DETERMINANTS OF QUALITY OF LAND TRANSPORT INFRASTRUCTURE IN DEVELOPING COUNTRIES

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Abstract

Land transport carries 90 per cent and 80 per cent of passengers and freight, respectively, in developing countries. However, the quality of road (3.3) and rail (2.6) infrastructure in these countries is below the world average (4.07 and 3.61), despite enormous investments, policies, and schemes geared towards the sector. Previous studies focused on determinants of stock and investment in road and rail infrastructure, which may not reflect the quality of road and rail infrastructure on the ground. Therefore, this study investigated the factors that determine the quality of land transport infrastructure in developing countries. The study was rooted in an extended endogenous growth model. Panel data from 106 developing countries spanning the period of 2007–2022 were sourced. The study used Driscoll-Kraaypanel estimation techniques. The results show that gross domestic product per capita, credit to the private sector, debt-to-GDP, urban growth, natural resources, and institutions have a significant impact on the quality of road and rail transport infrastructure. There is evidence that institutions in developing countries are too weak to create an investment climate for quality road and rail to improve. The overall findings show that developing countries need to strengthen their institutions.

Keywords: Land transport; Quality; Determinants; Socio-economic; Institutions, Developing Countries

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Introduction

The provision of a well-developed infrastructure is necessary for development (see Rodrigue, 2024; Farhadi, 2015; Timilsina, Stern and Das, 2023; Foster, Gorgulu and Vagliasindi, 2023). Accumulated infrastructure is both a cause and a parameter for measuring the success of a country, among other factors (Lebrand and Herrera, 2021; Khanna and Sharma, 2021). This includes the stock and quality of transport networks, power supply, communication technology and internet connectivity, and water supply and sanitation (World Bank, 2014). Rokicki and Stępniak (2018) argued that all components of the infrastructure are important, and none is less inferior nor superior. The World Bank (2021) noted that transport infrastructure has continued to be a driver and connector of other components of infrastructure and, therefore, an interface between other components of infrastructure and economic development. Transport infrastructure bridges the gap between where other infrastructures are produced and where they are needed (Shabani and Safaie,2018; Chakamera and Alagidede, 2018; Timilsina et al., 2023). Over the past decades, the nexus between transport infrastructure and economic development has continued to dominate research and policy spaces (See Banerjee, Duflo and Qian, 2020; Baum-Snow, Henderson, Tuner, Zhang and Brandt, 2020; Donaldson, 2018).

Foster, Rana and Gorgulu (2022) showed that government spending on transport infrastructure boosts the private economy, thereby resulting in economic growth. This has been firmly supported by the theoretical exposition of endogenous growth theories. Conversely, the World Bank (1994) shows that economic growth also exerts pressure on transport infrastructure via urbanization, thereby resulting in traffic congestion and wear and tear on the transport infrastructure. Despite the controversies surrounding the transport-growth nexus, the majority of studies support the transport-led growth hypothesis, especially land transport, which includes road and rail (Jedwab and Storeygard, 2017 and 2019; Zheng, Law, Wong and Ng, 2024; Liu, Zhang and Chen, 2024; Donaldson, 2018).

The comparative advantages of land transport over other transport modes, in terms of salient roles such as accessibility, flexibility, and cost efficiency, make it the most useful. Hence, land transport modes play a major role in terms of the functionality, efficiency, and productivity of the local economy (Banerjee et al, 2020; DiRuocco and D'Auria, 2024). The submissions of these studies as progressively documented in the development literature are not without convergent and divergent views. The very point of convergence of these studies described land transport infrastructure as sin qua non for sustainable and inclusive development (World Bank, 1994; Jedwab and Storeygard, 2017 and 2019). The importance of land transport infrastructure to economic development could be logically viewed from both micro- and macroeconomic perspectives.

From the perspective of macroeconomics, existing studies show that the provision of efficient road and rail transport infrastructure has a positive impact on economic growth and inclusive development via different dimensions, which are better explained by the multiplier principle. For instance, in some developing and emerging countries like Brazil, China, India, Malaysia, South Africa, and South Korea, among others, investment in paved roads has been found to have doubled total factor productivity (Rokaciki and Stepniak, 2018; Banerjee et al., 2020). More so, efficient road and rail systems facilitate the exchange of goods and services and open up economies to larger markets, thus creating a larger scale of production at a lower average cost (World Bank, 2014; Baum-Snow et al., 2020; Banerjee et al., 2020). The provision of efficient road and rail systems promotes industrialization, regional trade, integration of the local economy into the regional economy, attraction of foreign direct investment, and stimulation of domestic investment. These, in turn, improve foreign earnings and the balance of payments (Soto and Martinez-Cobas, 2024; Liu, Zhang and Chen, 2024; Banerjee et al., 2020; Baum-Snow, 2017). Conversely, inefficient land transport networks reduce the pace of regional mobility of capital and labour, reduce regional division of labour and specialization, and hinder regional competitiveness and value addition.

From a microeconomic perspective, an efficient land transport system provides door-to-door services and facilitates the distribution of finished goods from the producers to the final consumers (Bonfatti et al., 2013; DiRuocco and D'Auria, 2024). Provision of an efficient road and rail transport network not only jointly promotes inter- and intra-city mobility, but also affords households access to markets, tourism, work and job opportunities, healthcare facilities, schools, and other social functions (Cervero, 2008; Zheng et al., 2024). The provision of all-weather and all-season roads and high-speed rail networks not only reduces the time and cost of moving passengers and freight but also links production zones to markets and promotes the growth of small and medium-scale businesses (Pradhan et al., 2013; Shabani and Safaie, 2018).

Although road and rail networks transport 90 per cent of passengers and convey 80 per cent of freight in developing economies (Africa, Asia, Latin America, and the Caribbean), about 55.6 per cent of the roads in these regions combined are unpaved (World Development Indicator, 2023). Except for the East Asian region, about 46.1 per cent of the population in developing countries lacks access to paved, all-season, and all-weather roads (Canning, 2023). Only 43 per cent, 39 per cent, and 61.4 per cent of roads in Africa, Latin America and the Caribbean (LAC), and Asian countries respectively are paved, compared to 85 per cent in Europe (World Bank, 2024). World Bank (2014) reveals that very little has been added to the old rail system since it was constructed during the colonial era. And except for East Asia, many developing countries still operate primitive rail systems (AfDB, 2019; World Bank, 2022). Thus, after several decades of independence, the length and quality of rails have declined considerably in many developing countries, especially the Sub-Saharan African (SSA) and Southeast Asia regions. For instance, the average railway speed in most developing countries is less than 90 km/h, compared to 250 km/h in developed economies. It is less than 50 km/h in most SSA countries, while 10 African countries do not have operational railways (UNCTAD, 2020). While the railway track per 1000 km^2 of land is estimated at 50km in Europe, it is 2.8km in Africa, 6.5 km in Asia, and 5.7 km in LAC (UNCTAD, 2020).

