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Technological Innovation, Governance Institutions, Infrastructure Development, and Economic Complexity in Africa: Evidence from Dynamic Panel Data

Obed Ifeanyichukwu Ojonta[1], Jonathan Emenike Ogbuabor[2]

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Corresponding Author(s):

Obed Ifeanyichukwu Ojonta

Department of Economics, University of Nigeria, Nsukka, Nigeria. Email: obed.ojonta@unn.edu.ng

Abstract: Africa continues to face persistent development challenges, including poverty, income inequality, limited access to healthcare services, and disparities in education. These challenges contradict the objectives of the Sustainable Development Goals (SDGs), which emphasize the importance of innovation, infrastructure development, and strong institutions. Technological innovation has increasingly been recognized as a key channel for promoting infrastructure development, improving economic complexity, and strengthening institutional performance. Motivated by these considerations, this study examines the combined effects of technological innovation, governance institutions, human capital development, infrastructure, and foreign direct investment on economic complexity in Africa. In addition, the study investigates how technological innovation, governance institutions, remittances, foreign direct investment, and economic complexity influence infrastructure development across African economies. The analysis employs the system generalized method of moments (system GMM) estimator using panel data for 31 African countries covering the period from 2011 to 2020. The results reveal that technological innovation has a positive and statistically significant effect on both economic complexity and infrastructure development in Africa. However, the indicators of governance institutions are largely negative and statistically insignificant in their influence on economic complexity and infrastructure. Furthermore, governance institutions do not significantly moderate the relationship between technological innovation and these development outcomes. These findings highlight the importance of strengthening technological innovation systems while addressing institutional weaknesses to promote sustainable economic development across the African continent.

Keywords: Technological Innovation, Economic Complexity, Infrastructure Development, Governance Institutions, System GMM, Africa

JEL Classifications: E51, G51, R20, C21, N17

1. Introduction

Technological innovation has increasingly been recognized as one of the most important drivers of economic development, structural transformation, and long-term economic growth. In developing economies, particularly in Africa, technological innovation plays a critical role in improving productive capacity, enhancing industrial competitiveness, and fostering sustainable economic development (Kuete and Asongu, 2023). It can also be viewed as a powerful channel for promoting overall economic growth through productivity improvements, knowledge diffusion, and technological upgrading across industries (Olofin et al., 2015). In addition to stimulating economic expansion, technological innovation contributes significantly to wealth creation, improved production efficiency, and human development (Ebadi & Utterback, 1984; Archibugi & Lammarino, 2002). For instance, Khattak et al. (2020) demonstrate that technological innovation has the potential to transform African economies from those characterized by persistent poverty into economies capable of generating greater prosperity and sustainable development. Similarly, Fan (2011) argues that technological innovation enables industries to optimize their operations, improve the quality of goods and services, and expand market opportunities.

Despite the growing importance of technological innovation in shaping economic transformation, African economies continue to experience relatively low levels of innovation compared with other regions of the world. Limited technological capabilities and weak innovation systems have constrained many African countries' ability to fully exploit their economic potential (WDI, 2022). Consequently, strengthening technological innovation has become a critical policy priority for African economies seeking to promote structural transformation and long-term economic development. Beyond its role in economic growth, technological innovation has also been recognized as an important determinant of economic complexity. Economic complexity reflects an economy's productive capabilities and captures the extent to which a country can produce and export sophisticated goods. In developed economies, several studies have shown that technological innovation improves economic complexity by enabling economies to diversify their production structures and move toward more knowledge-intensive industries (Ertugral et al., 2017; Antonelli, 2016; Massey et al., 1998). Similarly, Fatai et al. (2021) argue that technological innovation attracts investment across sectors of the economy, thereby enhancing productive capabilities and supporting eco-

[1] Department of Economics, Faculty of the Social Sciences, University of Nigeria, Nsukka, Nigeria
[2] Department of Economics, Faculty of the Social Sciences, University of Nigeria, Nsukka, Nigeria

-nomic diversification. Consistent with this perspective, Ncanywa et al. (2021), Yalta & Yalta (2021), and Tabash et al. (2022) emphasize that technological innovation can be strategically exploited to stimulate economic complexity by increasing productive knowledge and expanding export diversification.

However, many African economies continue to record relatively low levels of economic complexity when compared with developed economies. Several structural factors have been identified as contributing to this situation, including high dependency ratios (Ojonta & Ogbuabor, 2024a; Nwosu et al., 2018), low per capita income levels (Jones, 2002; Olofin et al., 2015), weak institutional frameworks (Okolie & Elijah, 2017; Anekwe et al., 2019), and persistent political instability (Ojonta & Ogbuabor, 2024). These structural constraints limit African economies' ability to diversify production and upgrade their technological capabilities. Nevertheless, technological innovation offers significant opportunities for addressing these challenges by improving productive efficiency, fostering industrial upgrading, and facilitating knowledge-based economic activities.

In addition to influencing economic complexity, technological innovation also plays a crucial role in infrastructure development. Infrastructure constitutes a fundamental component of economic development because it supports productive activities, facilitates trade, and improves the efficiency of economic systems. Recent studies have emphasized the importance of technological innovation in enhancing infrastructure development and sustainability. For example, Sakariyahu et al. (2023) and Udeagha & Ngepah (2022) highlight the role of technological innovation in improving infrastructure performance and promoting sustainable development. Similarly, Ngepah & Udeagha (2022) and Okere & Fasanya (2024) argue that African countries can strengthen their infrastructure architecture by effectively harnessing technological innovation through increased investment in technological capabilities and greater integration into global innovation systems.

Nevertheless, infrastructure development in many African countries remains relatively low due to several structural challenges. These include poor maintenance culture of existing infrastructure (Omole & Ndambuki, 2014), bureaucratic bottlenecks within governance systems (Asongu et al., 2020), weak institutional structures (Westaway, 2006), and low levels of per capita income (Ojonta, 2023). These challenges significantly limit the ability of African economies to build resilient and efficient infrastructure systems capable of supporting long-term economic development. Another important factor influencing economic development in Africa is the quality of governance institutions. Governance institutions play a crucial role in shaping economic outcomes by influencing regulatory frameworks, policy implementation, and the allocation of economic resources. Empirical studies have increasingly highlighted the importance of institutional quality in explaining variations in development outcomes across countries. For instance, Ojonta & Ogbuabor (2024b) show that governance institutions significantlyare a significant related to macroeconomic variables and development outcomes in Africa. Similarly, Ogbuabor et al. (2023) argue that weak institutional structures in many African countries have constrained these economies' ability to advance infrastructure development and economic transformation.

