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GLOBAL TRANSPORTATION EXPENDITURE AND ECONOMIC PERFORMANCE: A COMPREHENSIVE ANALYSIS OF TRANSPORTATION EXPENDITURE'S IMPACT ON ECONOMIC DEVELOPMENT IN KEY GLOBAL ECONOMIES (1990-2023)

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Abstract

This study examines the relationship between transportation expenditure and economic performance across 41 countries over the period 1990–2023, highlighting the global role of transportation investment in economic development. Using descriptive statistics, correlation analysis, and hierarchical linear regression, the research investigates the association between gross domestic product (GDP) and multiple dimensions of transportation expenditure. The results indicate a strong positive relationship between GDP and total transportation expenditure, as well as passenger transportation expenditure, underscoring the close linkage between transportation investment and economic activity. In contrast, a significant negative relationship is observed between GDP and transportation expenditure as a share of GDP, suggesting that higher-income countries invest more in transportation in absolute terms while allocating a smaller proportion of national output to this sector, likely reflecting efficiency gains and economies of scale in mature transportation systems. Hierarchical regression results indicate that transportation expenditure is a statistically significant predictor of GDP, with the baseline model accounting for a substantial share of cross-country variation. The inclusion of relative expenditure measures yields modest additional explanatory power, with the second model providing the most stable specification by effectively mitigating multicollinearity. Overall, the findings emphasize the continued importance of sustained transportation investment, while highlighting differences in investment intensity across stages of economic development. For developing economies, strategic and efficient transportation investment remains critical for supporting long-term economic growth. The study contributes to the literature by offering a comprehensive, cross-national perspective on the scaling of transportation expenditure with economic performance and its implications for transportation policy and planning.

Keywords: Transportation Economics, GDP, transportation expenditure, econometric model, Hierarchical Linear Regression (HLR)

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INTRODUCTION

Transportation is a linchpin of the global economy, facilitating economic activity by connecting producers with raw materials, markets, and consumers, and constituting a major economic sector (Washington et al., 2020). The strong interdependence between transportation, production, and consumption makes transportation activity a valuable indicator of overall economic performance (Yousefi et al., 2023). As a result, the transportation sector plays a critical role in economic development, particularly within an increasingly globalized economy where growth prospects are closely tied to the efficient movement of people, freight, and information (Alstadt et al., 2012; Harmatuck, 1991). A well-established body of literature demonstrates a clear relationship between the quality and quantity of transport infrastructure and levels of economic development, with robust and well-connected transportation networks consistently associated with higher productivity and regional competitiveness (Ivanova, 2003; De Palma et al., 2011). Efficient transportation systems generate positive multiplier effects by improving market accessibility, supporting employment growth, and attracting additional investment, whereas inadequate or unreliable systems impose economic costs through congestion, lost productivity, and reduced quality of life (Kessides, 1993).

At the macroeconomic level, transportation's contribution to output, employment, and income is substantial. In developed economies, transportation activities typically account for approximately 6%–12% of gross domestic product (GDP), while logistics costs, including transportation, may account for 6%-25% of GDP. Moreover, the total value of transportation assets, encompassing infrastructure and vehicle fleets, can approach nearly half of GDP in advanced economies (World Bank; OECD). These figures highlight transportation's central role in sustaining national economic systems.

At the microeconomic level, transportation significantly influences production, consumption, and distribution costs across sectors. The economic impact of transportation infrastructure varies by industry, with higher-income economies generally exhibiting a greater share of transportation-related expenditures within household consumption (Gao et al., 2016). On average, households allocate approximately 10%–15% of total expenditures to transportation, while transportation costs account for roughly 4% of manufacturing output, although this share differs substantially across sub-sectors (Weisbrod & Reno, 2009). Together, these macro- and microeconomic perspectives underscore the pervasive influence of transportation systems on economic structure, efficiency, and development outcomes.

LITERATURE REVIEW

Commissioner of Building (COB)

Transportation economics is a multidisciplinary field concerned with the allocation and utilization of resources within transportation systems and their interaction with economic outcomes (Washington et al., 2020; De Palma et al., 2011). At its core, the discipline emphasizes the efficient allocation of limited resources to maximize societal welfare, with transportation infrastructure and services forming the supply side and the mobility needs of households, firms, and trade activities representing the demand side (Washington et al., 2020).