The quality of rail on average for the world is 3.61, while for Africa, Asia and LAC they are 2.26, 3.13 and 1.9 respectively. In terms of roads, the quality for Africa, Asia and LAC are 3.3, 4.01 and 3.5 respectively, which are below the world average quality of 4.07 (World Development Indicator, 2023). Given the above, it is therefore pertinent to ask; what are the factors that determine the quality of land transport infrastructure in developing countries? Do these factors vary among the developing regions? The objective of this study, therefore, is to examine the factors that determine the quality of land transport infrastructure in developing countries, and if these factors are region-specific. The rest of the paper is structured into a review of literature; methods and materials; results and discussion; and conclusion and policy recommendations.

Review of Literature

Theoretical issues

Both the classical and the neoclassical schools did not accord infrastructure as an entity within the growth model (Aschauer, 1989). Away from the traditional classical belief, the neoclassical attributes long-run growth to technological progress, implicitly conditioned on the efficiency of public infrastructure (Agenor, 2010). Thus, labour, capital and technology were explicitly recognised as the core components of the growth model while public infrastructure as an entity was missing in the neoclassical growth model. According to Aschauer (1989), it was rooted in the assumption that infrastructure, a subset of public capital, is ceded to the government in terms of operation and funding. Thus, not considered as a direct input in production function as far as a perfect competitive economy is concerned.

Following the novelty effort of endogenous growth models by Romer (1986) that endogenized capital accumulation in the growth model, ASchauer (1989) became the first study to consider an endogenized infrastructure as a variable entity in the growth model. The study provided a theoretical proposition that defines output as an increasing function of infrastructure, while several studies lend credence to his argument (Cockburn, Dissou, Duclos and Tiberti, 2013; Das and Dutta, 2023; Bhattacharya, Gupta and Sikdar, 2020). The study paved the way for infrastructure to be incorporated and examined as explained variable within the growth model. Holtz-Eakin and Schwarz (1995) incorporated public capital into the neoclassical growth model, and interestingly, the theoretical proposition of the study found infrastructure as an increasing function of output and private capital, but a decreasing function of population. In addition, the infrastructure-led theory by Agenor (2010) further provided a clearer picture of the causal-effect relationship between infrastructure and growth. The study revealed that infrastructure is an increasing function of government spending on public capital and a decreasing function of spending on non-productive sectors. While infrastructure is strongly linked to government spending, the latter is an increasing function of tax revenue from economic growth. Intuitively, infrastructure is directly related to output.

In the last three decades, the New Institutional Economic (NIE) pioneered by North (1990) provided a theoretical proposition on the nexus between institutions and macroeconomic performance. Following North's argument on the nexus between institutions and macroeconomics, empirical studies have found institutions significant in explaining the stock, investment and quality of infrastructure, especially land transport components (Jedwab & Storeygard, 2019; Trebilcock & Rosenstock, 2015). Therefore, the model of this study captures both economic and institutional factors.

Previous studies

Developing countries are characterised by huge transport deficits, which over the past decades have limited their pace of development (World Bank, 2021). For instance, Ruiz-Nunez and Wei (2015) examined the transport deficit in 145 countries for the period 1960–2012 and estimated 6.1 per cent of GDP as expenditure required to close the transport deficit in most developing countries. The deficits vary across the three developing regions considered in this study (Africa, Asia, and LAC). For instance, the report of the Africa Development Bank (AfDB, 2020) shows that Africa has the highest transport deficit in the world in terms of quality, quantity, and accessibility. More than 80 per cent of roads and rail in the continent are only in fair condition, while 83 per cent of the rural roads are not accessible during the rainy season. The Asian Development Bank (ADB, 2020) estimated a $26 trillion infrastructure deficit for Asia for the period of 2016–2030, equivalent to $1.7 trillion annually. About 32 per cent ($8.4 trillion) is projected for the transport sector. Similarly, Marsh, Guy, Mercer, and Oliver (2018) found Latin America and the Caribbean (LAC) lagging behind the global average in terms of transport infrastructure. Brichetti, Rivas, Serebrisky and Solís (2020) estimated $2.2 billion in infrastructure needs for the LAC region, an annual 2 per cent of GDP for transport infrastructure for the period 2020–2030.

Studies also addressed the source of finance and stock of transport infrastructure and why they are low in developing countries. Both the public and private sectors contribute to the stock of transport infrastructure. Calderon and Serven (2014) and Marsh et al. (2018) attributed the low stock of transport infrastructure to contractions in both the private and public sectors during 2005–2010. The former remains the major funding source for transport infrastructure, while private concessions have gained momentum over the last three decades, though the volume of projects and factors that drive them vary across countries and regions (Marsh et al., 2018; Amadou, 2017; Calderon et al., 2014). For instance, the World Bank (2021) shows that the private sector contributes 20–25 per cent of transport infrastructure in developing countries, less than 10 per cent in Africa, 23-25 per cent in LAC, and 18–21 per cent in Asia. The document also revealed that only one-third of developing countries depend on the private sector for land transport infrastructure. The combination of the public and private sectors, or the partnership of the two, remains one of the major drivers of transport infrastructure in most developing countries, though less than the feat recorded in developed economies due to certain factors. Trebilcock and Rosenstock (2015), Amadou (2017), Ittmann (2017), and UN-Habitat (2011) found institutions and an unbiased judicial system as factors that drive the involvement of public-private- partnerships in the transport sector. Kumar (2019) attributed the success and failure to stable macroeconomics, a large market, and good governance.

The tentacles of previous studies also cover factors that drive the stock of investment in transport infrastructure. These include both socioeconomic and institutional factors, and the impact of these factors varies across regions of developing countries. Jedwab and Storeygard (2019) and Maparu et al. (2017) attributed the stock of transport infrastructure to economic growth, while Nashizawa (2018), Conor and Daniel (2016), and the Asia Development Bank (ADB, 2017) found domestic and foreign direct investment as important determinants. Other socioeconomic-related factors include natural resources (Jedwab et al., 2019), corruption (Galilea & Medda, 2010), pensions (Amadou, 2017), fiscal policy (Carranza, Daude & Melguizo, 2011; Cerra et al., 2018), and urbanisation (Maparu et al., 2017 and 2020; Li and Xu, 2017; Jedwab et al., 2019). Empirical studies also link both stock and investment transport infrastructure to institutional factors. These include regulatory quality (Galilea & Medda, 2010; Jedwab et al., 2019), rule of law (Jedwab et al., 2019), quality of governance (Nashizawa, 2018), and index of institutions (Galilea et al., 2010; De Prabir, 2010).

