

Exploring The Potential Asymmetric Structures in The Causal Relationship Between Financial Development and Economic Complexity: Empirical Insights from Nigeria

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ABSTRACT

This study is one of the earliest to examine the potential asymmetry in the causal relationship between financial development (FD) and economic complexity (ECI), using Nigeria's dataset for the period 1964-2023. Unlike previous studies, which assume impractical linear and symmetric features in the causal analysis between FD and ECI, this study examines the potential asymmetry. The study employs unit root tests (linear and nonlinear), Hatemi-J's data decomposition procedure, and a leverage-adjusted bootstrap simulation of Hatemi-J's causality test. The findings reveal robust asymmetric structures in both ECI and FD data distribution. The results indicate neither symmetric nor asymmetric causality between ECI and FD. These findings have some profound implications. On the one hand, it shows that neither Nigeria's financial sector's expansionary (positive change components) nor contractionary (negative change components) policies are causal drivers of ECI upgrades or deterioration. On the other hand, ECI-related initiatives lack the causal potency to spur the development of Nigeria's financial sector. The study concludes that evidence of asymmetric causality between ECI and FD depends on context and scope.

Keywords: Asymmetry, financial development, economic complexity, causality, Nigeria

JEL Classification: O16, O32, N27, G23

1 Introduction

An economy's ability to manufacture a chain of knowledge-based, high-tech products that can compete in international markets relies on the extent of its economic complexity (Olaniyi & Odhiambo, 2023). Economic complexity (ECI) explains the extent of knowledge intensity, technological capability, and sophisticated manufacturing skills inherent in an economy's productive structure, enabling it to produce an array of high-tech, globally competitive products for export (Olaniyi & Odhiambo, 2025). This metric has become a standard approach for explaining variations in development across countries worldwide (Avom et al., 2022; Antonietti & Franco, 2021). A recent strand of the literature classifies countries into underdeveloped, developing, emerging, and developed economies based on their ECI rankings and performance (Yu & Qayyum, 2023; Njangang & Nvuh-Njoya, 2023; Hidalgo & Hausmann, 2009). This metric is more comprehensive than the traditional economic growth measure because it captures structural changes in development, including productive and social structures, the knowledge economy, and structural transformation (Ajide, 2022). Hence, scholars, governments, and policymakers have prioritised transitioning from primitive technology to sophisticated methods of production to raise their countries' capacity to produce a sophisticated basket of high-quality products. This quest to raise ECI has continued to spur scholars and development experts to investigate its fundamental determinants. Recent studies identify financial development as one of the essential drivers of ECI (Ajide, 2025; Kamdem & Toukam, 2025; Ajide et al., 2025; Emeka, 2025; Izadi et al., 2025; Özbek & ŞahİN, 2025; Zechlin, 2025; Maxwele, 2025; Low et al., 2024; Chu, 2020; Olaniyi & Odhiambo, 2023; Olaniyi & Odhiambo, 2025; Kamguia et al., 2023; Ndoya et al., 2024; Nguyen & Su, 2021), yet findings are divergent.

The instrumentality of financial development is critical to upgrading ECI, as it requires substantial, strategic investment and capital to transition from crude production methods to sophisticated ones that produce a wide range of globally competitive, high-quality products and exports (Olaniyi & Odhiambo, 2023). An efficient financial sector bridges the gap between surplus and deficit units by mobilising and channelising financial resources to initiatives and activities that enhance research and development, skill acquisition, knowledge intensity, innovation, and technological advances (Njangang & Nvuh-Njoya, 2023), which are essential to upgrading ECI. A well-performing and efficient financial system reduces the cost of sourcing and borrowing funds to finance innovative initiatives and productive investments (Ajide et al., 2023; Nguyen & Su, 2021; Fan et al., 2015; Levine, 1999 ; King & Levine, 1993), eases the bureaucracies and bottlenecks in securing credit facilities (Arooj & Sajid, 2022), reduces the extent of asymmetric information phenomenon exploitations in financial transactions (Ang, 2008; Chu, 2020), and provides technical expertise to innovators and entrepreneurs (Olaniyi & Oladeji, 2021). If the financial sector plays these roles efficiently, financial development spurs the efficient allocation of resources, promotes knowledge intensity, advances technology, enhances innovation, and strengthens the productive structure, enabling the production of advanced, internationally competitive products for export. Thus, higher financial development spreads risks (Greenwood & Jovanovic, 1990; Ahmad et al., 2024) and supports better financial management for innovation and technology (Pagano, 1993), as well as for ECI (Chu, 2020; Nguyen & Su, 2021).

Given the critical role of financial development, studies have continued to investigate its effects on ECI, with mixed findings. Most of these studies neglect the feedback effects

from ECI to FD by overstressing the supply-driven roles of the financial sector, with little or no attention to the demand-driven roles it could play in providing financial services and resources that arise from upgrades in ECI. This neglect overlooks the argument that an increase in ECI may translate into higher knowledge-driven productivity and cutting-edge technological sophistication, producing technical and advanced products for globally competitive exports, which often go along with a rise in demand for better financial services, financial resources and more technical expertise from financial systems. Thus, enhancing ECI may lead to a more developed financial sector, as demand for capital and financial services increases to support investments in innovation, technology, research and development, and other initiatives essential to further ECI. This innovative line of thought suggests that the state of ECI (weak or strong) may explain differences in financial development across countries. Based on our critical survey of the existing literature, only one study (Nya et al., 2025) examines and finds an important role for ECI in expanding FD. A few other studies acknowledge the potential for reverse causality from ECI to FD, but do not test it (Olaniyi & Odhiambo, 2023; Nguyen & Su, 2021; Ajide, 2022; Avom et al., 2022).

Based on these two strands of the literature, it is clear that there may be a two-way causal relationship between FD and ECI. It is more appropriate to capture the issues of reverse causation and simultaneity bias, as estimates and policy implications may be incorrect if they are not. Thus, this study treats FD and ECI as endogenous variables to better align with real-world fundamentals, thereby yielding more robust policy recommendations. Only a handful of studies (Özbek & Şahin, 2025; Karasoy, 2022; Şahin & Durmuş, 2020) examine the causal relationship between FD and ECI. These studies neglect fundamental features of asymmetry and nonlinearity in their causal analyses. Hence, this study is among the earliest to examine asymmetric and nonlinear features in the causality between ECI and FD. All the previous studies on the nexus between the two variables assumes symmetries and linearities. These assumptions might be impractical because data distributions and the dynamics of these variables exhibit asymmetric features. Besides, recent empirical research and econometric studies have challenged the assumptions of symmetry and linearity in causality (Hatemi-J, 2012; Olaniyi & Ologundudu, 2020; Osinubi et al., 2021). Hence, this study integrates asymmetries into the examination of the causality between FD and ECI. This study extends the causal analysis to asymmetries and nonlinearities due to the following reasons:

Second, there are potential asymmetries of information in the financial system (Stiglitz & Weiss, 1981; Chen et al., 2020), as both lenders and borrowers tend to have unequal information in their dealings (Tchamyou, 2019; Olaniyi et al., 2023). This phenomenon may give rise to adverse selection, which in turn may lead to moral hazard and the misuse of credit facilities. It may distort lenders' choice of potential borrowers, leading them to channel credit to unproductive activities that hamper innovation and knowledge intensity in the productive structure of the economy. Asymmetric information is deeper in financial markets compared to other markets (Capasso, 2004; Leland & Pyle, 1977). Under robust asymmetric information, higher financial development may not translate into better economic performance. Thus, ignoring asymmetric structure in causal analysis of the FD-ECI nexus may yield suboptimal estimates and policy recommendations that oversimplify real-world fundamentals. Also, asymmetric information phenomena are among the reasons for testing for asymmetric causality (Hatemi-J, 2012).

