Institutional Quality, Innovation Diffusion and the Dynamics of Income Inequality in Nigeria and South Africa: Evidence from the Fourier ARDL Framework.

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ABSTRACT

This research work investigates the dynamic and long-run relationships among institutional quality, innovation diffusion and income inequality in Nigeria and South Africa using annual time series data. In order to take care of the gradual structural shifts embedded in developing and emerging economies, this study incorporates the Fourier unit root test and Fourier Augmented Autoregressive Distributed Lag (FARDL) techniques, which give room for smooth and unknown structural breaks. The Fourier unit root results confirm cross-country heterogeneity in the stationary properties of the series and reveal the importance of modelling gradual structural transitions in inequality dynamics. The short-run FARDL results reveal that enhancements in institutional quality reinforce income inequality in both countries, which implies uneven distribution of early institutional gains. Innovation diffusion reveals varying effects, worsening income inequality in Nigeria and reducing inequality in South Africa. Government expenditure on infrastructure and GDP per capita exhibit weak and statistically insignificant short-run impacts on income inequality. In the long-run, institutional quality maintains positive relationship with income inequality in both countries. While innovation diffusion keeps increasing inequality in Nigeria, innovation continues to impact a persistent equalising effect in South Africa. The Significance of the Fourier terms in both economies stresses the influence of smooth structural transitions in moulding inequality outcomes. Generally, the findings in the study substantiate the importance of inclusive institutional reforms and broad-based innovation diffusion in tackling income inequality in African economies

Keywords: Income Inequality; Institutional Quality; Innovation Diffusion; Fourier ARDL; Structural Shifts; Nigeria ; South Africa.

INTRODUCTION

The widening gap between the rich and the poor has emerged as a global concern, prompting international efforts, as reflected in Sustainable Development Goal 10, to address and reduce disparities within and among nations. The implications of persistent and widening inequality extend beyond economic consequences, it equally affects political stability, social cohesion and overall well-being (Berg & Ostry, 2011; Jauch &Watzka, 2016). Considering this global perspective, Nigeria and South Africa stand as prototypes that confront with unique challenges that require context-specific investigations. Based on historical background, the lines of movement of both countries have been shaped by factors such as colonization apartheid in South Africa and post-colonial governance in Nigeria. These historical trajectories have left lasting imprints on the distribution of wealth, access to resources and opportunities for various segments of their population. The reflections of these historical foundations reverberate in contemporary challenges, thereby contributing to structural inequalities that are deeply embedded in societal structures.

Nigeria and South Africa, two of the African Continent's largest and most diversified economies, exhibit though contrasting but worrying forms of inequality. Despite their substantial resource endowments and intermittent episodes of economic growth, both countries continue to face the challenges of high and rising income inequality. South Africa, for example, stands to be one of the most unequal societies globally, this is quite evident in the country's Gini coefficient of 63.0 as recorded in the comparable household survey (World Bank, 2023). In the same vein, Nigeria's measured inequality though lower than South Africa's, but remains significant with a Gini coefficient of 35.1 and approximately 40% of its population living below standard survey (World Bank, 2023). The socio-economic implications of this inequality are mirrored in persistently high unemployment rates and

low social mobility. South Africa's unemployment rate has moved above 30% with the youth unemployment exceeding 50% in some quarters (Statistics South Africa, 2024). Nigeria in its own case continues to face a complex employment crisis. Its official unemployment rate rose to 5.0% in Q3 of 2023 (National Bureau of Statistics, 2023). These patterns actually pointed to the fact the economic growth in both countries has been largely non-inclusive, with wealth and opportunity concentrated in limited sectors and among privileged groups.

In addressing all these complex web of challenges, the focus now turns to the quality of institutions. The institutional quality which is the effectiveness of governance, regulatory frameworks, rule of laws and control of corruption, plays a crucial role in determining how economic gains are distributed across society (Acemoglu & Robinson, 2012; North, 1990). Weak institutions often put barriers to equitable access to resources, distort incentives and give room for rent-seeking behaviour, thereby worsening income inequality. Conversely, strong and healthy institutions give room for an enabling environment for fair competition, transparency and accountability, which are essential for inclusive growth. According to the World Governance Indicators (WGI), Nigeria consistently records below the regional average on key indicators such as rule of law, government effectiveness and control of corruption; while South Africa scores relatively better but still confronts governance challenges, particularly in political stability and regulatory quality (World Bank, 2023).

Moreover, innovation also is well recognised as a key determinant of long-term economic performance and income distribution (Aghion, Akcigit, Bergeaud & Hemous, 2019). Innovation stimulates productivity, technological growth and new employment opportunities. However, when innovation systems are impaired or selective, then the rewards of technological advancement are therefore concentrated disproportionately to a small segment of the population. According to the Global Innovation Index (2023), South Africa is ranked 59th globally and 1st in Sub-Saharan Africa, which implies a relatively strong innovation network. Nigeria in its own case, is ranked 109th which indicates weak innovation frameworks (World Intellectual Property Organisation, 2023). These imbalances signal that unequal innovation diffusion may give room for inequality in countries with frail institutional system.