Studies on infrastructure cover different scopes of infrastructure which include energy, communication technology and connectivity, water supply and sanitation, and health. In most studies that addressed transport infrastructure, different modes are aggregated. Hence, there are scarce studies on determinants of the quality of land transport infrastructure. Jedwab and Storeygard (2019) are one of the few studies that examined the determinants of road and rail transport infrastructure extensively. Though the study provided an x-ray of history and trends in investment and an in-depth analysis of political and economic determinants of road-rail transport, it focused on investment in road and rail transport infrastructure. The submission of the World Bank (1994) shows that neither stock nor investment is proportionate to the quality of roads and rail in developing countries. The discrepancies between the investment and quality of land transport infrastructure have been attributed to prevalent cases of corruption that permeate the awarding and costing of road and rail projects (Infrastructure Consortium for Africa, 2013). Consequently, the cost of road and rail maintenance resurfaces annually in the fiscal budget, while the quality of road and rail declines. Therefore, since access to quality land transport infrastructure assumes an indispensable role in building modern-day economies, it is imperative to look beyond investment and stock of land transport infrastructure, hence the need to x-ray why the quality of road and rail in developing countries has remained poor over the decade despite the investment.

Methods and Materials

Model specification

Following Holtz-Eakin and Schwartz (1995), this study incorporates the quality[1] of land transport infrastructure into Mankiw et al.'s version of the extended endogenous growth model. The model specification covers socioeconomic, historical-physical, and institutional variables. Our choice of these variables is informed by past studies, as documented in the literature review. Thus, the model for the study is stated as:

$$\mathrm{LIT}_{it} = \alpha + \sum_{j=1}^{8} \omega_j \mathrm{X}_{j,it} + \sum_{j=1}^{2} \mathrm{ɥ}_j \mathrm{Z}_{j,it} + \sum_{j=1}^{6} \emptyset_j \mathrm{PI}_{j,it} + \mathrm{e}_{it} \qquad (1)$$

The vector X includes lag of real GDP per capita (θ_{t-1}), total natural resources as a percentage of GDP (NR_{it}), rate of inflation (INF_{it}), credit to the private sector as a percentage of GDP (CPS_{it}), foreign direct investment in transport projects as a percentage of total foreign direct investment (FIT_{it}), degree of trade openness (DOT_{it}), total debt as a percentage of GDP (DBT_{it}), and lag of urban growth rate (UR_{it-1}). Vector Z includes a dummy for landlocked countries ($LDUM_{it}$), a dummy for natural resources ($RDUM_{it}$), and a dummy for colonization ($CDUM_{it}$). Five institutional factors and the quality of democracy are bundled into one to form the institutional factors index (PI). The institutional factors include the control of corruption index (CC_{it}), political stability (PS_{it}), rule of law (RL_{it}), regulatory quality (RQ_{it}), and voice and accountability (VA_{it}).

Model (1) is estimated under two scenarios. First, the model is estimated using data from 106 developing countries to examine and establish determinants of the quality of land transport infrastructure. Second, for a robust test, the quality of land transport infrastructure is further disaggregated into road and rail. Thus, the study verified whether the determinants of the quality of land transport infrastructure are significantly different from disaggregated (road and rail). Empirical studies by Acomoglu (2003, 2010) and Jedwab et al. (2017, 2019) have shown that institutions play an intermediary role between macroeconomic variables. Acemoglu (2010) revealed that countries with strong institutions record better macroeconomic performance, while Jedwab et al. (2019) reveal that better institutions attract an inflow of both domestic

[1] Quality of road is measured by indices which includes curvature state of the road, suitability of crosswalk and pedestrian path, asphalt roads, road roughness, availability and suitability of length of road shoulder, drainage system, illumination devices, global positioning system (GPS). Quality of rail is measured by track quality, cross level, gauge, speed of rail, and efficiency and effectiveness in service delivery (World Economic Forum, 2022)

and foreign direct investment in transport infrastructure. This suggests that poor macroeconomic performance in developing economies cannot be isolated from weak institutions (Acomoglu, 2003, 2010). Therefore, this study proceeded further to test whether institutional and economic factors jointly impact the quality of land transport infrastructure in developing countries. Thus, the Model (1) is further stated as:

$$\mathrm{LTI}_{it} = \lambda_0 + \lambda_1 \left(\mathrm{PI}_{it} . \sum_{j=1}^{8} \mathrm{X}_{j,it} \right) + e_{it} \qquad (2)$$

All variables in Model 2 remain as defined in Model 1.

Sample, sources, and description of data

One hundred and six (106) developing countries spanning the period of 2007–2022 were considered based on data availability. The definition of developing countries is based on the World Economic Situation and Prospect (World Economy Situation and Prospect, 2022) classification. Details of the countries considered are presented in Table 1. The sources of data, variable descriptions, and measurement of variables are well summarized in Table 2. Also, the five institutional variables and the quality of democracy are reduced to an index using Principal Component Analysis (PCA). The institutional variables are treated as individual variables and as a single index exclusively in the model.

Table 1: Selected Countries for the Study

African Countries		Asian Countries		Latin and Caribbean Countries	
Algeria	Malawi	Armenia	Macedonia	Argentina	Suriname
Angola	Mali	Azerbaijan	Malaysia	Barbados	Uruguay
Benin	Mauritania	Bangladesh	Mongolia	Brazil	Venezuela
Botswana	Mauritius	Bahrain	Myanmar	Bolivia	
Burundi	Mozambique	Bhutan	Nepal	Chile	
Burkina Faso	Morocco	Cambodia	Oman	Colombia	
Cape Verde	Namibia	China	Pakistan	Costa Rica	
Chad	Niger	Georgia	Philippine	Dominican	
Congo DR	Nigeria	Hong Kong	Qatar	Ecuador	
Cote d'Ivoire	Rwanda	India	Saudi Arabia	El-Salvador	
Egypt	Senegal	Indonesia	Singapore	Guatemala	
Ethiopia	Sierra Leon	Iran	Sri Lanka	Guyana	
Gabon	South Africa	Israel	Syria	Honduras	
Gambia	Swaziland	Papua New Guinea	Taiwan	Jamaica	
Ghana	Seychelles	Jordan	Timor-Leste	Latvia	
Guinea	Tanzania	Kazakhstan	Tajikistan	Mexico	
Kenya	Tunisia	South Korea	Turkey	Nicaragua	
Lesotho	Uganda	Kyrgyz Republic	Thailand	Panama	
Liberia	Zambia	Kuwait	Vietnam	Paraguay	
Libya	Zimbabwe	Lao	United Arab Emirate	Peru	
Madagascar		Lebanon		Trinidad and Tobago	