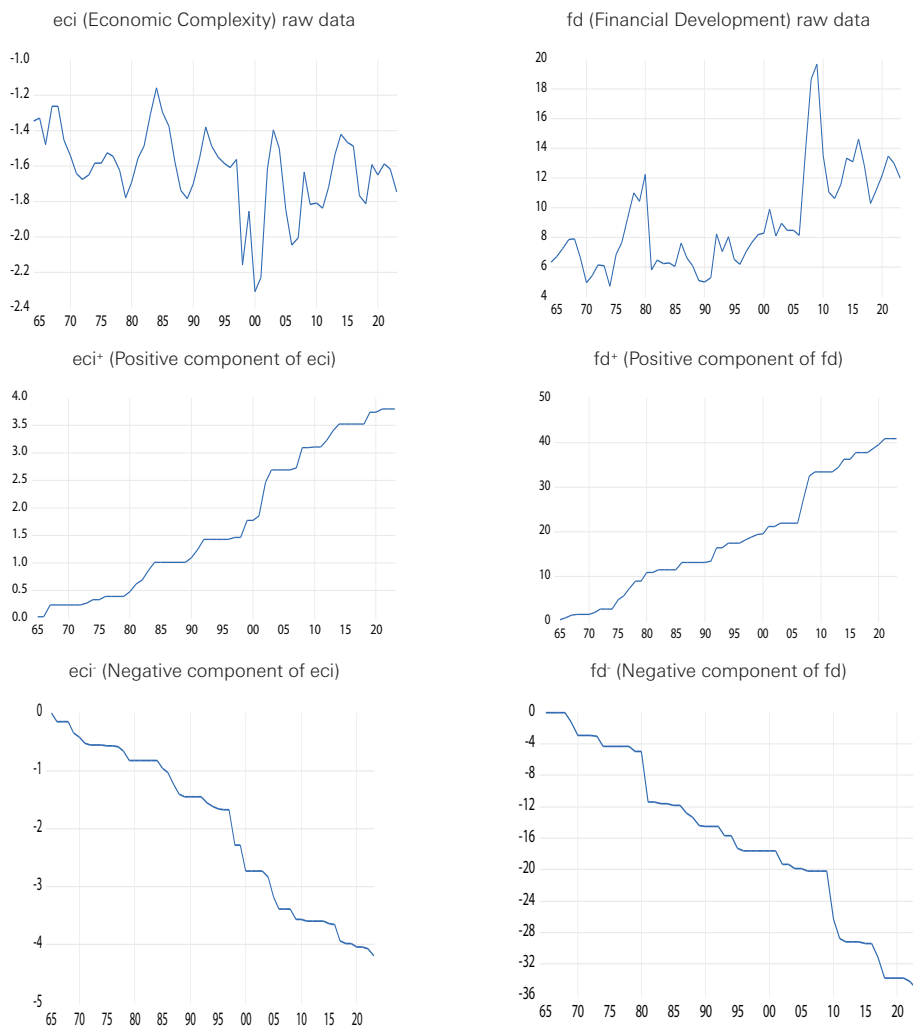


Figure 1. Economic complexity (eci), Financial development (fd), and their positive (eci+, fd+) and negative (eci-, fd-) components

Third, the distributions of FD and ECI data often exhibit robust asymmetries and nonlinearities (see Figure 1; Olaniyi et al., 2023; Olaniyi & Odhiambo, 2025). Thus, excluding asymmetries from the causal analysis may not reflect the realities. Fourth, the asymmetric causality method unravels hidden causality by separating positive and negative change components for deeper analysis beyond the realm of symmetric, linear causality. Hence, this approach provides more insights and information than traditional causal methods can detect. Fifth, the asymmetric causal approach has an edge over traditional causal methods because it provides more pragmatic, flexible policy options by uncovering hidden, multifaceted causal inferences that simplify the complexities in the nexus between FD and ECI. Sixth, this approach is more flexible and accommodates the real-world realities of asymmetries in the complex, diverse socioeconomic dynamics in the relationship between FD and ECI. The method is well-suited to explain how the

financial system’s contractionary and expansionary policies are causally related to changes in economic complexity. Asymmetric causality offers novel insights into how to leverage various financial sector policies to enhance ECI and how ECI upgrades could help develop an efficient financial system. Seventh, this study differs from other studies by adopting the leverage-adjusted bootstrapping simulation of causality developed by Hatemi-J (2012). This approach performs efficiently and delivers robust critical values and Wald values even in the presence of outliers, non-normality, and volatility in the data distribution. This approach is robust to ARCH effects in causal analysis. It performs 10,000 iterations and delivers the best causal estimates for optimal, efficient policy options.

Due to these factors, this study incorporates asymmetries in the causality between FD and ECI, using Nigeria’s data spanning 1964 to 2023. The choice of Nigeria aligns with the fundamentals that birthed this study in the following ways: First, there is significant evidence of asymmetries in the analysis of Nigeria’s ECI and FD data (see Figure 1). The negative and positive change in the two variables provide robust evidence of asymmetries and nonlinearities. Hence, utilising a linear, symmetric approach to causality may be inappropriate. Second, the existing literature indicates that Nigeria has one of the lowest ECI rankings in the world (Tabash et al., 2022 ; Ajide, 2022, 2025; Olaniyi & Odhiambo, 2025). The country remains on the negative side of ECI performance across all years under consideration. Figure 2 also affirms that Nigeria has the least sophisticated manufacturing capabilities and productive structure to produce high-quality, exportable products in Africa. It thus becomes a puzzle to unravel how Nigeria’s FD is causally related to ECI.

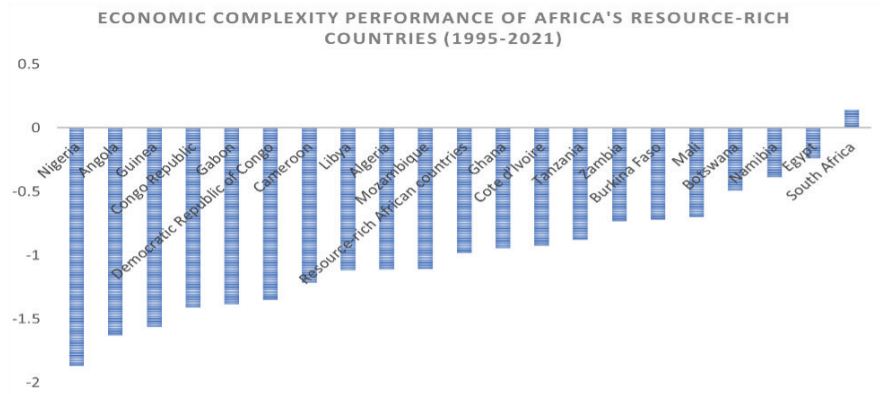


Figure 2. Average performance of Africa’s resource-rich countries (1995-2021)

Third, the underdeveloped financial sector in Nigeria constitutes a setback to the appropriate financing of ECI-related initiatives. Figure 3 also shows that Nigeria’s financial sector is weaker and less developed than South Africa’s. These statistical facts indicate Nigeria’s performance in both FD and ECI. This indicates a challenging issue in determining the nature of the causal relationship between the two variables. Fourth, Nigeria’s financial system is highly likely to experience widespread credit diversion to unproductive ventures and ECI-impeding initiatives (Olaniyi & Odhiambo, 2025) because the country suffers from widespread corruption and weak institutional frameworks to guide the operations of financial markets and institutions. These challenging circumstances intensify the risk that the financial sector will divert resources from initiatives that could enhance ECI.