Despite global efforts and commitments to reduce income inequality, Africa continues to struggle with persistent economic challenges that impede her sustainable development (HLPE, 2023). According to Ncube & Anyanwu (2021), the extreme income inequality in Sub-Saharan Africa, in which Nigeria and South Africa are embedded, exacerbates social tensions and undermines efforts to achieve inclusive growth. In recent years, numerous efforts have been undertaken to address Africa's economic challenges, ranging from foreign aid to policy reforms and investment initiatives. For instance, the African Union's Agenda 2063 provides a strategic framework for promoting inclusive growth and sustainable development across the continent (African Union, 2021). In addition, initiatives such as the United Nations Sustainable Development Goals (SDGs) and the African Continental Free Trade Area (AFCFTA) aim to stimulate economic growth and reduce inequality through targeted interventions (UNCTAD, 2021).

However, despite these efforts, several challenges persist, hindering the effectiveness of interventions aimed at addressing Africa's economic problems. One significant barrier is the issue of corruption, which undermines governance structures and siphons resources intended for development (Transparency International, 2022). In this regards, the nexus between institutional quality, innovation and income inequality in Africa nations represents a critical problem that demand thorough examination. Examining Nigeria and South Africa as the two of Africa's most influential economies comparatively presents a valuable opportunity to understanding the complexities surrounding institutional quality, innovation diffusion and income inequality within the African context, as this will inform evidence-based policy making efforts aimed at fostering sustainable development and social equity in the two countries.

In literature, the relationship among institutional quality, innovation diffusion and income inequality has been a topic of debate. However, existing findings on this relationship remains largely disjointed, with most studies examining the relationships among these three concepts separately, thereby overlooking their potential interdependence. Examples of this can be found in the works of Aghion et al (2019) and Frydman and Papanikolaou (2015) who only concentrated on the impact of innovation on the income inequality. Moreover, the research works of Kunawotor, Bokpin and Barnor (2020), Asamoah (2021) and Nkoa (2022) focused on the effect of institutional quality on the income inequality. Whereas, this empirical gap is majorly significant for

African economies where both institutional weakness and uneven innovation advancement are the key features of economic development.

Another area of setbacks in the past research works is their methodological treatment of structural breaks. Many of the past empirical works focused on examining the income inequality and its determinants by relying on the abrupt structural break models propounded by Perron (1989), Zivot and Andrews (1992), and Gregory and Hansen (1996). These estimation methods suggest that breaks occur suddenly at specific point in time, even despite the fact that institutional reforms, technological progress and socio-economic breaks typically happen smoothly over time. Example of this gap can be found in the research work of Adeleye (2021) who adopts the techniques of Zivot-Andrews and Gregory-Hansen tests to study inequality dynamics in Nigeria, modelling structural adjustments as abrupt jumps. This methodological approaches may misrepresent gradual transformations in institutional quality, technology diffusion, thereby setting spurious long-run parameters estimates. To correct these past shortcomings, this current research work adopts the Fourier ARDL model that integrates flexible Fourier terms to approximate multiple smooth breaks in both short-run and long-run dynamics. This therefore offers a more realistic and statistically robust framework for analysing macroeconomic relationships in countries where institutional quality and innovation diffusion are gradual and persistent, thereby making it fit for studying Nigeria and South Africa.

LITERATURE REVIEW

Aghion et al (2019) used data from advanced and emerging economies that captured cross-country evidence. Their findings revealed that the higher innovation performance tends to increase top income shares. They argued that the innovation process, while enhancing growth, tends to benefit individuals at the technological frontier, thereby amplifying distributional disparities. Also, Aghion (2022) revealed that innovation can lower inequality in the long run by stimulating productivity and expanding economic opportunities, but the short-to-medium term efforts often remain unequalizing without strong complementary institutions.

Frydman and Papanikolaou (2015) adopted intra-firms data analysis to provide further evidence that innovation disproportionately raises the earnings of investors, executives and high-skilled workers. Their findings indicated that technological breakthroughs tends to reallocate rewards within firms towards innovators, creating wage dispersion that contributes to broader inequality trends.

Odedokun's (2016) study specifically delves into the causal relationship between corruption and income inequality in Nigeria. The data used covers annual records from Nigeria spanning the years 1981-2012. In the study, the Gini coefficient of income inequality serves as the dependent variable, and corruption is measured by the Transparency International Corruption Perception Index (CPI) as the independent variable. Control variables encompass GDP per capita, the inflation rate, and the oil revenue share. Methodologically, the study adopts a vector autoregression (VAR) analysis with Granger causality tests to discern the direction of causal relationships between corruption and income inequality. The findings reveal a bidirectional causal relationship between corruption and income inequality in Nigeria. The study underscores the importance of addressing corruption not only for its direct impact on inequality but also to break the vicious cycle it creates.

