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INFRASTRUCTURE DEVELOPMENT AND EXTERNAL FINANCING NEXUS IN SUB-SAHARAN AFRICA: PANEL VECM ANALYSIS

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Abstract

Research background: It is evident that relying solely on domestic financing cannot bridge the infrastructure gap in the Sub-Saharan African (SSA) region. Therefore, exploring alternative sources of financing becomes crucial to complement domestic efforts and address the infrastructure needs effectively.
Purpose: This study investigates the relationship between infrastructure development and external financing factors (foreign direct investment – FDI, private participation in infrastructure – PPI, and official development assistance – ODA) by considering the short- and long-run equilibrium and their causal direction.
Research methodology: These objectives are achieved by employing the panel vector error correction mechanism (PVECM), impulse response functions (IRF), variance decomposition analysis (VDCs), and VAR causality on a dataset covering 43 SSA countries from 2000 to 2021.
Results: The results reveal the presence of feedback causal relationships between infrastructure development and external financing factors, and PVECM results demonstrate that only private participation in infrastructure has a positive influence on infrastructure development both in the long and short-run, while ODA and FDI only influence infrastructure development in the long- run.

Novelty: The current study contributes to the existing literature by examining the impact of external financing factors on infrastructure development, with a specific focus on SSA, by considering the three major external financing factors (PPI, FDI, and ODA) as the determinants of infrastructure.

Keywords: infrastructure development, official development assistance, private participation in infrastructure, foreign direct investment, Sub-Saharan Africa

JEL classification: C33, C38, H54, N77

Introduction

Extensive observations conducted in developed and developing countries have consistently demonstrated that investment in infrastructure is an indispensable requirement for achieving sustainable development. According to Saghir (2017), infrastructure development and financing are indispensable components of growth and an essential building block for Sub-Saharan Africa (SSA) countries to get on the path of sustainable development. Traditionally, infrastructure spending has largely been financed by the national government in most of the SSA countries, while domestic financing remains the primary source of financing infrastructure through public funds as captured in annual capital budgets (Infrastructure Consortium for Africa – ICA, 2010). However, despite significant domestic investments in infrastructure, a substantial infrastructure deficit persists, placing the region significantly behind other global counterparts in terms of infrastructural development. The stringent budget constraints and competing spending priorities that most of these countries have faced in recent decades have made it very difficult for them to allocate the necessary resources to finance the infrastructure required to improve their standard of living (Africa Development Bank, 2018).

This shows that considering the limited national government spending and domestic private investment in infrastructure, the SSA's infrastructure gap cannot be met by domestic financing alone unless other sources of financing are given proper consideration as complementary. Therefore, there is a need to consider alternative sources as a complement to domestic financing (Noah, 2023; Noah et al., 2023). Increasing attention is turning to the potential role of external financing in infrastructural development in SSA. However, despite a substantial influx of external financing to the region over the past two decades, SSA continues to face a significant infrastructure deficit. For instance, foreign direct investment (FDI) inflows

to SSA were $9.6 billion in 2002, and by 2019 they had risen to $32.9 billion, but declined in 2020 due to the COVID-19 pandemic, falling to $28.5 billion. Official development assistance (ODA) also increased from $27.6 billion in 2000 to $48.8 billion in 2010, before falling slightly to $47.8 billion in 2019 (World Bank 2021; OECD, 2021).

This implies that to close the infrastructure deficit in the SSA, new funding sources, or external sources, must be explored and given thorough consideration. In addition to domestic funding, foreign direct investment, private infrastructure investment, and official development assistance have been the main external sources of financing infrastructure that have sparked growth recently, particularly since 2005 (The Infrastructure Consortium for Africa – ICA, 2010). It is generally acknowledged that increasing external financing for infrastructure in developing countries offers a number of benefits in addition to helping to close the infrastructure deficit (Nam et al., 2023; Noah et al., 2023). The primary inquiry lies in examining the extent to which the increased flows of external financing result in enhanced infrastructure and overall economic development in SSA. The specific focus centers on determining the relationship between external financing and infrastructure development within SSA and understanding the direction of causality between these two variables.

The current study contributes to the existing body of research by addressing these specific questions. It investigates the presence of short- and long-run equilibrium as well as the causal direction between major external financing factors (FDI, PPI, and ODA) and infrastructure development in SSA. In particular, by addressing the gaps in the existing literature, the current study makes significant contributions to empirical research. To determine if the recent infusion of external financing has truly improved the region's infrastructure, the current study first looks at the infrastructure effects of external financing components (FDI, PPI, and ODA) based on the SSA context. Secondly, the present study uses techniques (PVECM) that have not been adopted in previous studies on the subject matter that are capable of handling endogeneity issues, supporting complex data structures, and increasing the accuracy of dynamic panel data models by yielding more accurate parameter estimates. Hence, this study has provided more efficient and unbiased findings compared to earlier studies in the contemporary literature. Specifically, these findings have offered policymakers solid and precise recommendations, since all previous studies that have addressed this problem have overlooked the aforementioned issue.