Source: World Economic Situation and Prospect (2022)

Table 2: Description of Variables and Sources of Data

Variables	Code	Description	Measurement	Source
Quality of Land Transport Infrastructure	LTI	1 = extremely poor; 7 = extremely good	Index in continuous value	World Economic Forum
Quality of Road Transport Infrastructure	QRO	1 = extremely poor; 7 = extremely good	Index in continuous value	World Economic Forum
Quality of Rail Transport Infrastructure	QRA	1 = extremely poor; 7 = extremely good	Index in continuous value	World Economic Forum
Lag of Real GDP per capita	θ_{t-1}	$\frac{Total\ Real\ GDP}{Total\ population}$	Nominal	World Development Indicator
Inflation	INF	Inflation rate	Percentage	World Development Indicator
Credit to private investment	CPS	Total credit to private investment scaled GDP.	Percentage of GDP	World Development Indicator
Degree of Openness to the Economy	DOT	Total trade as a percentage of GDP.	Percent of GDP	World Development Indicator
Foreign Direct Investment in transport	FIT	FDI is transport project as a percentage of total FDI.	Percentage of FDI	Global Competitive Index
Total Debt	DBT	The sum of internal and external as a percentage of GDP.	Percentage of GDP	World Development Indicator
Total natural resources	NR	The total value of natural resources as a percentage of GDP.	Percentage of GDP	World Development Indicator
Rate of Urbanization	UR_{t-1}	$\frac{UR_{t-1} - UR_t}{UR_{t-1}}$	Percentage	World Development Indicator
Resource dummy	RDUM	1, if the share of natural resources to GDP is 30% or more, and 0, if otherwise	Dummy	Computed by the author using data for natural resources from WDI
Colonization	CDUM	1, if a country was colonised, and 0, if a country is not colonized	Dummy	World Atlas Data
Landlocked country	LDUM	1, if a country is landlocked, and 0, if not	Dummy	World Atlas Data
Quality of Democracy	QD	Polity-2	Index Score -10 to 10	Polity-IV database
Political Stability	PS	Absence of domestic violence and terrorism	Index Score -2.5 to +2.5	World Governance Indicator
Control for Corruption	CC	The extent to which public power is exercised for private gain	Index Score -2.5 to +2.5	World Governance Indicator
Rule of Law	RL	Confidence that economic agents have in and abide by the political and economic institutions.	Index Score -2.5 to +2.5	World Governance Indicator
Regulatory Quality	RG	Quality of sound policies and regulations that permit and promote private sector development	Index Score -2.5 to +2.5	World Governance Indicator
Voice and Accountability	VA	The extent to which citizens can participate in selecting their government.	Index Score -2.5 to +2.5	World Governance Indicator

Source World Economic Forum, World Development Indicator, World Governance Indicator World Atlas Dataset, and Polity-IV dataset

Results and Discussions

Summary of descriptive statistics

Quality of land (road and rail) transport infrastructure is measured in index[2]. As shown in Table 3, the 106 countries sampled have an average quality of land transport of 3.11 (below the world average of 3.85). It has a minimum value of 1.48 and a maximum value of 6.48. Both scenarios are found in Asia. The standard deviation value (0.99) shows a low level of dispersion among developing countries. This came as no surprise because developing countries have similar socioeconomic and political performances. From the continental view, Africa, Asia, and LAC have average values of 2.98, 3.61, and 2.74, respectively; LAC

[2]The index ranges from 1-7 in continuous form. Close to 7 means better scenario while close to 1 means worse scenario.

has the lowest average (2.74). The maximum values across the three continents show that Asia has the highest quality, while Africa is slightly ahead of LAC. The values of the standard deviation show that Africa (0.64) and LAC (0.75) have less dispersion than Asia (1.3). The wider variation in Asia, perhaps, can be attributed to East Asia as an outlier.

Table 3: Descriptive Statistics of the key variables

Items	Africa			Asia			LAC		
	Mean (Std. Dev)	Min	Max	Mean (Std. Dev)	Min	Max	Mean (Std. Dev)	Min	Max
LTI[3]	2.98(0.64)	1.82	4.74	3.61(1.3)	1.48	6.48	2.74(0.75)	1.73	4.3
QRO	3.33(0.78)	2.1	5.2	4.1(1.2)	1.94	6.45	3.55(0.84)	1.94	5.4
QRA	2.62(0.87)	1.4	4.7	3.13(1.3)	1.01	6.63	1.94(0.64)	1.12	3.58
The world average of roads[4]4.07				Average of the road (106 countries) 3.67* (1.04)					
The world average of rail is 3.61				Average of rail (106 countries) 2.56* (1.1)					
The world average of LTI 3.85				Average of LTI (106 countries) 3.11* (0.99)					

LTI is quality of land transport infrastructure; QRO is quality of road transport infrastructure; QRA is quality of rail transport infrastructure. *Standard deviation in parentheses (). Source:* Authors' computation

Correlation

Correlations among explanatory variables have a significant negative impact on the regression estimates. The stronger the correlation between the explanatory variables, the more difficult it is to estimate the relationship between the explained and individual explanatory variables (Greene, 2003). The results of the correlation, as reported in Table 4, show that there is a weak correlation among the socioeconomic variables. Thus, it allays the fear of multicollinearity among the explanatory variables. However, there is a strong correlation among institutional variables. The implication of a strong correlation among the institution factors is that the standard errors become inflated, thereby making it difficult to test for individual regression coefficients (Greene, 2003). Therefore, the institutional factors are entered into the regression in a step-wise format.

[3] LTI is quality of land transport infrastructure; QRO is quality of road transport infrastructure; QRA is quality of rail transport infrastructure

[4]The World Average of Quality of Road (4.07) and Rail (3.61) for 191 countries was computed by the World Economic Forum (2022), while this study computed the average for 106 countries covered. The average for this study is 3.67 for road and 2.56 for rail.

