and ARCH are employed to check the serial correlation of the residuals in the model, and the heteroskedasticity of the model respectively. CUSUM tests were used to test the study's model stability.

Table 7. *Diagnostic Test Results*

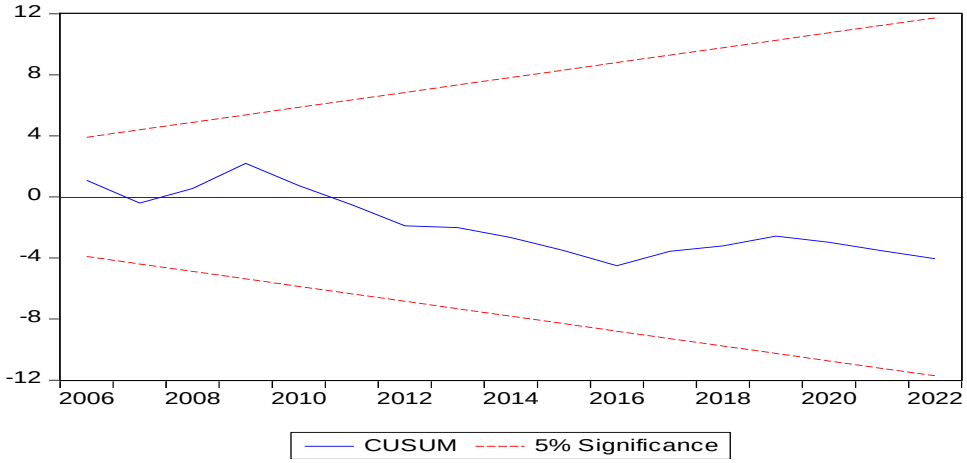
Test Statistics	F-statistics	Probability
Breusch-Godfrey LM test	2.3197	0.1325*
Heteroskedasticity (ARCH) test	0.1650	0.6891*
Linearity test	4.7913	0.0002***
CUSUM test	Stable	

Source: Author's computations (2024).

The Breusch-Godfrey LM test result has the F-statistics of 2.3197 with a probability value of 0.1325 as shown in Table 7. These results indicate that the model is free from serial correlation. Similarly the ARCH heteroskedasticity test has the F-statistics of 0.165 with significant probability value of 0.6891. This shows that there is absence of heteroskedasticity in the model.

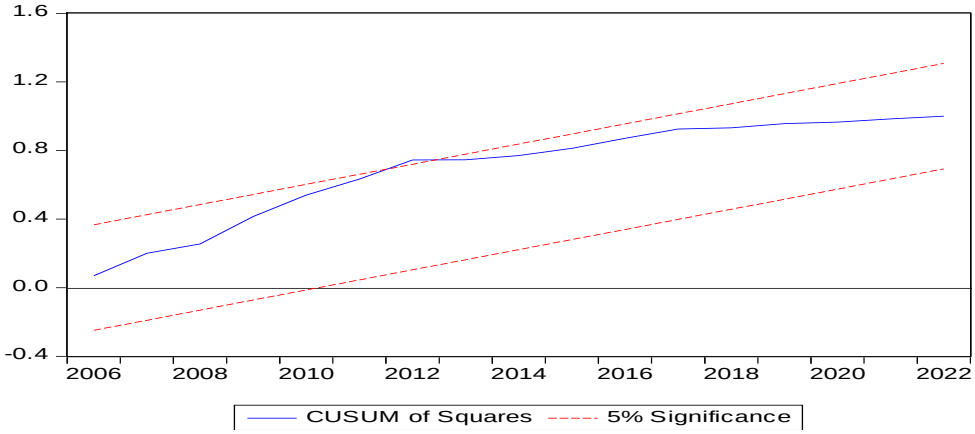
The Ramsey reset of the linearity test with significant probability of 0.0002 confirms that the model is linear. The study conducted a stability test using the recursive estimates cumulative sum tests (CUSUM test and CUSUM of square test) as shown in Figures 2 and 3 respectively. The tests in both figures further confirm that the long-run coefficients were stable between 1990 and 2022, the period covered by the study.

Figure 2. *Stability Test, Recursive Estimates CUSUM Test*



Source: Author's computations (2024).

Figure 3. *Stability Test, Recursive Estimates CUSUM Test*



Source: Author's computations (2024)

5.0 Conclusion and Policy Recommendations

This research focused on advancing digital economy in developing countries instead of economic growth that has been extensively researched. It specifically investigated the long-run and dynamic interaction between electricity consumption and digital economy, as well as the impact of renewable energy on digital economy in Nigeria. Unlike existing studies, it considered the impact of

electricity net consumption, renewable energy consumption, and per capita income in the study's model in order to articulate strategies to ensure a better economic landscape in Nigeria.

The main findings indicate that Nigeria's digital economy depends on energy, such as electricity and renewable energy as well as per capita income in the long-run. It found positive connections between these variables and digital economy in the short-run. Both long- and short-run findings reveal dynamic interaction between energy and digital economy and that energy is crucial to digital economy actualization in Nigeria.

In view of these findings, therefore, the study recommends that government increase access to electricity, encourage more renewable energy consumption, and improve the welfare of citizens through effective fiscal policies to enhance and promote digital economy in Nigeria.

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Dynamic Productivity of Nigerian Electricity Distribution Companies: The Biennial Malmquist Index Approach

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Abstract

Investment is encouraged when consistent productivity and profitability are guaranteed. The Nigerian Electricity Distribution Companies (DisCos) were privatized to guarantee their consistent productivity and profitability. However, since privatization, there appears to be neither a significant productivity improvement nor significant investment in the sector. This study consequently assessed the dynamic productivity of the DisCos using the Biennial Malmquist Productivity Index (BMPI). Relevant data from 2014-2021 was collected for this purpose. To ascertain the sources of productivity dynamics, the Wheelock and Wilson (1999) decomposition was used. The result showed that DisCos had no consistent productivity improvement and on average regressed by 1.1%. While pure efficiency change (PEC) had marginal positive impact of 0.06% on productivity dynamics/change, pure technical change (PTC) showed negative contribution to productivity change. The position of the firms on the technology set represented by scale technical change (STC) also contributed positively to the DisCos' productivity. The implication of this outcome is that the sector may not be able to attract meaningful investments as it stands. As a consequence, therefore, the following recommendations are made: (i) that other DisCos copy Abuja Electricity Distribution Company (AEDC)'s managerial expertise since the contribution came mainly from them. Continuous training *and retraining of management for optimality; (ii) that DisCos leverage on the technological environment to enhance productivity and (iii) since firm's position in the technological set favours expansion, DisCos' heavy investment in capital will improve their productivity.*

Keywords: Dynamic Productivity, Electricity Distribution Companies, Index, Optimization, Technological Change
JEL classification: D24, L94, C43, C61, O33

1.0 Introduction

For long, the electricity sector of most economies remained with the public sector for reasons such as welfarism, its capital-intensive nature, and populist political ideology. More recently however, states, especially developing ones like Nigeria, have begun to relinquish the power sector management to private institutions for reasons such as: (i) government bureaucracy, which is often said hampers its efficiency and productivity; (ii) inability of governments to make the needed investments into the sector because of competing needs (Bureau of Public Enterprise [BPE], 2018) and (iii) in some instances, assuaging the pressure from the Bretton Woods Institutions, particularly the International Monetary Fund (IMF) and World Bank, which always advocate a market-driven economy (Central Bank of Nigeria [CBN], 2021). For these reasons and following the global trend on private management of the electricity sector, the Nigerian electricity industry was privatized in 2013. As a consequence of the privatization, it was expected that the industry, especially the distribution sub-sector, would address the agelong yearnings of stakeholders such as power access, reliability of supply, reduction in energy, and collection losses of Electricity Distribution Companies (DisCos), among others.

Despite the fact that about 60% of the shareholding resides with the private sector since privatization, government has been lending support to the sector owing to its centrality to national development (Banwo & Ighodalo, n.d.). This support has come in the form of subsidy payment to close the gap between the cost reflective tariff and allowed tariff. Another form is the meter rollout which avails the DisCos loan facilities to meter customers. These interventions were aimed at stabilizing the nascent firms and improving their operational efficiency and productivity within a reasonable time frame. Despite the privatization and several governments' bailouts, it appears that the sector is yet to meet the yearnings of the stakeholders in terms of efficiency and productivity. For instance, among others, it has become a trend for customers to replace or fix their faulty distribution transformers and buy their own prepaid meters. Additionally, the DisCos' are unable to curb energy loss and break even in revenue collection to meet the market obligations and their investment needs.

The Association of Nigerian Electricity Distributors (ANED, 2021) reports that the total value of electricity received by all DisCos except Yola Electricity Distribution Company (YEDC) between July 2020 to June 2021 stood at 29,549 GWh while 22,545 GWh representing 76.3% was actually billed, leaving a loss of 23.7% in energy. Within the same period, the value of billed energy stood at 963 billion. Out of this amount, only ₦648 billion, representing 67.3% was collected, leaving a collection loss of 32.7%. By implication, the aggregate, technical, commercial and collection (ATC&C) loss stood at 48.7% [1- (billing efficiency*collection efficiency)]. This means that, close to half of the revenue that could have accrued to the sub-sector was actually lost within the one-year period.

Faced with these statistics, a few authors in Nigeria have attempted to assess the efficiency and productivity of the electricity distribution sub-sector. Olayemi et al. (2022) used the Data Envelopment Analysis (DEA) approach to estimate the technical efficiency of the eleven DisCos but regrettably, a methodological gap of not accounting for stochastic error arose. In a bid to address this gap, Olayemi et al. (2024) used the same methodology but applied the bootstrapping technique to account for the statistical error. Their results show that the DisCos have not been technically efficient since they were privatized. While these authors focused on efficiency, Olayemi and Bernard (2024) approached the topic from the productivity perspective, using two DisCos as samples – Ibadan Electricity Distribution Companies (IBEDC) and Kano Electricity Distribution Companies (KEDCO) – and deploying the DEA-based Biennial Malmquist Productivity Index (BMPI) approach. To account for the sources of productivity dynamics, Ray and Desli's (1997) 3-part decomposition was applied to disaggregate the productivity index into its component sources.

While efficiency and productivity are often interchangeably used, the two concepts differ (Ohene-Asare, 2020). It is possible for a firm to be efficient and yet stagnate without positive productivity improvement (Wheelock & Wilson, 1999) giving it a false sense of accomplishment. Conversely, a firm may not be optimal in the use of resources, yet, it may be making steady progress towards the frontier (Ohene-Asare, 2020). Though going by previous studies (Olayemi, et al., 2022), the Nigerian DisCos are not technically efficient, they may, however, be making steady progress in terms of productivity. Where they are actually making progress, and the effort is not recognized, the firms' morale may be dampened and hence, performance may deteriorate further. Besides, the sector is not likely to

attract the much-needed investments without evidence of consistent productivity growth.

It is on the basis of this, therefore, that this study set out to assess the DisCos' productivity dynamics from 2014-2021 using the Pastor, Asmild, and Lovell (2011) Biennial Malmquist Productivity Index (BMPI), given its ability to resolve the infeasibility problem associated with other approaches, such as the Pastor and Lovell (2005) Global Malmquist Index. It also compares the take-off year, 2014 with 2019, the licence window, and 2014 with 2021, the terminating year of this research, which was chosen based on data availability. In addition, this study also seeks to identify the sources of productivity dynamics/change based on the Wheelock and Wilson (1999) 4-part decomposition. The rest of this study is presented as follows: literature review in section 2, methodology in section 3, presentation and analysis of results in section 4, and the conclusion and recommendations in section 5.

2.0 Literature Review

2.1 Conceptual review

Productivity is the ratio of output to input; a measure of performance over a period of time; it is dynamic, that is, it measures performance change between two time periods (Ohene-Asare, 2020). Productivity is more about the quantity of product and not necessarily the quantity of resources used. The approach can be input or output oriented. This study adopts the input orientation, because the demand for electricity is externally determined (Lee et al., 2021), that is, not controlled by the DisCos.

Efficiency, however, entails resources optimization; that is, achieving the maximum level of output from a committed level of input resources (output-orientation) or committing least quantity of resources to producing a fixed amount of output (input orientation). It measures performance at a point in time, that is, it is time invariant (Ohene-Asare, 2020).

Electricity Distribution Companies (DisCos) are the third layer of the electricity industry. Electricity is generated and then transmitted at high voltages in a form inappropriate for end users. The energy received at distribution substations is

stepped down from 33 kilovolts (kv) to either 11kv or 0.415kv to serve different customer categories. Table 1 shows the list of the eleven DisCos in Nigeria.

Decision Making Units (DMUs). These are entities whose efficiency or productivity is being assessed. In this case, the DMUs are the eleven DisCos whose productivities are being measured. For any entity to qualify as a DMU, their inputs and outputs must be identical to the other DMUs in the study (Charnes, Cooper, and Rhodes, 1978).

Table 1. *Electricity Distribution Companies in Nigeria*

S/N	DisCos
1	Abuja Electricity Distribution Company (AEDC)
2	Jos Electricity Distribution Company (JEDC)
3	Kaduna Electricity Distribution Company (KAEDCO)
4	Kano Electricity Distribution Company (KEDCO)
5	Yola Electricity Distribution Company (YEDC)
6	Benin Electricity Distribution Company (BEDC)
7	Eko Electricity Distribution Company (EKDC)
8	Enugu Electricity Distribution Company (EEDC)
9	Ibadan Electricity Distribution Company (IBEDC)
10	Ikeja Electricity Distribution Company (IKEDC)
11	Portharcourt Electricity Distribution Company (PHEDC)

Source: NERC, 2023.

2.2 Theoretical review

2.2.1 *Resource-based Theory of the Growth of the Firm (Penrose, 1959)*

Penrose advanced a model on the strategic and effective management of firms' resources and productive opportunities. This theory assumes that firms' resources are heterogeneous, that is, they possess unique resources in a specific situation, which can give them an edge over their competitors and that these resources are immobile thereby creating persistent differential in resources among the rival firms. The theory asserts that the firm embodies an assortment of resources and capabilities. While resources encompass tangible components, such as property, plant and equipment, capabilities are the non-tangible components such as organizational processes, human capital, patent, and technical expertise that are developed over time and cannot be easily bought (Teece et al., 1997). The firms that blend both resources and capabilities most efficiently will outsmart the performance of rival firms. Impliedly, firms can attain productivity improvement not just by better resources but by a perfect blend between resources and capabilities (Kaleka, 2002).

2.2.2 *Extreme Point Theorem*

The extreme point theorem is the basis of the Farrell (1957) methodology which birthed Data Envelopment Analysis (DEA), the non-parametric approach to efficiency and productivity assessment. The theorem is based on production frontier boundary. According to the theorem, the achievable or optimal solution of a Linear Programming Problem (LPP) is located on the boundary or the convex combination of the extreme or corner points. The efficiency and productivity of points not located on the frontier can therefore be measured against points on the boundary.

2.2.3 *Endogenous Growth Theory (Romer, 1986)*

This theory holds that growth is from within and not external, hence, it is driven by individuals' desires and wants. It emphasizes that there is no end to growth/productivity if an endogenous force like knowledge spillover, human capital, and information technology are allowed to thrive. As a consequence, per capita output rises continuously because individuals crave profits. Where there is a decline in earnings, labour strives for a better way to work to sustain their

income and in the process, the organization's growth becomes perpetual too. It views novel technologies and innovations as a result of the concerted efforts of the seekers and not a coincidence. It views knowledge as an intangible asset, which is neither constrained nor declines as land and capital do, but which propels organizational growth from within. Individuals are self-driven to innovate where resources and opportunities really abound. Working along the same line, Aghion and Howitt (1992) implied that technical progress occasioned by the research activities of competing firms also brings about growth/productivity. In the same spirit, Medda and Piga (2014) showed that technical spill-over propelled productivity change of manufacturing firms in Italy. Given that this study is based on a non-parametric frontier approach, and its emphasis on the sources of productivity growth, it is therefore situated within both the extreme point theorem and the endogenous growth theory.

2.3 Empirical review

The new growth theory assigned a significant role to technology and innovation in productivity dynamics. As a consequence, the literature has tried to authenticate this role. For instance, Tengey et al. (2022) explored the productivity dynamics of electricity regions (EDRs) in Ghana using the Biennial Malmquist Productivity Index (BMPI) approach within the slack-based model. Data between 2012 and 2018 were used for the analysis. The index was decomposed into efficiency change (EC), technical change (TC), and scale change (SC) to account for change drivers. The BMPI result showed that the firms progressed yearly by 16.23% within the period. However, TC was found to be responsible for the growth. Cambini et al. (2014) also had a similar result, where productivity change was mainly driven by TC. Other works, however, did not find that TC had a positive role on productivity dynamics. Such works include Mirza et al. (2021) which assessed the impact of the Service Quality Parameters (SQPs) on Pakistan's electricity distribution sector's total factor productivity (TFP) in the post-reform era. Data was collected on relevant variables from 2006-2016 and analysed using the stochastic frontier analysis approach. A three-factor decomposition of the TFP via the Malmquist Productivity Index into SC, TC and EC was also done. The results indicate that SC had a negative trend on TFP, hence, companies were operating at sub-optimal scale size.