Fifth, the exploitation of asymmetric information by stakeholders may be extremely high in Nigeria’s financial sector due to a weak financial system, poor corporate

governance practices, and a weak institutional framework that guides their operations (Olaniyi et al., 2022) Thus, these fractured systems may weaken the ability of financial intermediaries to efficiently allocate resources to initiatives that promote productive knowledge, technological capabilities and manufacturing acumen of the economy to produce sophisticated and competitive products with a high likelihood of penetrating international markets (Olaniyi & Odhiambo, 2023). Hence, it is of utmost importance to account for asymmetric information in the causal relationship between FD and ECI in Nigeria. This pragmatic step will help to align empirical estimates and policy implications with real-world features of nonlinearities and asymmetries.

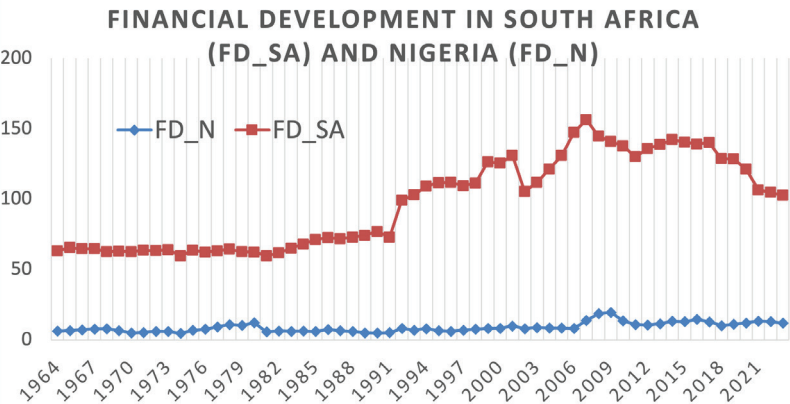


Figure 3. Comparisons of financial development in Nigeria and South Africa (1964-2023)

In summary, this study makes a distinctive contribution to the existing knowledge base in the following ways. One, it is a pioneering effort to examine causality between ECI and FD in Africa, using a unique dataset from Nigeria. Two, the study extends global research by making one of the earliest attempts in the existing literature to account for asymmetries and nonlinearities in the theoretical and empirical explanations of the causal relationship between FD and ECI. This novelty reveals hidden insights in the causal analysis. It provides more comprehensive, flexible policy recommendations that explain the real-world fundamentals beyond the scope of traditional causal methods.

In addition to this introduction, we structure the rest of the paper as follows: Section 2 presents a theoretical and empirical review of the literature. Data descriptions, sources, and methodological procedures are the primary focus of Section 3. Section 4 focuses on data analysis, results presentation, and discussion of findings. In Section 5, this study presents the summary, conclusions, and policy recommendations, and Section 6 highlights the study’s shortcomings and recommendations for further research.

2 Literature review

2.1 Theoretical evidence

This research effort provides a theoretical foundation for the causal relationship between economic complexity (ECI) and financial development (FD), grounded in the demand-following and supply-leading hypotheses originally advanced by Patrick (1966) in the theoretical exposition of endogenous growth theory. The extant literature contextualises these hypotheses to explain the causality between economic growth and

FD. However, this study extends and rationalises it to explain the causal nexus between FD and ECI. The supply-leading hypothesis, as outlined in the existing literature, suggests that FD enhances ECI (Nguyen et al., 2020; Chu, 2020; Nguyen & Su, 2021). This enhancement occurs through the financial sector, which provides technical support, financing, and various credit facilities that promote technology, innovation, and ECI initiatives (Kamdem & Toukam, 2025; Ajide et al., 2025; Ajide, 2025; Emeka, 2025; Izadi et al., 2025; Özbek & ŞahİN, 2025; Zechlin, 2025; Maxwele, 2025; Soumtang Bime et al., 2024; Low et al., 2024; Chu, 2020; Olaniyi & Odhiambo, 2023, 2025 ; Kamguia et al., 2023; Ndoya et al., 2024; Nguyen & Su, 2021). These efforts enhance technological sophistication, expand knowledge components, and improve manufacturing dexterity within an economy's productive structure, enabling the manufacturing of a diverse array of sophisticated exportable products. These expositions explain that FD drives ECI, not the other way around.

On the contrary, following the theoretical exposition, the demand-following hypothesis posits that “where enterprise leads, finance follows”. This theoretical stance stresses that financial development occurs only as a responsive force to meet the financial needs arising from the expansion of the real sector's enterprising activities (Nya et al., 2025). It implies that expansion in innovation, technology, creative destruction, knowledge-driven productivity, and manufacturing capabilities to produce sophisticated products for export generates higher, more advanced demand for financial services and technical support, thereby driving the development of the financial sector. Consistent upgrades in ECI require substantial capital investments in research and development, the acquisition of skills, the adoption of sophisticated production techniques, enhanced human capital development programmes, and other initiatives that could spur improvements in knowledge-based productive capacity and high-tech manufacturing capabilities. Sustained increases in demand for financial services to support higher new and replacement investment in these essential components are necessary to maintain and enhance the extent of technological innovations and knowledge-driven productivity inherent in the economy's productive structure, enabling the manufacture of globally competitive products for export. Thus, ECI may also lead to an expansion in FD, as where ECI leads, finance follows. The third viewpoint hinges on the feedback hypothesis, which emphasises a two-way causal relationship between ECI and FD. Mutual causation occurs between the two: as the financial sector develops through the expansion of ECI-related initiatives and innovations, these, in turn, serve as a stimulus for further upgrades in ECI. The last theoretical possibility is the neutrality hypothesis, which emphasises the case of neither the supply-leading hypothesis nor the demand-following hypothesis. It explains the phenomenon of the absence of a causal relationship between FD and ECI. In addition to these theoretical expositions, which assume unrealistic symmetry in data analysis, this study introduces the realities of asymmetric phenomena and nonlinear dynamics in the causal relationship between FD and ECI. Integrating these real-world fundamentals and the socioeconomics of nonlinearities and asymmetries into causal analysis increases the reliability of causal estimates and policy options. This novel idea aligns with real-world dimensions of the theory of imperfect information in markets (Bardhan, 2000). This reality explains the operations of financial markets and institutions, which are characterised by information asymmetry, adverse selection, and moral hazard in the transactions between lenders and borrowers. Hence, asymmetric causal analysis yields more pragmatic, flexible, and insightful policy options in explaining the relationship between FD and ECI.

2.2 Empirical evidence

Empirical investigation into the causal relationship between financial development (FD) and economic complexity (ECI) is still in its infancy. The extant literature predominantly focuses on the role of financial development in enhancing or retarding ECI, with little or no emphasis on its feedback effect (see Table 1 for details). A critical survey of existing research reveals that only three studies have conducted causal analyses of the relationship between FD and ECI (Özbek & Şahin, 2025; Karasoy, 2022 ; Şahin & Durmuş, 2020). This study sectionalises the literature on the relationship between FD and ECI into three phases, as shown in Table 1. The first phase presents the literature on the effect of FD on ECI.