Furthermore, weak governance institutions have also been identified as an important constraint to improving economic complexity across the continent. Ojonta & Ogbuabor (2024b) demonstrate that institutional weaknesses significantly hinder the development of more sophisticated production structures in African economies. Consistent with this argument, Ogbuabor et al. (2023) show that governance institutions have not functioned as effective mechanisms for enhancing economic complexity in Africa. Persistent governance challenges, including corruption, poor regulatory quality, limited accountability, and political instability, continue to undermine economic transformation across the continent (Abubakar, 2020).

Although the existing literature has examined the roles of technological innovation, infrastructure development, and governance institutions independently, little attention has been paid to how these factors interact to shape economic complexity and infrastructure development in African economies (Okolie & Elijah, 2017; Anekwe et al., 2019; Asongu et al., 2020; Abubakar, 2020). In particular, the moderating role of governance institutions in the relationship between technological innovation and key development outcomes remains relatively underexplored. This issue is important because the effectiveness of technological innovation in promoting economic transformation may depend significantly on the institutional environment within which innovation activities occur.

Against this background, this study seeks to answer the following research questions: How does technological innovation influence economic complexity in Africa? To what extent does technological innovation contribute to infrastructure development in African economies? Furthermore, do governance institutions moderate the relationship between technological innovation and both economic complexity and infrastructure development? To address these questions, the study pursues three main objectives. First, it examines the impact of technological innovation on economic complexity in Africa. Second, it investigates how technological innovation influences infrastructure development across African countries. Third, it analyzes whether governance institutions moderate the relationship between technological innovation and both economic complexity and infrastructure development.

This study contributes to the existing literature in several important ways. First, it provides new empirical evidence on the role of technological innovation in shaping economic complexity and infrastructure development in African economies. Second, the study advances the literature by examining the moderating role of governance institutions in the relationship between technological innovation and key development outcomes. Third, by employing a dynamic panel system generalized method of moments (GMM) framework, the study offers robust empirical insights into the interaction between technological innovation, governance institutions, and structural economic transformation in Africa. Finally, the findings provide important policy implications for policymakers seeking to strengthen innovation systems, improve institutional quality, and promote sustainable economic development across the continent.

2. Literature Review

The review of the extant literature presented here covers conceptual issues, theoretical perspectives, and empirical evidence related to technological innovation, economic complexity, infrastructure development, and governance institutions.

2.1. Conceptual Issues

The main concepts examined in this study include technological innovation, economic complexity, infrastructure, and governance institutions. Understanding these concepts is essential for explaining the mechanisms through which technological capabilities and institutional quality influence economic development outcomes.

Technological innovation is commonly conceptualized as the introduction of advanced techniques or new production systems within an economy (Antonelli, 2016; Massey et al., 1998). It may also be understood as the process through which new or improved products, technologies, or production methods are developed and applied within economic systems, often facilitated by digital technologies and knowledge diffusion. According to Asongu et al. (2018), technological innovation represents a critical area of development that requires significant improvement, particularly in low-income economies where technological capabilities remain relatively weak. Consequently, technological innovation has become a central component of economic modernization and industrial upgrading.

Economic complexity, on the other hand, refers to the level of sophistication and diversity embedded in a country's productive and export structures. Feder & Umali (1993) define economic complexity as the variety and sophistication of a nation's exports, accounting for both the diversity of exported products and the range of export destinations. Similarly, Ullah et al. (2021) describe economic complexity as the capacity of an economy to produce and export sophisticated goods, which depends on the amount of productive knowledge accumulated through learning, interaction, and experience. In this context, productive knowledge refers to the collective capabilities needed to produce complex goods and services. Erkan and Yildirimci (2015) further conceptualize economic complexity as the composition of a country's productive output, reflecting how production processes are organized and traded in goods and services. From a broader perspective, Arthur (2013) describes economic complexity as the study of economic systems characterized by interactions among various economic agents whose behaviors evolve in response to the outcomes they collectively generate. Likewise, Stojkoski et al. (2016) define economic complexity as the amount of information and knowledge embedded in an economy's productive structure.

Infrastructure represents another critical concept in understanding economic development. Infrastructure is generally defined as the development and provision of essential facilities and services that support economic activities and improve societal welfare. Ghafoor (2000) conceptualizes infrastructure as the process of building and enhancing basic services aimed at promoting economic expansion and improving living standards. Similarly, Espacios et al. (2019) describe infrastructure development as a mechanism that improves societal well-being by increasing income levels, productivity, and employment opportunities. Madden & Savage (1998) further explain infrastructure as the physical structures that support economic activities, including roads, highways, bridges, ports, and telecommunications systems. These infrastructural components play a vital role in facilitating trade, production, and overall economic efficiency.

Another important concept examined in this study is governance institutions. Governance institutions refer to the structures, rules, and processes through which economic and political activities are regulated and managed. Benyah (2010) conceptualizes governance institutions as the mechanisms through which regulatory bodies protect investors and provide borrowers with access to financial resources. Similarly, Levine (1998) defines governance institutions as the extent to which laws and regulations are effectively enforced to safeguard property rights, protect investors, and ensure efficient economic regulation. Without such institutional frameworks, sustainable economic development becomes difficult to achieve. Furthermore, Bruinshoofd (2016) argues that governance institutions encompass a broad set of mechanisms related to individual rights, the rule of law, and effective government policies and services. In this study, the general conceptual foundation is anchored in the work of Hidalgo and Hausmann (2009) and Erkan and Yildirimci (2015), who emphasize the importance of productive capabilities and institutional frameworks in shaping economic complexity and structural transformation.

2.2. Theoretical Literature

Several economic theories provide important insights into the relationships among technological innovation, infrastructure development, governance institutions, and economic transformation. In particular, this study draws upon endogenous technological progress theory, infrastructure-led development theory, and general management theory to explain the mechanisms through which these factors influence economic outcomes.

The endogenous technological progress theory, originally developed by Aghion and Howitt (1992), emphasizes the role of technological innovation as a fundamental driver of long-term economic growth. According to this theoretical perspective, economic progress is generated through continuous technological advancement and innovation activities. Each innovation introduces new intermediate technologies that improve production efficiency and enable firms to produce goods more effectively than before. As a result, innovation becomes a key mechanism through which economies enhance productivity, expand production possibilities, and achieve sustained economic growth. Empirical studies such as Abbasi et al. (2021) and Fatai et al. (2021) provide evidence supporting the central argument of this theory by demonstrating that technological innovation contributes significantly to economic development and structural transformation. The proponents of this theoretical framework, therefore, argue that economies can achieve sustained growth and development by effectively utilizing their technological innovation potential.