In a related study, Marinho and Resende (2019) embarked on a dynamic analysis for service quality among Brazilian electricity distribution firms between 2010 and 2014 using the DEA-based Malmquist index. The result showed only 21.4% of all

cases had service quality improvement. On applying the Malmquist index decomposition, TC did not have a positive impact, but the result suggested that EC had a dominant impact on the Malmquist index. Fallahi et al. (2021) estimated the efficiency and productivity change of 39 Iranian electricity distribution firms between 2005 and 2014 using a robust data envelopment analysis model. The result showed a slight productivity growth driven mainly by efficiency change rather than technical change. Cambini et al. (2014) also had a similar conclusion. Outside the electricity industry, other works have also tried to account for the sources of productivity growth. For example Deb and Ray (2014) did a comparative analysis of the pre- and post-reform TFP growth of manufacturing firms among Indian states from 1970/71 to 2007/08 using the Biennial Malmquist Index. The result showed that faster growth was recorded post-reform than pre-reform in most of the states. In addition, technical improvement became the key component of the change both at the pre- and post-reforms. Jreisat et al. (2018) evaluated the TFP of fourteen Egyptian banks between 1997 and 2013 using the input-oriented Malmquist Index. The TFP were disaggregated into technical change (frontier shift) and efficiency change (catch-up). The result showed that TFP declined by 0.9% yearly; the retrogression was due to the negative impact of technical change.

In Nigeria, very few works have been done on the industry using this approach. These include the study by Olayemi and Bernard (2024) who used the Biennial Malmquist Productivity Index to estimate the productivity growth of Nigerian electricity distribution firms between 2014 and 2020, using two DisCos as samples. They adopted the Ray and Desli three-part decomposition to account for the sources of productivity dynamics. The outcome showed a minor growth in productivity which was mainly driven by pure technical change (PTC), that is, through technology and innovation. Pure efficiency change (PEC) and scale change (SC), however, produced no positive effect. Also, Barros et al. (2014) assessed the productivity change in nine electricity generation companies in Nigeria between 2004 and 2008 using the Malmquist productivity index. The result showed that, productivity increased slightly within the period. Besides, both efficiency change (EC) and technical change (TC) drove the minor progress though the bulk was from TC, that is, a frontier shift rather than catching up to the frontier.

From the literature, it is clear that within the Nigerian context, very few works apply the approach used in this work within the electricity industry. While Olayemi

and Bernard embarked on a 3-part decomposition, accounting only for SC, TC and EC, they only used two DisCos as proxies for the subsector. Barros et al. (2014) on their part focused on generation and not distribution. No work, to our knowledge, has employed all the eleven DisCos in a productivity analysis. Besides, none has embarked on the Wheelock and Wilson (1999) 4-part decomposition which, in addition to TC, EC and scale efficiency change (SEC) of previous decompositions such as Ray and Desli (1997), accounts for the impact of firms' position on the technology set, that is, impact of scale technical change (STC) on their productivity.

3.0 Methodology

3.1 Source of data

Data for capital, labour and revenues were extracted from the DisCos' statutory financial statements and that of customer population was obtained from the Electricity Report for June 2022 of the National Bureau of Statistics (NBS, 2022). The data on energy delivered to customers and energy received from generation through transmission lines were extracted from the Nigerian Electricity Regulatory Commission (NERC, 2023). The electricity implicit price deflator figures between 2014-2021 were obtained from the Central Bank of Nigeria's Annual Statistical Bulletin's (CBN, 2023) and used to convert the nominal financial variables to their real terms based on 2018 base year. The data for all the variables were organized into a panel of eleven DisCos across the eight-year period, 2014-2021. Some DisCos, however, had some missing data namely: BEDC, 2020-2021; JEDC, 2019-2021; IBEDC, 2021; YEDC 2014-2017. This, however, was not a major challenge because the BMPI methodology used in this study does not treat the panel data as a pool but rather estimates each DMU at every time period. According to Pastor et al. (2011), a re-computation of indices would be unnecessary if additional time periods are added to the data set.

3.2 Data analysis technique

Productivity assessment begins with a simple input-output ratio which helps to estimate output per unit of input employed. This is a simplistic approach which does not reflect the real-life situation where multiple heterogenous inputs and or outputs are involved. The Stochastic Frontier Analysis (SFA), which is a parametric approach, partially addresses this, but its major limitation is its inability to concurrently incorporate multiple inputs and output. The Malmquist Productivity

Index (MPI), which is non-parametric DEA-based approach, resolves the SFA challenge. Since its inception, several variants of the MPI have emerged to address one specific gap or the other. These variants include: Adjacent index by Färe, Grosskopf, Lindgren and Roos (FGLR, 1992); Base period index by Berg et al. (1992); Sequential Malmquist index by Shestalova (2003); and Global Malmquist index (Pastor & Lovell, 2005). All these approaches are perfect when the nature of technology is constant returns to scale (CRS) but where the technology exhibits variable returns to scale (VRS), the problem of infeasibility arises under cross-period estimation. To resolve the infeasibility problem under VRS and when cross-period index estimation is involved, Pastor et al. (2011) introduced the DEA-based non-parametric Biennial Malmquist Productivity Index (BMPI) used in this study.

3.3 Biennial Malmquist Productivity Index technique

The DEA-based Malmquist Index assesses the productivity change of DMUs between two time periods. The Malmquist index benchmark (CRS) technology, which is defined as the convex combination of the two adjacent time periods being treated, has the general formulation for times *t and t+1* respectively of the form:

$$T_c^t = \{Min\ \theta_c(x,y)\epsilon R_+^{m+s} | x \leq \Sigma_{j=1}^n \lambda_j^t x_j^t, y \geq \Sigma_{j=1}^n \lambda_j^t y_j^t, \lambda_j^t \geq 0, j = 1, \dots n\} \qquad (1)$$

where: *c* denotes constant returns to scale (CRS) technology; $(x,y)\epsilon R_+^{m+s}|$ represents the vector of inputs *m* and output *s,* which are positive real numbers; the T_c^t= CRS technology at time t; (t=2014…, 2021). θ= productivity contraction factor (input-oriented technical efficiency score); λ_j^t= weight of firm *j* (the eleven DisCos) at time *t*; x_j^t and y_j^t represent the vectors of input and output of firm *j* at time *t* respectively. The technology of the subsequent period (T_c^{t+1}) is defined in the same manner as equation 1

The BMPI for DisCo *j* under CRS can therefore be stated in the form:

$$M_c^B(x_j^t, y_j^t, x_j^{t+1}, y_j^{t+1}) = \frac{\theta_c^B(x_j^t, y_j^t)}{\theta_c^B(x_j^{t+1}, y_j^{t+1})} \qquad (2)$$

The numerator of the right-hand side of equation 2 estimates the efficiency of the DMU in period t, in relation to CRS biennial frontier technology (θ_c^B); the

denominator measures the efficiency of DMU in subsequent, period t+1 against the biennial frontier (θ_c^B).

Unlike the standard MPI where the geometric mean of the two frontiers is required, biennial CRS technology incorporates the times t and t+1 technologies into its frontier and therefore the geometric mean is not required (Ohene-Asare, 2020).

To disentangle the influence of scale economy on the Malmquist index, we allow for variable returns to scale or best practice technology which is of the form:

$$T_v^t = \{Min\ \theta_v(x,y)\epsilon R_+^{m+s} | x \leq \Sigma_{j=1}^n \lambda_j^t x_j^t, \\ y \geq \Sigma_{j=1}^n \lambda_j^t y_j^t, \Sigma_{j=1}^n \lambda_j^t = 1, \lambda_j^t \geq 0, j = 1, \dots n\} \quad (3)$$

where: *v* = variable returns to scale, and T_v^t = variable returns to scale technology at time *t*. The technology of the subsequent period (T_v^{t+1}) is defined in the same manner as equation 3.

Note that the convexity constraint, $\Sigma_{j=1}^n \lambda_j^t = 1$ in equation 3, is what differentiates T_c^t from T_v^t.

The BMPI for DisCo *j* under VRS is further stated in the form:

$$M_v^B(x_j^t, y_j^t, x_j^{t+1}, y_j^{t+1}) = \frac{\theta_v^B(x_j^t, y_j^t)}{\theta_v^B(x_j^{t+1}, y_j^{t+1})} \quad (4)$$

The numerator of the right-hand side of the quotient of equation 4 estimates the technical efficiency of the DMU in the initial period *t* in relation to VRS biennial frontier technology (θ_v^B); the denominator measures the technical efficiency of DMU in succeeding period *t* +1, against the biennial frontier (θ_v^B).

3.4 Decomposition of the Malmquist Productivity Index within the biennial approach

The Malmquist Productivity Index (MPI) has been disaggregated into different components by different authors to account for contributors to firm productivity growth under different technologies — benchmark technology, which is

synonymous with CRS, and best practice technology, akin to VRS. These decompositions include: Färe et al. (FGLR, 1992) 2-factor decomposition; Färe, Grosskopf, Norris, and Zhang (FGNZ, 1994) 3-factor decomposition; Ray and Desli (1997) 3-part decomposition; and the 4-part decomposition by Wheelock and Wilson (1999). Of these decompositions, Wheelock and Wilson's is adapted in this study because, in addition to EC, TC, and SC as in FGNZ or SEC as in Ray and Desli, it is able to further decompose MPI to include scale technical change (STC)/scale bias. The STC concept stands as an entirely new concept which accounts for the role a DMU's position in the technology set plays in their overall productivity growth. Since all these approaches suffer from infeasibility when technology is VRS and when cross-period productivity is involved, the model is therefore situated within the biennial framework.

The biennial approach becomes ideal to address the infeasibility challenge while estimating cross-period efficiency under VRS using different decomposition approaches and also guarantees empirically suitable productivity scores where CRS is the case (Pastor et al., 2011). The BMPI frontier is constructed to envelop the contemporary production frontier (VRS^{t} and VRS^{t+1}) to form a meta-frontier technology known as biennial production technology, which allows computation of technical efficiency from both initial time, *t* and succeeding time t+1, relative to the biennial frontier. Pastor et al. (2011) stated the merits of this approach to include resolving the infeasibility challenge of earlier approaches and avoidance of re-computation of indices when another time period is introduced to the data set. The biennial frontier serves as a pooled data from both adjacent periods *t* and *t + 1*.

The Wheelock and Wilson (1999) decomposition within the biennial framework is thus presented:

$$M_c^{B(WW)} = PEC_v^B * PTC_v^B * SEC^B * STC^B \quad (5)$$

where:

$$M_c^{B(WW)} = \frac{\theta_v^t(x_j^t, y_j^t)}{\theta_v^{t+1}(x_j^{t+1}, y_j^{t+1})} * [\frac{\theta_v^{t+1}(x_j^{t+1}, y_j^{t+1})}{\theta_v^B(x_j^{t+1}, y_j^{t+1})} * \frac{\theta_v^B(x_j^t, y_j^t)}{\theta_v^t(x_j^t, y_j^t)}] * [\frac{\theta_v^{t+1}(x_j^{t+1}, y_j^{t+1})}{\theta_c^{t+1}(x_j^{t+1}, y_j^{t+1})} * \frac{\theta_c^t(x_j^t, y_j^t)}{\theta_v^t(x_j^t, y_j^t)}]$$

$$EC_v^B = BPEC \qquad TC_v^B = BPTC \qquad SEC^B = BSEC$$

$$*[\frac{\theta_v^B(x_j^{t+1},y_j^{t+1})/\theta_c^B(x_j^{t+1},y_j^{t+1})}{\theta_v^{t+1}(x_j^{t+1},y_j^{t+1})/\theta_c^{t+1}\left(x_j^t,y_j^t\right)} * \frac{\theta_v^t(x_j^t,y_j^t)/\theta_c^t(x_j^t,y_j^t)}{\theta_v^B(x_j^t,y_j^t)/\theta_c^B(x_j^t,y_j^t)}] \quad (6)$$

$$STC^B = BSTC$$

where: the PEC_v^B and PTC_v^B are respectively known as the catching up or movement towards own period frontier and frontier shift components. The EC_v^B measures the changes in the efficiency of a DMU over a period of time; the impact of changes in managerial acumen on productivity over time as well as appropriate allocation of available resources (Ohene-Asare & Turkson, 2018).

According to Färe et al. (1994), PTC_v^B measures the effect of change in production technology such as process or product innovation, which may influence productivity change over a time period; how firms have been able to leverage on technological environment to influence performance; this may either shift the frontier forward or backward. Scale efficiency change (SEC) measures the impact of change in the scale of operations on firms' productivity growth; it measures the impact of optimal or non-optimal scale of operations on productivity growth. Scale technological change (STC) also measures the impact of changes in the scale or shape (returns to scale frontier) of technology on productivity change; it represents the scale bias of PTC_v^B, that is, the geometric mean of two scale efficiency quotients — change in the scale of the technology from *t* to *t*+1 and change in the scale of the technology from *t* to *t*+1 relative to the location of the DMU in time *t* (Wheelock & Wilson ,1999).

Given their merits, the BMPI and the Wheelock and Wilson 4-part decomposition are blended and adapted in this study to estimate the productivity dynamics among the Nigerian DisCos. This is done by consecutively comparing two adjacent years from 2014 (the year of privatization take-off) till 2021, 2014 and 2019 (the licence window for DisCos), and 2014 and 2021 (the terminal year of this research). This, therefore, makes this work a dynamic measurement. The initial work of Pastor et al. (2011) was stated in terms of distance function (DF), which is the inverse of technical efficiency change, the reason being to ease interpretation of the result. Whereas, DF allows BMPI <1 equals progress, BMPI >1 equals regress; the technical efficiency change approach allows BMPI >1 equals progress while BMPI <1 equals regress. Also, the original work of Caves, Christensen, and Diewert (1982) was presented in an output orientation form, but this research is presented in an input orientation form because the demand for

electricity is said to be out of the firms' control but within the customers' purview (Lee et al., 2021). Thanassoulis (2001) however stated that the choice between both orientations is more theoretical than practical as their results are equivalent.

3.5 Decision criteria

In this study, where BMPI >1, progress is concluded from period *t* to period *t+1;* where BMPI <1 productivity decline is concluded, that is a regress from period *t* to period *t+1*. Where BMPI =1, stagnation is concluded, that is, zero productivity growth. The reverse, however, holds in the case of distance function.

3.6 Test of returns to scale in DEA space

Given the significance of a firm's returns to scale technology, CRS or VRS (Dyson, et al, 2001), the Simar and Wilson (2002) mean of ratio ($\hat{s}_1$) and ratio of mean ($\hat{s}_2$) and the Simar and Wilson (2011) mean of ratio ($\hat{S}_3$) techniques, which are based on bootstrapping methodology, as stated in equations 7-9, are employed in this work.

Simar and Wilson (2002)

$$\hat{S}_1 = n^{-1} \sum_{j=1}^{n} \left[\frac{\hat{\theta}_j^{CRS}(x,y)}{\hat{\theta}_j^{VRS}(x,y)} \right] \tag{7}$$

$$\hat{S}_2 = \left[\frac{\Sigma_{j=1}^{n} \hat{\theta}_j^{CRS}(x,y)}{\Sigma_{j=1}^{n} \hat{\theta}_j^{VRS}(x,y)} \right] \tag{8}$$

Simar and Wilson (2011)

$$\hat{S}_3 = n^{-1} \sum_{j=1}^{n} \left[\frac{\hat{\theta}_j^{CRS}(x,y)}{\hat{\theta}_j^{VRS}(x,y)} - 1 \right] \geq 0 \tag{9}$$

The hypotheses:

$$\boldsymbol{H_o}: T \; is \; CRS \tag{10}$$

$\boldsymbol{H_1}: T \; is \; VRS;$ $\quad T$ = Technology

where: $\hat{\theta}_j^{CRS}(x,y)$is the CRS TE score and $\hat{\theta}_j^{VRS}(x,y)$ is the VRS TE score.

To be able to make inference from the ratios, there is the need to compute the p-value, however, the distribution of $\hat{S}$ is not known, hence, bootstrapping becomes ideal to appropriate the critical values following Lee et al. (2021) and Ohene-Asare et al. (2017). Based on the null hypothesis (*Ho: T=CRS*), if the test statistic is less than the critical values at 5% P-value, then, it is concluded that DisCos exhibit VRS, if otherwise, then CRS.