In contrast, the second phase presents the literature on the role of ECI in financial sector development. The third phase discusses studies on the causal relationship between FD and ECI. These three-dimensional reviews of the literature reveal interesting facts and identify strengths and weaknesses of existing studies. These emerging highlights from the extant knowledge space provide the present study with leverage to bridge the knowledge gap to make marginal and global contributions. Firstly, current research primarily examines the impact of FD on ECI, with little consideration of the potential feedback effect from ECI to FD. These studies argue and establish the critical role that efficient and well-performing financial systems play in enhancing the level of knowledge intensity and technological capabilities inherent in manufacturing and the productive structure, enabling the production of a range of diverse and sophisticated products for export.

Meanwhile, the findings of these studies range from significant positive roles to strong adverse effects. The bulk of these studies affirm the significant positive role of FD in ECI; only a handful of studies find a negative effect of FD on ECI. In contrast, a few others find an insignificant impact of FD on ECI, suggesting that the existing research remains conflicting and inconclusive (see Table 1 for further details). Secondly, evidence from our critical reviews of extant studies reveals little or no emphasis on the role that ECI initiatives could play in explaining the expansion or growth of the financial sector. While few studies, such as Olaniyi & Odhiambo (2023), Nguyen & Su (2021), Ajide (2022), and Avom et al. (2022), acknowledge there may be a reverse causality from ECI to FD, only the study by Nya et al. (2025) examines the effect of ECI on FD. The study's outcome confirms that persistent expansions or upgrades in ECI could stimulate higher demand for more sophisticated financial services and greater capital investment in ECI-related initiatives. These could result in a stronger financial sector. Thirdly, extant studies have not prioritised examining the possibility of a causal relationship between ECI and FD. A few studies, three specifically, that examined it did so not as a priority in their empirical investigation. Özbek & Şahin (2025) and Karasoy (2022) establish a unidirectional causality from FD to ECI, while Şahin & Durmuş (2020) find a case of conflicting results. The study detects bidirectional causality in some models, whereas in others it observes unidirectional causality from FD to ECI. These mixed findings provide room for further empirical scrutiny to gain deeper insights into the relationship and yield findings that align more closely with the real-world fundamentals for enhanced, flexible policy perspectives.

Overviews of existing research reveal that they all assume symmetry and linearity, which are impractical and oversimplify the relationship between FD and ECI in the real world. Traditional causal methods within the frameworks of symmetric and linear perspectives may yield misleading causal estimates and incorrect policy implications, as they are unable to explain the real-world fundamentals of nonlinear and asymmetric features in

socioeconomic dynamics and asymmetric structures in the distribution of FD and ECI data (Olaniyi & Odhiambo, 2025; Hatemi-J, 2012). To address the highlighted deficiencies in existing studies, this study is one of the earliest to explore asymmetric causality between FD and ECI within the framework of Hatemi-J's (2012) approach. The approach captures asymmetric and nonlinear features in causal analysis. It provides more comprehensive, insightful, and flexible causal estimates, along with broader policy implications aligned with real-world fundamentals. It uncovers hidden dimensions of causal analysis that traditional approaches cannot explain or detect, thereby enhancing policy options on the link between FD and ECI. This idea of asymmetric causality follows recent developments in research and econometrics that challenge the assumptions of linearity and symmetry in causality (Hatemi-J, 2012; Olaniyi, 2020). Asymmetric causality approaches offer more comprehensive causal analyses and more revealing policy instruments to scholars, stakeholders, policymakers, and the government for strategically planning and linking FD and ECI. This study enhances the theoretical and empirical understanding of the causal relationship between ECI and FD by incorporating asymmetric and nonlinear features within the leverage-adjusted bootstrapping simulation of causality developed by Hatemi-J (2012) and Hacker & Hatemi-J (2010). This novelty produces multidimensional results and more flexible policy options to align with real-world fundamentals and socioeconomic dynamics. Also, a critical review of the literature reveals that no study on Africa has empirically investigated the causal relationship between FD and ECI. Hence, this study enhances Africa's literature in this aspect.

Table 1. The presentation of extant studies on the sensitivity of ECI to changes in FD

Study	Data Span	Country	Techniques	Findings
Olaniyi (2026)	1995-2023	30 African economies	MMQR, Driscoll-Kraay, Lewbel 2TLS, and FGLS	FDev↑EC
Maxwele (2025)	1995-2022	South Africa	FMOLS	FDev↓EC
Olaniyi & Odhiambo (2025)	1984–2021	Nigeria	FMOLS and Nonlinear ARDL	FDev↓EC
Özbek & ŞahİN (2025)	1996–2021	12 Eastern European countries	FMOLS, DOLS, MG, PMG, and SGMM	FDev↑EC
Kamdem & Toukam (2025)	1995-2017	28 countries in sub-Saharan Africa	SGMM	FDev↑EC
Imam et al., (2025)	1995-2019	71 countries	Dynamic panel threshold and SGMM	FDev↑EC
Ajide et al., (2025)	2003-2022	34 economies in Africa	QR, TSLS, and Driscoll-Kraay	FDev↑EC
Ajide (2025)	1995-2018	32 African economies	Pooled OLS, random effect, fixed effect, and SGMM	FDev↑EC
Zechlin (2025)	1996-2020	24 European Union countries	Fixed effect	FDev↑EC
Izadi et al., (2025)	2005–2021	10 countries in MENA	FMOLS	FDev≠EC
Olaniyi & Odhiambo (2025)	1995-2021	20 RRC in Africa	DCCE, FMOLS, Driscoll-Kraay, and QR	FDev↑EC
Emeka (2025)	2010–2020	45 economies in Africa	SGMM and Lewbel 2TLS	FDev↑EC
Ndoya et al. (2024)	1995–2018	92 countries	Fixed effect	FDev↑↓EC
Soumtang Bime et al., (2024)	1995-2020	28 countries in sub-Saharan Africa	IV-2SLS	FDev↑EC