In addition, the study further tests for the existence of a causal relationship using a dynamic panel estimation approach. This is conducted to capture the direction of causality between external financing and infrastructure development in SSA, this study adopts the

pairwise Dumitrescu-Hurlin (2012) panel causality approach. The justification for this is that it is a dynamic panel estimation approach and it is more robust and efficient in terms of estimation because it addresses the presence of heterogeneity in the causal relationship (Dumitrescu-Hurlin, 2012). The reciprocal advantages that external financial sources and infrastructure development provide support the causal link between the two. Large-scale infrastructure projects can be financed by the public and private sectors since external financing factors serve as crucial sources of capital. Because improved infrastructure lowers operating costs and improves market accessibility, increasing the economies' attractiveness to foreign investors. This constructive feedback loop promotes economic growth and development by fostering an atmosphere that is conducive to investment. Studies have indicated that enhancements to the infrastructure have a direct impact on the inflow of external capital (Donaubauer et al., 2016; Lu, Wilson, 2024; Owusu-Manu et al., 2017; Zhao et al., 2024), since improved facilities lower risks and boost returns for foreign investors. As a result, infrastructure development as well as external funding are intimately related, with each promoting the expansion and long-term viability of the other. Therefore, external financing and infrastructure development are closely linked, with each driving the growth and sustainability of the other. To the best of our knowledge, none of the existing studies have examined the causal relationship among the variables.

Furthermore, this study investigates the presence of short- and long-run equilibrium to clarify the differential effects of external financing factors on infrastructure development in SSA in the long- and short-term. Theoretically, this study employs the simple accelerator theory of investment as the theoretical basis for the estimations of the infrastructure development model, since very few of the prior research on the topic was founded on a generally accepted theoretical approach (except Noah, 2021; Noah, David, 2024). Moreover, this research assesses the influence of external financing factors on infrastructure development in SSA by using a better measurement of infrastructure (composite index of infrastructure indicators). This includes the six basic infrastructure indicators (energy, transport, telecommunication, education, health, and water) that are essential to the development of the SSA economy. This not only incorporated the physical infrastructure but also included the social infrastructure which has largely been neglected by most of the studies on infrastructure development in SSA.

The rest of the study is organized into four sections. Section 1 provides a comprehensive literature review on external financing and infrastructure. Section 2 outlines the methodology employed to assess the relationship between external financing and infrastructure development. Section 3 presents the data and empirical results obtained using the panel vector

error correction model (VECM) technique. Finally, Section concludes the study with policy recommendations based on the findings.

1. Review of related literature

The bulk of the empirical literature on infrastructure is focused more on measuring the growth and development gains from infrastructure (Owusu-Manu, Jehuri, Edwards, Boateng, Asumadu, 2019; Syadullah, Setyawan, 2021; Noah, 2021; Onwuemeka, Du, Zhang, Han, 2022). Although there are some studies on various means of infrastructure financing (Gasmi, Lika, Noumba, 2010; Hovel, 2016), and determinants of infrastructure, most especially physical infrastructure (Akanbi, 2013; Gillanders, 2014), the literature on external financing as a whole and infrastructure development is thinner, especially in SSA.

Even though some empirical studies have established a strong relationship between foreign direct investment (FDI) and infrastructure (Ur-Rehman, Khan, Khan, Pervaiz, Liaqat, 2019; Samir, Mefteh, 2020; Sarania, 2021), much has not been done in the case of private participation in infrastructure (PPI), and official development assistance (ODA). For instance, while Acheampong and Osei (2014); Pradhana, Normanb, Badirc, and Samadhan (2016); and Nguea (2021) found a causal relationship between FDI and specific indicator(s) of infrastructure in the long-run, others like Ur-Rehman, Khan, Khan, Pervaiz and Liaqat (2019); Ogunjimi and Amune (2019) found no relationship in the short-run. In addition, Pradhana, Normanb, Badirc, and Samadhan (2016); and Ur-Rehman, Khan, Khan, Pervaiz, and Liaqat (2019) found bidirectional causality between infrastructure and FDI, while Ibrahim, Appiah, and Zamore (2018) reported that there is a positive relationship between net inflow of FDI and electricity consumption but the reverse is not the case.

Recent studies on the relationship between ODA and infrastructure include the studies conducted by Choi, Jin, Chang, Jang, and Chon (2018); Quitzow, Thielges, Goldthau, Helgenberger, and Mbungu (2019); Cha, Park, and Seo (2020). Additionally, Botting Porbeni, Joffres, Johnston, Black, and Mills (2010); Gopalan and Rajan (2016); and Steckel, Rao, and Jakob (2017) using different methodologies to conduct empirical analyses on the effectiveness of aid disbursements in improving access to water supply and sanitation facilities. They concluded that there was a robust and significant positive impact of aid disbursements on access to water supply and sanitation facilities. In their studies, Sahoo and Bishnoi (2016); Lee and Jeon (2018); and Danga, Nguyena, Trinha, Banha, and Nguyen (2021) investigate the dynamic relationship between ODA and infrastructure development among Asian countries, using both

descriptive statistics and vector error correction mechanisms. Their findings revealed a causal connection between the amount of ODA provided by donors to the receivers for infrastructure development projects in those nations.

Specifically, some of the most recent related literature regarding the subject matter includes Tei and Ferrari (2018) which examined the transportation-related projects that are part of the World Bank database on private infrastructure investment from 1980 to 2015. They identified the key institutional, social, and economic trends that could affect the amount of money invested in transportation infrastructure in the Caribbean and Latin America. Their panel regression analyses' results demonstrated a strong correlation between government initiatives and the corresponding result regarding transportation spending. In addition, the causal, linear, and nonlinear relationships between sectoral-level FDI inflows and Pakistan's infrastructure (transport, telecommunication, finance, and energy sectors) are examined by Ur-Rehmana et al. (2020). Autoregressive distributed lag (ARDL) was used in the investigation. Granger causality and the ARDL approach to cointegration imply that infrastructure and FDI have long-term, bidirectional causal relationships, while the nonlinear ARDL confirms the asymmetries in this relationship. The findings imply that both immediately and over time, sector-specific FDI inflows are critical to improving infrastructure across a range of industries.