Kunawotor et al (2020) focuses on investigating the role of institutional quality among various drivers of income inequality in Africa. The data used spans 47 African countries over the period 1990-2017, encompassing both aggregate and individual-level variables. The study employs the Gini coefficient of income inequality as the dependent variable. Independent variables include various dimensions of institutional quality such as control of corruption, government effectiveness, voice and accountability, regulatory quality, political stability, and an aggregate index of institutional quality. The findings reveal that, overall, institutional quality has a mixed and weak effect on income inequality in Africa. The study emphasizes the importance of considering specific aspects of institutional quality rather than relying solely on aggregate measures.

Asamoah (2021) delves into the question of whether institutional quality can mitigate income inequality, exploring the potential existence of a threshold effect where the impact varies based on the level of institutional quality. The data span for the study covers the years 1995-2017 and involves panel data from 158 countries, comprising both aggregate and individual-level variables. The primary variables include the Gini coefficient of income inequality as the dependent variable, and two indices measuring institutional quality: the World Governance Indicators (WGI) and the International Country Risk Guide (ICRG), as independent variables.

Control variables encompass GDP per capita, trade openness, government effectiveness, and the rule of law. Employing a dynamic panel threshold analysis (DPT), the study uncovers a negative relationship between institutional quality and income inequality, suggesting that higher institutional quality tends to decrease inequality. Notably, WGI exhibits a threshold effect, indicating that the reduction of inequality is observable only above a certain institutional quality level in developing economies. In contrast, ICRG shows a consistently negative effect across all countries, implying a straightforward linear relationship.

Ongo, Nkoa and Song (2021) analyzed the relationship between institutional quality and income inequality in African countries. The dataset spans from 1996 to 2016, covering panel data from 48 African countries. The study employs the Gini coefficient as the dependent variable, representing income inequality, while independent variables include various aspects of institutional quality, control variables related to economic and political factors, and measures to capture potential negative aspects of entrenched power. Utilizing a panel fixed-effects regression model with robust standard errors and instrumental variable (IV) estimations, the study reveals that governance indices generally exhibit a negative relationship with inequality, emphasizing the positive impact of good governance, yet individual dimensions show varying effects. Economic factors, such as GDP per capita and growth rate, exhibit mixed effects, adding layers of complexity to the relationship between economic development and inequality distribution.

Vu (2022) investigates the relationship between political instability and income inequality using a panel of countries. The study uses data from 143 countries for the period 1996-2015. The data includes both aggregate and individual-level variables. The study employed Variables on the Gini coefficient of income inequality, political instability, measured by the Polity V Composite Political Instability Index, GDP per capita, growth rate, trade openness, human capital, democracy score and government effectiveness, rule of law, ethnic fractionalization, and linguistic fractionalization. The study uses pooled Ordinary Least Squares (OLS) regressions and panel fixed-effects models as a tool of analysis. It also employs instrumental variable (IV) estimations to address potential endogeneity concerns. The study finds a positive and significant relationship between political instability and income inequality. This means that higher levels of political instability are associated with greater income inequality. However, the effect of political instability is stronger in nondemocratic and highly diverse societies, as well as in low-income economies.

Opoku and Agyapong (2022) study investigates the relationship between various aspects of governance and income inequality in South Africa, employing a dynamic fixed-effects panel approach. The data used spans panel data from 9 provinces in South Africa for the period 2000-2018. Methodologically, the study utilizes a dynamic fixed-effects panel regression with robust standard errors to address potential unobserved heterogeneity and autocorrelation issues. This method enables the analysis of the long-term impact of governance on inequality. The findings reveal a mixed relationship between governance quality and income inequality in South Africa. Control of corruption and the rule of law exhibit significant negative effects on inequality, indicating that improvements in these areas tend to reduce inequality. The study emphasizes the significance of focusing on specific dimensions of governance, particularly control of corruption and the rule of law, to effectively tackle inequality in South Africa.

Abedini and Asafu-Adjaye (2023) research delves into the intricate relationships among income inequality, economic growth, and governance in African countries, utilizing panel data from 54 nations over the period 1996-2019. The study employs a two-step system Generalized Method of Moments (GMM) approach with robust standard errors to tackle potential endogeneity and autocorrelation. Additionally, a dynamic panel threshold analysis is applied to explore non-linear relationships between income inequality, growth, and governance. The findings reveal a positive relationship between economic growth and income inequality in Africa, suggesting an initial increase in inequality during economic expansion. The study underscores the pivotal role of good governance, especially the rule of law and control of corruption, in alleviating income inequality in Africa.