Table 4: Pairwise correlation of the variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) LTI	1.000														
(2) LOGθ_{t-1}	0.494	1.000													
(3) FIT	-0.011	0.018	1.000												
(4) NR	-0.445	0.096	0.052	1.000											
(5) UR	-0.457	-0.544	0.015	0.159	1.000										
(6) CPS	0.553	0.436	-0.078	-0.342	-0.473	1.000									
(7) INF	-0.066	-0.063	-0.012	-0.005	-0.065	-0.093	1.000								
(8) DOT	0.225	0.584	0.236	0.009	-0.489	0.215	-0.021	1.000							
(9) DBT	0.175	0.291	-0.024	0.051	-0.333	0.312	0.042	0.173	1.000						
(10) CC	0.575	0.374	0.082	-0.570	-0.353	0.493	-0.113	0.392	0.075	1.000					
(11) PS	0.390	0.376	0.130	-0.374	-0.288	0.337	-0.055	0.426	0.144	0.723	1.000				
(12) RQ	0.513	0.239	-0.017	-0.584	-0.136	0.566	-0.141	0.116	0.161	0.759	0.653	1.000			
(13) RL	0.588	0.376	0.011	-0.583	-0.302	0.571	-0.110	0.262	0.168	0.892	0.748	0.875	1.000		
(14) VA	0.262	0.214	0.111	-0.503	-0.125	0.485	-0.086	0.249	0.149	0.684	0.617	0.684	0.728	1.000	
(15) DEM	0.058	0.152	0.149	-0.310	-0.058	0.229	0.000	0.212	0.095	0.383	0.326	0.333	0.367	0.802	1.000

Source: Authors' computation

Principal component analysis (PCA)

This study used Principal Component Analysis (PCA) to aggregate the six institutional factors (see Table 5). PCA is a preferred multivariate approach because of certain strengths it possesses. First, it aggregates variables into reduced form without losing the relevant information (Chakamera & Alagidede, 2018). Second, it selects maximum variation and technically ignores small variation, therefore reducing the noise in the data (Chakamera et al., 2018). The variables considered are control of corruption, political stability, rule of law, regulatory quality, voice and accountability, and polity II (quality of democracy). Since the quality of democracy ranges from -10 to +10 and other institutional factors assume -2.5 to +2.5, standardization is performed before PCA. Thus, the data is transformed and rescaled to have a scale of 0–1 to reduce bias (0 means poorest, 1 means best).

Table 5: Principal Component Analysis (PCA) of Institutional Quality

The number of comp. = 6
Trace = 6

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	4.25362	3.26569	0.7089	0.7089
Comp2	.987927	.618008	0.1647	0.8736
Comp3	.369919	.139177	0.0617	0.9352
Comp4	.230742	.139312	0.0385	0.9737
Comp5	.0914307	.0250682	0.0152	0.9889
Comp6	.0663626	.	0.0111	1.0000

Authors' computation

As reported in Table 5, PC1 is retained because of logical reasons. First, only PC1 has an eigenvalue greater than the average. Second, the eigenvalue shows that PC1 accounts for about 71 per cent, while the value of the eigenvector is positive across the six variables.

Cross-sectional dependence

The presence of cross-sectional dependence has serious implications for regression results because the estimators become inefficient and the standard errors are biased. Table 6 clearly shows the results of both the Pesaran and Friedman tests. Except for Friedman's result on the quality of rail transport infrastructure, both tests strongly reject the null hypothesis of no cross-sectional dependence. Therefore, there is sufficient evidence of cross-sectional dependence in the panel data. By implication, the results of the Ordinary Least Squares (OLS) estimator become inconsistent, while the standard error becomes biased.

Table 6: Cross-sectional dependence test for LTI, QRO and QRA

	Pesaran		Friedman	
	Statistics	P-value	Statistics	P-value
LTI	16.74	0.000	75.23	0.000
QRO	33.93	0.000	134.54	0.027
QRA	18.320	0.000	58.51	0.999

LTI is quality of land transport infrastructure; QRO is quality of road transport infrastructure; QRA is quality of rail transport infrastructure

Authors' computation

Regression results

This study employs Driscoll and Kraay standard error regression (D-K) because it takes care of cases of cross-sectional dependence (Driscoll and Kraay, 1998; Hoechle, 2007). Furthermore, the study examines disaggregated land transport infrastructure- road and rail. Model (1) is estimated under land, road, and rail models using Driscoll-Kraay regression. In Table 7, the first three columns present the results of the quality of land, road, and rail, respectively, without controlling for the resource dummy (30% threshold), landlocked dummy, and colonial dummy. Foreign direct investment in transport as a percentage of GDP, inflation, and the degree of trade openness are not significant under the land model. 1-year lag of GDP per capita (θ_{t-1}) has a positive impact on the quality of land transport infrastructure, with a coefficient of 0.015. The impact on the quality of the road is relatively higher, while it is less for the rail. This finding aligns with Jedwab et al. (2019). As reported in Table 7 (see columns 4, 5, and 6), when the three dummies are introduced, the impact of GDP per capita on the quality of land remains unchanged, while it decreases under the road and increases under the rail.

Table 7: Driscoll and Kraay regression (dependent variables: LTI[5], QRO and QRA)

Var.	LTI(I)	QRO(II)	QRA(III)	LTI(IV)	QRO(V)	QRA(VI)
$LOG\theta_{t-1}$	0.015^{+}	0.016^{+}	0.013^{+}	0.015^{+}	0.013^{+}	0.015^{+}
	(0.002)	(0.003)	(0.001)	0.006	(0.003)	(0.005)
FIT	0.0011	-0.0012	0.004*	0.0016	-0.0016	0.0032*
	(0.0015)	(0.0013)	(0.0021)	0.0012	(0.0014)	(0.002)
NR	-0.010**	-0.0126**	-0.0086**	-0.011**	-0.015**	-0.007**
	(0.0037)	(0.004)	(0.0033)	0.0036	(0.0041)	(0.003)
UR_{t-1}	-0.0191^{+}	-0.0081**	-0.0348^{+}	-0.019**	-0.007**	-0.031**
	(0.0025)	(0.0042)	(0.0081)	0.0022	(0.0031)	(0.006)
DBT	0.0157^{+}	0.0164^{+}	0.0141^{+}	0.013^{+}	0.0162^{+}	0.016^{+}
	(0.0024)	(0.0025)	(0.019)	0.0014	(0.0023)	(0.0017)
CPS	0.0038^{+}	0.0024^{+}	0.005^{+}	0.0033^{+}	0.003^{+}	0.004**
	(0.0009)	(0.0011)	(0.0009)	0.0062	(0.0009)	(0.0007)
INF	-0.0013	-0.0017	-0.0007*	-0.0014	-0.001*	-0.0006
	(0.0012)	(0.0009)	(0.0003)	0.0041	(0.0006)	(0.0004)
DOT	-0.0023	-0.0004	-0.0038^{+}	-0.003*	-0.0004	-0.003**
	(0.0016)	0.0005	0.0004	0.0017	(0.0005)	(0.0006)
RDUM				-0.345*	-0.072*	-0.0062*
				0.188	(0.038)	(0.0033)
LDUM				-0.266**	-0.009**	-0.0047^{+}
				0.1128	(0.0046)	(0.0012)
CDUM				-0.027*	-0.016**	-0.005
				0.014	(0.0079)	(0.003)
Const.	3.1801^{+}	3.5291^{+}	2.8096^{+}	3.118^{+}	3.5604	2.5473
	(0.7051)	(0.9381)	(0.8123)	0.559	(0.7743)	(0.856)
R^2	0.1267	0.1715	0.1278	0.1382	0.1838	0.1264
F-Stat.	83.15	128.37	107.67	88.23	121.35	112.45
(P-value)	(0.003)	(0.0012)	(0.001)	(0.003)	(0.0011)	(0.001)
Obs.	1680	1680	1680	1680	1680	1680