The primary issue with using Waqf for infrastructure development in Indonesia is examined by Fawwaz et al. (2021) from the perspectives of regulations, management, programs, and literacy. The Analytical Hierarchy Process (AHP) is the data analysis method employed. Five experts presented their views on the issues and potential solutions for developing Indonesia's infrastructure utilizing productive Waqf. According to experts' opinions, the study's findings showed that a major obstacle to Indonesia's effective Waqf use for infrastructure is the absence of professional waqf (Nazhir) management for the administration of waqf assets. It was anticipated that as Nazhir's proficiency in managing the productive Waqf grew, so did the waqf assets, which could be utilized to advance and enhance Indonesia's infrastructure. Smaoui et al. (2021) also looked at how Sukuk has affected the growth of infrastructure in a sample of 15 developing countries between 1997 and 2018. The importance of Sukuk in infrastructure development was also compared in the study to the growth of the banking system, the development of the bond market, and the development of the stock market. The generalized least squares (GLS) method with random effects and robust standard errors was used to estimate the panel model. Their findings indicated that while a larger banking system and a better-capitalized stock market have no discernible impact on infrastructure development, a well-developed Sukuk market does contribute to the nation's infrastructure growth.

Furthermore, Waqar et al. (2021) looked into the possible effects of historically high levels of Chinese FDI on the growth of infrastructure in 28 particular African nations between 2003 and 2015. A panel data technique was used for the empirical analysis. The fixed effects technique was used to conduct the empirical estimations. The study's conclusions show that Chinese investment has a favorable effect on the growth of the sample countries' infrastructure. Phalatse (2022) assessed the influence of private financing on South Africa's infrastructure development between 2010 and 2020 through descriptive analysis. The study concludes that de-risking to gain support from the private sector eclipses the state's critical role in spearheading the structural change of the economy, despite the nation's urgent need for infrastructure development. Berawi and Sari (2023) also explored the use of insurance money as an alternative funding source for infrastructure investment in Indonesia by evaluating the risks encountered by insurance companies engaging in infrastructure investment. The study's quantitative approach employed the analytical hierarchical process (AHP) technique to assess the risks insurance firms face when investing in infrastructure and to pinpoint the study's advantages and disadvantages. The findings indicated that insurance funds could be a viable substitute source of funding for infrastructure projects in Indonesia.

In SSA, Cédric et al. (2024) evaluated the role that insurance plays in the growth of infrastructure. They used panel data collected between 2003 and 2020 to select a sample of 31 Sub-Saharan African nations. The panels corrected standard error (PCSE) and Driscoll-Kraay techniques were employed. The findings demonstrated that life and non-life insurance positively explains SSA's infrastructure level. Lu and Wilson (2024) examined the state of affairs and barriers to infrastructure funding in Africa. They look at how ownership and capital structure decisions for private and public-private partnership infrastructure projects are impacted by infrastructure development in African countries, spanning 17 years, using data from 33 African countries. Descriptive and regression analyses were used, and the results indicated that infrastructure projects in African countries with stronger infrastructure development typically involve higher levels of long-term and private investment, as well as a greater proportion of debt financing, particularly commercial debt, and lower levels of equity in their capital structure. Infrastructure funding in the least developed African nations, where debt financing is scarce, depends heavily on equity investment. Using panel data from 29 Belt and Road Initiative (BRI) nations, Shinwari et al. (2024) investigated the relationship between FDI and energy consumption from 2000 to 2021. Both the static and dynamic panel techniques were utilized. The findings indicated that while China's FDI dominance has a beneficial impact on energy consumption, worldwide FDI has a positive impact on energy consumption as well.

2. Research methodology

A vast number of different strands of research focus on infrastructure, it is imperative for economic growth, costs, and the financing gap, as well as the studies on private participation (Kasper, 2015). However, since infrastructure development is a form of investment in real assets, it can be treated as an investment, and investment theory is more relevant for this study. Drawing from various investment theories, this study adopts the simple accelerator theory of investment to examine the empirical relationship between external financing and infrastructure development in sub-Saharan Africa (SSA). The accelerator theory is a straightforward model that takes into account the feedback loop from current output to investment. Mathematically, this relationship can be expressed as follows:

$$K_t = \sigma Y_t \tag{1}$$

The relationship between total capital stock (K), the level of output (Y), and the capital-output ratio (σ) at a given time (t) is given by Equation (1). In the context of this study, the focus is on infrastructure development and economic growth.

2.1. 2.1 Analytical framework

Following the empirical and theoretical justifications, to examine the relationship between external financing and infrastructure development, the model for the current study is derived from the expansion of Equation (1) by holding economic growth (output level) constant to capture the precise direction of causality that exists between infrastructure development and external financing. The model is therefore stated as follows:

$$K_{it} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 PPI_{it} + \alpha_3 ODA_{it} + U_{it} \tag{2}$$

where K is the composite index of infrastructure, a proxy for infrastructure development, and external financing is disaggregated into the three major sources which include; foreign direct investment (FDI), private participation in infrastructure (PPI), and official development assistance (ODA), U is the error term, α_0 is the intercept, and $\alpha_1 - \alpha_3$ is the slope coefficients, while i and t are country and time respectively. Given the earlier discussion on the specified models, it is anticipated that the inequality notations of the *a priori* expectations for each parameter in the model would be positive.