Adeleye (2021) studied relationships among income inequality, human capital, and institutional quality in SubSaharan Africa, utilizing unbalanced panel data covering 46 countries from 2010 to 2019. The research employs two quantitative methodologies to comprehensively explore these dynamics. The Driscoll and Kraay (1998) Panel Spatial Correlation Consistent (PSCC) regression addresses potential spatial correlation issues in the data, while the Firpo *et al*. (2007) Unconditional Quantile Regression (UQR) method allows for a nuanced

analysis of variable impacts across different income levels. Key findings reveal a seemingly counterintuitive positive relationship between income inequality and both human capital (measured by the Human Capital Index) and institutional quality (measured by the Institutional Quality Index). However, the study unveils a crucial nuance— the interaction effect between human capital and institutional quality is negative. This implies that enhancements in institutional quality can offset the inequality-increasing impact of human capital investments.

Agwu and Ugboh (2023) study provides a nuanced examination of income inequality by employing a quantile regression approach, offering insights into how various factors influence inequality across different income levels. The research utilizes recent data from the Nigeria Bureau of Statistics covering the period 2010-2019, specifically drawing from household income and expenditure surveys. The result of their study indicates a positive relationship between economic growth and income inequality in Nigeria. The study emphasizes the importance of investing in quality education at all levels and promoting the formalization of the informal sector as a crucial aspect of tackling inequality in the country.

RESEARCH METHOD

THEORETICAL FRAMEWORK

The analysis of the relationship among institutional quality, innovation diffusion and income inequality in this study is rested on the intersection of institutional economics theory and innovation-driven growth theory, both of which have theoretical underpinning for income distribution dynamics. The theory of institutional economics which was propounded by North (1990) and later revised by Acemoglu and Robinson (2012), explains that institutions (formal and informal rules) governing economic, political and social interactions, determines the incentives that guide production, innovation and wealth distribution. The theory posits that when institutions are inclusive, they promote equal access to opportunities, protect property rights and encourage entrepreneurship, which at the end stimulate broad-based growth. In the other way round, weak institutions tend to debar economic mobility and exacerbate inequality.

The innovation-driven growth theory in its own case, which was propounded by Schumpeter (1942) and later extended by Aghion et al (2019), emphasizes that innovation drives creative destruction (a system through which new technologies and firms dislodge old ones, thereby fostering productivity and growth). However, the distributional impact of innovation depends critically on the institutional environment. In a country with transparent governance, effective regulation and strong intellectual property rights, innovation can lead to inclusive growth by creating new markets and jobs. In contrast, economies with weak institutions, innovation may increase income inequality by disproportionately benefiting capital owners, skilled workers and high-placed elites.

Therefore, combining the two concepts, the theoretical expectation is that institutional quality and innovation do interact to shape income inequality. High quality institutions can moderate the inequality-inducing effects of innovation by ensuring fair competition, efficient redistribution and equitable diffusion of technological benefits. Meanwhile, in the economies characterized by poor governance, corruption and regulatory inefficiency, innovation tends to amplify inequality.

Model Specification

Based on the theoretical foundations of institutional economics and innovation-driven growth theory, the model in this study is specified in functional form as follows:

$$INEQ = F(IQ, INNV, GI, GDPK) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq\ 3.1$$

In econometric and explicit forms, equation 3.1 is expressed as follows:

$$INEQ_t = \alpha_0 + \alpha_1 IQ_t + \alpha_2 INNV_t + \alpha_3 GI_t + \alpha_4 GDPK_t + {}_t \ldots\ldots\ldots\ldots\ldots eq\ 3.2$$

Where:

INEQ is the Income Inequality

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IQ is the Institutional Quality Index

GI is the Government Expenditure on Infrastructure

GDPK is the GDP per capita

Sources Of Data

The data set for this research work involve yearly secondary data spanning from 1990 to 2023. Data on the dependent variable, Income Inequality, which is proxied by the absolute gini coefficient, were sourced from the World Income Inequality Data base (WIID) for both countries. Data on one of the main explanatory variables, Institutional Quality, which is measured by the average value of control of corruption, government effectiveness, political stability, absence of terrorism, regulatory quality and rule of law, were sourced from the World Bank Databank for both countries. Data on government capital expenditure on infrastructure, a control explanatory variable, were sourced from Central Bank of Nigeria (CBN) for Nigeria and South Africa Reserve Bank (SARB) for South Africa. Data on per capita GDP, another control explanatory variable which is measured in constant US dollar, were sourced from World Bank Databank for both Nigeria and South Africa. Data on another main explanatory variable, innovation diffusion, which is measured by the expenditure on research and development, were sourced from World Bank Databank for both Nigeria and South Africa.