Transportation infrastructure investment has long been recognized as a fundamental driver of economic growth. Foundational studies have documented a positive relationship between transport infrastructure development and economic productivity, establishing transportation investment as a critical component of regional and national development strategies (Ivanova, 2003; De Palma et al., 2011). From a public policy perspective, understanding the marginal utility of additional transportation investment, identifying optimal geographic and modal allocation, and developing mechanisms to quantify the transportation sector's contribution to gross domestic product (GDP) are essential for informed decision-making (National Academies of Sciences, Engineering, and Medicine, 2002; Alstadt et al., 2012).

The importance of transportation to economic activity predates globalization, as transportation has historically served as a prerequisite for trade by enabling the movement of goods, people, and information. While the fundamental role of transportation has remained unchanged, its scale, capacity, speed, and efficiency have evolved in response to economic expansion and structural transformation, giving rise to new trade corridors and circulation patterns (Kessides, 1993; *The Geography of Transport Systems*).

Despite broad theoretical consensus on the role of transportation infrastructure in economic performance, empirical evidence remains mixed. Prior studies report heterogeneous results across regions and methodological frameworks, leading to continued debate regarding the magnitude and direction of transportation's economic impacts (Gao et al., 2016). To address this complexity, Limani (2016) adopted a mixed-methods approach combining qualitative insights with quantitative analysis to examine contextual and empirical dimensions of the transportation–economy relationship.

Advances in data availability have enabled recent studies to leverage large-scale transportation big data to better capture mobility patterns and regional economic activity. Li et al. (2020), using approximately 3.5 billion highway toll records in China, demonstrated that transportation network characteristics derived from complex network metrics and traffic flow indicators explain a substantial share of variation in city-level GDP. Their findings further revealed

temporal changes in distance-decay effects, reflecting evolving spatial interaction patterns associated with regional economic development.

A wide range of econometric approaches have been employed to analyze the linkages between transportation and economic growth. These include production and cost function models (Bröcker, 2004; Harmatuck, 1991), cross-sectional and panel data analyses (Berechman et al., 2006; Boopen, 2006), and dynamic time-series models such as Vector Autoregressive (VAR) and Vector Error Correction (VEC) frameworks, which capture both short-run adjustments and long-run equilibrium relationships (Kulshreshtha et al., 2001; Koo et al., 2013).

At more disaggregated levels, studies have shown that transportation capital enhances economic performance by improving technical efficiency and facilitating freight movement. Berechman et al. (2006) found that both the quality and quantity of highway infrastructure significantly contribute to economic growth across U.S. states and local jurisdictions. Similarly, Wang and Shi (2012) demonstrated that truck freight demand can be effectively modeled using traffic volumes and socioeconomic indicators, underscoring the close linkage between freight activity and regional economic structure. Additional freight-focused analyses further support the strong association between transportation demand and economic indicators (Yousefi et al., 2023).

From a broader policy perspective, public transportation investment has been shown to generate substantial economic benefits, including employment, income, and business productivity (Weisbrod & Reno, 2009). At the international scale, panel data studies confirm a long-run causal relationship between transport infrastructure development and economic growth, even after controlling institutional and socioeconomic factors (Cigu et al., 2018). Evidence from China similarly indicates that land and water transport infrastructure play a significant role in regional economic growth, while spatial disparities and threshold effects contribute to uneven development outcomes (Hong et al., 2011).

Despite the extensive body of literature examining the relationship between transportation systems and economic performance, several important gaps remain. First, much of the existing empirical work focuses on specific regions, individual countries, or single transportation modes, limiting the generalizability of findings across diverse economic contexts. Second, many studies rely on infrastructure stock measures or disaggregated demand indicators, whereas relatively few systematically evaluate transportation expenditure as a comprehensive, comparable measure of investment intensity across countries. Third, although recent studies have employed advanced econometric techniques and large-scale transportation data, challenges related to scale effects, multicollinearity, and the interaction between absolute investment levels and relative expenditure shares persist, particularly in cross-national settings.