2.2. Analysis methods

The data analysis in this study encompasses the use of panel estimation techniques, specifically the panel vector error correction model (panel VECM). The panel VECM enables the estimation of short- and long-run effects of external financing factors on infrastructure development. To ensure the selection of appropriate estimation techniques, pre-estimation tests were conducted, which include panel unit root tests, cointegration tests, and causality tests. The panel unit root test conducted in this study include: Harris-Tzavalis (HT), ADF – Fisher, Im-Pesaran-Shin (IPS), Levin-Lin-Chu (LLC), and Breitung methods. These tests were used to assess the order of integration and determine the stationarity properties of each series in the dataset. Also, the Johansen approach was employed to assess the level of cointegrating vectors. Two probability estimators, namely the Maximum Eigenvalue test and the Trace test, were utilized to determine the cointegration rank.

To examine the direction of causality between external financing and infrastructure development in SSA, this study adopts the pairwise Dumitrescu-Hurlin (2012) panel causality approach. The justification for this is that it is a dynamic panel estimation approach and it is more robust and efficient in terms of estimation because it addresses the presence of heterogeneity in the causal relationship (Dumitrescu-Hurlin, 2012). The following equations are used:

$$\Delta K_{it} = \beta_{1p} + \sum_{m-1}^{q1} \lambda_{1im} \Delta ODA_{it-m} + \sum_{m-1}^{q2} \delta_{1im} \Delta PPI_{it-m} + \sum_{m-1}^{q3} \psi_{1im} \Delta FDI_{it-m} + \sum_{m-1}^{q4} \pi_{1im} \Delta K_{it-m} + \varepsilon_{1it} \quad (3)$$

$$\Delta ODA_{it} = \beta_{2p} + \sum_{m-1}^{q1} \lambda_{2im} \Delta K_{it-m} + \sum_{m-1}^{q2} \delta_{2im} \Delta PPI_{it-m} + \sum_{m-1}^{q3} \psi_{2im} \Delta FDI_{it-m} + \sum_{m-1}^{q4} \pi_{2im} \Delta ODA_{it-m} + \varepsilon_{2it} \quad (4)$$

$$\Delta PPI_{it} = \beta_{3p} + \sum_{m-1}^{q1} \lambda_{3im} \Delta K_{it-m} + \sum_{m-1}^{q2} \delta_{3im} \Delta ODA_{it-m} + \sum_{m-1}^{q3} \psi_{3im} \Delta FDI_{it-m} + \sum_{m-1}^{q4} \pi_{3im} \Delta PPI_{it-m} + \varepsilon_{3it} \quad (5)$$

$$\Delta FDI_{it} = \beta_{4p} + \sum_{m-1}^{q1} \lambda_{4im} \Delta K_{it-m} + \sum_{m-1}^{q2} \delta_{4im} \Delta ODA_{it-m} + \sum_{m-1}^{q3} \psi_{4im} \Delta FDI_{it-m} + \sum_{m-1}^{q4} \pi_{4im} \Delta PPI_{it-m} + \varepsilon_{4it} \quad (6)$$

where the first difference operator (Δ) is applied to the variables, and the lag lengths (q_1, q_2, q_3, and q_4) are determined based on the Akaike information criterion (AIC) and are set at Lag 2, i represents the specific country in the panel, ranging from 1 to N, while t denotes the year in the panel, ranging from 1 to T. The stochastic term (ε_{it}) is a normally distributed random variable that accounts for unobserved factors and serves as the error term in the model for each country i at time t.

The cointegration test results guided the adoption of the panel vector error correction mechanism (panel VECM) technique. The panel VECM model is a modified version of the panel VAR model specifically suited for cointegrated non-stationary series. It enables the capture of both the short-run adjustment dynamics and the long-run behavior of the endogenous variables, ensuring that the variables do not solely converge to their cointegrating equilibrium relationships, the cointegration component is also known as the error correction term (Das, Chavan, 2020). More intuitively, equations (3–6) are re-written in the following formula:

$$\begin{pmatrix} \Delta \ln K_{it} \\ \Delta \ln ODA_{it} \\ \Delta \ln PPI_{it} \\ \Delta \ln FDI_{it} \end{pmatrix} = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{pmatrix} + \sum_{m=1}^{q} \begin{pmatrix} \upsilon_{11,m} \upsilon_{12,m} \upsilon_{13,m} \upsilon_{14,m} \\ \upsilon_{21,m} \upsilon_{22,m} \upsilon_{23,m} \upsilon_{24,m} \\ \upsilon_{31,m} \upsilon_{32,m} \upsilon_{33,m} \upsilon_{34,m} \\ \upsilon_{41,m} \upsilon_{42,m} \upsilon_{43,m} \upsilon_{44,m} \end{pmatrix} \begin{pmatrix} \Delta \ln K_{it-1} \\ \Delta \ln ODA_{it-1} \\ \Delta \ln PPI_{it-1} \\ \Delta \ln FDI_{it-1} \end{pmatrix} + \begin{pmatrix} \vartheta_1 \\ \vartheta_2 \\ \vartheta_3 \\ \vartheta_4 \end{pmatrix} ECT_{it-1} + \begin{pmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \end{pmatrix} \quad (7)$$

The lagged error correction term (ECT_{it-1}) derived from the long-run relationships of the variables, and the speed of adjustment coefficients ($\vartheta_1 - \vartheta_4$) indicates how quickly the variables adjust towards their equilibrium. A larger absolute value of ϑ indicates a faster adjustment. The remaining variables retain their definitions as stated in Equations 3–6.