3.7 Input variables

Real capital (₦)x_1, comprises firms' total shares and liabilities; it was used also by Mirza et al. (2021). Labour (No.), x_2, comprises all categories of staff and is one of the most used variables in the literature (see Mirza et al., 2021; Olayemi & Bernard, 2024). Energy received (MWh), x_3, is the amount of energy DisCos receive annually from generation companies (GenCos) in megawatt hour (MWh) through the transmission lines. It is also popular in the literature (Cambini et al., 2014).

3.8 Output variables

Energy delivered (MWh), y_1, is the electrical energy that DisCos avail their customers in a year. In this work, the total energy billed is used as the proxy for energy delivered because of lack of reliable data (also used by Olayemi and Bernard, 2024). Real operating revenues (₦), y_2, constitute the annual collections from delivering energy to customers (also employed by Tengey et al., 2022). Number of customers (No.), y_3, is also prominent in the literature (Tengey et al., 2022; Mirza et al., 2021).

4.0 Presentation and Analysis of Results

4.1 Descriptive statistics

Table 2. *Descriptive Statistics of the Input and Output Variables*

Variables	Real Capital (N'M)	Labour No.	Energy Received MWh	Customer No.	Real Ope. Rev (N'M)	Energy Delivered MWh
Mean	148,657	2,149	2,738,899	819,472	76,582	2,015,912
Min	22,765	779	901,744	348,014	10,296	419,848
Max	828,771	3,494	5,890,988	2,136,857	448,216	4,158,700
N	78	78	78	78	78	78

Source: Author's computation using R 4.3.0 (2024); *p<0.10; **p<0.05; t-stat.=Welch two sample t-test

Table 2 presents the summary statistics of input and output variables used in the estimation. The table shows there is a wide variation in the sizes of DisCos, given the large margin among the resources deployed. Real capital, averaged at about ₦148 billion, with maximum being ₦829 billion for IBEDC and the least being ₦23 billion for YEDC. Labour and energy offtake also varied widely, implying that the DisCos vary in size. With the average of 2,015,912 MWh, and the highest and lowest energy delivered being respectively 4,158,700 MWh and 419,848 MWh, there is a strong inclination to suggest a divergence in DisCos operational sizes because of the wide differences between the inputs and outputs of individual DisCos. The other output variables, customer number and real operating revenues, also suggest variation in the sizes of the DisCos.

4.2 Test of returns to scale

Table 3 presents the result of the global returns to scale technology

Table 3. *Returns to Scale Result*

	$\hat{S}_1$	$\hat{S}_2$	$\hat{S}_3$	Conclusion
$\boldsymbol{H_o}$: T *is CRS*				
Test statistic	0.9939647**	0.9555317**	-0.006188244**	
Critical: 5%	0.9944953	0.9930728	-0.005568126	Reject $\boldsymbol{H_o}$ at 5%

Source: Author's computation using R 4.3.0 software. ***p<0.01; **p<0.05 (2024)

Given *Ho: T = CRS*, the results of the three-test statistics in Table 3 are less than the critical values at 5% P-value. It is safe therefore to conclude that DisCos' underlining technology is VRS, that is, size of DisCos matters. For comparison, both VRS and CRS are estimated.

4.2 Biennial productivity change

Table 4. *DisCos Biennial Productivity Change (2014-2021)*

DisCos	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	Geomean	2014/19	2014/21
AEDC	0.8860	1.0000	1.0000	1.0310	0.8744	1.3261	0.7720	**0.9717**	0.9428	0.9776
BEDC	1.0000	1.0000	1.0000	0.9140	1.0000	-	-	**0.9822**	1.0000	-
EKEDC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	**1.0000**	1.0000	1.0000
EEDC	0.9340	1.0000	1.0000	0.9450	1.0000	1.0000	1.0000	**0.9823**	0.8888	1.0000
IBEDC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-	**1.0000**	1.0000	-
IKEDC	1.0000	1.0000	1.0179	0.8730	0.8758	1.0000	1.0000	**0.9648**	1.0000	1.0000
JEDC	1.0000	1.0000	1.0000	1.0000	-	-	-	**1.0000**	-	-
KAEDC	0.8433	1.0014	1.0555	1.0260	0.8630	1.2591	0.8423	**0.9749**	0.8184	0.8348
KEDCO	1.0000	1.0000	1.0026	1.0000	0.9609	1.0297	1.0031	**0.9993**	1.0000	1.0000
PHEDC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0569	0.9878	**1.0062**	1.0000	1.0000
YEDC	-	-	-	-	1.0000	1.0000	1.0000	**1.0000**	-	-
Geomean	**0.9647**	**1.0001**	**1.0075**	**0.9776**	**0.9556**	**1.0686**	**0.9465**	**0.9891**	**0.9590**	**0.9714**

Source: Author's computation using R 4.3.0 software (2024)

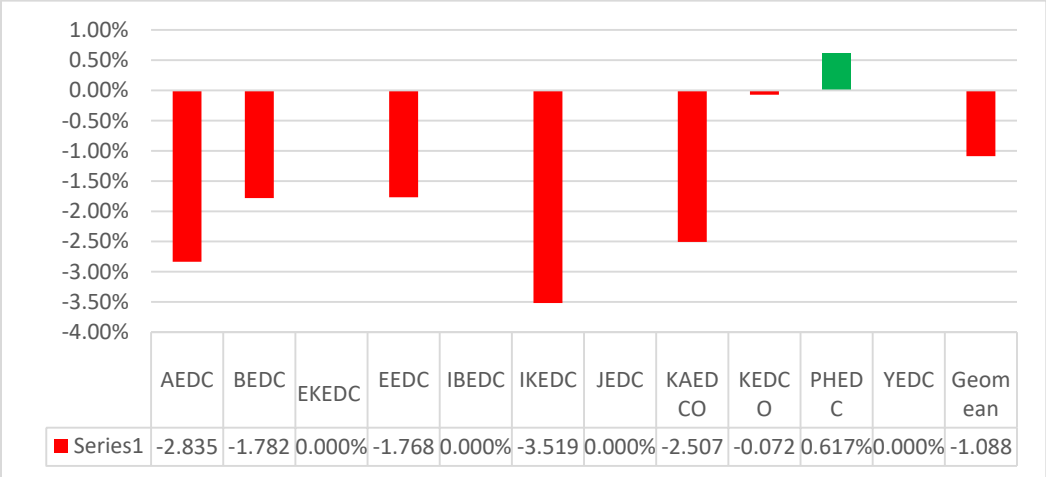
Table 4 shows the BMPI of each DisCo and the entire distribution sub-sector from 2014/15 to 2020/21. From the table, EKEDC, IBEDC, JEDC and YEDC were stagnated as there was zero productivity growth across the years under consideration (BMPI=1). All other DisCos had fluctuations in their growth. For instance, in 2015, AEDC regressed by 11.40% (0.8860-1) from what it was in 2014, then stagnated in the two subsequent years. In 2017/18, it had a growth of 3.10% then regressed by12.56% in 2018/19 before peaking in 2019/20 with productivity growth of 32.61% just before COVID-19 that led to the shutdown of most economic activities. In 2020/21, a significant decline of 22.80% in productivity followed the giant stride recorded in 2019/20, which is not surprising considering COVID-19. Over the eight-year period, on average, AEDC regressed by 2.84% and in comparison, with the base year, 2014, it regressed in comparison with 2019 (year of licence window) and 2021 (the terminal year of this research) by 5.72% and 2.24% respectively.

BEDC, for most of its appearances stagnated, except when it had an 8.60% decline in 2017/18 and an average regress of 1.78% over the years. EKEDC had zero productivity growth or stagnation all through the comparative years and

overall average stagnation. EEDC also did not witness growth in most of the years, it however, had a productivity decline of 6.60% and 5.51% in 2014/15 and 2017/18 respectively, with an overall average regress of 1.77%. The performance of EEDC in 2014 against 2019, showed a regress of 11.11% while it stagnated against 2021. Though IKEDC had a slight productivity growth of 1.79% in 2016/17, it had major declines of over 12.70% and 12.42% in 2017/18 and 2018/19 respectively. It, however, had no growth in the remaining years under consideration while the eight-year mean showed a 3.52% regress.

KAEDCO, though on average retrogressed over the period with 2.51% in productivity, it had some positive moments as it grew productivity by 0.14%, 5.55%, 2.60%, and 25.91% in years 2015/16, 2016/17, 2017/18 and 2019/20 respectively. Years 2014/15, 2018/19 and 2020/21 were, however, characterized with major regress in productivity with respective declines of 15.67%, 13.70% and 15.77% respectively. When 2014 is measured against 2019 and 2021, KAEDCO suffered productivity regresses of 18.16% and 16.52% respectively. KEDCO on the other hand, had on average a minor retrogression of 0.07% over the period but had positive productivity changes of 0.26%, 2.97% and 0.31% in 2016/17, 2019/20 and 2020/21 respectively although it stagnated every other year. PHEDC had productivity stagnation from 2014/15-2018/19 but grew in 2019/20 by 5.69%, but subsequently declined in 2020/21 by 1.22%. On average, PHEDC grew by a margin of 0.64% over the period making it the only DisCo that had a slight growth in output per unit of input employed, although it stagnated against 2019 and 2021 on a baseline of 2014. While PHEDC is the only firm that on average had productivity growth (0.62%) over the eight-year period in the industry, IKEDC was the least in terms of productivity growth, with an average of -3.52%. The industry for the entire period, regressed by 1.09%. This can be seen in Figure 1.

Figure 1: *DisCos' Average Productivity Change, 2014/15-2020/21*

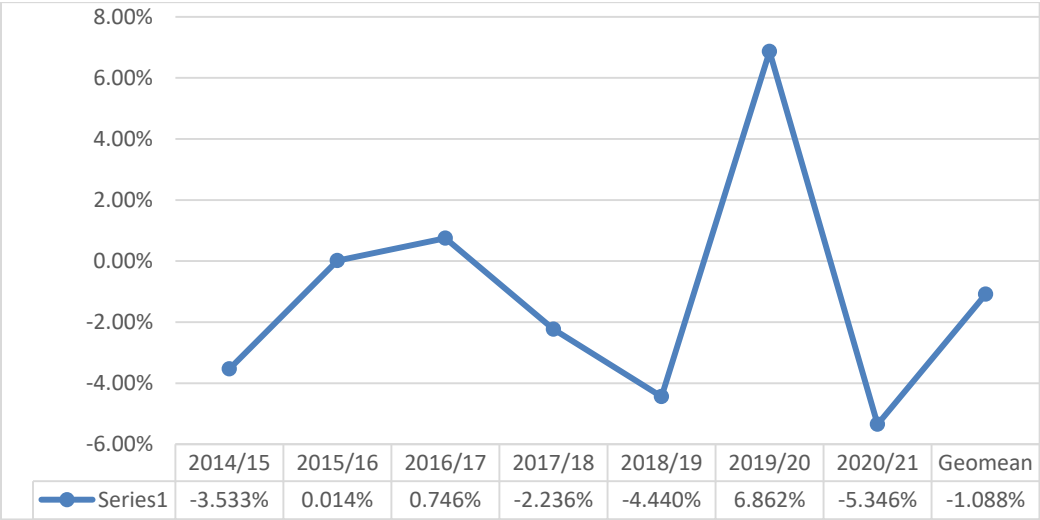


	AEDC	BEDC	EKEDC	EEDC	IBEDC	IKEDC	JEDC	KAEDCO	KEDCO	PHEDC	YEDC	Geomean
Series1	-2.835	-1.782	0.000%	-1.768	0.000%	-3.519	0.000%	-2.507	-0.072	0.617%	0.000%	-1.088

Source: Author's estimation (2024).

Figure 2 shows that while there was no consistent productivity growth for the entire period, the worst productivity change occurred in 2020/21 with the DisCos' average of -5.35%, This is not surprising because this was the COVID pandemic year and businesses across the globe were all almost grounded. The best year was 2019/20, just before the COVID outbreak, with an average of 6.86%.

Figure 2: Industry's Annual Productivity Change, 2014/15-2020/21



	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	Geomean
Series1	-3.533%	0.014%	0.746%	-2.236%	-4.440%	6.862%	-5.346%	-1.088%

Source: Author's estimation (2024).

4.3 Sources of productivity change

Table 5. *Industry-wide Productivity Growth and Decomposition*

Period	BMPIc	BMPIv	PEC	PTC	SEC	STC
2014/15	0.9392	0.9647	0.9840	0.9803	0.9885	0.9850
2015/16	1.0032	1.0001	0.9994	1.0007	1.0133	0.9899
2016/17	0.9937	1.0075	1.0104	0.9970	0.9697	1.0172
2017/18	0.9741	0.9776	1.0008	0.9768	1.0296	0.9678
2018/19	0.9697	0.9556	0.9848	0.9704	1.0089	1.0058
2019/20	1.1101	1.0686	1.0459	1.0218	1.0312	1.0074
2020/21	0.9189	0.9465	0.9801	0.9658	0.9401	1.0327
Geomean	**0.9854**	**0.9879**	**1.0006**	**0.9874**	**0.9968**	**1.0006**
2014/19	0.9845	0.9590	0.9782	0.9804	1.0294	0.9973
2014/21	0.9754	0.9714	0.9747	0.9966	1.0077	0.9964

Source: Author's estimation with R 4.3.0 (2024).

Table 5 indicates that for the entire period, there was a productivity decline of 1.21% (0.9879-1), driven mainly by PTC, which added 1.26% (0.9874-1) to the inward shift of the technological frontier. This further implies that firms did not leverage on the technical environment during the period to enhance productivity. Besides, lack of significant investment in key assets or firms' infrastructure could also be a culprit. This surprisingly negates the endogenous growth theory which asserts that growth is propelled by technological innovation and deliberate investment in novel ideas and technology by profit optimizing firms. It is also at variance with the works of Fallahi et al. (2021), Cambini et al. (2014), and Çelen (2013), who found PTC as main driver of productivity change.

The deviation of the scale efficiency change (SEC), that is, the scale of operations from its optimum, equally produced a 0.003% (0.9968-1) negative impact on the BMPI, implying that on the whole, DisCos are moving away from their optimal scale size. The productivity decline could have been worse, if not for: (i) the marginal positive impact of PEC, 0.06% (1.006-1), which implies that managerial capacity slightly improved within the period, which rubbed off on performance, and (ii) the STC, which connotes the shape of the technology, which also produced a similar positive impact on the productivity of DisCos as did PEC, that is, the position of the firm, either at the increasing returns to scale (IRS) segment or at the decreasing returns to scale (DRS) segment of the technology

set. The implication of this marginal impact is that firms are mostly within the IRS segment of the technology set where productivity improves with expansion.

Table 6 shows that while EKEDC, IBEDC, JEDC and YEDC did not experience growth over the study period, given their $BMPI_v$ =1, AEDC, BEDC, EEDC IKEDC, KAEDCO and KEDCO regressed ($BMPI_v$ <1). Only PHEDC had a marginal productivity rise of 0.62%. On the decomposition, the result in table 5 shows that most DisCos recorded stagnation in the PEC component except AEDC which recorded growth in the PEC and KAEDCO which recorded a decline. Even though AEDC had productivity regress, the managerial competence within the period prevented the performance from being worse. On PTC, only KAEDCO and PHEDC progressed with 0.25% and 0.62% respectively. While BEDC, EEDC, IKEDC and KEDCO had negative contribution from PTC to BMPI, EKEDC, IBEDC, JEDC and YEDC had neutral effect from it. Though the contribution of SEC to productivity change was neutral for most of the DisCos, given the scores equal to 1, KAEDCO, KEDCO, PHEDC and YEDC had positive contributions of 0.34%, 0.5%, 0.35% and 6.57% respectively. This shows that size matters among these DisCos. AEDC and JEDC, however, had negative impact. On STC, most of the DisCos showed negative impact except for AEDC, IKEDC and YEDC which showed positive contribution to productivity growth. EKEDC and IBEDC, however, had no impact.