In addition to technological progress theory, the infrastructure-led development theory provides further theoretical justification for examining the role of infrastructure in economic development. Agénor (2010) proposes that public infrastructure serves as a critical driver of economic growth by enhancing productivity and supporting long-term development strategies. According to this theory, government investment in infrastructure improves the efficiency of economic activities by reducing transaction costs, facilitating trade, and enhancing connectivity within and across regions. When infrastructure investment is implemented efficiently, it can generate significant economic benefits by improving productivity and stimulating private sector investment. Consequently, infrastructure development is widely regarded as a fundamental component of economic transformation.

Another theoretical perspective relevant to this study is the general management theory originally proposed by Fayol (1949). This theory emphasizes the importance of effective management practices in organizational performance and governance structures. Fayol argues that successful management requires the integration of several key elements, including planning, organizing, commanding, coordinating, and controlling. Although the theory was initially developed within the context of organizational management, its principles can also be applied to broader governance frameworks. In particular, the emphasis on effective management and administrative coordination is relevant for understanding how governance institutions influence economic outcomes. Effective governance institutions require strong management structures that promote accountability, regulatory efficiency, and transparency in public administration. In this context, governance institutions play an important role in controlling corruption and ensuring that public authority is exercised in ways that

promote economic development (Challe et al., 2019). Consequently, the theoretical insights derived from general management theory help explain the institutional mechanisms through which governance quality may influence economic complexity and infrastructure development.

2.3. Empirical Literature and Hypothesis Development

2.3.1. Technological Innovation and Economic Complexity

Technological innovation has been widely recognized as a key driver of structural transformation and productive sophistication in modern economies. Empirical studies suggest that technological progress enhances the ability of countries to diversify production structures and develop more complex export baskets. For example, Ibrahim et al. (2022) examined the effects of technological innovation on sustainable development in China using time series data from 1996 to 2010 and the bound test model. Their findings indicate that technological innovation plays a fundamental role in supporting sustainable development. Similarly, Sun et al. (2024) investigated the relationship between green innovation and economic complexity using the bootstrapping autoregressive distributed lag (BARDL) framework and found that economic complexity significantly promotes innovation activities.

Other studies highlight the broader implications of economic complexity for economic performance and environmental sustainability. Safi et al. (2023) found that increasing economic complexity contributed to reducing carbon emissions in G-7 economies. Likewise, Dogan et al. (2021) reported that higher levels of economic complexity can help mitigate environmental degradation in advanced economies. In addition, Adam et al. (2023) examined the relationship between economic complexity and labour market outcomes in OECD countries and found that increasing economic complexity does not lead to employment losses.

Although these studies provide important insights into the relationship between technological innovation and economic complexity, most of them focus on developed economies or emerging economies outside Africa. Empirical evidence examining how technological innovation influences economic complexity in African economies remains limited. Therefore, further investigation is required to understand whether technological innovation can stimulate productive sophistication and structural transformation in African countries.

Based on the foregoing discussion, the following hypothesis is proposed:

H1: *Technological innovation significantly influences economic complexity in Africa.*

2.3.2. Technological Innovation and Infrastructure

Infrastructure development is widely regarded as an essential component of economic development because it supports production activities, facilitates trade, and improves economic efficiency. Several empirical studies suggest that technological innovation can enhance infrastructure development by improving efficiency, reducing operational costs, and enabling the adoption of modern technologies in infrastructure systems.

For example, Osei (2024) examined the relationship between technological innovation and infrastructure development in Africa using the GMM estimation technique for the period 2011–2019. The study revealed a positive relationship between technological innovation and infrastructure development. Similarly, Ajakaiye and Ncube (2010) investigated the relationship between infrastructure investment and economic progress in Sub-Saharan Africa using panel data for 136 countries and found that infrastructure development contributes positively to economic progress.

Other studies have also highlighted the importance of infrastructure in promoting economic transformation. Abdullahi and Sieng (2023) found that infrastructure development measured using the electricity composite index has a positive and significant impact on economic development in Africa. Likewise, Kuete and Asongu (2023) showed that infrastructure development accelerates structural transformation in African economies. Adeola and Evans (2019) also reported that infrastructure development contributes positively to tourism development in Africa.

Furthermore, Baita & Suleiman (2021) examined the potential role of Sukuk financing in achieving Sustainable Development Goal nine (SDG-9), which focuses on industry, innovation, and infrastructure in Sub-Saharan Africa. Their findings suggest that Sukuk financing remains an underutilized instrument for promoting infrastructure development. Similarly, Rammile et al. (2024) found that improvements in infrastructure and innovation contribute to achieving sustainable development goals and improving public health outcomes in African cities. Despite these contributions, limited empirical studies have examined how technological innovation directly influences infrastructure development in African economies. Therefore, further investigation is required to better understand this relationship. Based on this discussion, the following hypothesis is proposed:

H2: *Technological innovation significantly influences infrastructure development in Africa.*

2.3.3. Governance Institutions and Moderation Effects

Governance institutions play an important role in shaping economic development outcomes because they influence regulatory frameworks, policy implementation, and resource allocation. Empirical studies suggest that institutional quality can moderate the effectiveness of economic policies and development strategies. For example, Ojonta & Ogbuabor (2024) examined the moderating role of institutional quality in the relationship between tourism and infrastructure development in Africa using panel data for 31 countries between 2011 and 2021. Their findings indicate that institutional quality significantly moderates the effects of tourism on infrastructure development. Similarly, Ogbuabor et al. (2023) employed a dynamic system GMM framework to investigate the role of international financial flows and governance institutions in shaping economic complexity in Africa. Their results show that governance institutions significantly moderate the effects of financial flows on economic complexity.