Moreover, existing research often emphasizes either macroeconomic or microeconomic impacts in isolation, with limited integration of both perspectives within a unified analytical framework. To address these gaps, this study provides a global, longitudinal analysis of transportation expenditure and economic performance across 41 countries from 1990–2023. By employing a hierarchical econometric framework and explicitly examining both absolute transportation expenditures and expenditure relative to GDP, this paper offers new insights into how transportation investment scales with economic development.

ECONOMETRIC MODEL AND DATA SOURCE

The economic indicators used in this study were sourced from reliable, authoritative sources, specifically the World Bank and the Organization for Economic Cooperation and Development (OECD), both of which referenced data from 2023. The World Bank served as a key data repository, providing essential variables, including demographic data and gross domestic product (GDP). The OECD, a reputable economic organization, complemented this dataset by providing valuable information on performance indicators, including the share of road infrastructure investment in total inland transport infrastructure investment, road infrastructure investment per GDP, total inland transport infrastructure investment, and road infrastructure investment and maintenance spending.

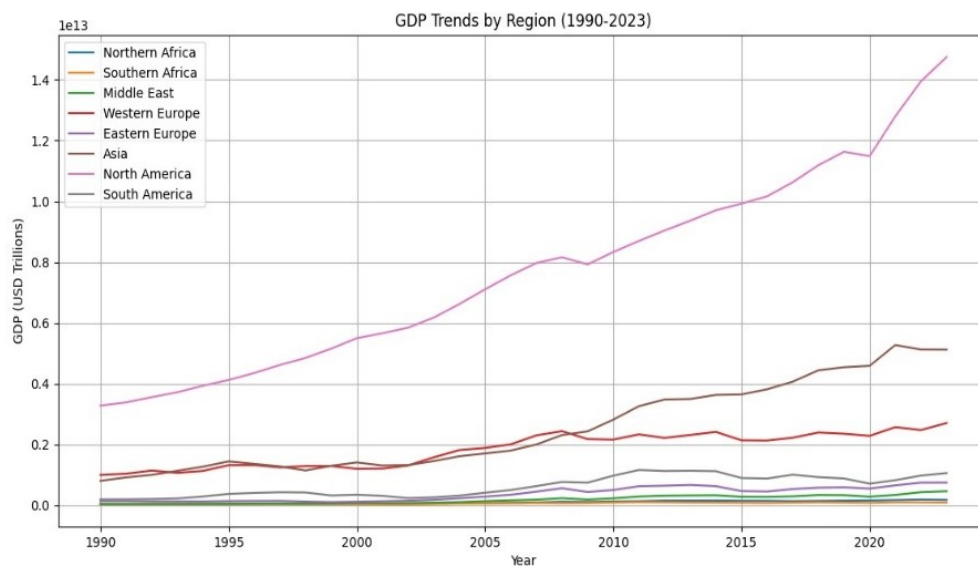


Figure 1: GDP trend by region 1990-2023

Figure 1 depicts the GDP trends of various regions from 1990 to 2023, with the y-axis representing GDP in USD trillions and the x-axis representing the years. The data shows that North America experienced the most significant GDP growth, particularly after the early 2000s, followed by Asia with a similar upward trend. Western and Eastern Europe displayed steady but moderate growth. In contrast, Northern Africa, Southern Africa, the Middle East, and South America had relatively lower GDP values with slight increases over time.