Note: (+), (**) and (*) imply statistically significant at 1%, 5% and 10% significant levels respectively. The standard error is presented in parenthesis (). Source: Authors' computation

Most developing countries are resource-based economies, and one would expect resource-based economies to have access to better roads and an efficient rail system. Surprisingly, natural resources as a percentage of GDP hurt the quality of land transport infrastructure. The impact on the quality of roads is relatively

[5]LTI is quality of land transport infrastructure; QRO is quality of road transport infrastructure; QRA is quality of rail transport infrastructure

higher than that of rail. By implication, as the share of natural resources in GDP increases, the quality of roads and rail tends to decline. Similarly, the sign and coefficients are not significantly different when the three dummies are introduced (see table 7; columns 4, 5, and 6). This finding validates the resource-curse hypothesis (Auty, 2007) and the empirical studies by Acemoglu (2003), Blomstrom and Kokko (2007), and Brunnschweiller (2008), whose findings show that countries endowed with natural resources in GDP are usually worse off in terms of physical and inclusive development.

Before and after the introduction of dummies, lagged urban growth (UR_{t-1}) is negatively significant across land, road, and rail transport infrastructure. Interestingly, as reported in Table 7, the coefficients of urban growth before and after the introduction of the dummy variables are not significantly different. The result contradicts Li and Xu (2017), Maparu et al. (2017 & 2020) in Asia, and Jedwab et al. (2019) in Africa. However, the contradiction is not a surprise because Maparu et al. (2017 and 2020) and Li and Xu (2017) use data on the stock of transport, Jedwab et al. (2019) use investment in transport, and the present study uses the quality of land transport infrastructure. Mostly, stock and investment measure the nominal worth of land transport infrastructure, especially roads, while quality measures functionality (World Bank, 2019).

Intuitively, expectations would be that more debt would result in better-quality and more productive projects like land transport infrastructure. Debt-to-GDP has a positive sign and is significant across the six columns (Table 7). Interestingly, the quality of roads and rail in most developing countries does not justify the debt accumulated. Debt in most developing countries emanates from deficit balances of payment, while it is also difficult to rule out accumulated debt from non-transport projects. This finding aligns with Bom and Ligthart (2014), whose finding reveals that public debt increases the stock of transport infrastructure.

According to the World Bank (2021), credit to the private sector is a better parameter for measuring the contribution of the private sector to the overall economy. As reported in Table 7 (See columns 1–3), credit to the private sector (CPS) has a positive and significant impact on the quality of land, roads, and rail. The coefficients after dummies are introduced (see columns 4–6) are not significantly different from columns 1–3. As the credit to the private sector increases, economic activities expand, resulting in an increase in private trips and the movement of freight via road and rail, especially in developing countries where road and rail carry 80–85 per cent of passengers and freight. Surprisingly, trade openness (DOT) has a negative sign but is only significant in rail mode. Our results reveal that the more an average developing country is opened to the rest of the world for trade, the lower the quality of rail. This questioned the assumption of the transfer of technology from developed to developing economies through trade openness.

Three dummy variables were considered. Although the results have a negative sign, there is no evidence that the quality of roads and rail in resource-dependent countries is significantly different from those that are less dependent on natural resources. Interestingly, the quality of roads and rail in landlocked countries is worse than in countries bordered by sea by 0.009 and 0.0047 indexes, respectively. The quality of roads in colonized countries is worse by a 0.016 index than in countries that were never colonized. There is no evidence that the quality of rail in colonized countries differs from non-colonized countries. This contrasts with Jedwab et al. (2019), whose findings show that investment in rail in African countries formerly colonized was better than that of their non-colonized counterparts.

Tables 8, 9, and 10 present results on the impact of institutions on the quality of land, road, and rail transport infrastructure, respectively. Six institutional factors considered were reduced to an index using principal component analysis (PCA). The result of pair-wise correlation shows evidence of multicollinearity among the institutional factors (Table 4). Therefore, index and individual institutional factors were entered into the regression in a step-wise order.

Table 8: Driscoll and Kraay Regression (dependent variables: LTI)

Var.	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
$LOG\theta_{t-1}$	0.015^{+}	0.014^{+}	0.016^{+}	0.013^{+}	0.010^{+}	0.015^{+}	0.014^{+}
	0.002	0.002	0.002	0.001	0.002	0.008	0.002
FIT	0.0014	0.0011	0.0005	0.0008	0.0002	0.0014	0.0014
	0.0015	0.0013	0.0013	0.0011	0.0014	0.0015	0.0015
NR	-0.010**	-0.010**	-0.010**	-0.011**	-0.0103^{+}	-0.010**	-0.01**
	0.0037	0.0038	0.0039	0.0038	0.0037	0.0037	0.0037
UR_{t-1}	-0.021^{+}	-0.0244^{+}	-0.0266^{+}	-0.0213^{+}	-0.0277^{+}	-0.020**	-0.021^{+}
	0.0026	0.0037	0.0031	0.0034	0.0044	0.0101	0.0028
DBT	0.0152^{+}	0.0147^{+}	0.0151^{+}	0.0148^{+}	0.014*	0.0153^{+}	0.015^{+}
	0.0022	0.002	0.0021	0.0020	0.0081	0.0021	0.0022
CPS	0.0037^{+}	0.0035^{+}	0.0035^{+}	0.0033^{+}	0.002**	0.0038^{+}	0.004**
	0.0007	0.0007	0.0006	0.0007	0.0009	0.0007	0.0007
INF	-0.0011	-0.0011	-0.007*	-0.0011	-0.001*	-0.0011	-0.0012
	0.0015	0.0041	0.004	0.0048	0.0071	0.0047	0.004
DOT	-0.0021	-0.0019	-0.0017	-0.0021	-0.0019	-0.002*	-0.0021
	0.0024	0.0017	0.0034	0.0040	0.0043	0.0011	0.0042
PI	0.1169^{+}						
	0.1635						
CC		0.2241^{+}					
		0.0668					
PS			0.1052^{+}				
			0.0084				
RQ				0.1673^{+}			
				0.0463			
RL					0.465		
					0.265		
VA						-0.0206	
						0.0284	
DEM							-0.031*
							0.0163
Const.	3.2029	3.2409^{+}	3.2097^{+}	3.2410^{+}	3.4246^{+}	4.213^{*+}	3.1694^{+}
	0.0614	0.0668	0.5811	0.5175	0.7479	0.834	0.5635
R^2	0.1435	0.1387	0.1360	0.1327	0.1653	0.1268	0.1267
F-Stat.	78.19	82.71	63.35	68.76	101.21	97.09	97.12
(P-value)	(0.003)	(0.003)	(0.0011)	(0.0014)	(0.001)	(0.0022)	(0.002)
Obs.	1680	1680	1680	1680	1680	1680	1680