Table 6: *Firm-wise Productivity Growth and Decompositions*

DisCos	BMPIc	BMPIv	PEC	PTC	SEC	STC
AEDC	0.9819	0.9717	1.0334	0.9402	0.9689	1.0429
BEDC	0.9711	0.9822	1.0000	0.9822	1.0000	0.9887
EKEDC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
EEDC	0.9764	0.9823	1.0000	0.9823	1.0000	0.9940
IBEDC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
IKEDC	0.9857	0.9648	1.0000	0.9648	1.0000	1.0216
JEDC	0.9322	1.0000	1.0000	1.0000	0.9556	0.9756
KAEDCO	0.9697	0.9749	0.9725	1.0025	1.0034	0.9912
KEDCO	0.9805	0.9993	1.0000	0.9993	1.0050	0.9764
PHEDC	0.9990	1.0062	1.0000	1.0062	1.0035	0.9894
YEDC	1.0757	1.0000	1.0000	1.0000	1.0657	1.0094
Geomean	**0.9878**	**0.9891**	**1.0005**	**0.9887**	**0.9999**	**0.9988**

Source: Author's' estimation with R 4.3.0 (2024).

5.0 Conclusion and Recommendations

This study assessed the dynamic productivity of the electricity distribution companies in Nigeria from 2014 to 2021. The results show that there was no productivity consistency among the DisCos. On average, they had 1.1% productivity regression over the eight-year period. However, PEC, which is managerial skill, contributed positively to productivity change, while PTC, which also represents the impact of innovation, process reengineering, capital investment and technical environment on productivity change, showed negative contribution. This implies that the industry neither took advantage of the technical environment, nor made significant investment in assets over the said period. The shape of the technology represented by STC also contributed positively to DisCos' productivity, that is, the position of the firms on technology set was mainly at the IRS segment. The significance of this outcome is that, it has empirically established that DisCos are not only inefficient, but also not productive.

In view of the findings, the following is recommended: (i) other DisCos should copy what AEDC is doing right in terms of management since the contribution came mainly from them. Training and retraining of management should also be routine to optimize performance; (ii) thorough process reengineering by DisCos to leverage on the technological environment such as optimizing the features of automatic meter infrastructure (AMI) of the current prepaid meters; and (iii) since most of the DisCos are still within the IRS segment of the technological set, they should invest in infrastructure to enhance productivity growth.

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Monetary Policy Rate and Foreign Portfolio Investment Inflows in Nigeria: A Structural VAR Analysis

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Abstract
This study examines the impact of the MPR on FPI inflows in Nigeria using a structural vector auto-regressive model after controlling for the influence of the domestic and global money market rates proxied by Nigeria's and the United States (US) treasury bill rates, respectively. The key finding of the study suggests that FPI in Nigeria responds positively to a positive shock to MPR. The policy implication of this finding is that tightening of the MPR attracts more inflows of FPI into Nigeria and vice-versa. Accordingly, the study recommends that Nigeria's apex bank should continue to monitor the movement of the portfolio yield in the rest of the world to ensure that the return offered in the domestic economy is reasonable enough to discourage portfolio reversal and induce more inflows of the investment.

Keywords: Foreign Portfolio Investment, Monetary Policy Rate, Structural Vector Auto-regression, Money market
JEL classification: C32, E52, F21, F41, E43

1. Introduction

Foreign portfolio investment is the purchase of financial assets in a domestic financial market by foreign investors. It involves investment in equity and debentures, bonds, promissory notes, and money market instruments like treasury bills, commercial papers, bankers' acceptance, and negotiable deposits. This form of foreign investment is beneficial to both the investors and the host economies. On one hand, the portfolio investors are entitled to dividends or interest rates and also gain from asset appreciation (Nwokoma, 2013). On the other hand, the investments help the recipient countries, particularly developing ones with means to: stabilize their economies by responding to their current account financing needs resulting from savings deficits; finance their fiscal deficits and imports; maintain exchange rate stability; meet their external debt obligations; and accelerate the development of their domestic financial markets by providing access to liquidity (Pal, 2010).

However, FPI is highly sensitive to interest rate differentials. For instance, when the monetary authority in the host economy eases its policy stance to accelerate economic growth, it is likely to experience a drop and reversal in FPI inflows, for rational portfolio investors prefer to invest in economies that offer higher returns on capital. Therefore, countries that use FPI as an alternative means of stabilizing their economies, of which Nigeria is not an exemption, face a trade-off between economic growth and FPI inflows while setting their MPR upon which most portfolio yields are determined. As a result, regardless of the growth rates in their economies, these countries do not fix their MPR independently of the rest of the world in order not to lose their share of FPI in the global economy. Taking Nigeria as a case study, amidst the slow growth of the country's economy, the MPR has exhibited an upward trend for over a decade with few periods of significant loosening. Specifically, from 2010Q1 to 2022Q4, the CBN has raised the MPR to 16.5 per cent from 6 per cent (CBN, 2022). Undoubtedly, the motive behind this tightening is not only to combat or moderate domestic inflation but also to induce more inflows of FPI which serve as alternative means of stabilizing the oil-exporting economy of Nigeria when the odds in the international oil market are unfavourable.

A survey of the empirical literature on the interest rate and FPI nexus in Nigeria reveals that studies like Golit et al. (2018), Jelilov et al. (2020), Can et al. (2022) and Nwadibe et al. (2023) investigated the impact of Nigeria's MPR on FPI inflows but reported mixed findings. The common gap identified in these studies is that they do not control for the influence of the global money market rate, which is a key external factor that influences the CBN's decision on MPR. Against this backdrop, this study investigates the impact of MPR on FPI flows to Nigeria, taking into cognizance the reaction of the CBN to changes in the global money market yield. To achieve this objective, we employ a structural VAR model which uses economic theories and intuitions to capture the contemporaneous and dynamic relationships among macroeconomic variables.

The remaining sections of the study are organized as follows: section 2 presents the literature review; section 3 deals with the methodology; section 4 presents the results and discussion; and section 5 contains the conclusion and recommendations.

2. Literature Review

A common driver of FPI identified by most of the theories of FPI determinants is interest rate. The earliest theory of FPI drivers, developed by Hymer (1976), presupposes that FPI is driven by interest rates in the host country, and therefore, interest parity will continue to attract foreign investors until the worldwide interest rate becomes the same. A major weakness of this theory is that it overlooked the influence of other internal and external drivers of FPI. Consequently, Fernandez-Arias and Montiel (1995) developed a theoretical portfolio balance model by classifying the driving factors of FPI into domestic (pull) and global (push) factors. Dua and Garg (2013) suggest that pull factors are country-specific elements related to investment risk and returns that attract foreign portfolio investment (FPI). These factors include the performance of the domestic stock market, exchange rate, domestic interest rate, domestic output growth, and exchange rate volatility. Conversely, push factors constitute the global influences that drive FPI out of host countries, such as foreign interest rates and foreign output growth (Mustafa & Hamid, 2021). According to Humanicki et al. (2013), key push factors include low returns in investors' home countries, changing conditions in the global economy, and international financial markets like the US output growth and interest rates. Contrarily, pull factors are related to the returns and investment risks of the host country, including stock market returns, the country's credit rating and investment climate, financial openness, external debt, foreign exchange reserves, and domestic interest rates.

Empirically, studies present conflicting findings regarding the influence of different interest rates on FPI inflows in Nigeria. Golit et al. (2018) for instance, examined whether the Central Bank of Nigeria's (CBN) monetary policy rate (MPR) served as a signalling tool for foreign portfolio investors from January 2001 to September 2018 using the Structural Vector Autoregression (SVAR) framework. Their model incorporated variables such as FPI, MPR, external reserves, and oil prices, and the study concluded that MPR significantly influences the behaviour of foreign portfolio investors in Nigeria.

Similarly, Nwadibe et al. (2023) examined the determinants of FPI flows to Nigeria between 2007 and 2021 using stepwise regression. They found that MPR is a key determinant of FPI inflows into Nigeria's equity and bond markets.

In contrast, Jelilov et al. (2020) assessed the response of FPI to CBN's monetary policy decisions from January 2001 to December 2018 using the Toda-Yamamoto causality model and the Generalized Impulse Response Function. Their findings indicate that monetary policy impacts FPI behaviour primarily through the treasury bill rate, rather than the MPR or the Cash Reserve Ratio (CRR), suggesting that FPI investors are more concerned with the future trajectory of policy rates.

Similarly, Can et al. (2022) explored the response of aggregate and disaggregated FPI to monetary policy decisions in Nigeria from January 2007 to March 2022 using the Toda-Yamamoto causality test. They used variables such as FPI, MPR, CRR, inter-bank interest rate, nominal exchange rate, consumer prices, and Nigeria's treasury bill rate. The study found no evidence of causality from any monetary policy tools to aggregate FPI. However, the disaggregated analysis identified the treasury bill rate as the primary driver of equity and money market FPI inflows, while the inter-bank rate is crucial for FPI inflows into the bond market. Each FPI component responds to specific monetary policy instruments with varying magnitudes.

Amaechi et al. (2020) on the other hand studied the key drivers of FPI in Nigeria for the period January 2001 to September 2019 using the ARDL bounds testing approach. Among the key findings of the study is that a hike in the treasury bill rate attracts more FPI inflows to Nigeria in the long run. Using quarterly data from 2010Q1 to 2019Q4, Karimo (2020) examined the impact of interest rate differentials and exchange rate movements on the dynamics of international private capital flows to Nigeria. Employing the Markov Switching Time-Varying Transition Probability Modelling approach, the study found that interest rate differentials significantly influence FPI flows to Nigeria. Duruechi (2020) applied VECM to study the factors that influence FPI inflows in the emerging economy of Nigeria. The study found that interest rate, market capitalization, all-share index, economic growth, foreign exchange rates, and inflation rates are the determinants of FPI in Nigeria.

From the above empirical review, Golit et al. (2018) and Jelilov et al. (2020) were found to be the closest empirical works to this study. A common limitation identified in these studies is that their model specifications do not control for the influence of the global money market rates, which is a key external factor that influences CBN decisions on MPR and subsequently the inflow of FPI in Nigeria. Against this backdrop, this study examines the impact of MPR on FPI flows to

Nigeria, taking into cognizance the reaction of the CBN to changes in global money market yield.

3.0 Methodology

3.1 Model specification

This study utilized a 4-variable SVAR model comprising the US treasury bill rate (USR), Nigeria's monetary policy rate (MPR), Nigeria's treasury bill rate (TBR), and foreign portfolio inflows to Nigeria (FPI) to examine the impact of monetary policy rate on FPI flows to Nigeria. The US and Nigeria's treasury bill rates were included in the model to control for the effects of the changes in the domestic and global FPI yield.

Different from the standard VAR, the Structural VAR framework used economic theories and stylized observed facts to study contemporaneous and dynamic relationships among the macroeconomic variables. It involved the use of theories rather than a recursive method to restrict the structural system and derive the variance-covariance matrix of the reduced-form VAR model that can be used to recover structural shocks that have theoretical meanings (Enders, 2004).

We begin with the specification of a multivariate SVAR of order P lags as:

$$AX_t = C + A_i X_{t-1} + - - - - - A_p X_{t-p} + \varepsilon_t \quad (1)$$

where: X_t is the vector of the endogenous variables [ΔUSR, ΔMPR, ΔTBR, ΔFPI], C is a 4×1 vector of the constant terms, A is a 4×4 vector matrix for the contemporaneous relationships, A_i is a 4×4 matrix of the parameters and ε_t is the vector of the structural innovations.

After transforming equation (1) by its inverse (A^-) and dropping the constant term, a reduced-form VAR model is obtained as follows:

$$X_t = \delta_1 x_{t-1} + - - \delta_p X_{t-p} + e_t \quad (2)$$

where: $\delta_1 = A^- A_i$ and the reduced-form shock $e_t = A^- \varepsilon_t$. Therefore, the solution for the structural innovations in the model is specified as:

$$\begin{bmatrix} e_{usr_t} \\ e_{mpr_t} \\ e_{tbr_t} \\ e_{fpi_t} \end{bmatrix} = \begin{bmatrix} 1 & \gamma_1 & \gamma_2 & \gamma_3 \\ \theta_1 & 1 & \gamma_4 & \gamma_5 \\ \theta_2 & \theta_3 & 1 & \gamma_6 \\ \theta_4 & \theta_5 & \theta_6 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{usr_t} \\ \varepsilon_{mpr_t} \\ \varepsilon_{tbr_t} \\ \varepsilon_{fpi_t} \end{bmatrix} \quad (3)$$

where: $A^{-1} = \begin{bmatrix} 1 & \gamma_1 & \gamma_2 & \gamma_3 \\ \theta_1 & 1 & \gamma_4 & \gamma_5 \\ \theta_2 & \theta_3 & 1 & \gamma_6 \\ \theta_4 & \theta_5 & \theta_6 & 1 \end{bmatrix}$ (4)

3.2 Identification and restrictions

To recover the structural shocks from the matrix of the reduced-form shocks, e_t, it is necessary to impose additional restrictions on the structural matrix A^{-1} in addition to the identity elements in the principal diagonal since the unknowns in the structural model are greater than the unknowns in the reduced-form variance-covariance matrix. The structural model has a total of n^2 unknown values [$n^2 - n$ unknowns of matrix B plus n unknown values of the $var(\varepsilon_{it})$] while the reduced-form variance-covariance matrix $\sum$ contains a total number of $(\frac{n^2+n}{2})$ independent elements. Thus, to identify n^2 unknowns of the primitive system from the known $(\frac{n^2+n}{2})$ variances and covariances of the reduced-form VAR, it is necessary to impose additional $n^2 - \left(\frac{n^2+n}{2}\right) = (\frac{n^2-n}{2})$ restrictions on the structural system (Enders, 2004). Thus, this study imposed $\left(\frac{4^2-4}{2}\right) = 6$ contemporaneous restrictions on matrix A^{-1} to recover structural shocks that have theoretical interpretations.

For the first equation, we assume that USR is contemporaneously exogenous to the rest of the variables in the model for the reason that the fundamentals of the small open economy of Nigeria cannot drive the US treasury bill rate. As a result, $\gamma_1 = \gamma_2 = \gamma_3 = 0$. And to impose restrictions on the second equation, we assume that MPR is contemporaneously endogenous to USR but exogenous to TBR and FPI. This is justifiable because, in recent years, the monetary policy stance of Nigeria's apex bank is closely tied to the Federal Reserve rate which determines the US short-term rates including the USR. As for TBR and FPI, the stance of the CBN on the MPR influences the TBR which in turn affects the quantum of the FPI flows to Nigeria contemporaneously but not the other way round. Hence, $\gamma_4 = \gamma_5 = 0$. The restriction on the third equation is that TBR contemporaneously reacts to innovations from USR and MPR for the reason stated above, but the rate is contemporaneously exogenous to innovation from FPI, for interest rate is a key driver of FPI. This restriction yields $\gamma_6 = 0$. Lastly, the restriction on the fourth

equation is that FPI inflows to Nigeria are assumed to respond contemporaneously to innovations in all the variables. A rise in USR relative to the domestic return on capital will drop FPI inflows to Nigeria as asserted by the theory of capital mobility. Also, tightening of Nigeria's MPR and increase in TBR raise the domestic return on capital which induces more FPI inflows, particularly the short-term instruments, and vice-versa.

Therefore, the identified system is given as:

$$\begin{bmatrix} e_{usrt} \\ e_{mprt} \\ e_{tbrt} \\ e_{fpit} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ \theta_1 & 1 & 0 & 0 \\ \theta_2 & \theta_3 & 1 & 0 \\ \theta_4 & \theta_5 & \theta_6 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{usrt} \\ \varepsilon_{mprt} \\ \varepsilon_{tbrt} \\ \varepsilon_{fpit} \end{bmatrix} - - - - - (5)$$

3.3 Data and data sources

This study used quarterly published data. The data on MPR, FPI, and TBR were sourced from the *CBN Statistical Bulletin* (2022) while the data on the USR was sourced from the *Federal Reserve Bulletin* (2022).

4.0 Result and Discussion

4.1 Descriptive statistics of the variables

The descriptive statistics of the series presented in Table 1 reveal that, except for MPR, the rest of the variables in the dataset exhibit a high rate of volatility having respective coefficients of variations greater than 50%. Also, the table shows that, for a particular quarter or some quarters, zero TBR was recorded in Nigeria.

Table1: *Descriptive Statistics*

Variables	Obs	Mean	Std. Dev.	CV	Min	Max
USR	52	0.0068096	0.0103217	151.576	0.0002	0.0454
MPR	52	0.1203365	0.023163	19.249	0.06	0.165
TBR	52	0.0792673	0.0460912	58.147	0	0.1449
FPI	52	2129.302	1793.828	84.245	35.15394	7145.979

Note: USR is the US treasury bills rate, MPR is the monetary policy rate, TBR is Nigeria's treasury bills rate and FPI is the foreign portfolio investment inflows.
Source: Author's estimation.

In addition to the descriptive statistics reported in Table 1, we examine the nature of the distribution of the variables individually by employing the joint Skewness and Kurtosis test for normality. Column 2 of Table 2 reports that while the null hypothesis for symmetry is rejected for all the variables except TBR, column 3 reveals that only FPI series are fairly flat. Consequently, the joint test for normality reported in the last two columns of the table shows that none of the variables is normally distributed.