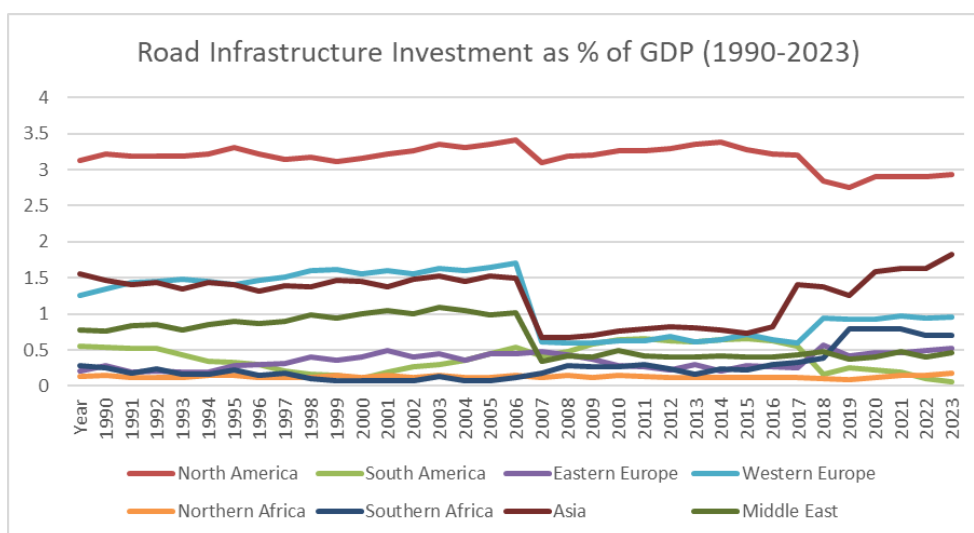


Figure 2: Road infrastructure investment as a percentage of GDP

Figure 2 illustrates regional investment trends in road infrastructure relative to GDP from 1990 to 2022. North America consistently leads in investment, allocating around 3% to 3.5% of its GDP to road infrastructure. Western Europe shows notable fluctuations, with significant peaks around 2007, 2010, and 2015. In contrast, Eastern Europe and South America maintain relatively steady investments, generally between 0.5% and 1.5% of GDP. Northern Africa and Southern Africa have lower investment levels, typically below 1%, while the Middle East and Asia show slight increases over time.

ECONOMIC IMPACT AND CORRELATION ANALYSIS OF TRANSPORTATION EXPENDITURE: A GLOBAL PERSPECTIVE (1990-2023)

The study aims to provide a comprehensive analysis of how investments in transportation infrastructure influence economic growth across key global economies. To investigate the economic ramifications of transportation

infrastructure expenditures, it is imperative to employ a statistical methodology that accounts for unobserved heterogeneity across countries. Historically, the predominant econometric framework utilized for assessing the economic impact of transportation infrastructure, whether within counties, states, or countries, has been Ordinary Least Squares (OLS) regression (*Berechman et al., 2006*)

While OLS regression is a general linear modeling technique, Hierarchical Linear Regression is an extension of linear regression that is specifically designed to handle data with a hierarchical or nested structure. In HLR, the data are organized into multiple levels or clusters, and the model allows for variation across these levels (Boopen, 2006).

A sequence of hierarchical linear regression models is systematically developed, with predictors introduced progressively to assess their individual and collective impact on the dependent variable, namely economic indicators. This hierarchical approach ensures a methodical examination of how each variable influences the overall model. Table 1 displays the descriptive statistics for the chosen variables across 41 countries from (1990-2023):

Table 1: Descriptive analysis

Descriptive Statistics		
	Mean	Std. Deviation
GDP (USD trillion)	56032.6818	39837.73153
Transportation Expenditure (USD billion)	4464.9091	3034.47132
Transportation Expenditure as a Percentage of GDP	.083045	.0060117
Passenger Transportation	2786.2273	1854.71037
Freight Transportation	1678.6818	1183.18539

The data encompass the entire global landscape and specifically focus on these four largest countries, revealing significant economic and transportation expenditure patterns. The mean Global GDP is 56032.6818, with a substantial standard deviation of 39837.73153, highlighting considerable variability across countries.

Table 2: Correlation Analysis of Key Economic and Transportation Indicators Across
 Selected Countries

Correlations						
		GDP (USD trillion)	Transportation Expenditure (USD billion)	Transportation Expenditure as a Percentage of GDP	Passenger Transportation	Freight Transportation
GDP (USD trillion)	Pearson Correlation	1	.999**	-.790**	.998**	.997**
	Sig. (2- tailed)		.000	.000	.000	.000
Transportation Expenditure (USD billion)	Pearson Correlation	.999**	1	-.769**	.999**	.998**
	Sig. (2- tailed)	.000		.000	.000	.000
Transportation Expenditure as a Percentage of GDP	Pearson Correlation	-.790**	-.769**	1	-.753**	-.790**
	Sig. (2- tailed)	.000	.000		.000	.000
Passenger Transportation	Pearson Correlation	.998**	.999**	-.753**	1	.995**
	Sig. (2- tailed)	.000	.000	.000		.000
Freight Transportation	Pearson Correlation	.997**	.998**	-.790**	.995**	1
	Sig. (2- tailed)	.000	.000	.000	.000	
**. Correlation is significant at the 0.01 level (2-tailed).						