2.3. Data

This study utilized annual data from 43 countries in Sub-Saharan Africa, collected from various secondary sources spanning the period from 2000 to 2021. The selection of countries and the time frame was based on data availability. Although SSA nations share some regional characteristics, such as being developing economies with relatively similar infrastructural challenges, the data set and scope offer a broad scope to assess infrastructure development and external financing trends across a diverse range of economies. Despite the heterogeneity of these countries in terms of economic size, political stability, and development levels, the comparability of countries can be somewhat challenging.

In addition, the period from 2000 to 2021 is sufficiently long enough to include important patterns in the development of infrastructure and external funding, including major regional and global events like the financial crisis of 2008, the booms and busts of various commodities, and political shifts that have affected economic policy. However, this timeframe also provides complexity, as countries in SSA have had diverse trajectories due to factors such as governance changes, variations in global aid programs, and fluctuations in FDI flows. The techniques adopted in this study are capable of handling these related challenges to arrive at valid conclusions.

The data used for infrastructure development is generated through a composite index of infrastructure indicators (energy, transport, telecommunication, education, health, and water). Given the potential correlation among these infrastructure indicators, the principal component analysis (PCA) was employed to construct a comprehensive infrastructure index. Taking the residuals from the regression of a certain composite infrastructure index is the first stage in creating a composite infrastructure index (David, 2019; Noah, 2021; Noah, David, 2024). PCA is used to merge the residual series that are obtained from each regression. The first set of eigenvectors from the PCA are utilized as the required weights to build an aggregated index for infrastructure development. The resulting linear combination is as follows:

$$K = \vartheta_1 egy + \vartheta_2 tlm + \vartheta_3 tsp + \vartheta_4 heh + \vartheta_5 edu + \vartheta_6 wae \tag{8}$$

where ϑ_1, ϑ_2, ϑ_3, ϑ_4, ϑ_5, and ϑ_6 are the eigenvectors (weights) from the PCA, and *egy*, *tlm*, *tsp*, *heh*, *edu*, and *wae* are energy, telecommunications, transport, health, education, and water indicators respectively. Data on infrastructure indicators and external financing factors were sourced from reputable international organizations. The World Bank's World Development Indicators provided the data on external financing factors (FDI, PPI, and ODA), energy, transport, and water infrastructure; the World Health Organization (WHO) provided data on health, the United Nations Educational, Scientific and Cultural Organization (UNESCO) provided data on education, and the International Telecommunication Union (ITU) provided the data on telecommunication infrastructure indicators (subscriptions to fixed-telephone, mobile telephony, and the internet access). The summary of the selected data and their sources are further presented in Table 1.

Table 1. The Descriptive Statistics

Variables	Mean	Median	Maximum	Minimum	Standard Deviation	Source
K	266	166	2155	–4.761	311	Authors' computation
PPI	0.019	0.005	1.256	0.001	0.057	World Bank's WDI
FDI	4.608	2.594	103.000	–6.057	8.481	World Bank's WDI
ODA	8.738	6.517	92.141	–0.251	8.864	World Bank's WDI

Note: K represents composite index of aggregate infrastructure, PPI is private participation in infrastructure, FDI is foreign direct investment, and ODA is official development assistance.

Source: own elaboration.

3. Results and discussion

The unit root tests for the panel series are presented in Table 2. The results indicate that most of the series are non-stationary at the level, as the null hypothesis of a unit root could not be rejected. This suggests that unit roots are present at levels in nearly all panel series. The panel series' stationarity is revealed when estimations are performed at first difference. The presence of a long-term relationship among the non-stationary variables used in the model is crucial to avoid spurious regression findings when estimating the parameters using the ordinary least squares (OLS) approach.

Table 2. Panel unit roots test results

Series	Stationary	HT	ADF – Fisher	LLC	Breitung	IPS	Remarks
K	Level	1.051 (1.000)	5.224 (1.000)	5.038 (1.000)	18.551 (1.000)	21.960 (1.000)	
	First difference	0.030*** (0.000)	268.169*** (0.000)	–5.985*** (0.000)	–4.557*** (0.000)	–6.426*** (0.000)	I(1)
ODA	Level	0.419*** (0.000)	164.625*** (0.000)	–1.487* (0.069)	–1.234 (0.109)	–2.397*** (0.008)	
	First difference	–0.176*** (0.000)	888.259*** (0.000)	–11.884*** (0.000)	–14.347*** (0.000)	–13.801*** (0.000)	I(1)
FDI	Level	0.488*** (0.000)	32.448 (1.000)	–2.247** (0.012)	–2.496*** (0.006)	–1.253 (0.105)	
	First difference	–0.153*** (0.000)	587.069*** (0.000)	–9.968*** (0.000)	–15.008*** (0.000)	–12.467*** (0.000)	I(1)
PPI	Level	0.631*** (0.000)	237.499*** (0.000)	6.889 (1.000)	6.784 (1.000)	9.218 (1.000)	
	First difference	–0.248*** (0.000)	677.204*** (0.000)	–5.698*** (0.000)	–3.889*** (0.000)	–9.282*** (0.000)	I(1)

Notes: ***, **, and * are 1%, 5%, and 10% significance levels respectively, Harris-Tzavalis (HT), ADF – Fisher, Im-Pesaran-Shin (IPS), Levin-Lin-Chu (LLC) and Breitung (Null: Panels contain unit roots). Also, K represents infrastructure development, ODA represents official development assistance, FDI represents foreign direct investment and PPI is private participation in infrastructure. Values in the parentheses ( ) are the p-values of the test statistic.