Other studies have also examined the moderating role of institutional quality in different economic contexts. Maduka et al. (2022) investigated the moderating effects of corruption control on the relationship between economic growth and environmental sustainability in Nigeria using ARDL and quartile regression techniques. Their findings reveal that interaction effects are not statistically significant. Similarly, Olaniyi & Oladeji (2021) found that governance institutions may negatively

influence the relationship between financial development and economic growth in West Africa. Furthermore, Ogbonna et al. (2021) examined how governance institutions moderate the effects of foreign aid on economic growth in Africa using system GMM estimation for 42 countries between 2010 and 2018. Their findings indicate that institutional quality across many African countries remains below the required threshold. In addition, Ojeka et al. (2024) found that institutional quality plays a significant moderating role in the relationship between external debt and domestic investment in Sub-Saharan Africa. Although these studies highlight the importance of governance institutions in shaping economic outcomes, limited empirical research has examined how governance institutions moderate the relationship between technological innovation and development outcomes, such as economic complexity and infrastructure, in Africa. Therefore, the following hypothesis is proposed:

H3: *Governance institutions moderate the relationship between technological innovation and both economic complexity and infrastructure development in Africa.*

3. Data and Methodology

3.1. Data

This study examines the role of technological innovation in enhancing economic complexity and infrastructure development in Africa. The empirical analysis is based on panel data from 2011 to 2020 for a sample of 31 African countries. These countries include Algeria, Angola, Egypt, Madagascar, Niger, Burkina Faso, Botswana, Ethiopia, Mali, Cameroon, Chad, Gabon, Mauritania, Democratic Republic of Congo, Republic of Congo, Ghana, Namibia, Nigeria, Mozambique, Senegal, Tanzania, Togo, Uganda, Tunisia, Côte d'Ivoire, Guinea, Kenya, South Africa, Sudan, Zambia, and Zimbabwe. The selection of these countries is primarily based on the availability of consistent data for the variables used in the analysis.

Appendix 1 presents the description of the variables and their respective data sources, while Appendices 2 and 3 provide the descriptive statistics and correlation matrix of the variables used in the study. The descriptive statistics indicate that the mean values for the governance institution variables and human capital are negative, suggesting that, on average, African economies are characterized by relatively poor institutional quality and low levels of human capital development. Furthermore, the proximity of the mean, maximum, and minimum values indicates that the dataset contains no significant outliers. The standard deviation values also suggest that the variables exhibit some variation across countries during the study period. The correlation matrix results indicate that the governance institution variables are correlated with one another, suggesting potential multicollinearity among them. Multicollinearity can distort regression estimates and reduce the reliability of econometric results. To address this issue, each governance institution variable is included separately in a separate model estimate.

3.2. Model Specification

2.3.4. Objective One and its Model Specification

The first objective of this study is to ascertain the impact of technological innovation on economic complexity in Africa. The measurement of the variables in this model follows the approaches adopted by Ojonta & Ogbuabor (2024a, 2024b), Archibugi & Lammarino (2002), and Ogbuabor et al. (2023). Accordingly, the panel data model is specified in its functional form as follows:

$$ECI_{it} = \alpha + \beta_1 TA_{it} + \beta_2 HCA_{it} + \beta_3 INF_{it} + \beta_4 FDI_{it} + \beta_5 INST_{it} + \beta_6 (TA \times INST)_{it} + \varepsilon_{it} \text{----------(1)}$$

where:

- **eci** represents economic complexity measured using the Economic Complexity Index compiled by the Massachusetts Institute of Technology;
- **ta** denotes technological innovation measured by total patent applications (residents and non-residents);
- **hca** represents human capital measured using the human capital development index.
- **inf** denotes infrastructure measured using the electricity composite index;
- **fdi** represents foreign direct investment inflows measured as net inflows (% of GDP);
- **inst** represents indicators of governance institutions, including political stability and absence of violence/terrorism, control of corruption, regulatory quality, government effectiveness, rule of law, and voice and accountability;
- **ta** × **inst** represents the interaction term between technological innovation and governance institution indicators.

To facilitate estimation, the functional form in equation (1) is expressed econometrically as a dynamic panel data model as follows:

$$eci_{it} = \beta_0 + \delta_1 eci_{it-1} + \delta_2 ta_{it} + \delta_3 hca_{it} + \delta_4 fdi_{it} + \delta_5 inf_{it} + \delta_6 inst_{it} + \delta_7 (ta * inst)_{it} + \varepsilon_{it} \text{----------(2)}$$

Where eci_{it-1}represents the lagged value of economic complexity and $\varepsilon_{it}$is the stochastic error term? The interaction term $(ta * inst)_{it}$is included to examine how governance institutions moderate the impact of technological innovation on economic complexity in Africa. This interaction variable is generated by multiplying technological innovation by the governance institution indicator (Ogbuabor et al., 2023). To ensure that the estimated coefficients remain within reasonable magnitudes, selected variables such as infrastructure and technological innovation are transformed using logarithmic scaling (Kamguia et al., 2023). Other variables, including economic complexity, human capital, foreign direct investment, and governance institutions, remain in their original form (Ketu et al., 2022).

2.3.5. Objective Two and its Model Specification

The second objective of this study is to examine the impact of technological innovation on infrastructure development in Africa. The functional specification of the model is expressed as follows:

$$INF_{it} = \alpha + \beta_1 TA_{it} + \beta_2 REM_{it} + \beta_3 FDI_{it} + \beta_4 ECI_{it} + \beta_5 INST_{it} + \beta_6 (TA \times INST)_{it} + \varepsilon_{it} \text{----------(3)}$$

where **inf** represents infrastructure measured using the electricity composite index, while the remaining variables retain their definitions provided earlier.

The econometric specification of the infrastructure model is presented as a dynamic panel model:

$$inf_{it} = \beta_0 + \delta_1 inf_{it-1} + \delta_2 ta_{it} + \delta_3 rem_{it} + \delta_4 fdi_{it} + \delta_5 eci_{it} + \delta_6 inst_{it} + \delta_7 (ta * inst)_{it} + \varepsilon_{it} \text{----------(4)}$$

Where inf_{it-1} represents the lagged value of infrastructure and ε_{it} is the error term. The interaction term $(ta * inst)_{it}$captures the moderating effect of governance institutions on the relationship between technological innovation and infrastructure development. In this specification, the interaction variable is generated by multiplying technological innovation with governance institution indicators (Ogbuabor et al., 2023). Furthermore, remittances and technological innovation variables are transformed using a logarithmic transformation to reduce scale differences and improve estimation stability, and stabilize the estimated coefficients (Kamguia et al., 2023). Other variables, including economic complexity, foreign direct investment, and governance institutions, remain in their original scale (Ketu et al., 2022).

2.3.6. Objective Three and Moderation Analysis

The third objective of this study is to examine the moderating role of governance institutions in the relationship between technological innovation and both economic complexity and infrastructure development in Africa. This objective is captured through the interaction terms included in equations (2) and (4). Specifically, the interaction terms $(ta * inst)$allow the study to assess whether the effectiveness of technological innovation in improving economic complexity and infrastructure depends on the quality of governance institutions in African countries.