Study	Data Span	Country	Techniques	Findings
Low et al., (2024)	1998–2017	107 countries	SGMM	FDev↑EC
Ajide & Osinubi (2024)	1996-2017	21 countries	PADRL and QR	FDev↑EC
Osinubi et al. (2024)	1984-2019	Nigeria	FMOLS and Nonlinear ARDL	FDev≠EC
Kamguia et al., (2024)	1998-2017	67 countries	Lewbel 2SLS and OLS	FDev↑EC
Avom & Ndoya (2024)	1995-2018	118 countries	SGMM	FDev↑EC
Shoufu et al. (2023)	2000-2016	194 Chinese cities	OLS and Two-step GMM	FDev↑EC
Kamguia et al., (2023)	2003–2016	45 economies in Africa	SGMM and QR	FDev↑EC
Njangang & Nvuh-Njoya (2023)	1982–2019	116 countries	SLPD Model	FDev↑EC
Ha (2023)	2011-2019	26 economies in Europe	Dynamic fixed effects, FGLS, PCSE, and PARDL	FDev↑EC
Olaniyi & Odhiambo (2023)	1995-2020	29 economies in Africa	QR, Driscoll-Kraay, and SGMM	FDev↑EC
Ndoya & Bakouan (2023)	1995-2018	29 economies in Africa	SGMM and OLS	FDev↑EC
Ajide (2022)	1995–2018	32 economies in Africa	SGMM, random effect, fixed effect, and Pooled OLS	FDev↑EC
Karasoy (2022)	1970-2017	Turkey	Fourier-Granger Causality Test	FDev↑EC
Aslam et al., (2022)	2000-2020	33 BRI participating countries	System GMM	FDev↑↓≠EC
Arooj & Sajid (2022)	1990-2019	Pakistan	ARDL	FDev↑EC
Ketu et al., (2022)	2003-2016	27 economies in Africa	OLS, SGMM, and QR	FDev↑EC
Kamguia et al., (2022)	1990–2017	78 countries	SGMM, IV-2SLS	FDev↑EC
Avom et al., (2022)	1995-2017	108 countries	Random, fixed effect, and SGMM	FDev↑EC
Nguyen & Su (2021)	2002–2017	86 countries	Robust OLS, pooled OLS, Random effect, Fixed effect, SGMM, and FGLS	FDev↑EC
Atasoy (2021)	1995–2017	61 countries	pooled OLS and SGMM	FDev↑EC
Njangang et al.,(2021)	1983-2017	24 economies in Africa	SGMM and Driscoll-Kraay	FDev↑EC
Nguyen & Su (2021)	1980–2014	128 countries	Robust OLS, pooled OLS, FGLS, SGMM, Fixed effect, and Random effect	FDev↑EC
Nguyen et al. (2020)	1995–2017	52 countries	PMG-ARDL, PCSE, and Robust pooled OLS estimator	FDev↑↓EC
Chu (2020)	1968-2015	94 countries	SGMM	FDev↑EC
Existing studies on the effect of ECI on FD				
Nya et al., (2025)	2002-2020	20 economies in sub-Saharan Africa	FGLS and PCSE	EC↑FDev
Ghislain et al., (2026)	1995-2020	131 countries	IV-2SLS	EC↑FDev
Existing studies on the causality between FD and ECI				
Özbek & Şahin (2025)	1996–2021	12 countries in Eastern Europe	Dumitrescu-Hurlin panel causality test	FDev→EC

Study	Data Span	Country	Techniques	Findings
Karasoy (2022)	1970-2017	Turkey	Fourier-Granger Causality Test	FDev→EC
Şahin & Durmuş (2020)	1990-2017	10 newly industrializing countries	Kónya's bootstrapping causality approach	FDev→↔EC

EC: economic complexity; FDev: financial development; BRI: belt and road initiative; RRC: resource-rich countries; MENA: Middle East and North Africa; MMQR: Method of moments quantile regression; QR: Quantile regression; PCSE: panel-corrected standard error; DOLS: dynamic ordinary least squares; FMOLS: PMG: Pooled mean group; SGMM: System generalized method of moments; OLS: ordinary least squares; IV-2SLS: SLPD: Sequential Linear Panel Dynamic; Instrumental Variable two-stage least squares; fully modified least square; FGLS: feasible generalised least squares; DCE: dynamic common correlated effect; MG: mean group; ARDL: autoregressive distributed lag; ≠ implies an insignificant effect; ↓ denotes a significant negative effect; ↑ stands for a significant positive effect

3 Data sources and descriptions, and methodological procedures

3.1 Data sources and descriptions

This study uses Nigeria's annual dataset spanning the period 1964-2023. Data availability determines the scope of the study. We use domestic credit to the private sector (% of GDP) as a metric of financial development (FD) from the World Development Indicators, the World Bank's databank. This study obtains economic complexity (ECI) data from the Observatory of Economic Complexity of the MIT Media Lab (<https://oec.world/en/rankings/ECI/hs6/hs96>).

3.2 Data decomposition and modelling procedures

We follow the original data decomposition approach developed by Granger & Yoon (2002), as used by Hatemi-J (2012), Olaniyi (2020), Olaniyi & Odhiambo (2025), and others, to explore asymmetric structures in the causality between financial development (FD) and economic complexity (ECI). We anticipate asymmetric causal inference because we expect positive and negative shock components to have varying causal impacts on the underlying variable. We assume that FD and ECI are stationary of order one. Also, by definition, the decomposed components of FD and ECI are integrated of order one. Thus, fd_t and eci_t follow the random walk processes

$$eci_t = eci_{t-1} + \varepsilon_{1t} = eci_0 + \sum_{j=1}^t \varepsilon_{1j} \quad (1)$$

$$fd_t = fd_{t-1} + \varepsilon_{2t} = fd_0 + \sum_{j=1}^t \varepsilon_{2j} \quad (2)$$

where fd_0 and eci_0 are the initial values of FD and the ECI, respectively. t is the time dimension. ε_{1i} and ε_{2i} are the stochastic error terms. Consistent with the paper of Hatemi-J (2012), we construct the positive and negative change components of ECI and FD as follows: $\varepsilon_{1i}^- = \min(\varepsilon_{1i}, 0)$; $\varepsilon_{2i}^- = \min(\varepsilon_{2i}, 0)$ and $\varepsilon_{1i}^+ = \max(\varepsilon_{1i}, 0)$; $\varepsilon_{2i}^+ = \max(\varepsilon_{2i}, 0)$, respectively. Hence, we define these components as follows: $\varepsilon_{2i} = \varepsilon_{2i}^+ + \varepsilon_{2i}^-$ and $\varepsilon_{1i} = \varepsilon_{1i}^+ + \varepsilon_{1i}^-$. In partial cumulative sums, this study specifies the two variables as follows:

$$eci_t = eci_{t-1} + \varepsilon_{1t} = eci_{1,0} + \sum_{j=1}^t \varepsilon_{1j}^- + \sum_{j=1}^t \varepsilon_{1j}^+ \quad (3)$$

$$fd_t = fd_{t-1} + \varepsilon_{2t} = fd_{1,0} + \sum_{j=1}^t \varepsilon_{2j}^- + \sum_{j=1}^t \varepsilon_{2j}^+ \quad (4)$$

In congruence with these explanations, this study defines the constructed components following this pattern: $eci_{1t}^- = \sum_{i=1}^t \varepsilon_{1i}^-$ and $eci_{1t}^+ = \sum_{i=1}^t \varepsilon_{1i}^+$; $fd_{2t}^- = \sum_{i=1}^t \varepsilon_{2i}^-$ and $fd_{2t}^+ = \sum_{i=1}^t \varepsilon_{2i}^+$. In alignment with the study's objective, we contextually define these constructed components as follows: eci_{1t}^+ represents cumulative increases in ECI (upgrades or improvements in knowledge-driven and technological sophistication in the productive structure of the economy); eci_{1t}^- denotes cumulative declines in ECI (persistent deterioration in technical expertise and knowledge intensity in manufacturing capabilities to produce quality products for competitive exports). fd_{2t}^+ stands for cumulative improvements in financial development or the expansionary policy of the financial sector, while fd_{2t}^- depicts the cumulative poor performance in FD or the financial sector under a contractionary policy. Following these constructed components and their associated definitions, we pair the constructed variables in turn, consistent with the influential work of Hatemi-J (2012), to explore asymmetries in the causality between ECI and FD. This study examines all the likely pairs of the constructed components (positive and negative), but only the pairs of positive components $[fd_{2t}^+, eci_{1t}^+]$ are modelled to reduce ambiguity and complexity. We follow VAR(p), the vector autoregressive model of order p, and the modeling procedures outlined by Hatemi-J (2012). The model revolves around the null hypothesis that there is no asymmetric causality between the two variables:

$$\begin{bmatrix} eci_{1t}^+ \\ fd_{2t}^+ \end{bmatrix} = \begin{bmatrix} \beta_0 \\ \alpha_0 \end{bmatrix} + \begin{bmatrix} \sum_{r=1}^p \beta_{1r} & \sum_{r=1}^p \beta_{21r} \\ \sum_{r=1}^k \alpha_{1r} & \sum_{r=1}^k \alpha_{21r} \end{bmatrix} \times \begin{bmatrix} eci_{1t-r}^+ \\ fd_{2t-r}^+ \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t}^+ \\ \varepsilon_{2t}^+ \end{bmatrix} \quad (5)$$