Estimation Techniques

In order to capture the dynamic interactions and long-run equilibrium, the model in eq 3.2 is reformulated in an Autoregressive Distributed Lag (ARDL) framework as proposed by Pesaran, Shin and Smith (2001). The standard ARDL ($P, q_1, q_2, \ldots\ldots\ldots\ldots$) model for this study is therefore presented as follows:

$$INEQ_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 INEQ_{t-1} + \sum_{j=0}^{q_1} \beta_j IQ_{t-j} + \sum_{k=0}^{q_2} \delta_k INNV_{t-k} + \sum_{l=0}^{q_3} \varphi_l GI_{t-l} + \sum_{m=0}^{q_4} \theta_m GDPK_{t-m} + \varepsilon_t \ldots\ldots eq\ 3.3$$

However, the above traditional ARDL framework exhibits constant parameters over time and this cannot sufficiently contain smooth structural changes, such as policy reforms, institutional transitions or steady innovation progress, which actually typify African economies. In order to guide against this shortcoming, this current research work therefore incorporates the Fourier ARDL framework, which gives room for the modelling of smooth and gradual structural breaks using trigonometric (Sine and Cosine) terms. Stemming from the propositions of Enders and Lee (2012) and Yilanci and Aydin (2017), the Fourier ARDL model embeds lowfrequency Sine and Cosine functions into the deterministic part of the model to actually define smooth structural shifts. The Fourier ARDL (FARDL) model is therefore specified as follows:

$$INEQ_t = \alpha_0 + \alpha_1 SIN\left(\frac{2\pi kt}{T}\right) + \alpha_2 COS\left(\frac{2\pi kt}{T}\right) + \sum_{i=1}^{p} \alpha_1 INEQ_{t-1} + \sum_{j=0}^{q_1} \beta_j IQ_{t-j} + \sum_{k=0}^{q_2} \delta_k INNV_{t-k} + \sum_{l=0}^{q_3} \varphi_l GI_{t-l} + \sum_{m=0}^{q_4} \theta_m GDPK_{t-m} + \varepsilon_t \ldots\ldots eq\ 3.4$$

Where:

K = Frequency of the Fourier function (determined to often stay between 1 and 3)

T = Total number of observations

$SIN\left(\frac{2\pi kt}{T}\right)$ and $COS\left(\frac{2\pi kt}{T}\right)$ define smooth structural changes in the mean of the series.

The incorporation of trigonometric properties gives room for the model to estimate gradual regime change without necessarily factoring in their numbers or timings. This component is specifically fit for examining

economies like Nigeria and South Africa, where institutional reforms and innovation policies transform continuously.

RESULTS AND DISCUSSION

Fourier Unit Root Tests Results

This section of the research work investigated the stationarity properties of the series. This is arrived at by testing the order of integration of the variables. In this regard, for the purpose of determining the stationarity process of the series, taking into consideration the smooth structural breaks, this study therefore incorporated the Fourier Augmented Dickey-Fuller (FADF) unit root test as presented in the table 1 and 2 below for both Nigeria and South Africa respectively.

Table 1: Fourier ADF Unit Root Test for Nigeria

Variables	K	t-statistic	Fourier Critical Value			Sine Term	Cosine Term	Decision
			1%	5%	10%			
INEQ	2	-4.514831***	-4.91	-4.15	-3.77	-3.860993***	0.790125	Stationary I(0)
IQ	2	-4.730235***	-4.91	-4.15	-3.77	-2.604553**	2.401669**	Stationary (0)
INNV	2	-1.022439	-4.91	-4.15	-3.77	-0.273708	-1.919175*	Non-stationary I(1)
GI	2	0.325110	-4.91	-4.15	-3.77	0.391390	1.385072	Non-stationary I(1)
GDPK	2	-0.393158	-4.91	-4.15	-3.77	0.906887	-2.304341	Non-stationary I(1)

Note: K (2) represents the Fourier term frequency. Fourier critical values at 1%, 5%, 10% are obtained from Ender and Lee (2012) Table 1. (***) (**) (*) represent 1%, 5%, 10% level of significance respectively.

The table 1 above shows the results of Fourier ADF unit root tests for Nigeria. The results reveal that income inequality in Nigeria is stationary which indicates that its response to shocks is temporary and will, in due course, revert back to a stable path. The statistical significance of the sine term only and not that of cosine term actually implies that income inequality in Nigeria is induced by cyclical process and not by level shifts. The results of institutional quality in the same table exhibit that there is stationarity, also both the sine and cosine terms are statistically significant. The implication of this is that Nigeria's institutional parameters (rule of law, regulatory quality, corruption perception etc) do not align with a random walk but would rather tend to self-stabilize over time if there are shocks exerted on them. The significance of both sine and cosine terms reveal a strong presence of complex non-linear structural transitions in Nigeria's institutions as they are faced with both cyclical fluctuations (captured by sine) and smooth level transitions (captured by cosine).