Note: (+), (**) and (*) imply statistically significant at 1%, 5% and 10% significant levels respectively. The standard error is presented in parenthesis ( ). LTI is quality of land transport infrastructure. Source: Authors' computation

Table 9: Driscoll and Kraay Regression (dependent variables: QRO)

Var.	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
θ_{t-1}	0.013^{+}	0.015^{+}	0.015^{+}	0.012^{+}	0.016^{+}	0.016^{+}	0.015^{+}
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
FIT	-0.0022	-0.0016	-0.0024	-0.0023	-0.0011	-0.0013	-0.0015
	0.0015	(0.0015)	(0.0013)	(0.0013)	(0.0015)	(0.0014)	(0.0013)
NR	-0.013**	-0.013**	-0.013**	0.0138^{+}	-0.012**	-0.0126^{+}	-0.012**
	(0.0046)	(0.0044)	(0.0046)	0.0046	(0.0043)	(0.0042)	(0.0043)
UR_{t-1}	-0.0169^{+}	-0.0121^{+}	-0.0147^{+}	-0.0078^{+}	-0.007**	-0.008**	-0.006**
	(0.0025)	(0.0036)	(0.004)	(0.0024)	(0.0035)	(0.0041)	(0.003)
DBT	0.0157^{+}	0.0157^{+}	0.0163^{+}	0.0157^{+}	0.0163^{+}	0.0167^{+}	0.0162^{+}
	(0.0022)	(0.0024)	(0.0024)	(0.0022)	(0.0025)	(0.0025)	(0.0023)
CPS	0.0019*	0.003**	0.002**	0.002**	0.0029^{+}	0.0032^{+}	0.0029^{+}
	(0.0010)	(0.0008)	0.0009	(0.001)	(0.0009)	(0.0009)	(0.0009)
INF	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0005)
DOT	-0.0006	-0.0002	0.00012	-0.0005	-0.0004	-0.0004	-0.0004
	(0.0004)	(0.0005)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)
PI	0.1567^{+}						
	(0.0318)						
CC		0.322^{+}					
		(0.052)					
PS			0.1420^{+}				
			(0.0283)				
RQ				0.348^{+}			
				(0.0227)			
RL					0.667^{+}		
					(0.047)		
VA						-0.129	
						(0.1258)	
DEM							-0.09**
							(0.045)
Const.	3.5742^{+}	3.6319^{+}	3.5836^{+}	3.6784	3.8962^{+}	3.4596^{+}	3.5604^{+}
	(0.7271)	(0.841)	(0.9368)	(0.0293)	(0.9304)	(0.9418)	(0.9472)
R^2	0.1902	0.1868	0.1820	0.1876	0.1715	0.1746	0.1730
F-Stat.	118.49	171.40	134.12	137.49	163.49	161.97	142.05
(P-value)	(0.004)	(0.002)	(0.001)	(0.0011)	(0.003)	(0.002)	(0.0021)
Obs.	1680	1680	1680	1680	1680	1680	1680

Note: (+), (**) and (*) imply statistical significance at 1%, 5% and 10% significant levels respectively. The standard error is presented in parenthesis ( ). QRO is quality of road transport infrastructure. Source: Authors' computation

Table 10: Driscoll and Kraay Regression (dependent variables: QRA)

Var.	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
θ_{t-1}	0.012+	0.013+	0.013^{+}	0.014^{+}	0.011^{+}	0.013^{+}	0.014^{+}
	(0.001)	(0.001)	(0.002)	(0.013)	(0.002)	(0.001)	(0.002)
FIT	0.0034*	0.004**	0.0034	0.004**	0.0031	0.0041*	0.0043*
	(0.0017)	(0.0018)	(0.0019)	(0.0019)	(0.0019)	(0.0022)	(0.0023)
NR	-0.008**	-0.0087^{+}	-0.008**	-0.008**	-0.008**	-0.008**	-0.008**
	(0.0035)	(0.0034)	(0.0034)	(0.0033)	(0.0033)	(0.003)	(0.003)
UR_{t-1}	-0.039^{+}	-0.0367^{+}	-0.038^{+}	-0.0348^{+}	-0.038^{+}	-0.037**	-0.035^{+}
	(0.0078)	(0.0078)	0.0082	(0.0079)	(0.008)	(0.003)	(0.007)
DBT	0.0137^{+}	0.0138^{+}	0.0140^{+}	0.0141^{+}	0.013^{+}	0.0138^{+}	0.0141^{+}
	(0.0018)	(0.0018)	(0.0019)	(0.0018)	(0.0018)	(0.0018)	(0.0021)
CPS	0.0041^{+}	0.0044^{+}	0.0044^{+}	0.0046^{+}	0.0037^{+}	0.0044^{+}	0.0045^{+}
	(0.0008)	(0.0009)	0.0009	(0.0008)	(0.001)	(0.0008)	(0.0009)
INF	-0.0007*	-0.0007*	-0.0006*	-0.0007*	-0.001**	-0.0007*	-0.0007*
	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0003)	(0.004)	(0.0003)
DOT	-0.0033^{+}	-0.0037^{+}	-0.0035^{+}	-0.0038^{+}	-0.0037^{+}	-0.0038^{+}	-0.0038^{+}
	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
PI	0.077**						
	(0.0270)						
CC		0.126**					
		(0.059)					
PS			0.068**				
			(0.023)				
RQ				0.0142^{+}			
				(0.0713)			
RL					0.262		
					(0.0497)		
VA						0.088	
						(0.079)	
DEM							-0.0096^{+}
							(0.0022)
Const.	2.8317^{+}	2.8498	2.8359	2.8035	2.9531	2.8571^{+}	2.778^{+}
	(0.9214)	(0.8122)	(0.9216)	(0.8004)	(0.9267)	(0.9062)	(0.9200)
R^2	0.1339	0.1310	0.1311	0.1278	0.1381	0.1298	0.1299
F-Stat.	127.38	103.77	102.27	143.47	133.58	124.66	126.4
(P-value)	(0.002)	(0.002)	(0.0021)	(0.003)	(0.0011)	(0.002)	(0.004)
Obs.	1680	1680	1680	1680	1680	1680	1680