Table 2: *Normality Test for the Variables*

Variable	Pr(Skewness)	Pr(Kurtosis)	Joint Statistics	
			Adj chi2(2)	Prob>chi2
USR	0.0000	0.0025	21.76	0.0000
MPR	0.0007	0.0442	12.55	0.0019
TBR	0.2889	0.0000	14.76	0.0006
FPI	0.0054	0.7274	7.06	0.0293

Source: Author's estimation.

4.2 Correlation among the variables

The pairwise correlation matrix presented in Table 3 reveals that the monetary policy rate in Nigeria tends to be positively associated with the US treasury bill rate. Similarly, Nigeria's treasury bill rate is positively correlated with FPI flows to Nigeria. This implies that raising the US treasury bill rate is associated with the tightening of the monetary policy stance in Nigeria while raising Nigeria's treasury bill rate is associated with more inflows of FPI into the country.

Table 3: *Correlation Matrix for the Variables*

	USR	MPR	TBR	FPI
USR	1			
MPR	0.5619***	1		
TBR	-0.1091	0.2292	1	
FPI	0.0235	0.1925	0.3691***	1

Note: *** and ** indicate that the statistics are significant at 1%, and 5%, respectively.
Source: Author's estimation.

4.3 Unit root test

To ensure that an appropriate model is selected and spurious results are avoided, we examined the order of integrations of the series using the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) tests, given the evidence of non-normality of

the variables established in Table 2. However, prior to the test, FPI was transformed by taking its natural logarithm.

It can be observed from Table 4 that TBR is stationary at level while log of FPI, USR, and MPR become stationary after the first difference according to both test statistics.

Table 4: *Unit Root Test*

Level			First Difference		Comment
Variable	ADF	PP	ADF	PP	
USR	-3.0386	-1.5075	-2.9616**	-2.9343**	I(1)
MPR	-3.0812	-2.1916	-5.2237***	-5.1959***	I(1)
TBR	-4.4489***	-4.3318***	-6.7499***	-12.8566***	I(0)
LFPI	-3.3412*	-3.3338	-10.0555***	-10.4112***	I(1)

Note: The line plots of the series indicate that trend and intercept should be included at levels while for their first differences, only intercepts should be included; ** and *** indicate rejection of the hypotheses at 5% and 1%, respectively.
Source: Author's estimation.

4.4 Co-integration test

Given that USR, MPR, and FPI are individually integrated, we employed the Johansen test for co-integration to examine the possible co-integration among them. Tables 5 and 6 indicate that the variables are not related in the long run, according to the results of the two test assumptions employed. Also, the result from the alternative auto-regressive bounds test to co-integration, which allows for the mixture of I (1) and I (0) variables, indicates that though the variables are co-integrated, the long-run impact of USR, MPR, and TBR on FPI is not significant. Hence, we proceed with the estimation of the standard VAR model in the first difference of USR, MPR, FPI and level form of TBR since no long-run information will be lost.

Table 5: Johansen Co-integration Test with Intercept

Maximum Eigenvalue (λ_{max})			
No. of CE(s)	None	At most 1	At most 2
Eigenvalue	0.285955	0.123954	0.060024
λ_{max} statistic	16.84049	6.616810	3.095023
Critical Value	21.13162	14.26460	3.841466
Trace (λ_{Trace})			
Eigenvalue	0.285955	0.123954	0.060024
λ_{Trace} statistic	26.55233	9.711833	3.095023
Critical Value	29.79707	15.49471	3.841466

Note: The stationary TBR variable is treated as exogenous, and * denotes rejection of the hypothesis at 5% significance level
Source: Author's Estimation

Table 6: *Johansen Co-integration Test with Intercept and Trend*

Maximum Eigenvalue (λ_{max})			
No. of CE(s)	None	At most 1	At most 2
Eigenvalue	0.327527	0.149067	0.123905
λ_{max} statistic	19.83968	8.071083	6.614065
Critical Value	25.82321	19.38704	12.51798
Trace (λ_{Trace})			
Eigenvalue	0.327527	0.149067	0.123905
λ_{Trace} statistic	34.52483	14.68515	6.614065
Critical Value	42.91525	25.87211	12.51798

Note: The stationary TBR variable is treated as exogenous, and * denotes rejection of the hypothesis at 5% significance level
Source: Author's Estimation

4.5 VAR estimation and diagnostic checks

Table 7 reports that all the information criteria suggest 1 lag as optimum. After fitting the first-order unrestricted VAR form of the model, the residuals of the model were found to be uncorrelated based on the statistics produced by the three serial correlation tests employed as shown in Table 8. Also part of the post-estimation checks, the VAR model, was found to be stable as all its roots of characteristic polynomials were within the unit circle (see Table 9).

Table 7: *VAR Orders Suggested by Different Information Criteria*

Optimum Lag Length				
LR	FPE	AIC	SC	HQ
1	1	1	1	1

Source: Author's estimation.

Table 8: *Serial Autocorrelation Test*

VAR Order	PT (asymptotic)	PT (adjusted)	BG (Rao F-stat)
1	10.20235*	10.55513*	0.464331*

Note: ** indicates the acceptance of the null hypothesis at 1%
Source: Authors' estimation.

Table 9: *Table of the Roots of the Characteristic Polynomials*

Roots of the Characteristic Polynomial
0.672456, 0.672456, 0.386259, 0.064163

Source: Author's estimation.

4.6 Dynamic elasticity of FPI

Dynamic elasticity is calculated as a ratio of impulse response, which traces the dynamic impact of a system of shocks to a variable in the system, to its standard deviation. Therefore, the dynamic elasticity of FPI inflows to shock from the monetary policy rates for instance can be expressed as:

$$EFPI_t = \frac{\%\Delta FPI_t}{\%\Delta MPR_0}$$

where: $EFPI_t$ is the elasticity of FPI inflows at time t; $\%\Delta FPI_t$ is the percentage change in FPI inflows between 0, when the initial MPR shock hits, and t; and $\%\Delta MPR_0$ is the percentage change in MPR at time 0. The percentage change in FPI is given by the impulse response while the percentage change in MPR is its standard deviation (see Sanusi, 2010).

Figure 1 presents the dynamic elasticity of FPI inflows in Nigeria to percentage increase in the US and the domestic treasury bill rates as well as the monetary policy rates. It can be observed from the figure that positive shocks to these rates induce more FPI flows to Nigeria and the full impacts of the shocks are maximized after the 25th, 26th, and 28th quarters for the Nigerian treasury bill rate, monetary policy rate, and the US treasury bill rate, respectively as shown in Table 10. The table reports that, at full impact, FPI flows to Nigeria increased by 18.059, 7.941,

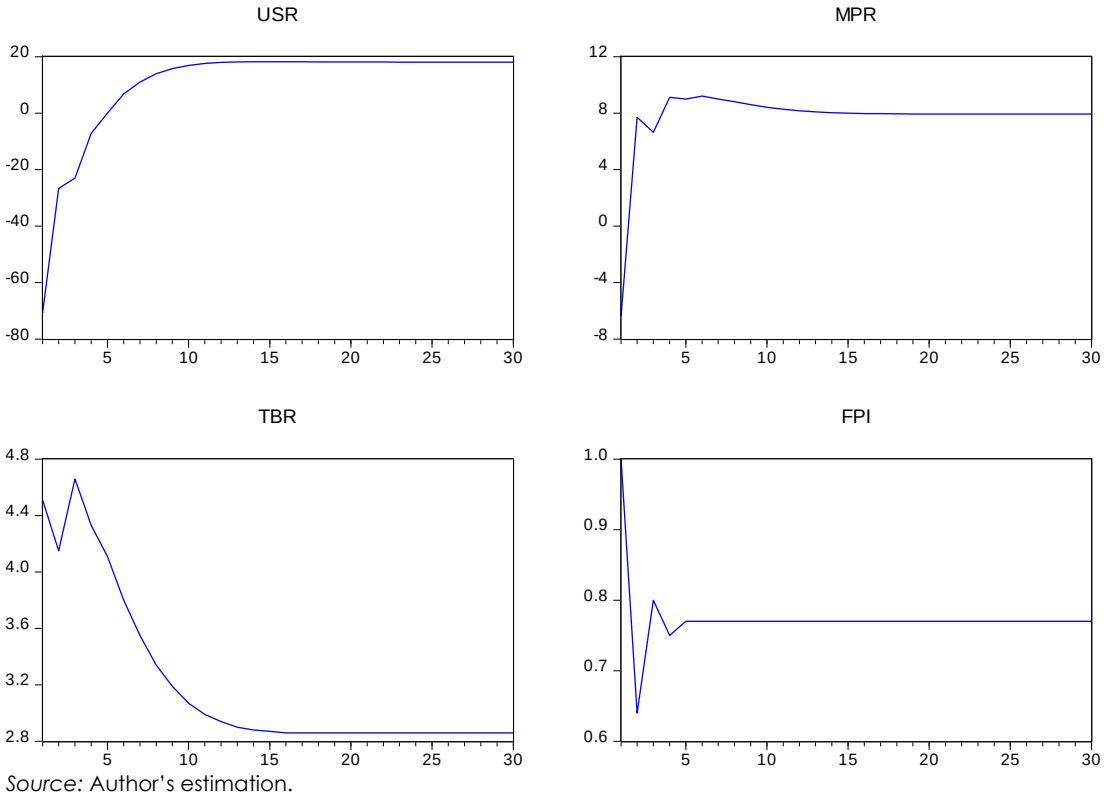
and 2.859 per cent respectively following a one per cent increase in the US treasury bill rate, monetary policy rate, and the treasury bill rate in the Nigeria's money market. Thus, a hike in these rates increases the flow of FPI to Nigeria.

Table 10: *Dynamic Elasticity of FPI Inflows in Nigeria*

	Shocks to:			
Quarters After Shock	USR	MPR	TBR	FPI
1	-70.762	-6.381	4.507	1.000
4	7.190	9.105	4.328	0.748
25	18.063	7.940	2.859	0.774
26	18.061	7.941	2.859	0.774
28	18.059	7.941	2.859	0.774
30	18.059	7.941	2.859	0.774
Structural S.D.	0.003	0.007	0.035	0.812

Source: Author's estimation.

Figure 1: *Dynamic Elasticity of FPI Inflows in Nigeria*



Source: Author's estimation.

4.7 Discussion of findings

The theories on the determinants of FPI argue that foreign portfolio investors invest their capital where it fetches a higher rate of return. As a result, monetary authorities of various economies have adopted the strategy of raising the MPR to accumulate more FPI. In this study, we established theoretically consistent empirical evidence of the effectiveness of MPR in influencing FPI flows to Nigeria. The finding corroborates the findings reported by Golit et al. (2018) and Nwadibe et al. (2023) but contradicts the finding of Jelilov et al. (2020) that MPR does not influence FPI inflows to Nigeria. Another theoretically consistent result found in this study is the positive response of FPI in Nigeria to a rise in the domestic treasury bill rate. This finding is in line with the finding suggested by Amaechi et al. (2020) that a rise in Nigeria's treasury bill rate attracts more FPI inflows. However, contrary to the a priori expectation that FPI flows to Nigeria will drop following an increase in the portfolio return offered in the rest of the world, the result obtained in this study indicates that an increase in the global money market rate proxied by the US treasury bill rate increases the flow of FPI in Nigeria. This shows how Nigeria's apex bank has carefully set its monetary policy rate over the sampled period in consideration of the trend in the portfolio yield obtainable in the rest of the world to prevent FPI drops and encourage more inflows thereby maintaining alternative sources of foreign exchange and stabilizing the domestic economy.

5.0 Conclusion and Recommendation

This study examined the impact of MPR on FPI flows to Nigeria for the period 2010Q1 to 2022Q4 using SVAR after controlling for the influence of the global and the domestic money market rates proxied by the US and Nigeria's treasury bill rates, respectively. We first estimated the accumulated response of the FPI to shocks to the MPR and the control variables and subsequently computed the dynamic elasticity of the FPI. The estimated result of the SVAR model suggests that tightening of the MPR in Nigeria increases the inflows of the FPI, which is in line with the theoretical postulations on the determinants of FPI flows. The study concludes that over the sampled period, the CBN tightening stance on the MPR was effective in motivating foreign portfolio investors to invest their capital in Nigeria's financial market. Accordingly, the study recommends that the CBN should continue to monitor the movement of the portfolio yield in the rest of the world to ensure that the return offered in the domestic economy is reasonable enough to prevent portfolio reversal and induce more inflows of investment.

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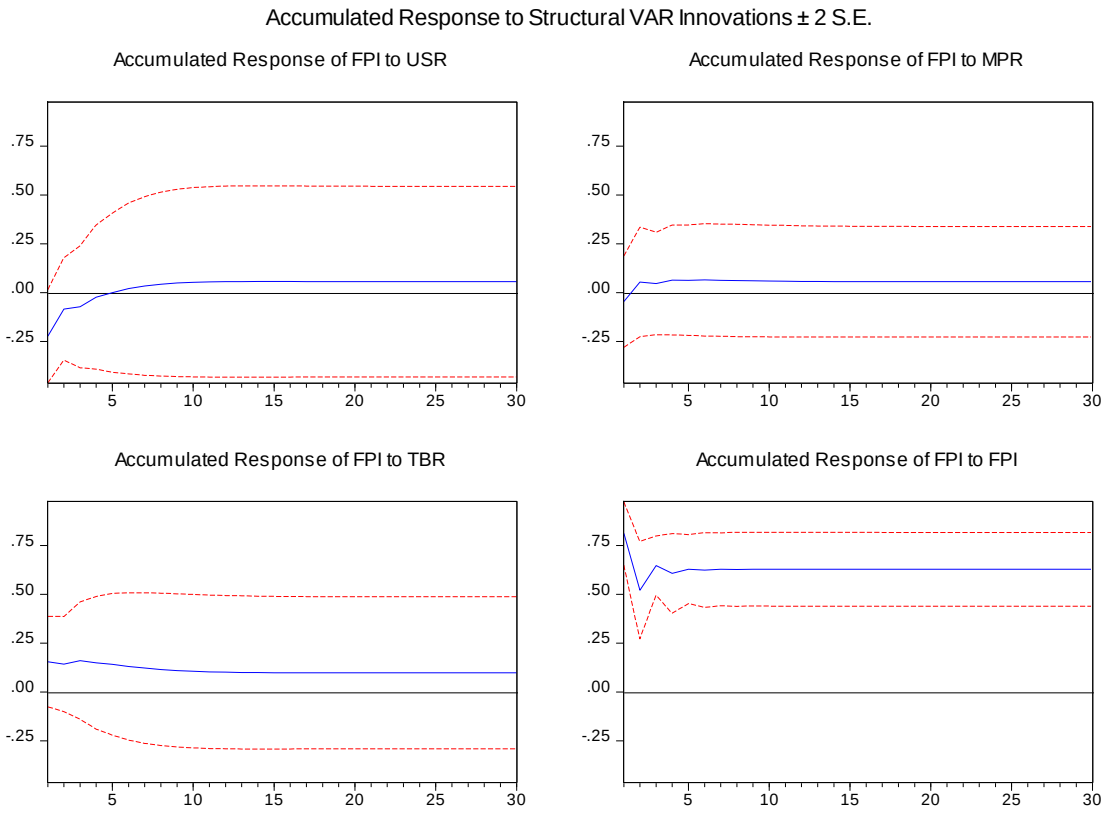
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Financing Models and Social Development in Low and Middle-Income African Countries: A Comparative Analysis

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Abstract
This study examined how different financing models including Islamic finance, foreign aid, and government budgets, impact social development in low- and middle-income African countries. Using data from 54 African countries between 2013 and 2022, the study employed a robust analytical method called the 2-Step System Generalized Method of Moments (SGMM). The findings show that all three financing models had positive impact on social development, but their effectiveness varied significantly. Islamic finance, with its ethical and responsible investment principles, shows promise in sectors like education and healthcare, particularly in middle-income countries. However, its impact in low-income countries is limited. Foreign aid has mixed results, and its effectiveness largely depends on the quality of governance and institutional frameworks. Government budget allocation has a positive impact, especially when directed towards health and education, but this is more evident in middle-income countries. The study highlights the importance of creating an enabling environment that enhances the efficiency of these financing models. Improving governance and institutional quality is crucial for maximizing the benefits of foreign aid. In addition, integrating Islamic finance principles into broader financial systems could foster sustainable and socially-responsible investments. The study recommends a balanced approach that utilizes the strengths of each financing model while addressing their respective challenges to achieve sustainable social development in low- and middle-income African countries. Further research is suggested to explore the long-term impacts of these financing models and their interactions with other macroeconomic variables.