Results of innovation diffusion confirm the presence of unit root which indicates that there is no stationarity for innovation diffusion in Nigeria. The meaning of this is that the growth or decline in innovation diffusion in Nigeria does not revert back to a fixed mean. Only the cosine term is significant while sine term is not significant for innovation diffusion in Nigeria, this implies that the structural shifts in innovation are more about smooth level shifts and not influenced by the cyclical transitions. Government expenditure on infrastructure is equally not stationary and both the sine and cosine terms are not significant. The implication of this is that the infrastructure expenditure series follows a persistent trend and the absence of Fourier term significance for both sine and cosine terms suggests that there is no meaningful non-linear or structural transitions in capital spending. The per capita GDP exhibits a non-stationary trend, which implies that shocks have permanent effects on

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Nigeria's economy path. The significance of the cosine term reveals smooth structural transitions, while the absence of a significant sine term indicates no cyclical shift for per capita GDP in Nigeria. Since the results of the Fourier unit root tests for all variables in Nigeria confirm the integration of mixed order [i.e I(0) stationarity and I(1) non-stationarity], then there is a strong support for the suitability of Fourier ARDL to investigate the dynamics of income inequality considering the impacts of institutional quality and innovation diffusion in Nigeria.

Table 2: Table 1: Fourier ADF Unit Root Test for South Africa

Variables	K	t-statistic	Fourier Critical Value			Sine Term	Cosine Term	Decision
			1%	5%	10%			
INEQ	2	1.350984	-4.91	-4.15	-3.77	0.388771	0.790125	Stationary I(0)
IQ	2	0.086689	-4.91	-4.15	-3.77	0.019201	0.688068	Stationary (0)
INNV	2	-4.584540**	-4.91	-4.15	-3.77	3.553537***	-1.988902*	Non-stationary I(1)
GI	2	-1.822856*	-4.91	-4.15	-3.77	-2.395522**	0.984822	Non-stationary I(1)
GDPK	2	-0.459872	-4.91	-4.15	-3.77	0.743786	-2.456661**	Non-stationary I(1)

Note: K (2) represents the Fourier term frequency. Fourier critical values at 1%, 5%, 10% are obtained from Ender and Lee (2012) Table 1. (***) (**) (*) represent 1%, 5%, 10% level of significance respectively.

The results of Fourier ADF unit root tests shown in table 2 above reveal that income inequality in South Africa is not stationary, which is an indication that income inequality follows a persistent long-term path and the shocks to income inequality have permanent impacts. Also, the absence of significant Fourier terms for both sine and cosine implies that the inequality in South Africa does not experience smooth non-linear structural breaks. The results equally show that institutional quality in South Africa is non-stationary which means that the governance indicators evolve over time without returning to a stable long-run path and the institutional shocks have permanent effects. The innovation diffusion results exhibit stationarity and statistical significance for both sine and cosine terms. The implication of this result is that despite shocks or disruptions, innovation diffusion tends to revert to a long-run mean and the significance of both sine and cosine terms suggests the presence of rich nonlinear structural shifts.

The results of government expenditure on infrastructure show a non-stationary trend which means that the infrastructure spending in South Africa reveals long-term upward and downward movements with permanent shocks. The sine term being significant implies cyclical shifts in infrastructural spending while the cosine term being insignificant suggests that the cycles are more wave-like rather than the smooth structural transitions. Per capita GDP in South Africa is non-stationary, which is an indication that the economic shocks have long-lasting impacts. Also, the significance of cosine terms implies the presence of smooth structural transitions in the economy, while the insignificant sine term reveals that GDP per capita does not follow meaningful cyclical nonlinear patterns. Just like in the case of Nigeria, the presence of mixed order of integration, I(0) and I(1), strongly justifies and supports the adoption of Fourier ARDL to examine the impact of institutional quality and innovation diffusion on the income inequality in South Africa.

Fourier ARDL Cointegration Test

This aspect of the study investigates the existence of a long-run equilibrium relationship among the variables of interest in the model. Having established under the unit root testing that the series are integration of mixed order, I(0) and I(1) for both Nigeria and South Africa considering the presence of smooth structural breaks in the models, this research work therefore adopts Fourier ARDL cointegration tests for both Nigeria and South Africa.

Table 3: Fourier ARDL Bound Test for Nigeria

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	39.63982	10%	1.99	2.94
k	6	5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99

Table 3 above depicts the Fourier ARDL bound test for Nigeria. Results from the table reveal that the F-statistic value of 39.64 is greater than all upper bounds I(1) at any significant level. The results therefore indicate the rejection of null hypothesis of no long-run relationship and accept that there is a strong existence of a long-term cointegrating relationship among the variables.

Table 4: Fourier ARDL Short-run Estimation of INEQ for Nigeria

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	68.00220	33.92310	2.004599	0.0603
INEQ(-1)*	-1.045491	0.093060	-11.23464	0.0000
IQ**	21.77735	1.659264	13.12470	0.0000
INNV**	12.41877	6.215606	1.997998	0.0611
GI**	0.390789	0.223991	1.744667	0.0981
GDPK**	-5.612124	5.211678	-1.076836	0.2958
SIN1**	0.585970	0.478372	1.224925	0.2364
COS1**	-0.752941	0.329080	-2.288015	0.0345
* p-value incompatible with t-Bounds distribution.				
** Variable interpreted as Z = Z(-1) + D(Z).				