3.3. Estimation Technique and Pre-Estimation Tests

The models specified in equations (2) and (4) are estimated using the dynamic panel system generalized method of moments (system GMM) estimator. The system GMM estimator is appropriate for panel data characterized by a relatively large number of cross-sectional units and a shorter time dimension. In this study, the dataset comprises 31 cross-sectional units (African countries) observed over a 10-year period, which justifies the use of the system GMM estimator. The system GMM approach effectively addresses several econometric challenges commonly associated with dynamic panel models, including unobserved panel heterogeneity, omitted variable bias, and endogeneity arising from the inclusion of lagged dependent variables (Arellano & Bond, 1991; Blundell & Bond, 1998). Furthermore, the system GMM estimator improves estimation efficiency by combining equations in levels and first differences, thereby reducing the finite sample bias typically associated with the difference GMM estimator (Blundell & Bond, 2000).

To confirm the appropriateness of the estimator, the study conducts the Bond (2002) test for the models specified in equations (2) and (4). The results of this test, presented in Appendix 4, indicate that the system GMM estimator is more appropriate than the difference GMM estimator for the present dataset. Prior to estimation, several diagnostic tests are conducted. First, a correlation matrix of the regressors is examined to identify potential multicollinearity among the explanatory variables. The results presented in Appendix 3 indicate that the governance institution variables exhibit relatively high correlations. To mitigate potential multicollinearity, each governance institution indicator is included separately in a separate model estimate.

In addition, cross-sectional dependence tests are performed given the increasing level of economic integration among African countries, particularly following the implementation of the African Continental Free Trade Agreement (AfCFTA) and the activities of regional economic communities within the African Union (AU). Cross-sectional dependence may arise because economic shocks or policy changes in one country may influence other countries within the region. In dynamic panel models with large cross-sectional units and relatively small time periods, cross-sectional dependence may lead to inefficient estimates (Sarafidis & Robertson, 2009). Therefore, this study follows the approach proposed by Pesaran (2021), which is asymptotically efficient in panels characterized by large cross-sectional units and relatively small time dimensions. Additional cross-sectional dependence tests, including Friedman (1937) and Frees (1995), are also conducted. The results presented in Appendix 5 indicate that the panel exhibits cross-sectional independence. Consequently, cross-sectional dependence is not considered a significant concern in this study.

4. Empirical Results

4.1. Results for the Panel Data Economic Complexity Model

This study has three objectives as previously stated. To achieve the first objective, the model specified in equation (2) was estimated using the system GMM estimator. The estimation results are presented in Table 1.

Table 1: Panel Data Results for the Economic Complexity Model

regressor	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 6
L1.ec_i	0.900871***	0.99451***	0.909929***	0.906183***	0.97789***	0.911547***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ta_t	0.96131***	0.57305***	0.85623***	0.82829***	0.4887**	0.03296***
	(0.000)	(0.009)	(0.003)	(0.000)	(0.018)	(0.000)
hca_p	0.1235***	0.12678***	0.11797***	0.11573**	0.12754***	0.15418***
	(0.000)	(0.002)	(0.005)	(0.011)	(0.005)	(0.000)
in_f	0.033704	0.013199	0.005596	0.123693***	0.030797	0.015798
	(0.374)	(0.706)	(0.885)	(0.005)	(0.507)	(0.651)
fd_i	0.551848***	0.572188***	0.60065***	0.289069**	0.490555***	0.634379***
	(0.001)	(0.000)	(0.000)	(0.037)	(0.004)	(0.000)
cf_c	0.00604*					
	(0.0661)					
ta_t*cf_c	-0.01017***					

regressor	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 6
	(0.000)					
gt_e		0.00201*				
		(0.0895)				
ta_t*gt_e		-0.00601***				
		(0.004)				
ro_l			0.002604*			
			(0.0869)			
ta_t*ro_l			-0.01142***			
			(0.001)			
va_c				-0.02919**		
				(0.020)		
ta_t*va_c				-0.0003		
				(0.0786)		
ru_q					0.010127	
					(0.564)	
ta_t*ru_q					-0.0053***	
					(0.009)	
pols_t						-0.01865*
						(0.058)
ta_t*pols_t						-0.0054***
						(0.001)
Constant	0.423884**	0.040454	0.311983	0.480936**	0.00485	0.411686**
	(0.045)	(0.823)	(0.173)	(0.012)	(0.976)	(0.040)
Diagnostic						
Observations	199	199	199	199	199	199
Hansen	0.369	0.239	0.305	0.373	0.224	0.348
AR(2)	0.13	0.132	0.129	0.124	0.131	0.131
No. of Instruments	27	27	27	27	27	27

Source: Author. Notes: Estimated coefficients are reported while the p-values are in parentheses. * p< 0.10. ** p < 0.05. *** p < 0.01.

The results in Table 1 show that technological innovation (ta_t) is positive and statistically significant across all panels. This indicates that technological innovation contributes positively to economic complexity in Africa. The positive coefficient suggests that increases in technological innovation, measured through patent applications, enhance the productive capabilities of African economies and promote the production of more sophisticated goods. This outcome conforms to theoretical expectations and is consistent with Archibugi & Lammarino (2002), who found that technological innovation significantly enhances economic complexity in OECD countries.

The lagged dependent variable (L1.ec_i) is positive and highly significant across all model specifications. This result indicates strong persistence in economic complexity. In other words, previous levels of economic complexity significantly influence current levels of economic complexity in Africa. Countries with higher productive sophistication in the past tend to maintain or improve their complexity over time. This result is consistent with Anthony-Orji et al. (2023), who also reported a positive and significant effect of lagged economic complexity. Human capital (hca_p) is positive and statistically significant across all panels. This result implies that improvements in human capital development contribute positively to economic complexity in Africa. Higher levels of education, skills, and knowledge accumulation enhance the productive capacity of economies and facilitate the production of technologically advanced goods.

Foreign direct investment inflow (fd_i) is also positive and statistically significant in all panels. This indicates that foreign investment plays an important role in improving economic complexity in Africa. FDI may contribute through technology transfer, managerial expertise, and integration into global value chains, thereby enhancing productive capabilities. Infrastructure (in_f) is largely insignificant in most of the model specifications, except in Panel 4 where it appears positive and statistically significant. This suggests that infrastructure development does not consistently influence economic complexity across the sampled African economies. The weak statistical significance may reflect the structural limitations of infrastructure development in many African countries. Regarding governance institutions, the results show mixed but predominantly negative effects on economic complexity. For example, voice and accountability (va_c) and political stability (pols_t) exhibit negative and statistically significant coefficients. This indicates that these governance indicators are associated with lower levels of economic complexity in the sample.

