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Public Debt and Transportation Infrastructure Development in Sub-Saharan Africa: Dynamic Panel Evidence

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Abstract: *Public borrowing can facilitate transport infrastructure development, although debt-service obligations and implementation inefficiencies may constrain its effectiveness. This study examines the relationship between public debt and transport infrastructure development across 24 Sub-Saharan African countries during 2011–2023. The balanced panel comprises 312 country-year observations, with 288 observations retained in the dynamic specifications. Using the African Development Bank's transport infrastructure index, the analysis incorporates public debt, GDP growth, population growth and CPIA corruption control. Estimation combines heterogeneous autoregressive distributed lag (ARDL) models using Mean Group (MG) estimation and a constrained Pooled Mean Group (PMG)-style nonlinear least-squares approach, supplemented by pooled error-correction models with Driscoll–Kraay standard errors. The PMG-style debt coefficient is positive but statistically insignificant ($\beta = 0.0495$, $p = 0.095$), declining to 0.0361 ($p = 0.252$) after controlling for common year effects. The unrestricted MG estimate is negative and insignificant ($\beta = -0.0712$, $p = 0.603$). Pooled error-correction estimates indicate a positive long-run debt association without year effects ($\beta = 0.0490$, $p = 0.031$), which becomes statistically insignificant when year effects are included ($\beta = 0.0431$, $p = 0.086$). Short-run debt coefficients are insignificant across both pooled specifications. These findings indicate that the debt–transport relationship is sensitive to estimator restrictions and common temporal influences, providing insufficient evidence of a robust positive long-run association. Limitations arising from the short time dimension, numerical parameter constraints and unconfirmed dependence-robust cointegration preclude causal and definitive long-run interpretations. The results underscore the importance of productive debt allocation, rigorous project appraisal and sustainable infrastructure financing over aggregate borrowing expansion.*

Keywords: *Public debt; Transport infrastructure; Institutional governance; Panel ARDL; Pooled Mean Group; Sub-Saharan Africa.*

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1.0 Introduction

Transportation infrastructure is central to market access, economic mobility and regional trade integration in Sub-Saharan Africa (SSA). Roads, railways, ports and aviation networks shape the cost and reliability of moving goods and people. Infrastructure deficiencies are

associated with higher transport costs and reduced trade (Limão & Venables, 2001), while improved regional road connections can expand trade opportunities (Akpan, 2014). Evidence from rural SSA also links road-induced changes in market accessibility with local economic activity (Berg *et al*., 2018). The importance of transport provision, however, does not establish how governments should finance it.

Transport assets often entail high initial costs, long gestation periods and recurrent maintenance liabilities. Public borrowing can distribute financing across time and potentially accelerate infrastructure provision when domestic revenue is insufficient. Conversely, accumulating debt can increase interest burdens, refinancing exposure and fiscal pressure on operations and maintenance. Krugman's (1988) debt-overhang argument and Clements *et al*.'s (2003) analysis of debt, public investment and growth highlight why public borrowing need not translate into productive capital formation.

Empirical findings in Africa are mixed. Ezeaku *et al*. (2023) report favourable associations of concessional debt with public investment, whereas Fonchamnyo *et al*. (2021) report crowding-out effects of external debt on domestic investment. Frimpong *et al*. (2024) provide evidence of asymmetric public debt–infrastructure investment relationships in Ghana. Because those outcomes measure investment flows or broad capital formation, their estimated effects cannot be transferred directly to a transport index. Research focusing on roads and trade typically considers transportation as a determinant of development, rather than as the outcome of public finance (Chuku *et al*., 2023; Tandrayen-Ragoobur *et al*., 2023).

Institutional performance may affect infrastructure provision through project screening, procurement integrity, contract management and maintenance. In the current data, governance is represented by the Country Policy and Institutional Assessment (CPIA) corruption-control indicator. This is a narrow governance proxy, not a multidimensional Institutional Quality Composite Index. The indicator enters as a standalone covariate, and the paper does not estimate an interaction with debt or claim to identify an institutional mediation pathway.

The paper contributes a transport-specific dynamic panel examination using a balanced dala of 24 SSA countries during 2011–2023. It tests whether the apparent long-run debt association survives country-specific dynamics and inference that is less sensitive to common shocks. The design identifies conditional relationships, not causal effects. Its primary finding is that statistical significance depends on the estimator and treatment of year effects, which should constrain both interpretation and policy prescriptions.