Source: own elaboration.

In selecting the appropriate lag, the study chose the lowest criterion/value as the primary issue in defining the proper lag order selection criteria (Kaleem, Wajid, Hussain, 2009). Lag 2 was chosen as the optimal lag length for the study based on the AIC statistics as well as the majority of the criteria that support this, which are shown in Table 3.

Table 3. Lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	–999.285	NA	0.003	5.380	5.423	5.396
1	521.743	3,001.277	7.970	–2.690	–2.480*	–2.607
2	561.523	77.637	7.020*	–2.818*	–2.439	–2.668*
3	574.076	24.233	7.150	–2.799	–2.253	–2.582
4	584.971	20.797	7.350	–2.771	–2.057	–2.488

Notes: LR = sequential modified LR test statistic (each test at 5% level), FPE = final prediction error, AIC = Akaike information criterion, SC = Schwarz information criterion, HQ = Hannan–Quinn information criterion.
* Indicates lag order selected by the criterion.

Source: own elaboration.

The empirical findings from Table 4 showed that there are at least four cointegrating vectors for infrastructure development, FDI, ODA, and PPI, as indicated by the Trace statistic and Eigenvalue. This indicates that the combined panel series of external financing factors and infrastructure development have long-term relationships in SSA.

Table 4. Panel Johanson Cointegration Test Results

Hypothesized No. of CE(s)	Trace Test				Maximum Eigenvalue Test		
	eigenvalue	trace statistic	0.05 critical value	p-value	max-eigen statistic	0.05 critical value	p-value
None*	0.13	187.8	47.9	0.00	82.0	27.6	0.00
At most 1*	0.09	105.8	29.8	0.00	54.5	21.1	0.00
At most 2*	0.05	51.4	15.5	0.00	28.0	14.3	0.00
At most 3*	0.04	23.3	3.8	0.00	23.3	3.8	0.00

* Indicates rejection of the null hypothesis at the 0.05 significance level. Both Trace and Max-eigenvalue tests indicate four cointegration equations at a 5% level.

Source: own elaboration.

Since the cointegration test found a long-run relationship among the panel series, the magnitude of the relationship could not be determined, as a result, the Dumitrescu-Hurlin is used to conduct bivariate panel causality tests. The results from Table 5 indicate that all the panel series in the study reject the null hypotheses at a 5 percent significance level. This suggests the presence of a significant bi-directional relationship between infrastructure development and external financing factors (FDI, ODA, and PPI) in SSA. This is in support of the previous empirical studies reported by Pradhana, Normanb, Badirc, and Samadhan (2016); and Ur-Rehman, Khan, Khan, Pervaiz, and Liaqat (2019).

Table 5. Panel causality test results

Model/Null hypothesis	w-statistics	zbar-statistics	p-value	The direction of the observed relationship
ODA does not homogeneously cause K	3.462	2.226	0.026**	ODA ⇔ K
K does not homogeneously cause ODA	3.918	3.183	0.002***	
FDI does not homogeneously cause K	4.712	4.848	0.000***	FDI ⇔ K
K does not homogeneously cause FDI	4.688	4.797	0.000***	
PPI does not homogeneously cause K	4.238	3.855	0.000***	PPI ⇔ K
K does not homogeneously cause PPI	5.364	6.217	0.000***	

Notes: ***, **, and * are 1%, 5%, and 10% significance level respectively. K represents infrastructure development, ODA represents official development assistance, FDI represents foreign direct investment and PPI is private participation in infrastructure.

Source: own elaboration.

Given the established long-run relationship between infrastructure development and external financing, the short-run dynamics and the speed of adjustment toward equilibrium is examined using the panel vector error correction mechanism (panel VECM) estimation. The panel VECM estimation results can be seen in Table 6.

Table 6. Panel VECM Results

Variable	Coefficient	Standard Error	t-statistic
Long-run Scenario			
LNODA	0.353***	0.091	3.887
LNFDI	0.159*	0.080	1.993
LNPPI	0.208***	0.060	3.460
Short-run Scenario			
ECT_{t-1}	–0.023***	0.003	–6.545
ΔLNODA	–0.003	0.007	–0.415
ΔLNFDI	0.003	0.003	0.755
ΔLNPPI	0.012***	0.003	3.943
C	0.023***	0.002	10.802
R-squared: 0.626			
F-statistic: 24.349 (0.000)			
Durbin-Watson statistic: 2.171			
Wald test: 22.951 (0.001)			

Notes: ***, **, and * are 1%, 5%, and 10% significance level respectively. Where LNODA is a log of official development assistance, LNFDI is a log of foreign direct investment and LNPPI is a log of private participation in infrastructure.

Source: own elaboration.

The findings of the panel VECM estimation results in Table 6 demonstrate that, in the long run, external financing factors (ODA, FDI, and PPI) all have a positive impact on infrastructure development. This finding is consistent with previous empirical studies conducted by Waqar et al. (2021), Nguea (2021) and Shinwari et al. (2024). Comparatively, while ODA and PPI are statistically significant at the 1 percent significance level, FDI is statistically significant at the 10 percent significance level in influencing infrastructure development. Based on the panel VECM estimation results in the short run, the adjustment term is found to be statistically significant at the 1 percent level and negative. This suggests that there is an adjustment process whereby the deviation from the long-run equilibrium in the previous year is corrected by approximately 2.3 percent annually in the current period.