The interaction terms between technological innovation and governance institutions are predominantly negative and statistically significant. For instance, the interaction terms ta_t*cf_c, ta_t*gt_e, ta_t*ro_l, ta_t*ru_q, and ta_t*pols_t are negative and significant across several panels. This suggests that governance institutions weaken the positive influence of technological innovation on economic complexity in Africa. In other words, the moderating effect of governance institutions reduces the contribution of technological innovation to economic complexity. The diagnostic statistics indicate that the models are econometrically valid. The Hansen test statistics confirm the validity of the instruments used in the GMM estimation. Furthermore, the AR(2) test results show no evidence of second-order serial correlation, indicating that the model specification is appropriate.

4.2. Results for the Panel Data Infrastructure Model

The second objective of this study examines the impact of technological innovation on infrastructure development in Africa. To achieve this objective, the model specified in equation (4) was estimated using the system GMM estimator. The estimation results are presented in Table 2.

Table 2: Panel Data Results for the Infrastructure Model

Regressor	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 6
in_f L1.	0.927915***	0.924943***	0.929697***	0.936617***	0.931799***	0.938174***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ta_t	0.0339819**	0.0359866***	0.0358144**	0.0531947***	0.0449142***	0.05023***
	(0.000)	(0.008)	(0.002)	(0.000)	(0.005)	(0.000)
re_m	0.0003484**	0.000014**	0.0001204***	0.0007012**	0.0003525**	0.0000555***
	(0.048)	(0.009)	(0.002)	(0.013)	(0.009)	(0.000)
fd_i	0.0387055***	0.04027***	0.0358638***	0.0386365***	0.0351677***	0.0372823***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ec_i	0.0026996**	0.0037312***	0.0033218**	0.0004967	0.0012545	0.0008907
	(0.017)	(0.000)	(0.011)	(0.527)	(0.227)	(0.163)
cf_c	0.0050951***					
	(0.000)					
ta_t*cf_c	-0.0003408					
	0.164					
gt_e		0.00688***				
		(0.000)				
ta_t*gt_e		-0.0003728***				
		(0.000)				
ro_l			0.0051711***			
			(0.000)			
ta_t*ro_l			-0.0001832			
			(0.123)			
va_c				0.0032347***		
				(0.000)		
ta_t*va_c				-0.0004174**		
				(0.016)		
ru_q					0.0047659***	
					(0.000)	
ta_t*ru_q					-0.0003712*	
					(0.090)	
pols_t						0.0017924***
						(0.000)
ta_t*pols_t						0.000041
						(0.545)
Constant	0.0398639***	0.0457236***	0.0378807***	0.0528801***	0.0459102***	0.048075***
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Diagnostic						
Observations	199	199	199	199	199	199
Hansen	0.409	0.412	0.392	0.309	0.252	0.431
AR(2)	0.212	0.199	0.198	0.209	0.208	0.215
No. of Instruments	27	27	27	27	27	27

Source: Author. Notes: Estimated coefficients are reported while the p-values are in parentheses. * p< 0.10. ** p < 0.05. *** p < 0.01.

The results in Table 2 indicate that technological innovation (ta_t) is positive and statistically significant across all panels. This suggests that technological innovation contributes positively to infrastructure development in Africa. The positive coefficient implies that technological innovation improves the development and efficiency of infrastructure systems. The lagged infrastructure value (in_f L1) is positive and statistically significant across all model specifications. This result indicates strong persistence in infrastructure development, implying that previous infrastructure levels significantly influence current infrastructure outcomes in Africa. Countries with higher levels of infrastructure development in the past tend to sustain or improve infrastructure development over time. This result aligns with Osei's (2024) findings. Remittances (re_m) are positive and statistically significant across all panels. This suggests that remittance inflows contribute positively to infrastructure development in Africa. Remittances may support household investments and infrastructure-related projects, thereby improving infrastructure availability.

Foreign direct investment (fd_i) is also positive and statistically significant in all panels. This indicates that FDI inflows contribute to improving infrastructure development in Africa. Foreign investments often support infrastructure projects through capital inflows, technology transfer, and private-sector participation. Economic complexity (ec_i) is significant only in the first three panels and insignificant in the remaining panels. This suggests that economic complexity does not consistently influence infrastructure development in Africa. The governance institution indicators generally show positive and statistically significant effects on infrastructure development. For example, control of corruption (cf_c), government effectiveness (gt_e), rule of law (ro_l), voice and accountability (va_c), regulatory quality (ru_q), and political stability (pols_t) are mostly positive and significant. This indicates that improvements in governance quality contribute to better infrastructure development.

However, the interaction terms between technological innovation and governance institutions are mostly negative and statistically significant. For example, ta_t*gt_e, ta_t*va_c, and ta_t*ru_q are negative and significant across several panels. This implies that the moderating effect of governance institutions weakens the impact of technological innovation on infrastructure development. The diagnostic statistics further confirm the models' robustness. The Hansen test results indicate

that the instruments used in the system GMM estimation are valid. In addition, the AR(2) test results show no evidence of second-order serial correlation, indicating that the models are correctly specified.

5. Discussion

The findings of this study provide important insights into the relationship between technological innovation, governance institutions, economic complexity, and infrastructure development in Africa. The empirical results reveal that technological innovation significantly improves economic complexity across the sampled African economies. This result indicates that innovation activities, particularly technological advancements reflected through patent applications, enhance the productive capabilities of economies and promote the development of more sophisticated production structures. The finding supports the theoretical argument of endogenous technological progress theory, which emphasizes the role of innovation in driving economic development. It also aligns with the findings of Archibugi & Lammarino (2002), who reported that technological innovation contributes significantly to economic complexity in developed economies. Therefore, technological innovation appears to serve as an important mechanism through which African economies can strengthen their productive structures and diversify economic activities.

Another important finding is the strong persistence observed in economic complexity across African economies. The significant influence of the lagged economic complexity variable suggests that the level of productive sophistication achieved in previous periods plays an important role in determining current economic complexity. This implies that economies with stronger productive structures tend to sustain their advantages over time. The result is consistent with Anthony-Orji et al. (2023), who reported that previous levels of economic complexity significantly influence current economic complexity outcomes. The results also demonstrate that human capital and foreign direct investment play important roles in enhancing economic complexity in Africa. Human capital contributes to economic complexity by improving the knowledge base, technical skills, and productive capacity required for sophisticated production processes. Similarly, foreign direct investment facilitates technology transfer, managerial expertise, and integration into international production networks. These findings are consistent with the studies of Nyong and Inyang (2018) and Mamirkulova et al. (2020), which emphasize the importance of human capital development and foreign investment in promoting productive sophistication.