Table 5: Fourier ARDL Long-run Estimation of INEQ for Nigeria

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IQ	20.82977	2.331817	8.932852	0.0000
INNV	11.87841	5.947610	1.997173	0.0612
GI	0.373785	0.193374	1.932962	0.0691
GDPK	-5.367930	4.839331	-1.109230	0.2819

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SIN1	0.560474	0.489038	1.146074	0.2668
COS1	-0.720179	0.280424	-2.568181	0.0193
C	65.04329	30.66095	2.121372	0.0480
EC = INEQ - (20.8298*IQ + 11.8784*INNV + 0.3738*GI -5.3679*GDPK + 0.5605*SIN1 -0.7202*COS1 + 65.0433)				

Table 4 and 5 above show the Fourier ARDL for both short-run and long-run estimations of INEQ for Nigeria. Results in the tables reveal that the impact of institutional quality (IQ) on income inequality is positive and statistically significant in both the short-run and long-run. The implication of this finding is that the institutional reform often generate opportunities that are disproportionately cornered by the politically connected firms or better-positioned households which eventually raises inequality in both the short-run and long-run in Nigeria. This finding actually aligns with the position of Asamoah (2021) who believes that the institutional quality's inequality-reducing effects can be non-linear, which explains why improvements might generate inequality. Also, from the results, innovation diffusion (INNV) impacts positively and significantly on income inequality in both short-run and long-run in Nigeria. This finding is attributed to the fact that new technologies increase demand for skilled labour and capital owners (higher wages/returns), therefore gains will definitely be accrued to workers and firms with the skills or capital in order to exploit innovation. In this regard, when skills and capital are immobile, it results to inequality. This finding conforms to the proposition of Aghion et al (2019) who posit that innovation is positively associated with the top end income shares and can raise inequality.

Government expenditure on infrastructure has positive and significant impacts on income inequality in both short-run and long-run. This finding literarily means that increase in public infrastructure spending in short-run and long-run are associated with higher income inequality in Nigeria. This finding hinges on the fact that if infrastructure spending disproportionately benefits urban areas, capital-intensive projects, wealthier firms and households capture the bulk of benefits and at the end raise inequality. Per capita income has negative impact on income inequality in the short-run and long-run, suggesting that growth could be inequality reducing. But the relationship is statistically insignificant in both short-run and long-run, the finding which also implies that growth alone does not robustly explain changes in both the short-run and long-run inequality in Nigeria.

Moreover, the results from table 4 and 5 depict a significant cosine Fourier term which indicate gradual and lowfrequency level shifts in the deterministic part of the relationships of economy, institution innovation with the income inequality which are relevant to both short-run and long-run in Nigeria. The insignificant sine Fourier term signifies a cyclical transitions which are less important. Furthermore, the relationships that exist between the dependent variables (income inequality) and the explanatory variables reflect gradual structural transition rather than the cyclical oscillations.

Table 6: Fourier ARDL Bound Test for South Africa

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	11.78865	10%	1.99	2.94
k	6	5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99

Results of the Fourier ARDL bound test for South Africa in table 6 above confirm that the f-statistics value of 11.79 is greater than all upper bounds I(1) at any significant level. Finding from the results therefore implies that the null hypothesis of no long-run relationship is rejected and there is an acceptance of a strong existence of a long-run co-movements among the variables of interest.

Table 7: Fourier ARDL Short-run Estimation of INEQ for South Africa

Variable	Coefficient	Std. Error	t-Statistic	Prob.
. C	66.78594	15.25898	4.376830	0.0004
INEQ(-1)*	-0.902862	0.150781	-5.987893	0.0000
IQ**	25.26005	4.150550	6.085954	0.0000
INNV**	-17.87512	8.814544	-2.027912	0.0576
GI**	1.51E-06	1.85E-06	0.818444	0.4238
GDPK**	-0.000624	0.001420	-0.439031	0.6659
SIN1**	-0.432363	0.597637	-0.723454	0.4787
COS1**	-3.446952	0.889171	-3.876589	0.0011
* p-value incompatible with t-Bounds distribution.				
** Variable interpreted as Z = Z(-1) + D(Z).				