2. 0 Theoretical Framework

2.1. Productive infrastructure financing

Infrastructure-led development arguments posit that transport networks reduce transaction costs, expand accessible markets and complement private capital. Public debt may facilitate these gains when financing is allocated to viable projects and the economic lifetime of assets exceeds their financing horizon. The aggregate debt-to-GDP ratio nevertheless captures outstanding obligations rather than the share of borrowing disbursed to transport. Thus, a positive debt coefficient is consistent with, but does not demonstrate, debt-financed transport development.

2.2. Debt overhang and fiscal displacement

The competing debt-overhang mechanism implies that rising debt obligations may restrict capital expenditure and maintenance, particularly where borrowing terms are costly or refinancing risks are high (Krugman, 1988). The net association between debt and transport infrastructure is therefore theoretically ambiguous, reflecting the balance between financing capacity and debt-service pressures.

A linear model does not identify an optimal borrowing threshold.

2.3. Governance and observable implications

Procurement quality, corruption control, expenditure execution and project governance can influence how effectively financial resources translate into physical assets. Studies of governance and infrastructure in SSA identify the importance of institutional conditions (Appiah *et al*., 2024; Ojeka *et al*., 2024). CPIA corruption control is included as a direct covariate; its coefficient cannot be interpreted as moderation of the debt effect. A negative error-correction coefficient is consistent with adjustment toward a fitted long-run relationship, but statistical evidence of cointegration must be independently established.

3. 0 Empirical Literature and Research Gap

3.1. Debt and public investment

Ezeaku *et al*. (2023) use dynamic panel estimators for 32 SSA countries and find that concessional financing can be associated with higher aggregate public investment in the long run. This result is sensitive to debt composition and does not imply that all borrowing funds transportation. Fonchamnyo *et al*. (2021), using a PMG–ARDL approach, identify an adverse long-run association of external debt with domestic investment. The opposing conclusions show why debt-financing effects cannot be presumed positive. Frimpong *et al*. (2024) find asymmetric debt–infrastructure investment responses in Ghana; this reinforces the importance of dynamic adjustment while limiting generalisation to regional transport indices.

3.2. Transport infrastructure and regional development

Limão and Venables (2001) link inadequate infrastructure to trade costs, and Akpan (2014) considers road improvements within ECOWAS. Berg *et al*. (2018) examine rural development and changes in road-based accessibility, whereas Beuran *et al*. (2015) caution against generalising infrastructure impacts without attention to local conditions. Chuku *et al*. (2023) and Tandrayen-Ragoobur *et al*. (2023) link infrastructure with African trade integration. These studies support the choice of a transport-specific outcome but do not directly estimate its debt-related determinants.

3.3. Institutional conditions and contribution

Institutional capacity may determine the effective delivery of infrastructure investments. Appiah *et al*. (2024) study governance and infrastructure, while Ojeka *et al*. (2024) consider institutional moderation of debt–investment relationships. Those interaction-based designs differ from the standalone CPIA control used here. The present study's contribution is deliberately bounded: it compares the nexus between public debt with a transport-specific index across heterogeneous dynamic specifications and explicitly evaluates the sensitivity of that association to common year effects.

4. 0 Data and Econometric Methodology

4.1. Sample and variable measurement

The sample comprises Benin, Burkina Faso, Burundi, Cabo Verde, Cameroon, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Tanzania, Togo, Uganda, Zambia and Zimbabwe. The 24 countries are observed annually from 2011 to 2023, giving 312 balanced country-year records. A one-period lag leaves 288 dynamic observations. The transportation, debt and macroeconomic data are matched to CPIA corruption control by country and year. There are no missing values or duplicate country-year combinations in the selected analytical panel. CPIA takes seven discrete values (1.5–4.5), with limited within-country variation.

4.1. Variable Description, Measurement and Data Sources

The analysis uses a balanced annual panel of 24 Sub-Saharan African countries for 2011–2023 (312 country-year observations; 288 observations after introducing a one-year lag). Transportation infrastructure is the dependent variable, and public debt is the principal explanatory variable. GDP growth, population growth and corruption control enter as controls. An alternative economic activity measure is considered in sensitivity analysis.

The variables employed in the empirical analysis, their corresponding symbols, operational definitions and measurement procedures, and the respective data sources are presented in Table 1. The table also distinguishes between the baseline economic activity measure (GDP growth) and the alternative GDP per capita (GDPPC) indicator used in the sensitivity analysis.