However, the findings indicate that infrastructure does not consistently influence economic complexity across African economies. This result suggests that the current level of infrastructure development in many African countries may still be insufficient to significantly support structural transformation and industrial diversification. In many cases, infrastructure remains unevenly distributed and may not yet provide the necessary support for advanced production systems. Regarding governance institutions, the findings reveal that several governance indicators exert negative effects on economic complexity. This suggests that institutional weaknesses, governance inefficiencies, and regulatory constraints may hinder the ability of African economies to translate technological innovation into improvements in productive sophistication. Similar findings were reported by Maduka et al. (2022), who observed that governance institutions may negatively influence economic complexity in Nigeria. These outcomes may be attributed to institutional challenges such as corruption, weak regulatory enforcement, and bureaucratic inefficiencies that persist across many African economies.

In terms of infrastructure development, the results indicate that technological innovation plays a significant role in improving infrastructure in Africa. Technological advancement contributes to infrastructure development through improved engineering techniques, digital infrastructure systems, and enhanced efficiency in infrastructure management. This finding supports the argument that technological innovation can strengthen infrastructure systems and enhance economic performance. The results also show that remittances and foreign direct investment significantly contribute to infrastructure development in Africa. Remittances provide an important source of financial inflows that may support infrastructure development through household investments and community projects. Similarly, foreign direct investment facilitates infrastructure expansion through capital inflows, technological transfer, and investment in infrastructure-related sectors. These findings are consistent with Abdullahi and Sieng (2023), Ajakaiye and Ncube (2010), and Adeola & Evans (2019).

However, the moderating role of governance institutions appears to weaken the relationship between technological innovation and infrastructure development. The negative interaction effects suggest that governance inefficiencies, institutional weaknesses, and bureaucratic bottlenecks may reduce the effectiveness of technological innovation in promoting infrastructure development in Africa. In many cases, governance challenges such as corruption, administrative inefficiencies, and policy inconsistencies may limit governments' capacity to fully harness technological innovation for infrastructure development. These findings, therefore, highlight the importance of institutional quality in determining the effectiveness of technological innovation in achieving development outcomes in Africa.

6. Policy Implications

The findings of this study provide several important policy implications for African economies. First, the empirical results reveal that technological innovation significantly enhances economic complexity in Africa. This suggests that policies promoting technological advancement should be prioritized across the continent. Governments should therefore strengthen investments in digital technologies, research and development, and innovation systems. In addition, programmes aimed at improving human capacity development and digital literacy should be encouraged in order to enhance technological capabilities across African economies.

Second, the results indicate that remittances and foreign direct investment positively contribute to economic complexity and infrastructure development. This implies that policies aimed at improving the investment climate and facilitating financial inflows should be strengthened. Encouraging foreign investment, reducing the cost of remittance transfers, and promoting financial inclusion may help increase the contribution of external financial inflows to economic development in Africa. Third, the results reveal that technological innovation contributes positively to infrastructure development. Therefore, policymakers should encourage the adoption of modern technologies in infrastructure development and management. Investments in digital infrastructure and technological modernization of infrastructure systems may significantly improve infrastructure efficiency and performance across African economies.

Finally, the findings highlight the importance of governance institutions in shaping development outcomes. Weak governance institutions remain a major challenge in many African economies. Consequently, reforms aimed at improving transparency, accountability, and regulatory efficiency should be strengthened. African leaders and policymakers may collaborate through regional organizations such as the African Union and sub-regional institutions like the Economic Community of West African States (ECOWAS) to promote institutional reforms that support sustainable development across the continent.

7. Conclusions

This study examined the influence of technological innovation on economic complexity and infrastructure in Africa, while also investigating the moderating role of governance institutions. Using panel data for 31 African countries over the period 2011–2020 and applying the system GMM estimator, the study provides empirical evidence on the relationship among technological innovation, institutional quality, economic complexity, and infrastructure development. The findings reveal that technological innovation plays a significant role in enhancing both economic complexity and infrastructure development in Africa. In addition, the results show that human capital, remittances, and foreign direct investment contribute positively to economic development outcomes. However, the moderating effects of governance institutions appear to weaken the impact of technological innovation on both economic complexity and infrastructure. This suggests that institutional weaknesses continue to limit the effectiveness of technological innovation across many African economies. Overall, the study highlights the importance of strengthening technological capabilities, improving institutional quality, and promoting investment inflows in order to support sustainable economic development in Africa.

8. Limitations of the Study

Despite the important contributions of this study, several limitations should be acknowledged. First, the study was limited by the availability of data for African countries. Due to data constraints, it was not possible to include a larger number of African economies in the analysis. Future studies may overcome this limitation by incorporating additional countries as more comprehensive datasets become available. Second, this study did not explore potential sub-regional differences within Africa. Africa consists of several distinct sub-regions, including Central Africa, East Africa, North Africa, Southern Africa, and West Africa. Economic structures, institutional environments, and technological capabilities may vary significantly across these sub-regions. Future research could therefore examine whether the relationships among technological innovation, governance institutions, economic complexity, and infrastructure differ across African sub-regions. Third, the empirical analysis in this study employed the system generalized method of moments (system GMM) estimator. Although this estimator is widely used in dynamic panel data analysis, future studies may apply alternative estimation techniques such as the difference GMM estimator in order to compare results and provide additional robustness checks. Finally, future research may consider alternative measurements for key variables used in this study. Different indicators of technological innovation, governance institutions, or infrastructure development may provide additional insights into the relationships examined in this research. Such extensions would further enhance the robustness and generalizability of the findings.

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Appendix 1: Data Description and Sources

Variable	Measurement	Acronym	Data source
Technological Innovation	Total Patent Applications (residents and non-residents)	ta_t	WDI
Economic complexity	The index is determined by the diversity of exports a country produces and its ubiquity	ec_i	MIT
Infrastructure	Africa Infrastructure Development Index	in_f	AIDI
Human capital development	Human Capital Index	hca_p	HCI
Foreign Direct Investment Inflow	Foreign Direct Investment Net Inflow (% of GDP)	fd_i	WDI
Remittance	Personal Remittances, Received (current US$)	re_m	WDI
Government Effectiveness	Government Effectiveness	gt_e	WGI
Voice and Accountability	Voice and Accountability	va_c	WGI
Regulatory Quality	Regulatory Quality	ru_q	WGI
Rule of Law	Rule of Law	ro_l	WGI
Control of corruption	Control of Corruption	cf_c	WGI
Political Stability and Absence of Violence/Terrorism	Political Stability and Absence of Violence/Terrorism	pols_t	WGI

Source: Author's compilation from WDI: World Development Indicator of the World Bank, WGI: World Governance Indicators of the World Bank, AIDI: African Development Bank's Africa Infrastructural Development Index: Human Capital Index, MIT: Massachusetts Institute of Technology's Observatory of Economic Complexity.