Note: (+), (**) and (*) imply statistically significant at 1%, 5% and 10% significant levels respectively. The standard error is presented in parenthesis (). QRA is quality of rail transport infrastructure.Source: Authors' computation

As reported in Tables 8, 9, and 10, the results of the socioeconomic variables are not statistically different from Table 7, but there are two notable scenarios. First, with the introduction of institutional factors, inflation and degree of trade openness become negatively significant under the road regression (Table 9) and rail regression (Table 10), with coefficient values of -0.001 and -0.0033 respectively. By implication, as developing countries become more open to the rest of the world, the quality of rail declines. Second, as reported in Table 10 (columns 2 and 4), the introduction of corruption control strategies and regulatory quality under rail regression saw foreign direct investment in transport (FIT) become positively significant. Similar to Nashizawa (2018), Conor and Daniel (2016) and the Asia Development Bank (ADB, 2017), show that the impact of foreign direct investment in the transport sector on the quality of rails depends on the strength of existing regulatory quality.

The index of institutional factors has a positive and significant impact on the quality of road and rail in developing countries. The coefficient for rail is less than for road. Perhaps this is not far from the fact that, aside from more resources being budgeted for roads than rail, institutional factors also address more issues revolving around roads than rail. Similar findings are reported by Hasselgren (2013), and Markovsek (2019). Control of corruption and political stability have a positive impact on the quality of roads and rail. The coefficients of both variables show that they have more on-road (0.3 and 0.14) than rail (0.12 and 0.068). It means fewer corruption cases and a more stable political atmosphere tends to promote better roads and rail. These findings align with Short and Kopp (2005), Marsh et al. (2018), and Jedwab et al.'s (2019) findings. Regulatory quality and rule of law are significant and have a positive impact on land transport infrastructure. Regulatory quality has more impact on roads than on rail. Similar findings are reported by Jedwab et al. (2019) and Caldron and Serven (2014). The rule of law has the highest impact on land (0.46) and roads (0.66) but is not significant under rail regression. The result under the road aligns with Jedwab et al.'s (2019) finding. Voice and accountability have negative signs, but not significant. The result under road regression differs; it is positively significant. The sign of the coefficient contradicts Lyvbjerg et al.'s (2004) findings but aligns with Galilea and Medda's (2010). There is evidence that the quality of road and rail transport in full-fledged or partially democratic developing countries is less than in full-fledged or partially authoritarian countries by 0.09 and 0.009, respectively (see Tables 9 and 10; column 7). This contradicts Galilea and Medda (2010) and Jedwab and Storeygard (2019). It further lends credence to Acemoglu's (2010) claim that inclusive growth is better in authoritarian countries than in democracies.

Further analysis

The study further estimated the second model to investigate whether economic and institutional factors jointly determine the quality of land transport infrastructure in developing countries. The results of interaction terms are presented in Table 11.

Table 11: Driscoll and Kraay Panel Regression (dependent variables: LTI[6], QRO and QRA)

VARIABLES[7]	LTI (I)	QRO (II)	QRA (III)
PI	0.3758⁺	0.1187⁺	0.0832**
	(0.0995)	(0.043)	(0.0401)
PNR	0.0124⁺	0.031**	0.3488
	(0.0044)	(0.0151)	(0.0193)
PFIT	-0.0080	-0.0228	-0.0161
	(0.0084)	(0.0255)	(0.0442)
PDBT	0.085**	0.0726**	0.0337
	(0.0411)	(0.0351)	(0.0212)
PDOT	-0.0009	-0.0489	-0.0632*
	(0.0008)	(0.0388)	(0.0344)
CONS	2.6429⁺	4.0283⁺	3.6673⁺
	(0.0485)	(0.8376)	(0.5837)
R^2	0.1738	0.1937	0.1774
F-Statistics	88.41	96.33	114.51
(P-value)	(0.0001)	(0.0004)	(0.0013)
Obs.	1680	1680	1680

Note: (+), (**) and (*) imply statistically significant at 1%, 5% and 10% significant levels respectively. The standard error is presented in parenthesis (). Source: Authors' computation

The interaction of the index of institutional factors and natural resources (PNR) has a positive sign across the three regressions. However, it is not significant under rail regression. The coefficient of road shows that better institutions in developing countries can transform the negative impact of natural resources on the

[6] LTI is quality of land transport infrastructure; QRO is quality of road transport infrastructure; QRA is quality of rail transport infrastructure.

[7] Quotient of index of institutional factors (PI) and selected economic variables (natural resource, foreign direct investment in transport, total debt (DBT), and trade openness (DOT).

quality of rail transport infrastructure (see Table 11 and Column 3). It further justifies the submission of Acemoglu et al. (2003 and 2010). Acemoglu revealed that developing countries are poor not because they lack much-needed resources, but because their institutions are too weak to drive development.

Interestingly, the interaction of institutions (PI) with foreign direct investment in transport (FIT) has a negative sign, though it is not significant. It reveals the weakness of institutions in developing countries. The interaction of institutions with debt has a positive impact on the quality of land transport infrastructure. When land transport infrastructure is disaggregated, there is clear evidence that debt and institutions jointly have a positive impact on the quality of roads but are not significant under rail. The interaction of institutions with the degree of trade openness is negative and not significant. The results of the four interaction terms show that institutions in developing countries remain weak and not sufficient to improve the quality of land transport infrastructure.

Conclusion and policy recommendations

This paper investigates the determinants of the quality of land transport infrastructure in developing countries. The study further disaggregates land transport into road and rail transport infrastructure, and as well investigates the role of institutions in moderating the impact of socioeconomic factors on the quality of land transport infrastructure. Data for 106 developing countries from 2007 to 2022, covering Africa, Asia, Latin America and the Caribbean, are sourced. The study found that socioeconomic factors are important determinants of the quality of land transport infrastructure in developing countries. It is also found that political institutions interface between socioeconomic factors and the quality of land transport.

The governments in developing countries must be intentional and consistent in investing a substantial percentage of their resource in building and maintaining quality roads and rail to close up the deficits in the next decade. The economic reality shows that ceding the funding of road and rail to the public sector only is no longer sustainable, the private sector must be involved strategically. Governments in developing countries need to strengthen the principle of the rule of law, and regulatory quality, and promote a politically stable environment. These will not only attract domestic investment but also foreign investment. In addition, these efforts will reduce the prevalence of rent-seeking while more resources can be channelled into the transport sector.

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