Table 8: Fourier ARDL Long-run Estimation of INEQ for South Africa

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IQ	27.97777	4.871261	5.743435	0.0000
INNV	-19.79829	10.54383	-1.877713	0.0767
GI	1.67E-06	2.13E-06	0.787591	0.4412
GDPK	-0.000691	0.001550	-0.445510	0.6613
SIN1	-0.478881	0.633805	-0.755565	0.4597
COS1	-3.817808	0.965790	-3.953042	0.0009
C	73.97141	13.15780	5.621869	0.0000
EC = INEQ - (27.9778*IQ -19.7983*INNV + 0.0000*GI -0.0007*GDPK				
-0.4789*SIN1 -3.8178*COS1 + 73.9714)				

Results of the Fourier ARDL estimation depicted in tables 7 and 8 above for both short-run and long-run in South Africa confirm that institutional quality (IQ) has positive and significant impacts on the income inequality during the period under review. This literarily implies that an increase in the institutional quality is associated with a rise in measured income inequality in both the short-run and long-run in South Africa. This finding might be as a result of the gains from institutional reforms which may be captured by better-connected firms and higher-income groups, thereby further increasing measured inequality. This finding is consistent with the position of Acemoglu and Robinson (2012) who opine that improvements in institutional quality do not automatically equalize outcomes but may increase inequality if reforms are captured.

The results from the table equally reveal that there is negative and significant impacts of innovation diffusion on the income inequality in both the short-run and long-run in South Africa. The implication of this is that, higher measured innovation diffusion is associated with lower income inequality in both short-run and long-run in South

Africa. This finding is attributed to the fact that innovation broadly diffused, such as ICT expansion, SME technological adoption, may raise income for lower and middle class, thereby reducing inequality in both the short and durable terms. The finding actually contrasts with the cross-country results of Aghion et al (2019) who posit that innovation often raises top incomes. Government infrastructure spending has positive but insignificant impacts on income inequality in both the short-run and long-run in South Africa. This literarily means that increase in public infrastructure spending in South Africa is associated with higher inequality, but the effect is statistically indistinguishable from zero. This finding equally connects with the fact that large-scale infrastructure end to benefit capital owners and urban population more than rural poor, thereby leading to pro-rich outcomes. The insignificant coefficient aspect of the finding suggests heterogeneity in project composition and offsetting channels. The impact of per capita GDP on income inequality reveals a negative point estimate but the relationship is not statistically robust in both short-run and long-run in South Africa. The finding points to the fact that growth alone is not a reliable driver of inequality reduction without redistributive mechanism, such as inclusive job creation or structural policies.

Just as in the case of Nigeria, the significant cosine term implies that the smooth level transitions are very crucial for the short-run and long-run equilibrium relationship between the dependent variable (INEQ) and the other explanatory variables, but the insignificant sine term suggests that the cyclical-like oscillations are not relevant.

CONCLUSION AND POLICY IMPLICATIONS

Based on the Fourier unit root results in this study, it is concluded that there is a substantial composition of diversity across the two countries and variables. Income inequality and institutional quality are stationary in the presence of smooth structural transitions in Nigeria, while only innovation diffusion is stationary in South Africa. The recurring significance of Fourier terms validates the empirical relevance of modelling smooth structural breaks and equally attests to the use of Fourier-based techniques in the assessment of inequality in African economies.

In addition, the short-run Fourier ARDL estimates point out some vital cross-countries variations. In both Nigeria and South Africa, progress in institutional quality are associated with higher income inequality in the short-run, which implies that early gains from institutional reforms may unequally benefit the well-placed economic agents. Innovation diffusion in its own case increases inequality in Nigeria but reduces inequality in South Africa. This divergent effects of innovation illustrates disparities in absorptive capacity, labour market structures and complementary policies that shape how innovation affects income distribution. Government infrastructure spending and GDP per capita growth impact weak and statistically insignificant short-run effects in both countries.

In the long-run results analysis, institutional quality remains positively and significantly associated with income inequality in both countries which implies that institutional growth alone do not guarantee inclusive outcomes. Innovation diffusion continues to exacerbate inequality in Nigeria but exerts a persistent equalising effect in South Africa, emphasizing the importance of diffusion mechanism, human capital and policy context in determining long-term distributional effects. Infrastructure spending and GDP per capita remain insignificant in the long-run, indicating that public investment and economic growth do not automatically translate into reduced inequality. The significant of the Fourier cosine term in the long-run estimates further suggests that inequality is driven by smooth structural transitions rather than cyclical shifts.

Based on the findings in this research work, the following policy implications are highlighted: First, institutional reforms should be channelled towards a comprehensive inclusiveness. Enhancement in governance must be combined with proper accountability, anti-capture measures and enriched access to economic opportunities to prevent institutional shift from reinforcing inequality. Second, innovation policy should emphasize a large-scale diffusion. The contrasting findings of Nigeria and South Africa reveal that innovation can either worsen or reduce inequality depending on investments in education, skills development and digital access. Third, infrastructure policy should prioritize all-inclusive projects, most especially those that favour disadvantaged regions and households. Finally, economic growth alone is not sufficient to decrease inequality, it should rather be synergized with redistributive fiscal policies, social protection and labour market interventions.

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