Appendix 2: Descriptive Statistics of the Variables

Variable	in_f	ta_t	ec_i	re_m	fd_i	hca_p	cf_c	ro_l	gt_e	ru_q	va_c	pols_t
No. of Obs.	310	310	310	310	310	310	310	310	310	310	310	310
Mean	0.0047	0.9567	-0.938	0.2022	0.6867	-0.937	-0.692	-0.654	-0.726	-0.646	-0.567	-0.779
Std. Dev.	0.2709	0.0401	0.5154	1.6567	0.0577	0.1493	0.5361	0.5046	0.5026	0.4801	0.6321	0.7838
Minimum	-1.171	0.7996	-2.228	-8.584	0.571	-1.252	-1.572	-1.791	-1.693	-1.673	-1.851	-2.523
Maximum	0.4055	1.0315	0.3903	2.6109	0.8014	-0.604	0.9956	0.6677	0.5295	0.6109	0.6972	1.1111

Source: Author's compilations using Stata

Appendix 3: The Variables and correlation Matrix results

	in_f	ta_t	ec_i	re_m	fd_i	hca_p	cf_c	ro_l	gt_e	ru_q	va_c	pols_t
in_f	1											
ta_t	0.649	1										
ec_i	0.311	0.677	1									
re_m	-0.042	-0.155	0.194	1								
fd_i	0.662	0.738	0.512	-0.376	1							
hca_p	0.658	0.675	0.124	0.141	0.634	1						
cf_c	0.304	0.374	0.649	-0.254	0.537	0.264	1					
ro_l	0.461	0.485	0.794	-0.108	0.544	0.325	0.995	1				
gt_e	0.518	0.585	0.691	-0.325	0.655	0.447	0.967	0.121	1			
ru_q	0.447	0.318	0.606	-0.142	0.427	0.152	0.858	0.963	0.856	1		
va_c	0.451	0.383	0.678	-0.134	0.468	0.224	0.914	0.943	0.931	0.105	1	
pols_t	0.387	0.253	0.528	-0.301	0.465	0.171	0.791	0.799	0.755	0.775	0.691	1

Source: Author's compilations using Stata.

Appendix 4: Bond (2002) test results for choice of GMM estimator

eci L1.	Bond_1	Bond_2	Bond_3	Bond_4	Bond_5	Bond_6
FE	0.4585289***	0.4556886***	0.4690806***	0.4714707***	1.106975***	0.2950033***
OLS	0.895324***	0.8672177***	0.8802308***	0.8862483***	0.9011676***	0.8997909***
FIRST DIFF	0.3107037***	0.3078397***	0.2950033***	0.3352028***	0.4028166***	0.341496***
SECOND DIFF	1.070454***	1.04368***	1.108992***	1.055424***	1.106975***	1.060353***
inf L1.	**Bond_1**	**Bond_2**	**Bond_3**	**Bond_4**	**Bond_5**	**Bond_6**
FE	0.7595838***	0.7561323***	0.7768042***	0.7573043***	0.7556944***	0.7450951***
OLS	0.995155***	1.000903***	1.00674***	1.007153***	1.007105***	0.9956148***
FIRST DIFF	0.5344427***	0.5175881***	0.5874233***	-0.0006706***	-0.0007999***	-0.0004542***
SECOND DIFF	1.000734***	1.016137***	1.030773***	1.034537***	1.028672***	0.9993377***

Source: Author's compilations using Stata.

Appendix 5: The cross-sectional independence test and results

Economic Complexity Model						
	(1) cf_c	(2) ro_l	(3) gt_e	(4) ru_q	(5) va_c	(6) pols_t
Pesaran - fe	1.648 (0.331)	1.653 (0.331)	1.667 (0.329)	1.619 (0.329)	1.644 (0.328)	1.621 (0.332)
Pesaran - re	1.146 (0.314)	1.142 (0.316)	1.128 (0.316)	1.224 (0.315)	1.144 (0.314)	1.088 (0.314)
Friedman - fe	1.000 (0.331)	1.000 (0.331)	1.000 (0.329)	1.000 (0.329)	1.000 (0.328)	1.000 (0.332)
Friedman - re	1.000 (0.314)	1.000 (0.316)	1.000 (0.316)	1.000 (0.315)	1.000 (0.314)	1.000 (0.314)
Frees' – fe	1.215 (0.331)	1.236 (0.331)	1.050 (0.329)	1.042 (0.329)	1.063 (0.328)	1.186 (0.332)
Frees' – re	-0.054 (0.314)	0.102 (0.316)	0.121 (0.316)	0.039 (0.315)	-0.005 (0.314)	0.103 (0.314)
Decision	CID	CID	CID	CID	CID	CID
Infrastructure Model						
Pesaran - fe	1.812 (0.394)	1.828 (0.395)	1.819 (0.394)	1.823 (0.391)	1.827 (0.394)	1.822 (0.395)
Pesaran - re	1.824 (0.324)	1.822 (0.329)	1.810 (0.330)	1.822 (0.327)	1.838 (0.328)	1.840 (0.333)
Friedman - fe	1.000 (0.394)	1.000 (0.395)	1.000 (0.394)	1.000 (0.391)	1.000 (0.394)	1.000 (0.395)
Friedman - re	1.000 (0.324)	1.000 (0.329)	1.000 (0.330)	1.000 (0.327)	1.000 (0.328)	1.000 (0.333)
Frees' – fe	1.986 (0.394)	2.088 (0.395)	2.054 (0.394)	2.072 (0.391)	2.067 (0.394)	2.084 (0.395)
Frees' – re	0.567 (0.324)	0.665 (0.329)	0.701 (0.330)	0.608 (0.327)	0.623 (0.328)	0.735 (0.333)
Decision	CID	CID	CID	CID	CID	CID

Source: Author's compilations**:** The table has six panels, as the variables of governance institutions are presented across different estimates of the underlying models. The values of Pr are presented for the tests, following Pesaran and Friedman, while the alpha values are shown for the Frees tests. The report n parentheses in all cases is the average absolute value. The cross-sectional independence is represented by CID.