Key words: Islamic Finance, Foreign Aid, Government Budget, Social Development, System Generalized Method of Moments (SGMM), African Countries
JEL classification: G20, F35, I38, C13, O55

1.0 Introduction

Financing social development is a critical challenge for low- and middle-income countries (LMICs). Despite progress made towards achieving the Sustainable Development Goals (SDGs), many LMICs continue to face significant social issues, such as poverty, inequality, and limited access to healthcare and education, among other things. In response to these challenges, LMICs have implemented various strategies, including increasing public investment in social infrastructure, seeking international aid, and adopting innovative financing mechanisms (Farah et al., 2018). However, the success of these approaches varies widely, necessitating a more thorough analysis of which financing models are most effective in driving sustainable social development. This study evaluates and compares different financing models, including Islamic finance, foreign aid, and government social spending, and their impacts on specific social development outcomes. The analysis focuses on key indicators of social development such as poverty reduction, school enrolment, and life expectancy to assess the relative effectiveness of each financing model.

Islamic finance, based on principles of risk-sharing, social justice, and ethical investment, offers an alternative financing model that may promote inclusive growth, balanced and equitable development, especially where traditional financial systems are grossly inadequate. Foreign aid has been a major source of funding for social development in Africa, supporting infrastructure, healthcare, education, and poverty reduction programmes (Moyo, 2009). Public budgetary provision for social spending is another critical mechanism, covering expenditures on health, education, social protection, and infrastructure. Gupta et al. (1998) highlights that budget is the principal vehicle through which any government conducts its core functions and that policies that reduce corruption will most likely reduce income inequality and poverty as well.

The motivation for this study arises from the persistent socio-economic challenges in African countries, despite various financing efforts. Issues such as poverty, inequality, and inadequate access to essential services persist, creating an urgent need to identify the most effective financing strategies. Although existing studies provide empirical evidence on the impact of different financing models on social development outcomes, the findings are mixed, and debates continue. This study seeks to clarify these issues by conducting a comparative analysis of Islamic finance, foreign aid, and government budget financing in African

countries, offering insights for policymakers to foster sustainable and inclusive development.

The main contribution of this study lies in its detailed evaluation of how different financing models specifically impact poverty reduction, school enrolment, and life expectancy. By disaggregating social development into these critical components, the study provides a clearer understanding of the effectiveness of each financing model in addressing specific social issues. The use of the system generalized method of moments (SGMM) addresses potential endogeneity issues and captures dynamic relationships in the data, ensuring a robust analysis of the impact of different financing models on these crucial social development outcomes. This approach allows for a comprehensive assessment of how these financing models impact poverty, education, and health, while accounting for unobserved heterogeneity and potential biases from reverse causality.

Following this introduction, Section 2 provides a critical review of the empirical literature that informs our study. Section 3 outlines the methodology employed, specifically the SGMM approach and section 4 presents and discusses the findings. Finally, Section 5 concludes with key recommendations based on the study's results.

2.0 Literature Review

2.1 Islamic finance and social development

Scholars have widely studied Islamic finance for its potential to drive social and economic development. Various studies have explored its impact on organizational performance, poverty alleviation, and sustainable growth. Guled (2022) found a positive correlation between Islamic finance and multiple developmental outcomes in Mogadishu, Somalia. The study highlighted that Islamic finance, particularly through *murabaha* (a cost-plus financing arrangement), also referred to as mark-up, significantly enhanced organizational performance, social development, poverty reduction, and job creation. Murabaha's structured financing has facilitated access to capital, encouraged entrepreneurial ventures, and contributed to economic stability. Alam and Ullah (2022) examined the role of participatory finance in Turkey, focusing on its capacity to address developmental crises. They identified interest-free capital formation as a crucial mechanism within participatory finance, which aligns with Islamic principles of equity and social justice. Their findings suggest that

participatory finance can mitigate economic challenges by fostering equitable wealth distribution and promoting inclusive economic development.

Zarrouk (2015) argued that Islamic finance contributes to sustainable development through risk-sharing mechanisms. Unlike conventional interest-based financing, Islamic finance emphasizes and asset-backed finance profit-and-loss sharing, which can stabilize economic systems and distribute financial risks more equitably. This approach supports sustainable infrastructure projects and aligns financial practices with ethical principles, enhancing social welfare. Islamic finance operates through solidarity-based financial practices that prioritize poverty alleviation and social welfare. Islamic banks offer products like *zakat* (charitable giving) and *qard hasan* (benevolent loans), which target the needs of the poor and marginalized. These practices are crucial for enhancing social cohesion and economic inclusion by providing financial support to vulnerable populations.

Ali and Pracha (2021) emphasized the role of Islamic microfinance in Pakistan as a driver of economic growth, poverty alleviation, and SME development. Their study demonstrated that Islamic microfinance generates employment opportunities and livelihoods, significantly contributing to socio-economic development. In particular, it is evident that Islamic microfinance supports entrepreneurship and economic empowerment by providing financial services to underserved communities. Rahman and Asyifaa (2021) found that Islamic finance, particularly through the deployment of *zakat* and *waqf*, positively impacts community welfare in Indonesia. These practices help reduce income disparities and promote economic equality. Zuchroh (2021) also highlighted the role of zakat and waqf in poverty reduction and social equality, supporting efforts to achieve equitable development. Similarly, Zainur (2021) showed that Shariah-based financial models, including Islamic banking and non-bank financial institutions, positively affect economic growth in Indonesia.

Several studies have illustrated how Islamic finance aligns with the Sustainable Development Goals (SDGs). Ahmed et al. (2015) discussed the potential of Islamic finance to drive SDG implementation through resource mobilization, economic growth, and financial inclusion. Islamic finance instruments, characterized by fairness, transparency, and social responsibility, can significantly contribute to achieving the SDGs. Daly and Frikha (2015) identified the role of zakat in promoting socio-economic stability, wealth redistribution, poverty

alleviation, and social cohesion, aligning with SDG objectives. Saba et al. (2021) posited that Islamic finance could serve as a major source of financing for infrastructure and development projects, supporting SDG-related initiatives. Laldin and Djafri (2021) discussed how Islamic finance instruments such as waqf and zakat could address social challenges, support SDG attainment, and ensure financial inclusion and stability. Gundogdu (2018) reiterated the alignment of Islamic finance with the SDGs, highlighting contemporary products and solutions for microfinance, SME financing, infrastructure development, affordable housing, international trade, complementary currency, cash waqf, zakat, economic empowerment funds, and crowdfunding.

Although much has been written theoretically in the area of Islamic finance, there is a notable scarcity of empirical research on its impacts. The literature is predominantly theoretical, with limited empirical evidence on the actual effects of Islamic finance on social development outcomes. This gap is particularly evident in Africa, where social development challenges are immense. Thus, more empirical studies are necessary to evaluate the effectiveness of Islamic finance in promoting social development and to provide concrete evidence of its impact.

2.2 Foreign aid and social development

The impact of foreign aid on development outcomes is highly debated and context-dependent, with various factors influencing its effectiveness. While some studies underscore the substantial positive effects of foreign aid on poverty reduction and social development, others highlight its limitations and potential adverse consequences. Mahembe and Odhiambo (2021) and Akobeng (2020) assert that foreign aid significantly reduces poverty in sub-Saharan Africa, particularly through multilateral aid and grants. However, the effectiveness of this aid is contingent upon institutional quality, democratic governance, and sectoral allocation (Signor & Vandernoot, 2021; Maruta et al., 2020; Farah et al., 2018). This highlights a critical challenge, as foreign aid is neither a one-size-fits-all or be all and end all solution, and its success depends heavily on the existing socio-political framework and governance structures.

Research highlighting the beneficial roles of foreign aid in fostering economic growth, enhancing human development, and improving social infrastructure is extensive (Gillanders, 2016; Kim & Lin, 2015; Asongu & Nwachukwu, 2017; Akinbode & Bolarinwa, 2020). The studies emphasize the importance of addressing internal issues such as corruption and trade openness in order to fully

leverage the benefits of aid. The presence of robust institutions and transparent governance appears crucial for translating foreign aid into tangible development outcomes.

On the other hand, some scholars raise significant questions about the efficacy of foreign aid, arguing that it may perpetuate dependency, undermine local initiatives, and fail to address the root causes of poverty. Clemens et al. (2004) and Mavrotas and Kelly (2001) support this view, suggesting that aid alone is insufficient for sustainable growth. Wrangberg (2018) and Deniz and Haidar (2019) further argue that corruption and adverse socio-economic conditions often compromise the benefits of foreign aid. These perspectives highlight the importance of combining aid with comprehensive governance and institutional framework reforms to improve its effectiveness.

Hana (2015) contends that foreign aid has different effects on poverty reduction in Ethiopia, with significant differences across poverty measures and macroeconomic policies. This suggests that a broader economic policy environment can significantly influence the effectiveness of aid. Similarly, Kim and Lin (2015) demonstrate the positive effects of targeted foreign aid on health outcomes in African countries, particularly when directed towards health infrastructure and service delivery. These findings highlight the transformative potential of well-targeted aid initiatives in achieving specific development goals. Sahoo and Sethi (2013) found that foreign aid significantly contributes to economic growth and development in India, with a stronger effect on economic growth than on economic development. This distinction underscores the complexity of aid effectiveness, suggesting that while foreign aid can stimulate economic activity, its broader developmental impacts might differ based on specific context.

The literature presents mixed findings on the impact of foreign aid on social development. Some studies show a positive effect of foreign aid on social development, while others give less conclusive results. This inconsistency calls for further research to better understand the conditions and contexts in which foreign aid contributes to social development.

2.3 Government budgets and the social development nexus

The literature consistently demonstrates that government budgets and budget policies have a profound impact on social development, poverty reduction, economic growth, and infrastructure development. Lysiak et al. (2021) emphasize how strategic budget policies can foster progressive social development and improve budgeting efficiency. Tatuev et al. (2018) provide examples of how to effectively use budgetary expenditures to improve health and educational outcomes.

Nemec et al. (2017) emphasize that public expenditures positively impact the human development index (HDI), especially when they allocate funds to productive sectors such as health, education, and social services. Such expenditures are pivotal for socio-economic advancement. Similarly, Sasmal and Sasmal (2016) assert that government investment in infrastructure is essential for economic growth and poverty alleviation. Fan and Rao (2003) found that government spending on agriculture and health significantly boosts economic growth in Africa, while in Asia, investments in agriculture, education, and defence are key drivers of growth. Their research also indicates that agricultural spending is particularly effective in reducing poverty in rural areas.

Previous studies on financing for social development have primarily employed panel econometric models such as 2SLS-IV regression and classic fixed and random effect models. While useful, these models frequently operate under strict assumptions of time-invariant cross-unit heterogeneity and face significant challenges in addressing the endogeneity of key explanatory variables. These limitations can lead to biased and inconsistent parameter estimates, thereby undermining the validity of the findings. The generalized method of moments (GMM) could address the shortcomings of these approaches. This approach is particularly effective in dealing with endogeneity issues, as it uses instrumental variables to provide more accurate and reliable parameter estimates. This approach enhances the robustness of the estimated parameters, offering deeper insights into the relationship between financing models and social development outcomes. This study employs GMM to better account for dynamic relationships and heterogeneity across units, leading to more credible and comprehensive results.

2.4 Theoretical framework

This study adapts a hybrid theoretical framework to develop a comprehensive analysis of social development financing in Africa. The Maqasid Al-Shariah Theory is employed to ensure that Islamic finance development aligns with principles of social justice and individual well-being. This implies that financial practices governed by Islamic principles can effectively support sustainable social development goals. The Human Development Theory highlights the significance of improving human life quality, which is directly measured by the Social Development Index or outcome (SDO), comprising longevity, education, and living standards. This supports the use of SDI as the dependent variable in our models, reflecting key human development aspects.

3. Methodology

3.1 Research design

This study followed a causal design and tried to establish a cause-and-effect relationship. It entailed the specification of an independent variable to identify its effect on some dependent variables while controlling other potential confounding variables (Sahed et al., 2020). In this regard, the research design is suitable for studying how Islamic finance, foreign aid, and government budgets differently impacted social development in low- and middle-income African countries.

3.2 Data and sources

This study employs a panel dataset consisting of 54 African countries, covering the period 2013 to 2022. The Social Development Index or outcome (SDO) is constructed using indicators such as the poverty line, secondary school enrolment ratios, and life expectancy at birth, all sourced from the World Bank Development Indicators. In addition to the SDI, the study incorporates several other key variables. It includes data on Islamic finance development, which measures the total funds provided through Islamic financial instruments specifically aimed at social development projects. This data is sourced from the Refinitiv DataStream. It is important to note that approximately 28% of the countries (16 out of 54) have missing data on Islamic finance, leaving data available for 72% of the countries included in the study.

Data on foreign aid (AID), represented by the total official development assistance (ODA) received by each country aimed at social development, is sourced from the World Bank Development Indicators. Similarly, government budget spending on social development (GBS), measured as the percentage of the national budget allocated to sectors such as education, healthcare, and social protection, is also obtained from the same source. These variables capture the financial resources dedicated to social development from both international and domestic sources.

The study uses an aggregate index to account for the quality of governance (QGG), comprising dimensions such as political stability, government effectiveness, regulatory quality, rule of law, and control of corruption, sourced from the World Bank Development Indicators. Urbanization, measured by the percentage of the population living in urban areas, and gross domestic product (GDP) per capita in constant 2010 US dollars are included as control variables, reflecting broader socio-economic conditions.

3.3 Model specification

Given that the social development index or outcome (SDO) for each country i at time t is constructed as a function of poverty reduction (PR), secondary school enrolment ratio (SER), and life expectancy at birth (LEB), the index is defined as follows:

$$SDO_{it} = f\ (PR_{it}, SER_{it}, LXP_{it}) \quad (1)$$

where:

- SDO_{it} = Social Development Index or outcome for country i in year t.
- PR_{it} = Poverty Reduction, measured as either the decrease in the percentage of the population living below the national poverty line or an increase in income levels among the lowest quintile, for country i in year t.
- SER_{it} = Secondary School Enrolment Ratio, defined as the proportion of eligible children who are enrolled in secondary school, for country i in year t.
- LXP_{it} = Life Expectancy at Birth, indicating the average number of years a newborn is expected to live if current mortality rates continue to apply, for country i in year t.

The general empirical model for estimating the social development outcome models can be given as:

$$SDO_{it} = f\ (IFD_{it}, AID_{it}, GBS_{it}, QGG_{it}, GDP_{it}) \quad (2)$$

where:

SDO_{it} = the social development outcome variable of country i at time t,

IFD_{it} = the Islamic finance development of country i at time t,

AID_{it} = the foreign aid of country i at time t,

GBS_{it} = the government budget spending on social development of country i at time t,

QGG_{it} = the governance quality as a measure of quality of governance of country i at time t,

GDP_{it} = the economic growth rate of country i at time t, as explained in the literature.

On this basis, the econometric model can be specified as follows:

$$SDO_{it} = \beta_0 + \beta_1 IFD_{it} + \beta_2 AID_{it} + \beta_3 GBS_{it} + \beta_4 QGG_{it} + \beta_5 GDP_{it} + \mu_{it} \quad (3)$$

where:

β_0, β_1, β_2, β_3, β_4, and β_5 respectively are the coefficients of Islamic finance development, foreign aid, government budget, governance quality, urbanization, economic growth rate and population growth rate, while μ_{it} is the error term which captured unobservable factors affecting poverty reduction variables that are not captured in the model. The error term is assumed to be normally distributed with zero mean and constant variance.

3.4 Estimation technique

System GMM (Generalized Method of Moments) is an econometric technique often used for dynamic panel data analysis, where the dependent variable is regressed on its own lagged values and other explanatory variables. This method is particularly useful when dealing with endogeneity issues in panel data. This study addresses endogeneity issues, including omitted variable bias and reverse causality, by utilising the GMM estimation technique, renowned for delivering unbiased and consistent results. Ullah et al. (2018) note that traditional approaches such as ordinary least squares (OLS), fixed effects, random effects, and generalized least squares often fail to adequately address these issues, especially when models include lagged dependent variables, resulting in biased and inconsistent outcomes.