To align with the influential works of Hatemi-J (2012) and Toda & Yamamoto (1995), this study adds an unrestricted extra lag to the VAR(p) in Equation (5). This process helps address the unit root issue. We adopt the Hatemi-J information criteria to determine the optimal lag to include. This criterion is specified as follows:

$$HJC = \ln \left(\left| \widehat{B}_r \right| \right) + r \left(\frac{n^2 \ln T + 2n^2 \ln (\ln T)}{2T} \right), \quad r = 1, \dots, p \quad (6)$$

$\left| \widehat{B}_r \right|$, in Equation (6), represents the factors in the VAR model that are used to compute the error terms' variance-covariance matrix with lag order r , n (the number of equations), and T (the study's timeframe). Hence, the research hypotheses to be tested from Equations (7) and (8) are as follows: fd_{1t}^+ does not cause eci_{2t}^+ and that fd_{2t}^+ does not cause eci_{1t}^+ , respectively, as follows:

$$H_0: \beta_{21r} = 0, \forall r, \quad (7)$$

$$H_0: \alpha_{21r} = 0, \forall r, \quad (8)$$

where lag length, r , ranges between 1 and ρ , we test the null hypotheses via a modified Wald test following the studies of Hatemi-J (2012) and Hatemi-J & El-Khatib (2016). The null hypothesis is accepted if the bootstrapped critical values exceed the modified Wald statistic at the traditional levels. Otherwise, the alternative hypothesis is accepted, and causality is confirmed. This study uses the recently developed GAUSS algorithm by Hatemi-J (2012) to decompose ECI and FD data into components (positive and negative). Furthermore, this study does not conduct a cointegration test, as Hatemi-J (2012) and Toda & Yamamoto (1995) argue that examining the long-run relationship is not mandatory as long as we incorporate additional unrestricted lags in the VAR framework. The unit root process in the series determines the number of extra unrestricted lags.

The study examines asymmetric and symmetric bivariate causality between FD and ECI. Thus, we exclude control variables from our analysis. This process does not invalidate the need to incorporate control variables. However, the study technically considers the peculiarities of the asymmetric causality approach, which is more suitable within the confines of bivariate causality as discussed by Hatemi-J (2012). To validate this position, we provide the following explanations for utilising the bivariate framework. First, the novel idea of asymmetric causality, conceptualised by Hatemi-J (2012), was developed within the bivariate causality framework. The components (negative and positive) are paired in turn to unravel the hidden dimensions of causality beyond the scope of symmetric approaches. Hence, the process excludes the inclusion of control variables. Second, asymmetric causality's main priority is to unravel causal sensitivity between negative and positive change components of the variables. Hence, the control variables' influence does not alter the causal estimates or policy suggestions. The approach matches the principles of bivariate causal analysis. Third, the principles in the GAUSS software codes provided by Hatemi-J (2012) and Hacker & Hatemi-J (2010) for performing asymmetric causality are designed to operate using bivariate causal analysis. There is no provision for including control variables, and this does not undermine its suitability or appropriateness. Fourth, this approach accounts for biases related to omitted-variable bias, simultaneity, and endogeneity in causal inference (Olaniyi & Odhiambo, 2024; Hatemi-J, 2012; Dedeoglu & Ogut, 2018). It implies that excluding control variables does not diminish the appropriateness of causal findings or the policy alternatives that follow. Fifth, this approach is consistent with other versions of the leverage-adjusted bootstrap causal methods that adopt bivariate frameworks. The examples of such influential works are Nazlioglu & Karul (2024), Hacker & Hatemi-J (2006), Hsueh et al. (2013), Kónya (2006), Dumitrescu & Hurlin (2012), Emirmahmutoglu & Kose (2011), Lopez & Weber (2017), Wolde-Rufael (2014), Juodis et al (2021), Olaniyi (2020), and Olaniyi & Odhiambo (2025).

4 Data analysis, interpretations of findings, and inferred implications

4.1 Descriptive statistics

This subsection presents and discusses the fundamental properties of the study's data distribution of the underlying variables using descriptive statistics. This exercise guides the choice and appropriateness of estimators. Table 2 provides the results. A scrutiny of the standard deviation and mean indicates that the mean values of financial development (FD) and economic complexity (ECI) closely reflect the actual data. Meanwhile, the skewness coefficients indicate that ECI has negative skewness, while FD shows positive skewness. These results confirm the violation of the symmetry assumption and indicate the presence of asymmetries in the data distribution. Also, the kurtosis coefficients indicate that both FD and ECI are leptokurtic, suggesting the presence of outliers in the data distribution. Jarque-Bera statistics also indicate that the FD and ECI distributions are non-normal. The distributions of the two variables exhibit varying levels of asymmetry and nonlinearity. These features align with the graphical illustrations presented in Figure 1, revealing robust evidence of positive and negative components in FD and ECI. These properties validate the study's argument in favour of the asymmetric approach to causality, as the data distribution violates the fundamental assumption of symmetry.

Table 2. Descriptive statistics

	eci	fd
Mean	-1.621	8.946
Median	-1.589	8.061
Maximum	-1.160	19.626
Minimum	-2.309	4.700
Standard deviation	0.229	3.315
Skewness	-0.788	1.110
Kurtosis	4.034	4.001
Jarque-Bera	8.888	14.825
P-value	0.012	0.001
Observation	60	60

4.2 Linear and nonlinear stationarity tests

We follow the influential works of Hatemi-J (2012) and Toda & Yamamoto (1995) to examine the integration order of the variables with a view to guiding the choice of additional unrestricted lags to include in the augmented VAR. This study considers both linear and nonlinear variants to enhance the robustness of the findings. Interestingly, the study's objective aligns more with the nonlinear approach, as it accounts for asymmetries observed in the distributions of FD's and ECI's data (see Figure 1). The descriptive statistics also highlight the appropriateness of the nonlinear unit root test. Hence, we use the KSUR nonlinear unit root test developed by Kapetanios & Shin (2008). The approach accounts for asymmetric and nonlinear characteristics and has higher predictive power than traditional methods. The KSUR approach uses the Monte Carlo simulation, utilising the principles of a global stationary process within the framework of an autoregressive exponential smooth transition.

Table 3. Linear Unit Root Tests

Augmented Dickey Fuller (ADF) test				
Variables	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
eci	-3.511**	-3.728**	-7.560***	-7.497***
fd	-2.242	-3.128	-6.589***	-6.535***

Phillips-Perron (PP) test				
Variables	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
eci	-3.277**	-3.483**	-9.217***	-9.207***
fd	-2.097	-2.932	-10.998***	-11.211***

***, **, and * stand 1%, 5%, and 10% significance levels, respectively

This study uses the Akaike Information Criterion (AIC) in choosing the optimal lag for unit root tests. We present the findings for both the intercept and trend, and for the intercept alone, in Tables 3 and 4. Table 3 contains traditional unit root tests, namely the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP), while Table 4 provides details of nonlinear unit root tests. The two tests indicate that ECI (economic complexity index)

is stationary at the level, while FD (financial development) follows an order one (I[1]) process. These results validate the inclusion of one extra unrestricted lag in the VAR. This study does not present cointegration results because Toda & Yamamoto (1995) and Hatemi-J (2012) argue that testing the long-run relationship is unnecessary once extra unrestricted lags are included in the augmented VAR.