Unlike official development assistance (ODA) and foreign direct investment (FDI), which are statistically insignificant in the short run, private participation in infrastructure (PPI) is found to be positive and statistically significant at the 1% level. This implies that PPI has a significant positive impact on infrastructure development in SSA in the short run, while the influence of FDI and ODA on infrastructure development is not significant. The implication of this is that a percentage increase in PPI will, on average, ceteris paribus, result in an increase of around 1.2 percent in infrastructure development in SSA in the short run. The short-run insignificant effects of ODA and FDI on infrastructure are consistent with previous empirical findings (Ur-Rehman, Khan, Khan, Pervaiz, Liaqat, 2019; Cha et al., 2020; Danga et al., 2021).

Furthermore, the results from other diagnostic tests such as DW statistics of serial correlation show no serial correlation in the model, and the overall significance of external financing to infrastructure development is tested through the F-statistic, which shows that external financing factors (ODA, FDI, and PPI) are jointly significant to infrastructure development in SSA. Further examination of short-run causality using Wald tests indicates a unidirectional causality between external financing factors and infrastructure development. The causality runs from external financing factors to infrastructure development without any feedback, with a probability value of less than 0.05%, indicating statistical significance.

The extent of causality is further supported by conducting variance decomposition and an impulse response analysis of the unrestricted VAR estimation process using the orthogonalized Cholesky ordering technique. Figure 1 depicts the impulse response functions of infrastructure development and external financing sources, while Table 7 displays the variance decomposition (ODA, FDI, and PPI).

Table 7. Variance decomposition analysis results

Period	Variance decomposition of K variables				
	SE	K	ODA	FDI	PPI
1	0.033	100.000	0.000	0.000	0.000
2	0.055	99.517	0.130	0.008	0.345
3	0.074	98.749	0.648	0.010	0.592
4	0.091	98.339	1.145	0.011	0.505
5	0.105	97.971	1.597	0.036	0.395
6	0.117	97.522	2.067	0.094	0.318
7	0.128	96.957	2.558	0.186	0.298
8	0.137	96.283	3.058	0.313	0.346
9	0.146	95.507	3.562	0.470	0.461
10	0.154	94.640	4.068	0.655	0.637
11	0.162	93.698	4.573	0.861	0.869
12	0.169	92.697	5.072	1.084	1.147
13	0.176	91.652	5.563	1.321	1.464
14	0.182	90.577	6.043	1.568	1.812
15	0.189	89.486	6.511	1.821	2.183

Notes: Orthogonalised Cholesky ordering was used. SE indicates a standard error, K indicates the composite infrastructure index, ODA indicates official development assistance, FDI is foreign direct investment and PPI is private participation in infrastructure.

Source: own elaboration.

The variance decomposition analysis presented in Table 7 provides insights into the breakdown of the variations in infrastructure development and external finance factors over 15 periods, with period 5 representing the short run and period 15 representing the long run. The results indicate that shocks to infrastructure development in SSA have a significant impact on its fluctuations, accounting for 97.971 percent in the short run and 89.486 percent in the long run. When considering the impact of external financing factors, shocks to ODA, FDI, and PPI contribute to 1.597 percent, 0.036 percent, and 0.395 percent of the short-run variations in infrastructure development, respectively. In the long run, shocks to ODA, FDI, and PPI account for 6.511 percent, 1.821 percent, and 2.183 percent of the variations in infrastructure development. The impulse response analysis further builds upon these shocks, fluctuations, and variations in the panel series, providing a deeper understanding of the dynamic interactions between infrastructure development and external financing factors.

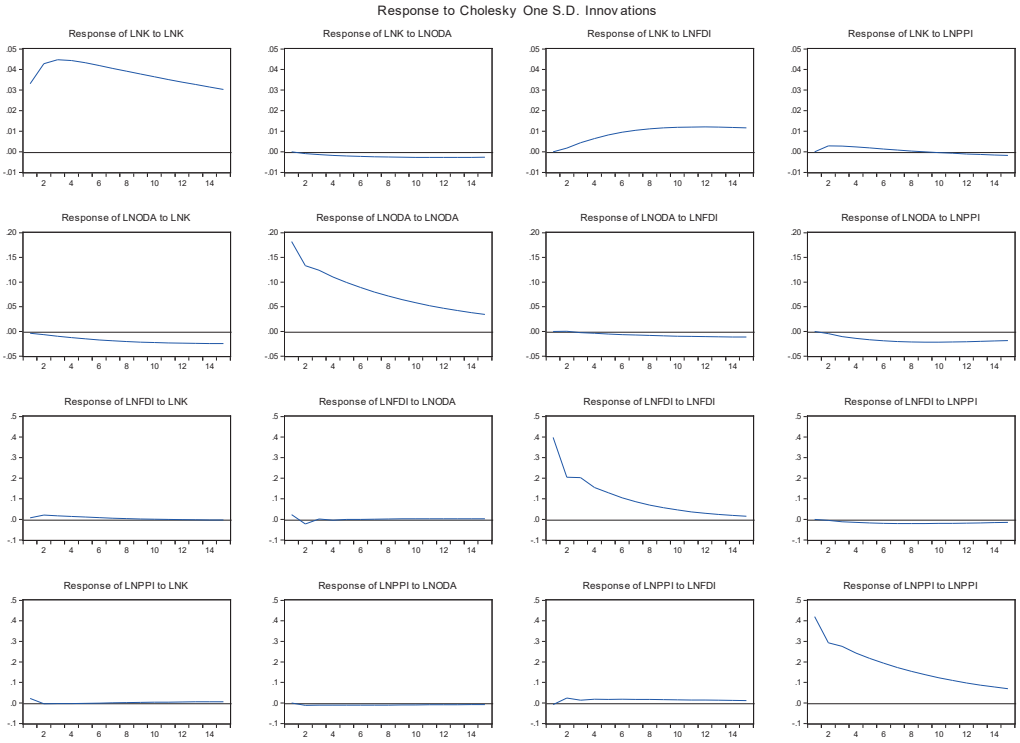

Figure 2. Impulse response functions

Source: own elaboration.