In contrast, instrumental variable (IV) techniques and GMM are designed to overcome these limitations. However, the use of the IV method is deemed unfeasible in this context due to data constraints. Therefore, this research opted for the system GMM (SGMM) estimator developed by Blundell and Bond (1998). SGMM is particularly advantageous for this study as it effectively addresses the

potential downward bias observed in small samples and ensured the consistency of parameter estimates, even in the presence of measurement errors (Roodman, 2009). In this study, the SGMM approach not only addresses the initial concerns regarding endogeneity but also enhances the robustness of the estimation process by effectively utilizing both level and difference equations in the analysis. The general model and the specific models (Islamic Financing Model, Foreign Aid Model, Government Budget Spending Model) derived using system GMM are shown below. This ensures that equation (3) is re-specified using the SGMM estimation.

$$InSDO_{it} = \beta_0 + \beta_1 InSDO_{it-1} + \beta_2 InIFD_{it} + \beta_3 InAID_{it} + \beta_4 InGBS_{it} + \beta_5 InQGG_{it} + \beta_6 InGDP_{it} + (\eta_t + \varepsilon_{it}) \quad (4)$$

$$\Delta InSDO_{it} = \beta_0 + \beta_1(\Delta InSDO_{it-1}) + \beta_2(\Delta InIFD_{it}) + \beta_3(\Delta InAID_{it}) + \beta_4(\Delta InGBS_{it}) + \beta_5(\Delta QGG_{it}) + \beta_6(\Delta InGDP_{it}) + \Delta\mu_{it} \quad (5)$$

where: InSDO$_{it}$ is the natural log of the dependent variable social development outcome, InSDO$_{it-1}$ is the lag value of the dependent variable, η_t is country unobserved specific effect, $\Delta\mu_{it}$ is the error term and the subscript i and t represent country and time series respectively.

In system GMM estimation, instrumental variables are used to address endogeneity. Specifically, lagged levels of the endogenous variables, such as InSDO$_{it-1}$, are employed as instruments in the level equation (equation 4). On the other hand, the lagged differences of potential endogenous variables, denoted as ΔInSDO$_{it-1}$, are utilized as instruments in the first difference equation (equation 5). This approach allows for the estimation of consistent and unbiased parameters in the system GMM framework.

The SDO can further be broken down into poverty reduction (PR), secondary school enrolment ratio (SER), and life expectancy at birth (LXP).
Thus, the model is re-specified as follows:

MODEL 1

$$InPR_{it} = \beta_0 + \beta_1 InPR_{it-1} + \beta_2 InIFD_{it} + \beta_3 InAID_{it} + \beta_4 InGB_{Sit} + \beta_5 QGG_{it} + \beta_6 InGDP_{it} + \mu_{it} \quad (6)$$

$$\Delta InPR_{it} = \beta_0 + \beta_1(\Delta InPR_{it-1}) + \beta_2(\Delta InIFD_{it}) + \beta_3(\Delta InAID_{it}) + \beta_4(\Delta InGBS_{it}) + \beta_5(\Delta QGG_{it}) + \beta_6(\Delta InGDP_{it}) + \Delta\mu_{it} \quad (7)$$

MODEL 2

$$InSER_{it} = \beta_0 + \beta_1 InSER_{it-1} + \beta_2 InIFD_{it} + \beta_3 InAID_{it} + \beta_4 InGBS_{it} + \beta_5 QGG_{it} + \beta_6 InGDP_{it} + \mu_{it} \quad (8)$$

$$\Delta InSER_{it} = \beta_0 + \beta_1(\Delta InSER_{it-1}) + \beta_2(\Delta InIFD_{it}) + \beta_3(\Delta InAID_{it}) + \beta_4(\Delta InGBS_{it}) + \beta_5(\Delta QGG_{it}) + \beta_6(\Delta InGDP_{it}) + \Delta\mu_{it} \quad (9)$$

MODEL 3

$$InLXP_{it} = \beta_0 + \beta_1 InLXP_{it-1} + \beta_2 InIFD_{it} + \beta_3 InAID_{it} + \beta_4 InGBS_{it} + \beta_5 QGG_{it} + \beta_6 InGDP_{it} + \mu_{it} \quad (10)$$

$$\Delta InLXP_{it} = \beta_0 + \beta_1(\Delta InLXP_{it-1}) + \beta_2(\Delta InIFD_{it}) + \beta_3(\Delta InAID_{it}) + \beta_4(\Delta InGBS_{it}) + \beta_5(\Delta QGG_{it}) + \beta_6(\Delta InGDP_{it}) + \Delta\mu_{it} \quad (11)$$

4.0 Empirical Findings and Discussion

The analysis of the elasticity coefficients from the nexus between financing models and social development reveals insights into how the various financing options, namely Islamic finance development, foreign aid, and government budget spending, affect the key social outcomes, that is, poverty reduction, school enrolment, and life expectancy at birth. These elasticity coefficients were derived from models where these components served as dependent variables. This makes it possible to assess the relative effectiveness of each financing option, alongside a set of control variables.

Table 1: *System GMM Estimation for Low-iincome Countries*

Independent Variable	Model 1: LogPR	Model 2: LogSER	Model 3: LogLXP
LogPR(-1)	0.4116** (2.15)		
LogSER(-1)		0.08189 (0.67)	
LogLXP(-1)			0.8126*** (16.03)
LogIFD	0.0115* (1.98)	0.0011 (0.18)	-0.0015 (1.13)
LogAID	0.0881** (2.14)	0.0117 (1.52)	-0.0121** (2.50)
LogGBS	0.0660 (0.11)	-0.1185* (2.04)	0.0316 (0.41)
P-value for Hansen Test	0.134	0.276	0.325
AR(2)	0.926	0.914	0.921
Groups/Instruments	10/10	9/9	10/10
Number of countries	19	19	19
Number Observations	100	84	100

Notes: ***, **, * are statistical significance at 1%, 5% and 10% respectively; t-statistics (in parentheses) are based on white heteroscedasticity-consistent standard errors; p-values reported for AR(2) and Hansen statistics.

Source: Author's computations.

Starting with poverty reduction, Table 1 shows that the elasticity coefficient for poverty reduction's lagged value (LogPR(-1)) is positive and statistically significant, with a value of 0.4116. This indicates that, a 1% increase in the previous year's efforts results in approximately a 0.41% increase in the current year's poverty reduction. This suggests that while positive, the influence of past poverty reduction efforts on future outcomes requires sustained and possibly increased efforts to compound over time. The implication of this finding for low-income countries in Africa is that there is a need for governments to continue to invest in and maintain proven poverty-reduction programmes. This includes securing long-term funding, establishing clear and consistent policy frameworks, and creating robust mechanisms for monitoring and evaluation to ensure these programmes continue to deliver results over time. It also implies that governments should consider multi-year funding commitments and robust policy frameworks to maintain and enhance poverty reduction programmes, which would require a systematic approach where successful initiatives are identified, supported, and scaled up to maximize their impact over time.

In the context of Islamic finance development, the elasticity coefficient of LogIFD, which is 0.0115, though marginally significant, confirms a positive influence on poverty reduction. However, the highly inelastic nature of this coefficient indicates that the effect, while beneficial, is modest. This suggests a critical need for enhancing how Islamic finance mechanisms contribute to poverty alleviation. However, strengthening these mechanisms could involve developing more targeted financial products, improving outreach and education, and ensuring that these initiatives are accessible to those most in need, thereby magnifying the impact of Islamic finance on reducing poverty levels. The coefficient of 0.0881 for foreign aid (LogAID) indicates that it has a significant positive effect on poverty reduction. Specifically, a 1% increase in foreign aid corresponds to a 0.0881% reduction in poverty. This supports the utilization of foreign aid as a strategic tool for combating poverty, aligning with previous findings which showed that foreign aid has contributed significantly to poverty reduction and an increase in aid should be substantial enough to make more significant impacts.

Turning to school enrolment, the lagged value of secondary school enrolment ratio (LogSER(-1)) has a positive but insignificant effect on current secondary school enrolment. Thus, prior year enrolment rates are not a strong predictor of current year rates. This implies that current policies may not be effectively sustaining improvements in school enrolment. Similarly, the elasticity coefficient of

Islamic finance development (LogIFD) has a positive but insignificant effect on secondary school enrolment. The negligible effect in this case indicates that while Islamic finance may boost economic opportunities broadly, it does not directly translate into higher school enrolment rates. The coefficient of foreign aid (LogAID) is positive but not statistically significant. The non-significant positive impact suggests that foreign aid does not robustly influence school enrolment directly, possibly due to other intervening variables or misallocation. Thus, foreign aid for education needs to be better targeted and more efficiently used to significantly impact secondary school enrolment rates.

The coefficient for government budget spending on social development value (LogGBS) is -0.1185, meaning a 1% increase in spending leads to a 0.1185% decrease in secondary school enrolment, and this is statistically significant. This unexpected result suggests possible inefficiencies or mismanagement of funds, which implies that current spending may be ineffective or misallocated, not improving educational infrastructure, teacher quality, or materials. Broader issues like governance, corruption, and inequality could also be factors. This finding supports the views of Alemayehu and Haile (2016) and Geda (2015), who argue that fund misallocation and corruption reduce the effectiveness of government spending on social development. Therefore, a thorough review of education spending policies is required to ensure funds are effectively contributing to higher enrolment rates.

The coefficient of the lagged value of life expectancy value (LogLXP(-1)), which is 0.8126, has a highly significant positive effect on current life expectancy. This high coefficient indicates that previous levels of life expectancy strongly influence current levels. This suggests that improvements in life expectancy have a lasting impact, and that the benefits of health policies and interventions implemented in the past persist over time. The coefficient for Islamic finance development value (LogIFD) is -0.0015, which is not statistically significant. This suggests that, within the sample, Islamic finance development does not have a significant impact on life expectancy at birth. The non-significant impact of Islamic finance development on life expectancy suggests that Islamic finance, in its current form, may not be directly contributing to health improvements, which is a majot issue of great concern.

The coefficient for foreign aid value (LogAID) is -0.0121, which is statistically significant at the 5% level. This negative and significant coefficient suggests that

an increase in foreign aid is associated with a decrease in life expectancy at birth. This counterintuitive result may indicate that foreign aid is not effectively improving health outcomes, possibly due to misallocation or inefficiencies or corruption, which cannot be ruled out. Therefore, foreign aid strategies need re-evaluation to ensure they positively impact life expectancy. The coefficient for government budget spending on social development value (LogGBS), which is 0.0316, has no significant effect on life expectancy. This implies that government spending is not translating into improved life expectancy, suggesting a need for more effective allocation and management of health-related expenditures. This could be due to inefficiencies in the allocation and utilization of these funds.

Table 2 shows the results from Model 1 for middle-income countries in Africa. At the 1% level, the elasticity coefficient for poverty reduction's lagged value (LogPR(-1)) is positive and statistically significant, with a value of 0.1915. This indicates that a 1% increase in poverty reduction in the previous year leads to a 0.1915% increase in the current year's poverty reduction, ceteris paribus. The relationship between current and lagged poverty reduction is inelastic, meaning that past successes in poverty reduction have a positive but less than proportional impact on current poverty reduction efforts. This finding highlights the importance of sustained and continuous efforts in the fight against poverty, as improvements made in the past contribute to further reductions, albeit at a diminishing rate. It also implies that consistent and ongoing poverty alleviation programmes are critical for maintaining progress over time.

The elasticity coefficient for LogIFD indicates that Islamic finance development has a negative impact on poverty reduction. Specifically, a 1% increase in Islamic finance development leads to a 0.0052% decrease in poverty reduction. This unexpected negative sign suggests that Islamic finance might not be effectively targeted or utilized in poverty reduction strategies. This finding implies a need for a re-evaluation of how Islamic finance funds are allocated and used in poverty reduction programmes, particularly qard hasan loans which can improve the standard of living of the poor who constitute *fuqaral* or *masakin*. Thus, directing these funds towards effective and efficient uses can enhance their impact on poverty alleviation. The coefficient for foreign aid (LogAID) is 0.0240, and it is statistically significant at the 1% level. This indicates that a 1% increase in foreign aid, on average, leads to a 2.4% reduction in poverty, ceteris paribus. The relationship is therefore elastic. This suggests that foreign aid can significantly contribute to poverty reduction by providing essential resources to these countries. This finding leads to the conclusion that foreign aid is beneficial for

poverty reduction. However, efforts should be made to ensure that aid is effectively targeted and managed to maximize its impact.

Table 2: *System GMM Estimation for Middle Income Countries*

Independent Variable	Model 1: LogPR	Model 2: LogSER	Model 3: LogLXP
LogPR(-1),	0.1915*** (5.49)		
LogSER(-1)		0.5257*** (4.64)	
LogLXP(-1)			0.3453*** (20.10)
LogIFD	-0.0052*** (4.48)	0.0042 (0.57)	0.0025*** (6.98)
LogAID	0.0240*** (4.73)	-0.0371 (1.21)	-0.0093*** (14.44)
LogGBS	0.8135*** (7.57)	-0.4326**(2.16)	0.0001 (0.01)
LogQGG	-5.8144*** (5.63)	5.2529 (1.53)	-1.5231*** (4.00)
LogGDP	-0.4589*** (15.35)	0.0359 (0.21)	0.0125*** (3.90)
P-value for Hansen Test	0.292	0.761	0.256
AR(2)	0.693	0.646	0.985
Groups/Instruments	25/25	17/17	25/25
Number of countries	35	35	35
Number Observations	250	164	250

Notes: ***, **, * are statistical significance at 1%, 5% and 10% respectively; t-statistics (in parentheses) are based on white heteroscedasticity-consistent standard errors.
Source: Author's computations

The coefficient for government budget spending (LogGBS) is 0.8135 and statistically significant at the 1% level. This indicates that a 1% increase in government budget spending results, on average, in a 0.8135% increase in poverty reduction, ceteris paribus. This suggests that allocating more resources to poverty reduction programmes and initiatives can lead to substantial improvements in poverty alleviation. Consequently, it highlights the importance of proper planning and budget allocation to ensure adequate funding for programmes aimed at reducing poverty and enhancing social welfare.

The coefficient for governance quality (LogQGG) is -5.8144 and statistically significant at the 1% level. This means that a 1% improvement in the governance quality index is associated, on average, with a 5.8144% decrease in poverty reduction, *ceteris paribus*. The relationship is elastic, suggesting that improvements in governance quality, as measured by this index, correlate with reduced effectiveness in poverty reduction efforts. This unexpected negative

relationship indicates that higher governance quality does not necessarily translate into better poverty reduction outcomes. Several factors could be influencing this result. For instance, political instability, lack of accountability, corruption, and other forms of bad governance can undermine the potential benefits of improvements in governance quality. Even with better governance indicators, the persistence of these issues may prevent the effective implementation of policies aimed at reducing poverty.

The coefficient for gross domestic product (LogGDP) is -0.4589, and it reaches statistical significance at the 1% level. This indicates that for every 1% increase in GDP growth, there is a corresponding decrease of 0.4589% in poverty reduction, assuming all other variables remain constant. This inverse relationship suggests that GDP growth is inelastic with respect to poverty reduction, implying that increased economic output does not necessarily benefit the poorer segments of the population. This finding underlines the fact that there is unequally distributed wealth and various resources within middle-income countries, where economic growth often benefits a select few. This finding calls for inclusive growth and policies targeting income inequities to curb poverty.

The coefficient of the lagged value of the school enrolment ratio ((LogSER-1) is 0.5257, indicating that a 1% increase in the previous year's school enrolment ratio results in an average increase of 0.5257% in the current year's enrolment ratio, ceteris paribus. This demonstrates that successful educational interventions have a lasting effect, as the continuity in enrolment ratios persists over time. This implies that the focus should be on maintaining and enhancing educational programmes to build on this momentum. Thus, sustaining efforts to improve school enrolment over multiple years can create compounding positive effects.

The coefficient of Islamic finance development (LogIFD), which is 0.0042 and positive, is not statistically significant. This suggests that changes in Islamic finance development have no clear impact on secondary school enrolment ratios. This calls for a re-evaluation of how Islamic finance is utilized to support educational projects. The coefficient of foreign aid (LogAID), which is 0.0371, is not statistically significant. This indicates that foreign aid does not have a discernible impact on secondary school enrolment ratios within the scope of this model. This implies that foreign aid allocated to education needs to be more effectively targeted or increased to make a measurable impact. Thus, the effectiveness of foreign aid in education should be evaluated to ensure that these funds are directed and utilized to improve enrolment rates effectively.

The coefficient of government budget spending (logGBS), which is -0.4327, indicates that a 1% increase in government budget spending on social development is associated with a 0.4327% significant decrease in school enrolment, ceteris paribus. This counterintuitive result suggests that increased government spending on social development does not translate into higher school enrolment ratios. Several factors could contribute to this issue, including the misallocation of funds, where increased spending may be diverted to non-educational sectors, and bureaucratic inefficiencies that can absorb budget increases without resulting in tangible improvements. Corruption, weak governance structures, and a focus on infrastructure over direct educational improvements also play significant roles. Additionally, insufficient investment in teacher training, learning materials, and programmes addressing economic barriers faced by families further explain this discrepancy.