Table 4. ESTAR variant of nonlinear unit root test

Variables	KS statistics (Intercept and Trend)		KS statistics (Intercept)	
	Level	First difference	Level	First difference
eci	-3.629**	-5.527***	-3.529***	-5.590***
fd	-2.472	-3.868***	-1.748	-3.796***

***, **, and * stand 1%, 5%, and 10% significance levels, respectively

4.3 Discussion on the causal analysis of economic complexity and financial development

We structure the main discussion of the findings into two phases for simplicity and robustness. Phase one deals with symmetric causality, while the second phase discusses asymmetric causal analysis.

4.3.1 Symmetric causal analysis

Before proceeding to asymmetric analysis and discussion, this study examines symmetric causality between financial development (FD) and economic complexity (ECI) as the baseline for empirical investigation. Thus, we follow the leverage-adjusted bootstrapping simulation of Hacker & Hatemi-J (2006, 2010), and Hatemi-J (2012). This approach performs 10,000 iterations to deliver robust causal estimates and more flexible policy options. Table 5 presents findings on both symmetric and asymmetric causality. The symmetric causal analysis reveals that there is no causal relationship between FD and ECI. The two macroeconomic variables are not causally related. These findings do not imply that there are no policy implications for guiding policymakers and shaping societal perspectives.

The absence of causal inference and the lack of a flow from financial development (FD) to economic complexity (ECI) indicate that financial sector development does not significantly cause ECI. It implies that technical support and credit facilities for activities and initiatives essential to ECI are not potent enough to spur upgrades in ECI. This fact shows that Nigeria’s financial system has not prioritised channelling credit facilities or providing the critical expertise and incentives to support ECI upgrades. The financial system’s efforts to support initiatives that promote technical sophistication and knowledge intensity, thereby enhancing manufacturing capabilities to produce high-tech, competitive exports, are negligible. From a policy standpoint, the Nigerian government and stakeholders should provide the necessary incentives and regulatory frameworks to encourage financial systems to channel larger credit facilities and other technical support to spur greater ECI. The findings may support our initial argument that Nigeria’s financial system is in a weak state, hindering the potency of financial development to drive significant upgrades in ECI. These findings may suggest that FD is below the optimal level required to propel upgrades in ECI. Thus, it becomes important for Nigeria’s financial sector to develop to meet the financial needs of ECI-related initiatives. These findings contrast with the studies of Özbek & ŞahİN (2025), Ajide (2025), Nvuh-Njoya et al. (2025), Olaniyi & Odhiambo (2023),

Chu (2020), Ndoya et al. (2024), and Low et al. (2024), which find that FD enhances ECI. Meanwhile, none of these studies establish a causal relationship between FD and ECI. They also contradict the research outcomes of Ajide et al. (2025), Olaniyi & Odhiambo (2025), and Olaniyi & Odhiambo (2025), which establish a diminishing effect of FD on ECI.

Similarly, evidence of no causality from ECI to FD indicates that ECI initiatives and upgrades do not generate significant demand for better financial services and expertise that could enhance and drive financial sector development. The expansion of activities and initiatives that emanate from ECI upgrades in Nigeria is too weak to spur higher demand for better financial services and sophisticated expertise from the financial sector. This result reaffirms prior statistics showing that Nigeria has the least sophisticated productive systems and the weakest manufacturing capabilities to generate exports that can compete in the international markets in Africa, thereby rendering ECI unable to spur greater financial sector development. This finding is incongruent with the study by Nya et al. (2025), which finds a significant role for ECI in driving FD. These findings reveal that weak ECI may be one of the reasons for weak FD in Nigeria. Evidence of no causal relationship between FD and ECI indicates that Nigeria’s government and stakeholders should design policies and regulatory frameworks to independently plan the development of the financial sector and the upgrading of ECI, without causally linking them.

Table 5. Symmetric and Asymmetric Bootstrap Causality with Leverage Adjustments

Null Hypothesis	Wald Test Statistic	Bootstrap Critical Value at 1%	Bootstrap Critical Value at 5%	Bootstrap Critical Value at 10%	Lag Order
eci≠>fd	0.096	7.538	4.179	2.838	1
fd≠>eci	0.300	7.524	4.113	2.840	1
eci+≠>fd+	0.392	19.452	3.826	2.228	1
fd+≠>eci+	0.611	19.272	3.754	2.254	1
eci≠>fdˆ	0.168	11.864	4.514	2.636	1
fdˆ≠>eciˆ	1.083	10.577	4.335	2.612	1
eci+≠>fdˆ	0.591	10.525	4.471	2.655	1
fdˆ≠>eci+	0.109	18.507	3.643	2.194	1
eci≠>fd+	0.025	17.89	3.906	2.198	1
fd+≠>eciˆ	0.243	20.720	3.842	2.220	1

The notation ≠> indicates the direction of the research hypothesis, which states that eci does not Granger-cause fd
 Note that eci and fd stand for economic complexity index and financial development, respectively
 fd+ is the positive component of financial development, while fdˆ is the negative component of it
 eci+ is the positive component of economic complexity, while eciˆ is the negative component of it

Meanwhile, symmetric causal analysis of FD and ECI has inherent limitations, as it fails to capture the real-world fundamentals of nonlinearities and data distribution asymmetries. In light of these weaknesses, this study considers asymmetric and nonlinear features in the causal relationship between FD and ECI. This process uncovers hidden dimensions of causality and offers more pragmatic, insightful policies that align with real-world socioeconomic realities in the nexus between FD and ECI.

4.3.2 Asymmetric causal analysis

This subsection extends the causal link between ECI and FD by integrating asymmetries and nonlinearities to align with socioeconomic realities and the real-world fundamentals

revealed in the data distribution (see Figure 1). The results in Table 5 highlight the absence of asymmetric causality. None of the pairs of positive and negative change components provides evidence of asymmetric causality. These findings provide evidence that could send strong signals to guide policymakers, stakeholders, and technocrats on strategic policy instruments and planning for financial sector development and upgrades to economic complexity (ECI). Thus, we consider all possible pairs and interpret them in the light of socioeconomic realities and contemporaries in Nigeria's setting. Absence of causal inferences between positive change components, (fd^+ and eci^+), of FD and ECI reveals some interesting facts. It suggests that improvements in Nigeria's financial sector do not significantly increase ECI. This finding suggests that the support, technical expertise, and credit facilities offered by Nigeria's financial sector to initiatives promoting knowledge intensiveness, technological sophistication, and skills in productive and manufacturing capabilities are inadequate and may have been below a critical threshold. As a result, these deficiencies hinder FD from having a significant causal impact on ECI upgrades. Nigeria's governments and policymakers need to create targeted incentives and implement measures to encourage the financial system to channel loans and credit facilities to finance and support initiatives that enhance ECI.