Table 1. Variable definitions, measurement and data sources

Variable	Symbol	Operational measurement	Data source
Transportation infrastructure	TI	Transportation component of the Africa Infrastructure Development Index (AIDI).	African Development Bank (AfDB) infrastructure dataset
Public debt	PD	Outstanding public debt as a percentage of GDP.	World Bank, World Development Indicators (WDI)
Economic growth	GDPgrowth	Annual GDP growth rate (%); used as a baseline control for economic activity.	World Bank, WDI
GDP per capita indicator	GDPPC	GDP per capita (GDPPC) field in the source dataset; used as an alternative measure of economic activity.	World Bank, WDI
Population growth	POPG	Annual population growth rate (%).	World Bank, WDI
Corruption control	CPIA	Country Policy and Institutional Assessment (CPIA) score for transparency, accountability and corruption control.	

Source: Authors' compilation from AfDB, WDI and CPIA datasets.
Note. GDP growth and GDPPC are used in separate specifications. GDPPC is retained as labelled in the source dataset and is not treated as log real GDP. CPIA is a standalone institutional indicator, not a composite institutional quality index.

4.2. Dynamic panel model specification

Following Pesaran *et al*. (1999), the study motivates a heterogeneous panel ARDL model for transportation infrastructure. With $X_{it} = (PD_{it}, GDPgrowth_{it}, POPG_{it}, CPIA_{it})'$, the general country-specific ARDL is:

$$TI_{it} = \alpha_i + \Sigma_{j=1}^{p} \varphi_{ij} TI_{i,t-j} + \Sigma_{k=1}^{4} \Sigma_{j=0}^{q} \beta_{kij} X_{ki,t-j} + \varepsilon_{it}. \quad (1)$$

Its error-correction representation can be written as:

$$\Delta TI_{it} = \lambda_i[TI_{i,t-1} - \theta'_i X_{i,t-1}] + \Sigma_{j=1}^{p-1} \psi_{ij} \Delta TI_{i,t-j} + \Sigma_{k=1}^{4} \Sigma_{j=0}^{q-1} \gamma_{kij} \Delta X_{ki,t-j} + \mu_i + \varepsilon_{it}. \quad (2)$$

Here λ_i is the adjustment coefficient and θ_i is the country-specific vector of long-run slopes. The Mean Group estimator estimates each country equation and averages the implied

long-run parameters. Pooled Mean Group restricts $\theta_i = \theta$ across countries but allows short-run dynamics, intercepts and adjustmentspeeds to differ (Pesaran *et al*., 1999). Given the short time dimension, the operational model uses ARDL(1,0). The PMG-style fits were obtained by constrained nonlinear least squares rather than Stata's standard PMG maximum-likelihood implementation. Thus, convergence and conventional uncertainty from this implementation must be interpreted cautiously. A separate pooled unrestricted error-correction model is estimated with country fixed effects and either without or with year fixed effects. Denoting the coefficients on lagged levels by π, the long-run slope for covariate k is computed as $-\pi_k/\pi_TI$ and its uncertainty approximated by the delta method. Driscoll–Kraay standard errors use a two-period bandwidth. This pooled model provides a dependence-aware sensitivity exercise; it is not a substitute for PMG.

4.3. Pre-estimation diagnostics and inference

The level-series Pesaran CD checks indicate common dependence in debt, GDP growth and population growth. Exploratory Fisher combinations of country-level ADF tests and an exploratory Chow-style slope comparison were also calculated. Because the first-generation stationarity results can be distorted by common factors and T = 13 is short, they are not treated as definitive integration evidence. A dependence-robust panel cointegration test, CIPS classifications and a valid MG–PMG Hausman statistic have not been established for this sample. Accordingly, the dynamic coefficients are interpreted cautiously. To assess the extent of cross-sectional dependence among the variables before conducting the dynamic panel estimations, preliminary Pesaran cross-sectional dependence (CD) tests were performed on the selected level series. The results, presented in Table 2, show statistically significant cross-sectional dependence in public debt, GDP growth and population growth, while transportation infrastructure and CPIA do not exhibit significant cross-sectional dependence. These findings highlight the need to exercise caution in interpreting the panel estimates, particularly because common economic shocks may influence the relationships among the variables.

The exploratory slope heterogeneity comparison yields F = 1.098 (p = .296), but this is a conventional Chow-type comparison based on assumptions not warranted under common shocks. It is not the Pesaran–Yamagata test. Consequently it does not establish valid long-run slope homogeneity.