The coefficient of the governance quality index (LogQGG), which is 5.2529, is not statistically significant, indicating that governance quality does not have a significant impact on school enrolment ratios in this context. Several factors might contribute to this outcome. For instance, weak policy implementation, pervasive corruption, and systemic inefficiencies within the educational sector could negate the potential benefits of improved governance. Furthermore, while good governance is expected to influence school enrolment, this finding suggests that such improvements may not be specifically targeted at the education sector. If governance reforms are more focused on broader macroeconomic stability or other sectors, rather than directly addressing educational challenges, their impact on school enrolment could remain negligible. In addition, without targeted efforts to address educational inequalities and ensure that reforms reach disadvantaged communities, the influence of governance quality on school enrolment may be limited.

The coefficient of economic growth (GDP per capita growth), which is 0.0359, while positive, is not statistically significant, suggesting that GDP per capita growth does not have a significant direct impact on secondary school enrolment ratios in this model. Several factors may contribute to this outcome. For example, economic growth may disproportionately benefit wealthier segments of the population, leaving lower-income families without the means to afford education. If the benefits of growth are not equitably distributed, poorer households may still struggle with the direct and opportunity costs of schooling,

such as fees, uniforms, and the need for children to work. In addition, even if a country experiences economic growth, the infrastructure needed to support education, such as schools, teacher training, and educational materials, may remain underdeveloped. Without targeted investments in these areas, growth in GDP per capita may not translate into better access to education. It is also important to note that economic growth does not automatically lead to increased government spending on education. If the government prioritizes other sectors, or if corruption and inefficiencies divert funds away from education, the potential benefits of economic growth for schooling could be diminished. In some middle-income African countries, social and cultural factors may still impede educational participation, particularly for girls. Thus, economic growth may have little impact on school enrolment if these barriers are not addressed through specific policies and community engagement.

The coefficient of the lagged value of life expectancy LogSER(-1), which is 0.3453, indicates that a 1% increase in life expectancy in the previous year leads to a 0.3453% increase in the current year's life expectancy, ceteris paribus. This suggests a strong persistence effect, where improvements in life expectancy are likely to continue and positively influence future outcomes. Therefore, policymakers should focus on sustaining and enhancing health interventions, as their positive effects are likely to persist and accumulate over time. This underscores the importance of continuous efforts to improve life expectancy, ensuring sustained improvements that contribute to better health outcomes in middle-income countries.

The coefficient of Islamic finance development (LogIFD), which is 0.0025, indicates that a 1% increase in Islamic finance development leads to a 0.0025% increase in life expectancy, holding other factors constant. Given that Islamic finance emphasizes social welfare and ethical investing, directing funds towards building hospitals, clinics, and research centres can enhance public health outcomes and potentially increase life expectancy. This finding has several policy implications and practical applications within the framework of Islamic finance principles. Although Islamic finance may contribute to life expectancy by funding health-related projects or services, the limited impact suggests that these funds might not be effectively channelled into widespread or impactful health interventions. Policymakers should therefore focus on more strategic allocation of Islamic finance resources to areas with the highest potential impact on public health, such as primary healthcare, maternal and child health, and preventive care. In addition, Islamic finance initiatives should be better integrated with

national health strategies to ensure that funds complement government efforts to improve life expectancy. This could involve partnerships between Islamic financial institutions and public health agencies to co-fund critical health projects.

The coefficient of foreign aid (LogAID), which is -0.0093, indicates that a 1% increase in foreign aid leads to a 0.0093% decrease in life expectancy. This negative relationship could stem from several factors, including the misallocation of foreign aid, dependency on aid without building sustainable health infrastructure, or the possibility that aid is not being effectively targeted towards health improvements. There is a critical need to reassess how foreign aid is allocated and utilized in the health sector. Foreign aid should be better targeted, monitored, and directed towards sustainable health projects that can tangibly improve life expectancy. Efforts should also be made to reduce corruption and ensure that aid is used effectively.

The coefficient of government budget spending on social development (LogGBS), which is 0.0001, is not statistically significant, suggesting that government budget spending on social development does not have a significant impact on life expectancy. This finding may reflect inefficiencies in how government funds are utilized or the possibility that increases in budget spending are not necessarily directed towards areas that directly influence life expectancy, such as healthcare infrastructure or services. Therefore, governments need to evaluate and improve the efficiency and targeting of their budget spending to ensure that funds are directed towards initiatives that can enhance life expectancy. This could involve prioritising healthcare services, improving access to medical facilities, and investing in public health campaigns.

The coefficient of governance quality (LogQGG), which is -1.5231, indicates that a 1% increase in governance quality results in a 1.5231% decrease in life expectancy. This negative relationship is surprising and suggests that improvements in governance quality, as measured by this index, do not translate into better health outcomes. This counterintuitive result could be due to a variety of factors. It is possible that governance reforms, although improving overall governance quality, are not sufficiently focused on or aligned with health-related outcomes. Corruption, inefficiency, or the prioritization of other sectors over health could also explain this result. This implies that governance reforms need to be more closely aligned with health objectives to improve life expectancy. It may be necessary to integrate health considerations into broader governance

strategies and ensure that governance improvements translate into better health services and outcomes.

The coefficient of gross domestic product per capita (LogGDP), which serves as a proxy for economic growth per capita, is 0.0125. This suggests that a 1% increase in GDP growth leads to a 0.0125% increase in life expectancy. While economic growth can contribute to improvements in living standards and access to health services, the modest size of the coefficient indicates that economic growth alone is insufficient to significantly impact life expectancy. The implication is that although economic growth is beneficial, it must be accompanied by targeted investments in healthcare and social services to more effectively improve life expectancy. Thus, policies that ensure an equitable distribution of the benefits of growth, particularly in healthcare, are essential. This underscores the need for inclusive growth strategies that directly address health and well-being.

4.1 Comparative analysis of major variables among African countries

4.1.1 *Poverty Reduction*

Foreign aid plays an important role in poverty reduction in both low- and middle-income countries. However, middle-income countries appear to have a more substantial impact due to their more effective use of foreign aid in poverty alleviation. These countries seem to better integrate foreign aid into their existing social and economic frameworks, resulting in more pronounced reductions in poverty. In contrast, low-income countries, while benefiting from foreign aid, may face challenges such as weaker institutional frameworks and limited absorptive capacity, which could dilute the overall effectiveness of aid in these contexts. This suggests that low-income countries may need to focus on strengthening their institutions and enhancing the management of aid resources to achieve more significant poverty reduction outcomes.

The impact of Islamic finance on poverty reduction varies significantly between low- and middle-income countries. Its contribution to poverty reduction in low-income countries is minimal, likely due to the early stage of development and limited reach of Islamic finance systems in these countries. The modest impact suggests that there is potential for growth, but this would require significant efforts in developing and tailoring financial products that meet the needs of the poor, along with increasing financial literacy and access. In contrast, a surprising negative association exists between Islamic finance and poverty reduction in

middle-income countries, suggesting that current practices may not effectively align with poverty alleviation goals. This finding necessitates a re-evaluation of the use of Islamic finance, indicating the need for improved targeting and more efficient integration into wider strategies for poverty reduction.

The analysis reveals that government budget allocation is a crucial factor in poverty reduction in middle-income countries, where strategic and well-funded government programmes significantly impact poverty levels. These countries likely have more developed administrative systems and better infrastructure, enabling them to allocate and utilize resources effectively. On the other hand, in low-income countries, government spending does not show a significant impact on poverty reduction, likely due to issues such as corruption, resource misallocation, and limited budgetary capacity. This underscores the significance of enhancing governance, transparency, and accountability in low-income countries to guarantee the efficient use of public funds in tackling poverty.

Governance quality and economic growth present complex challenges, particularly in middle-income countries, where they are paradoxically associated with less effective poverty reduction. This suggests that despite improvements in governance or economic growth, underlying issues such as corruption, political instability, and unequal wealth distribution may prevent these improvements from translating into better poverty outcomes. This highlights the need for more inclusive growth strategies and comprehensive governance reforms that address these systemic issues to ensure that economic and governance improvements benefit the broader population, especially the poor.

4.1.2 *School Enrolment*

The analysis of school enrolment across low- and middle-income African countries highlights several critical patterns and challenges, particularly concerning government spending, foreign aid, and other factors. In middle-income countries, the previous year's school enrolment ratio positively influences the current year's enrolment, indicating a relatively strong continuity in educational participation. This suggests that successful educational interventions can have lasting impacts in these contexts, with past efforts compounding to sustain enrolment rates over time. However, in low-income countries, this lagged effect is positive but statistically insignificant, suggesting that the factors driving school enrolment are more volatile and less predictable. This disparity points to a need for more

consistent and sustained educational policies in low-income countries to build momentum in school enrolment.

Across both income groups, Islamic finance development has a positive but statistically insignificant impact on secondary school enrolment. This finding indicates that while Islamic finance might contribute to broader economic opportunities, it does not directly influence educational outcomes. The negligible effect in both contexts suggests that Islamic finance mechanisms need to be more explicitly linked to educational funding or initiatives. In both low- and middle-income countries, re-evaluating how Islamic finance is utilized to support education could enhance its impact on school enrolment.

Foreign aid shows a positive but statistically insignificant effect on school enrolment in both low- and middle-income countries. This suggests that foreign aid, as currently allocated, does not robustly influence educational outcomes. The non-significant impact implies that foreign aid for education may be poorly targeted or misallocated, failing to address the specific needs of the education sector in these regions. Therefore, there is a critical need for better-targeted aid interventions that directly support educational infrastructure, teacher training, and access to schooling, ensuring that aid effectively contributes to increasing enrolment rates.

In both low- and middle-income countries, the most striking finding is the negative and statistically significant relationship between government budget spending on social development and secondary school enrolment. This counterintuitive result suggests significant inefficiencies or mismanagement in how educational funds are allocated and utilized. In both contexts, increased spending does not translate into higher enrolment rates, likely due to issues such as corruption, fund misallocation, and inadequate investment in crucial areas like teacher quality, educational materials, and infrastructure. However, the overall finding suggests the need for comprehensive education reforms that go beyond merely increasing financial allocations. These reforms should include strategies to improve the quality of education, enhance the accessibility of schooling for marginalized groups, and ensure that all resources are used transparently and effectively.

In middle-income countries, governance quality and economic growth also fail to have significant impacts on school enrolment. The lack of significance in governance quality suggests that better governance does not always lead to

better educational outcomes. This could be because of widespread corruption or because governance reforms have not been tailored to the needs of the education sector. Similarly, economic growth does not significantly influence enrolment, highlighting issues such as the unequal distribution of economic benefits and the persistence of economic barriers to education, particularly for disadvantaged populations.

4.1.3 *Life Expectancy*

The comparative analysis of the factors influencing life expectancy in low- and middle-income African countries reveals key factors affecting social development. In low-income countries, the lagged value of life expectancy shows a strong positive and significant effect, indicating that past gains in life expectancy continue to influence current levels. This underscores the importance of maintaining and enhancing successful health interventions. In middle-income countries, although the lagged effect is also significant, it is less pronounced. This finding suggests that while past health gains are critical in both contexts, sustained efforts and continuous health investments are essential to ensure ongoing improvements in life expectancy. There is need for inclusive health care provision systems that affect both workforce and non-workforce, elite and non-elite, male and female, adults and children.

The role of Islamic finance in improving life expectancy shows varying effects between the two groups. In middle-income countries, Islamic finance development shows a positive but modest influence on life expectancy, implying that its contributions to public health may be more effective when Islamic finance is more established and better integrated into national health strategies. On the other hand, the development of Islamic finance in low-income countries does not significantly influence life expectancy. The lack of impact may be due to the nascent stage of Islamic finance in these countries, which has not yet sufficiently adapted or targeted towards health-related initiatives. The findings suggest that to meaningfully contribute to life expectancy improvements, especially in low-income countries, there needs to be a stronger focus on developing Islamic-compliant products and integrating Islamic finance into broader health and social development strategies.

The relationship between foreign aid and life expectancy is negative and significant in both low- and middle-income countries, indicating that increased

foreign aid is paradoxically associated with lower life expectancy. In low-income countries, this negative impact may be due to misallocation, inefficiency, or a lack of sustainable health infrastructure. In middle-income countries, the inverse relationship could be driven by similar issues or by foreign aid being offset by other factors such as governance challenges. These findings suggest a critical need to reform foreign aid strategies, ensuring that aid is more effectively targeted, better managed, and directed towards sustainable health improvements that can genuinely enhance life expectancy.

In low- or middle-income countries, government budget spending on social development does not have a significant positive impact on life expectancy. In fact, the relationship is negative in middle-income countries, suggesting that increased spending does not necessarily translate into better health outcomes. This may be due to inefficiencies in how funds are allocated or utilized, with resources potentially being diverted away from critical health services or absorbed by bureaucratic inefficiencies. This finding underscores the necessity for governments to enhance the efficiency and targeting of their spending, directing budget increases towards initiatives that directly boost life expectancy, like healthcare infrastructure, public health campaigns, and medical service access. Therefore, the findings suggest that merely augmenting government spending is insufficient, as it necessitates strategic allocation towards sectors with the greatest potential to enhance health outcomes, like primary healthcare, disease prevention, and maternal and child health services.

In middle-income countries, governance quality has a surprising negative relationship with life expectancy, which is significant. This counterintuitive finding may reflect governance reforms that are not sufficiently focused on health outcomes, or it may indicate systemic issues such as corruption and bureaucratic inefficiencies that undermine health service delivery. In contrast, economic growth, measured by GDP per capita, has a positive impact on life expectancy in middle-income countries. This suggests that economic growth in middle-income countries contributes to better health outcomes by improving living standards, nutrition, and access to healthcare.

5.0 Conclusion and Recommendations

5.1 Conclusion

This study compared different financing models for social development in low- and middle-income African countries between 2013 and 2022. The analysis examined the impact of these models on poverty reduction, school enrolment, and life expectancy. The findings reveal that some factors have a positive impact, while others have limited or unexpected effects, highlighting areas that require attention for more effective policy formulation. In low-income countries, previous efforts to reduce poverty have a positive but gradual impact, which suggests the need for sustained initiatives. Islamic finance development has a modest positive effect on poverty reduction but does not significantly impact school enrolment or life expectancy. Foreign aid significantly reduces poverty but has a surprising negative impact on life expectancy, indicating possible inefficiencies in its allocation. Government budget spending, particularly on social development, also shows unexpected outcomes, with negative effects on school enrolment and no significant impact on life expectancy. These findings suggest a need for better management and allocation of resources.

In middle-income countries, previous poverty reduction efforts and school enrolment rates have a lasting positive effect, but this influence diminishes over time. Islamic finance development negatively affects poverty reduction but shows a small positive impact on life expectancy. Foreign aid benefits poverty reduction but negatively impacts life expectancy, similar to the findings in low-income countries. Government budget spending positively influences poverty reduction but has adverse effects on school enrolment, indicating potential inefficiencies. Governance quality shows an unexpected negative relationship with poverty reduction and life expectancy, suggesting that improvements in governance do not automatically lead to better socio-economic outcomes.

5.2 Recommendations

Based on the study's findings, the following policy recommendations are made:

i. Governments should prioritize integrating Islamic finance into comprehensive poverty reduction strategies. This can be achieved by designing financing products that cater for the needs of the poor and ensure they are accessible to vulnerable groups.

ii. To maximize the impact of foreign aid, particularly in health and education, a more strategic approach is necessary. This includes targeting aid more effectively, reducing corruption, and ensuring funds are used for sustainable projects that directly enhance life expectancy and educational outcomes.
iii. The unexpected negative effects of government spending on school enrolment and its limited impact on life expectancy suggest a thorough review of budget allocation processes is necessary. Governments should prioritize education and health spending, ensuring efficient utilization of funds and directing them towards initiatives that yield tangible improvements.
iv. Eliminating corrupt and fraudulent practices in budgeting and misallocating funds in low-income countries is crucial. This requires making the budgetary process more accountable to all stakeholders and ensuring resources are directed towards effective initiatives.
v. The negative impact of governance quality on poverty reduction and life expectancy highlights the need for governance reforms to align with socio-economic objectives. Efforts should focus on ensuring improvements in governance lead to better policy implementation and programmes that directly benefit the population. In addition, enhancing good governance, promoting transparency in government operations, increasing accountability, and improving efficiency in public administration are essential steps towards achieving desired outcomes.
vi. Economic growth alone is insufficient to significantly improve life expectancy or reduce poverty. Policies should focus on ensuring the benefits of growth are equitably distributed, with investments in healthcare, education, and social services to directly address the needs of the poor and vulnerable populations.

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