The intricate relationships within the transportation sector, along with key economic indicators, yield compelling insights. A notably robust positive correlation of 0.999 is observed between a nation's Gross Domestic Product (GDP) and its total transportation expenditure, indicating that wealthier countries make a greater commitment to transportation investments. Similarly, a substantial positive correlation of 0.998 is observed between GDP and passenger transportation expenditure, indicating a consistent trend in which affluent nations prioritize facilitating passenger movement. The relationship between passenger and freight transportation expenditures exhibits a strong positive correlation of

0.995, suggesting potential interdependence driven by shared infrastructure or logistical networks.

Conversely, intriguing negative correlations emerge, providing nuanced perspectives on economic dynamics. A strong negative correlation of -0.790 is identified between GDP and the percentage of GDP allocated to transportation. This paradoxical finding implies that more prosperous nations, while investing more in absolute terms, allocate a smaller share of their GDP to transportation, potentially due to economies of scale or increased efficiency in transportation systems. Additionally, a moderate negative correlation of -0.753 is evident between the percentage of GDP devoted to transportation and the portion allocated specifically to freight. This implies that countries with larger transportation budgets, relative to their GDP, tend to prioritize passenger movement over freight.

Table 3: Hierarchical Linear Regression Analysis for the Impact of Transportation Expenditure on Economic Indicators

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. Change
1	.999a	.998	.997	2033.48161	.998	8039.869	1	20	.000
2	.999b	.999	.999	1480.02192	.001	18.755	1	19	.000
3	1.000c	.999	.999	1322.05334	.000	5.812	1	18	.027
a. Predictors: (Constant), Transportation Expenditure (USD billion)									
b. Predictors: (Constant), Transportation Expenditure (USD billion), Transportation Expenditure as a Percentage of GDP									
c. Predictors: (Constant), Transportation Expenditure (USD billion), Transportation Expenditure as a Percentage of GDP, Freight Transportation									

Table 3 presents the hierarchical linear regression results, showing that transportation expenditure is a powerful predictor of economic indicators, with the first model explaining 99.8% of the variance in the dependent variable. Adding transportation expenditure as a percentage of GDP in the second model increases the explanatory power slightly to 99.9%, though the improvement is minimal. The final model, which includes freight transportation, maintains a perfect R value of 1.000 and an R squared of 0.999, indicating that while freight transportation contributes additional explanatory value, the overall impact is modest.

Table 4: ANOVA Summary for Hierarchical Linear Regression Models Predicting GDP (USD billion)

ANOVA(a)						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	33245240969.523	1	33245240969.523	8039.869	.000b
	Residual	82700949.249	20	4135047.462		
	Total	33327941918.773	21			
2	Regression	33286323086.022	2	16643161543.011	7598.004	.000c
	Residual	41618832.751	19	2190464.882		
	Total	33327941918.773	21			
3	Regression	33296481068.071	3	11098827022.690	6350.079	.000d
	Residual	31460850.702	18	1747825.039		
	Total	33327941918.773	21			
a. Dependent Variable: GDP (USD trillion)						
b. Predictors: (Constant), Transportation Expenditure (USD billion)						
c. Predictors: (Constant), Transportation Expenditure (USD billion), Transportation Expenditure as a Percentage of GDP						
d. Predictors: (Constant), Transportation Expenditure (USD billion), Transportation Expenditure as a Percentage of GDP, Freight Transportation						

Across all models, the F-statistics for the regression effects exhibit highly significant p-values ($p < 0.000$), underscoring the statistical importance of the selected predictors in influencing the dependent variable, GDP. This robust statistical significance substantiates that the observed associations between transportation variables and GDP are highly unlikely to occur by chance.

Comparing the various models reveals nuanced insights into the interplay between predictors and model performance. Incremental additions of predictors yield marginal increases in the F-statistic and associated significance levels, suggesting that the core relationship between transportation expenditure and GDP is effectively captured by the initial model. Notably, Model 2, incorporating Transportation Expenditure and Expenditure as a Percentage of GDP, strikes a commendable balance between explanatory power and model simplicity, yielding a substantial F-statistic without introducing excessive predictors.