These research outputs suggest that Nigeria's financial markets and institutions need more substantial incentives to foster innovation and a knowledge economy, thereby strengthening technical productive structures and manufacturing capabilities. Nigeria's governments should establish additional regulatory frameworks to encourage financial sector stakeholders to intentionally direct more credit toward initiatives that can enhance ECI and provide greater technical support. These research outcomes may indicate that the financial system's credit facilities, intended to fund and drive initiatives that promote ECI, have been diverted due to corruption, weak institutions, and porous regulations that allow rent-seeking and opportunistic tendencies to thrive. Hence, there is a need to review the institutional structures that guide the operation of the financial sector to finance and support ECI-related initiatives in Nigeria.

Similarly, the inability of ECI upgrades, eci^+ , to spur causal impacts on FD indicates that activities around ECI initiatives are not strong enough to drive causal impacts that generate demand for better financial services and technical support to stimulate further development of the financial sector, fd^+ . This finding aligns with statistical evidence that Nigeria has the least sophisticated productive structure in terms of knowledge intensity and technological capabilities to manufacture high-quality, competitive products for export among resource-rich African countries (see Figure 2). This result shows that the country's low ECI is unable to drive or meaningfully spur financial sector development in Nigeria. These findings further reinforce the need to strategically plan the development of the financial sector and the upgrading of ECI in Nigeria, independently of each other. Another implication of these findings is that there is an urgent need to design critical policies and initiatives related to ECI upgrades, as this may increase demand for greater financial resources and provide more comprehensive technical expertise to support technological capabilities and knowledge intensity to manufacture high-tech and competitive products for export, thereby fostering financial sector development. Based on our findings, this study suggests that Nigerian governments and stakeholders should address the issues surrounding the country's weak productive structure and manufacturing capabilities without causally linking them to the challenges posed by the country's weak financial system. The country must address these two challenging issues independently

of each other. Symmetrically and asymmetrically, FD and ECI are causally independent of each other. Hence, the country should address specific issues related to ECI and FD independently within its developmental agenda and priorities. This study adds novel insights into the intricate relationship between FD and ECI by incorporating asymmetric and nonlinear features. Our inability to establish causality (symmetric and asymmetric) in the case of Nigeria does not invalidate the possibility of detecting it in other countries. More empirical analyses within the context of the asymmetric causal approach, using datasets from other countries, are necessary to complement our argument and enhance the credibility of our findings. This study has enhanced the knowledge base on the causality between FD and ECI by applying the leverage-adjusted bootstrap simulation method for causality developed by Hacker & Hatemi-J (2010) and Hatemi-J (2012) in both symmetric and asymmetric settings.

5 Summary, conclusion, and policy implications

Existing research on the relationship between financial development (FD) and economic complexity (ECI) predominantly focuses on the impact of the former on the latter, with little attention paid to the effect of the latter on the former. Previous studies have yet to capture the potential causality between FD and ECI. Hence, this study extends the knowledge base in the following ways: one, we provide the first attempt to examine the causal relationship between FD and ECI. Two, this study accounts for probable asymmetric and nonlinear features in the causality between FD and ECI using the leverage-adjusted bootstrap simulation developed by Hatemi-J (2012) and Hacker & Hatemi-J (2006, 2010). This approach is robust and captures real-world fundamentals of non-normality in data distributions, potential volatility, and cyclical fluctuations in financial data. We use Nigeria's data from 1964 to 2023, given robust evidence of asymmetries in the ECI and FD data for the country, as well as challenging issues surrounding weak financial sector development and the report that the country has the least sophisticated knowledge-based manufacturing capabilities and a productive structure for manufacturing high-quality exportable products in Africa.

The findings support neither symmetric nor asymmetric causality between FD and ECI in Nigeria. On the one hand, it implies that Nigeria's financial sector development does not provide adequate support, technical services, and credit facilities that are potent enough to serve as a causal factor in spurring improvements in ECI-related initiatives. On the other hand, activities and initiatives to expand ECI in the country are not strong enough to generate higher, more sophisticated demand for financial services and other technical support from the financial sector, thereby driving better financial development. The results of the asymmetric causality tests indicate that Nigeria's financial-sector expansionary policy does not lead to an increase in ECI. Also, an increase in ECI does not translate into a better, more robust financial system in Nigeria. A more comprehensive analysis of asymmetric causal analyses indicates that neither the expansionary nor the contractionary policy of the financial sector in Nigeria drives ECI expansion or contraction. It also shows that neither ECI expansion nor contraction drives financial sector development in Nigeria. Clearly, there are complex and puzzling policy issues inherent in the relationship between FD and ECI in Nigeria.

These findings yield several policy suggestions to assist governments and stakeholders in the strategic design and planning of the FD-ECI nexus in Nigeria. One, there is a need to assess the efficiency of institutional architectures and regulatory apparatuses

governing how the financial sector channels credit facilities and provides technical support for ECI initiatives. This policy suggestion stems from the fact that the financial sector's expansionary policies do not spur ECI upgrades. Two, the findings indicate that Nigeria's financial sector expansionary policy does not cause ECI upgrades. Hence, governments and policy implementers need to incentivise and provide a more efficient regulatory framework that will encourage financial institutions and markets to channel more credit facilities to initiatives designed to enhance ECI. This policy is important because a mere increase in FD may not propel greater and better ECI. Thus, there is a need to increase the financial sector's credit facilities to a significant, optimal level that will be strong enough to crystallise ECI upgrades in Nigeria. Three, governments and stakeholders should massively invest in initiatives and activities such as research and development, human capital development, technical skills, knowledge-based productivity, and the intensification of manufacturing capabilities. These innovative activities are essential to spur ECI upgrades, which, in turn, create higher demand for sophisticated financial services and drive financial sector development. This policy is necessary because our findings indicate that Nigeria's ECI is not a significant driver of the financial sector's development. Fourth, the pace of financial sector development in Nigeria appears slow and lags behind the level required to foster ECI-related initiatives, as the prevailing cumulative FD expansions are causal factors that spur ECI upgrades. Further development of the financial sector targeted toward ECI initiatives should be prioritized by government and all relevant stakeholders. Nigeria's government and stakeholders must consistently and deliberately work to develop a financial system that favours ECI-related initiatives.

6 The study's limitations and recommendations for future research

This study makes two significant contributions to existing research on the relationship between financial development (FD) and economic complexity (ECI) by examining potential causality and incorporating real-world fundamentals, such as asymmetries and nonlinearities, into the analysis. Meanwhile, future research should address some of the constraints encountered by the study. These include: first, the study uses Nigeria's dataset, which may limit the universal acceptability and generalizability of our findings. Hence, other scholars should complement our findings by using datasets from other countries. Second, this study focuses on Nigeria's country-specific time-series analysis. Thus, this study does not address the panel analysis dimension. Future research should consider panel data analysis to enhance the study's global acceptability. Third, heterogeneity and cross-sectional dependence are not captured in this study's causal analysis. Hence, we suggest that future research should consider using the panel causal approach of Dumitrescu and Hurlin. This approach addresses heterogeneity and cross-sectional dependence in causal inference. It is more appropriate because it reports both the country-specific cases and the panel results. Fourth, our dataset only covers the period 1964-2023. We encourage future scholars to extend the period to more recent years. Data availability determines the scope of the study. Fifth, this study excludes control variables in the causal analysis. The asymmetric causality approach pairs the positive and negative change components of variables in turn to uncover a hidden dimension of probable causal inferences. Thus, asymmetric causality tests work better within the bivariate causality framework.

Disclosure

Data availability

Data will be available upon request from the corresponding author.

Ethical approval

The author has followed all necessary ethical guidelines for publication.

Consent to participate

Not applicable.

Consent for publication

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