The impulse response analysis is a valuable tool for understanding how the VAR system reacts to shocks and innovations. It measures the response of endogenous variables in the VAR system to unit shocks applied to each series, providing insights into the dynamic behavior of the system. Figure 1 displays the reactions of the VAR system to standard deviation shocks and innovations in SSA from 2000 to 2021. The results show that infrastructure development responds positively to its standard shock in both the short run and long run, indicating a sustained positive impact throughout the 15 periods. However, the positive response gradually declines from period 3 to period 15. When it comes to shocks in ODA, infrastructure development initially responds neutrally or insensitively in the short run from period 1 to period 3. However, in the long run, it exhibits a permanent negative reaction to ODA shocks from period 3 to period 15. For shocks in FDI, infrastructure development shows a positive and permanent response in both the short run and long run, indicating a sustained positive impact over time. Regarding shocks in PPI, infrastructure development initially exhibits a positive response in

the short run from period 1 to period 4, followed by a decline. However, from period 5 to 12, it shows a positive response again, but this response gradually declines and becomes neutral or insensitive from period 13 to 15 in the long run.

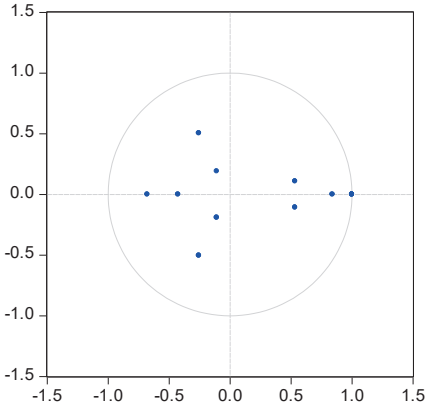

Figure 2. Inverse roots od AR characteristic polynominal

Source: own elaboration.

Figure 2 presents the inverse roots of the panel vector error correction mechanism (VECM) and is used to assess the stability and reliability of both the panel VECM and the impulse response functions (IRFs). Stability is indicated when the polynomial roots fall within the circle. Therefore, based on the inverse of the AR characteristics polynomial, the panel VECM is considered stable, and the IRFs derived from it are deemed reliable.

Conclusion and policy recommendations

This study presents an empirical analysis of the relationship between infrastructure development and external financing in Sub-Saharan Africa (SSA) using data from 2000 to 2021. In terms of impulse response functions (IRFs), variance decomposition analysis (VDCs), and causality. The outcomes of the vector error correction mechanism (VECM) showed some intriguing results. According to the IRFs, infrastructure development first responded negatively to official development assistance (ODA) but later became indifferent or neutral over time. The results of the analysis indicate that foreign direct investment (FDI) has a positive influence on infrastructure development both in the long run and the short run. Similarly, in the short run, private participation in infrastructure (PPI) has a positive effect on infrastructure

development. The evidence of the positive effects of these external financing factors is supported by the previous studies such as Waqar et al. (2021), Nguea (2021) and Shinwari et al. (2024). However, over time, the impact of PPI becomes neutral and negative, suggesting that its influence on infrastructure development diminishes. The VDCs also demonstrated that ODA, followed by PPI and FDI respectively, contributes more to the difference in infrastructure development.

The panel VECM Granger causality test revealed that external financing Granger causes infrastructure development. Specifically, while ODA and FDI have a causal relationship with infrastructure development in the long run, PPI shows a causal relationship with infrastructure development in both the long run and short run. This implies that PPI mainly Granger causes infrastructure development in SSA. This, therefore implies that PPI provides much more explanation for changes in infrastructure development in SSA than ODA and FDI. In addition, the findings of this study support the Two-Gap theory and studies like Ur-Rehman et al. (2019), which emphasizes the significance of external financing for developing countries.

Based on the findings presented above, the study, therefore, suggests that policymakers should give priority to creating favorable investment environments to attract and retain FDI, which is essential for promoting infrastructure growth. This can be accomplished by taking steps like improving property rights safeguards, streamlining regulatory procedures, and offering tax incentives. Even though PPI has clear short-term benefits, regulatory frameworks that encourage private sector investment are still required. However, as PPI projects may find it difficult to sustain long-term momentum, thorough planning is crucial. Therefore, SSA governments should constantly monitor and analyze PPI agreements to ensure their sustainability and effectiveness over time. ODA's short-term neutral or negative effects underscore the need for reforms in ODA implementation and allocation, as well as a reevaluation of the aid's capacity to spur urgent infrastructure development. SSA countries should also diversify their funding strategies by looking into alternate forms of infrastructure financing, such as public-private partnerships, green bonds, and blended finance models, which combine public funds, private investment, and development aid, in order to lessen their reliance on a single external source of funding.

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