Table 2. Preliminary Pesaran CD tests on selected level series

Variable	CD statistic	p-value
TI	0.281	0.779
PD	30.648	< .001
GDPgrowth	19.215	< .001
POPG	12.840	< .001
CPIA	-1.175	0.240

5. 0 Empirical Results

5.1. ARDL(1,0) MG and PMG-style estimates

The long-run relationships between public debt, transportation infrastructure and the selected control variables were examined using the heterogeneous ARDL(1,0) framework. Table 3 presents the estimated long-run coefficients obtained from the constrained PMG-style specifications, with and without year fixed effects, alongside the unrestricted Mean Group (MG) estimates. The comparison provides insight into the sensitivity of the estimated relationships to alternative estimator restrictions and the inclusion of common year effects. Particular attention is given to the magnitude, direction and statistical significance of the public debt coefficient across the three specifications.

The PMG-style public debt coefficient is positive (0.0495) but not significant at 5% (p = .095). With year effects, the estimate declines to 0.0361 (p = .252). The MG point estimate is negative (−0.0712, p = .603). Therefore, the

debt slope is not stable in sign across the unrestricted MG and constrained PMG-style estimators, and the constrained specifications do not provide strong conventional evidence for a positive long-run association.

The mean PMG-style error-correction parameters are −0.258 and −0.295, compared with −0.772 under MG. However, eight country autoregressive estimates in the first PMG-style specification and four in the model with year effects reach imposed parameter bounds. These bound solutions prevent treating the fitted PMG-style equilibrium as fully validated and motivate robust comparison with the pooled error-correction regressions.

Table 3. Estimated long-run coefficients from heterogeneous ARDL(1,0)

Regressor	PMG-style, no year FE	PMG-style, year FE	MG
PD	0.0495 (0.095)	0.0361 (0.252)	-0.0712 (0.603)
GDPgrowth	0.4045 (0.052)	0.4318 (0.040)	-0.6082 (0.140)
POPG	25.2820 (0.001)	30.4615 (0.000)	1.1289 (0.912)
CPIA	21.3413 (0.000)	18.7569 (0.000)	-0.6283 (0.901)
Mean error-correction	-0.2576	-0.2949	-0.7724

Note. Parentheses report approximate p-values, not standard errors. PMG-style estimates use constrained nonlinear least squares and conventional uncertainty, not dependence-robust PMG maximum likelihood. MG averages country regressions; sample N = 24 and 288 dynamic observations.

5.2. Pooled error-correction robustness estimates

To further examine the robustness of the estimated relationship between public debt and transportation infrastructure, pooled error-correction models were estimated using Driscoll–Kraay standard errors. The results are presented in Table 4, covering specifications with country fixed effects alone and specifications incorporating both country and year fixed effects. The table reports the estimated error-correction coefficients, long-run relationships and short-run effects of public debt and the control variables. This comparison helps establish whether the estimated debt–transport infrastructure relationship remains statistically significant after accounting for common annual shocks and potential cross-sectional dependence.

Table 4. Pooled ECM coefficients with Driscoll–Kraay inference

Parameter	Country FE	Country and year FE
Error-correction coefficient	-0.5426 (p < .001)	-0.5384 (p < .001)
Long-run PD	0.0490 (p = 0.031)	0.0431 (p = 0.086)
Long-run GDPgrowth	-0.7077 (p = 0.056)	-0.2769 (p = 0.499)
Long-run POPG	4.7706 (p = 0.083)	4.2503 (p = 0.164)
Long-run CPIA	4.9527 (p = 0.055)	5.3924 (p = 0.068)
Short-run ΔPD	0.0066 (p = 0.877)	-0.0060 (p = 0.885)
Short-run ΔGDPgrowth	-0.1240 (p = 0.222)	0.0201 (p = 0.883)
Short-run ΔPOPG	0.4234 (p = 0.669)	0.7728 (p = 0.359)
Short-run ΔCPIA	-1.3100 (p = 0.272)	-1.6912 (p = 0.193)

Note. N = 24, observations = 288. Long-run coefficients are nonlinear ratios with delta-method standard errors. Driscoll–Kraay maximum lag = 2, with normal-approximation p-values; T = 12 limits precision.

The pooled adjustment coefficient is negative in both specifications (−0.5426 without and −0.5384 with year effects, p < .001 for both). The long-run debt coefficient is positive and significant at the 5% level without year effects (0.0490, p = .031), but falls below that threshold when year effects are included (0.0431, p = .086). The contemporaneous debt-change coefficients are small and insignificant in both specifications (p = .877 and .885). Thus the claim of a robust short-run effect is unsupported, while the long-run inference is sensitive to common annual shocks.

The CPIA long-run estimates in the pooled models are positive (4.953 and 5.392), but their p-values are .055 and .068, respectively. These do not establish a direct governance effect at 5%, and the narrow discrete indicator has limited within-country variation. The residual CD p-values are .417 and .983 for the pooled specifications, respectively; these model-specific tests do not reject residual independence, but they do not prove complete elimination of common factors.

5.3. Alternative economic activity control

A sensitivity analysis was conducted to examine whether the estimated relationship between public debt and transportation infrastructure remains consistent when the baseline GDP growth variable is replaced with the alternative GDP per capita (GDPPC) indicator. Table 5 presents the estimated long-run public debt coefficients and their corresponding Driscoll–Kraay p-values under the alternative economic activity specifications, with and without year fixed effects. The comparison provides an indication of the extent to which the estimated debt relationship is sensitive to the choice of economic activity control and the inclusion of common year effects.

The alternative GDPPC regressions show a similar decline in statistical significance when year effects are added. This provides a limited specification check, not validation of the economic activity measure: negative values in the source GDPPC field preclude its use as a logarithmic GDP level, and neither available control substitutes for a verified real GDP series

Table 5. Debt estimates under alternative GDP controls

GDP control	Year FE	Long-run PD	Driscoll–Kraay p
GDP growth	No	0.0490	.031
GDP growth	Yes	0.0431	.086
GDPPC field	No	0.0505	.029
GDPPC field	Yes	0.0436	.088

Note. All values refer to pooled ECM, not PMG. GDPPC is the supplied provided field and is not validated as log aggregate GDP. The estimates use the same 24-country sample and 288 dynamic observations.

.6. 0 Discussion

The empirical findings provide mixed and specification-sensitive evidence on the relationship between public debt and transport infrastructure development in Sub-Saharan Africa (SSA). The constrained Pooled Mean Group (PMG-style) estimates yield positive but statistically insignificant long-run debt coefficients, both without year effects (β = 0.0495, p = 0.095) and with year effects (β = 0.0361, p = 0.252). In contrast, the unrestricted Mean Group (MG) estimator produces a

negative, insignificant coefficient (β = −0.0712, p = 0.603). The pooled error-correction estimates similarly indicate a positive debt association, significant at the 5% level without year effects (β = 0.0490, p = 0.031), but not after controlling for common annual shocks (β = 0.0431, p = 0.086). This sensitivity suggests that the estimated relationship depends on model restrictions and common macroeconomic influences, limiting evidence of a robust positive debt–transport infrastructure association.

These findings are consistent with competing productive-investment and debt-overhang mechanisms. Public borrowing may support transport infrastructure by financing connectivity improvements that reduce trade costs, expand market access and facilitate regional integration (Limão & Venables, 2001; Akpan, 2014). Conversely, rising debt obligations may constrain fiscal space and displace productive capital expenditure and infrastructure maintenance (Krugman, 1988). The resulting association depends on financing composition, resource allocation and investment efficiency rather than aggregate indebtedness alone. This interpretation aligns with the contrasting evidence of Ezeaku *et al*. (2023), who document favourable associations between concessional borrowing and public investment, and Fonchamnyo *et al*. (2021), who report adverse relationships between external debt and domestic investment. The asymmetric debt–infrastructure responses identified by Frimpong *et al*. (2024) further illustrate the importance of financing conditions and dynamic adjustment. However, differences in debt measures, infrastructure outcomes and estimation methods preclude direct equivalence between these findings and the present results.

The analysis extends existing research by examining transport infrastructure as a distinct development outcome rather than relying on aggregate public investment. Previous studies establish the economic relevance of transport connectivity for trade costs, rural accessibility and market integration (Limão & Venables, 2001; Berg *et al*., 2018; Beuran *et al*., 2015), while related African evidence emphasizes the role of infrastructure in regional trade integration (Chuku *et al*., 2023; Tandrayen-Ragoobur *et al*., 2023). Nevertheless, these contributions do not directly establish whether sovereign borrowing translates into measurable improvements in transport networks. The present findings demonstrate that such an association is sensitive to econometric specification, particularly the treatment of common year effects.

The estimated relationships involving demographic and institutional variables also warrant caution. Population growth and CPIA corruption control exhibit positive, statistically significant coefficients in the constrained PMG-style specifications, but these relationships are not consistently supported by the unrestricted MG estimates. In pooled error-correction models, the positive CPIA coefficients remain marginally insignificant at the 5% level (p = 0.055 and p = 0.068). Although institutional effectiveness may influence procurement quality, expenditure execution and infrastructure delivery (Appiah *et al*., 2024; Ojeka *et al*., 2024), these findings provide limited evidence of a stable institutional association. Moreover, the inclusion of CPIA as a direct covariate does not establish governance moderation of the debt–transport relationship.

Short-run debt changes are statistically insignificant in both pooled error-correction specifications (p = 0.877 and p = 0.885), indicating no precisely estimated contemporaneous association. The negative and statistically significant adjustment coefficients (−0.5426 and −0.5384, both p < 0.001) are consistent with adjustment toward the fitted equilibrium relationship but do not independently establish cointegration. The relatively short time dimension, boundary solutions in constrained PMG-style estimation

and incomplete dependence-robust integration and cointegration testing further restrict long-run interpretation. Although Driscoll–Kraay inference addresses certain forms of temporal and cross-sectional dependence in the pooled models, the limited time dimension and potential endogeneity remain important concerns.

Sensitivity analysis reinforces the importance of common temporal influences. Replacing GDP growth with the supplied GDPPC variable produces comparable debt estimates, but the positive association again loses conventional statistical significance when year effects are included. Given the unverified interpretation of the GDPPC field, this exercise provides only limited evidence of robustness to alternative measures of economic activity.

Overall, the study contributes to the public debt–infrastructure literature by identifying the specification dependence of the debt–transport relationship within a sector-specific African panel. The results suggest that positive associations obtained under restricted models or without common year effects should not be interpreted as robust evidence of debt-financed transport development. More credible identification requires disaggregated debt instruments, transport-specific investment expenditure, project implementation data and econometric approaches capable of addressing common shocks and endogenous financing decisions.

7.0 Conclusions

This study examines the relationship between public debt and transport infrastructure development in 24 Sub-Saharan African countries over 2011–2023, using heterogeneous panel ARDL(1,0) and pooled error-correction specifications. The findings reveal a positive but specification-sensitive debt–transport association. While the pooled Driscoll–Kraay estimates indicate a statistically significant positive long-run debt coefficient without year effects ($\beta = 0.0490$, $p = 0.031$), the association becomes insignificant after controlling for common annual shocks ($\beta = 0.0431$, $p = 0.086$). The unrestricted Mean Group estimate is negative and statistically insignificant, while constrained PMG-style estimates exhibit numerical identification concerns. Short-run debt coefficients are also insignificant. Consequently, the evidence does not establish a robust positive relationship between aggregate public indebtedness and transport infrastructure development.

The findings underscore the importance of prioritizing financing quality over debt accumulation. Public borrowing for transport infrastructure should be guided by debt sustainability, rigorous project appraisal, transparent procurement, effective contract management and adequate maintenance financing. Strengthening the disclosure of borrowing terms, project-level disbursements and measurable connectivity outcomes would improve fiscal accountability and enable more credible assessments of infrastructure financing effectiveness. These recommendations reflect broader public-finance principles rather than causal policy effects established by the estimates.

The study contributes to the debt–infrastructure literature by examining transport infrastructure as a distinct development outcome and demonstrating the sensitivity of estimated debt associations to long-run restrictions and common temporal influences. Nevertheless, the short panel dimension, parameter-bound concerns, potential endogeneity and incomplete dependence-robust cointegration testing limit definitive long-run and causal interpretations. Future research should integrate disaggregated debt instruments, transport-specific capital expenditure and project implementation data within more robust identification frameworks to establish the conditions under which public borrowing supports sustainable transport infrastructure development.

8.0 References

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Declarations

Consent for publication

Not Applicable

Data Availability Statement:

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

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David Alaba Makanjuola, Adamu Mohammed Bara, Oluwasola Oni, and Gilbert Deinde Ifarajimi collectively contributed to the study's conceptualisation, research design, literature review, data compilation, and econometric analysis. They participated in interpreting the findings, drafting and critically revising the manuscript, and approving the final version for publication. All authors accept responsibility for the integrity and accuracy of the work and its conclusions.