Table 5: Coefficients and Significance Levels

Coefficients ^a								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1521.29	121.43		-3.441	.001		
	Transportation Expenditure (USD billion)	0.1	.1248	.999	310.542	.000	1.000	1.000
2	(Constant)	1496.92	340.267		-6.301	.000		

	Transportation Expenditure (USD billion)	0.14356	.064	1.018	202.570	.000	.492	2.032
	Transportation Expenditure as a Percentage of GDP	1094.59	40.591	.026	5.130	.000	.492	2.032
3	(Constant)	1468.78	339.160		-6.083	.000		
	Transportation Expenditure (USD billion)	0.11	.995	1.162	14.994	.000	.002	495.055
	Transportation Expenditure as a Percentage of GDP	1177.03	40.172	.026	5.268	.000	.491	2.036
	Passenger Transportation	0.02	2.431	-.243	-1.870	.064	.002	491.976
a. Dependent Variable: GDP (USD trillion)								

Among the hierarchical regression models analyzed, Model 2 emerges as the most robust and insightful. This model incorporates both Transportation Expenditure (USD billion) and Transportation Expenditure as a Percentage of GDP, delivering a balanced approach that enhances explanatory power while managing complexity. The coefficient for Transportation Expenditure (USD billion) is notably significant with a t-value of 202.570 and a coefficient of 0.14356, indicating a strong positive relationship with GDP. Additionally, the inclusion of Transportation Expenditure as a Percentage of GDP further refines the model, with a coefficient of 1094.59 and a t-value of 5.130, demonstrating its significant contribution to explaining variations in GDP. Despite moderate collinearity (Tolerance = 0.492, VIF = 2.032), Model 2 effectively balances predictive accuracy and model simplicity, avoiding the severe multicollinearity issues observed in Model 3.

Table 6: Excluded variables.

Excluded Variables ^a							
Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
					Tolerance	VIF	Minimum Tolerance
1 Transportation Expenditure as a Percentage of GDP	-.055 ^b	-4.331	.000	-.705	.409	2.443	.409
Passenger Transportation	-.196 ^b	-.658	.519	-.149	.001	695.780	.001
Freight Transportation	.125 ^b	.658	.519	.149	.004	283.156	.004

2	Passenger Transportation	.579 ^c	2.411	.027	.494	.001	1101.544	.001
	Freight Transportation	-.370 ^c		.027	-.494	.002	448.286	.002
			2.411					
3	Passenger Transportation	. ^d	.	.	.	.000	.	.000
a. Dependent Variable: GDP (USD trillion)								
b. Predictors in the Model: (Constant), Transportation Expenditure (USD billion)								
c. Predictors in the Model: (Constant), Transportation Expenditure (USD billion), Transportation Expenditure as a Percentage of GDP								
d. Predictors in the Model: (Constant), Transportation Expenditure (USD billion), Transportation Expenditure as a Percentage of GDP, Freight Transportation								

Table 6 illustrates the exclusion of certain variables from the hierarchical regression models due to their impact and collinearity. In Model 1, Transportation Expenditure as a Percentage of GDP is excluded due to its significant negative partial correlation (-0.705) and moderate collinearity (VIF = 2.443). Passenger Transportation and Freight Transportation are also excluded due to severe collinearity, with extremely high VIF values (695.780 and 283.156, respectively), rendering their individual contributions ambiguous. In Model 2, both Passenger Transportation and Freight Transportation are excluded despite their significant effects, due to their severe multicollinearity (VIFs of 1101.544 and 448.286). By Model 3, Passenger Transportation is omitted, likely due to its redundancy or problematic collinearity. The econometric model, based on the results provided above, can be expressed as follows:

$$GDP = 1496.92 + 0.10 * Transportation\ Expenditure + 1094.59 * Transportation\ Expenditure\ as\ a\ Percentage\ of\ GDP$$

Table 7: Collinearity Diagnostics

Collinearity Diagnostics							
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	Transportation Expenditure (USD billion)	Transportation Expenditure as a Percentage of GDP	Freight Transportation
1	1	1.833	1.000	.08	.08		
	2	.167	3.314	.92	.92		
2	1	2.757	1.000	.00	.01	.00	
	2	.242	3.377	.00	.36	.00	
	3	.001	54.293	1.00	.63	1.00	
3	1	3.622	1.000	.00	.00	.00	.00
	2	.376	3.103	.00	.00	.00	.00
	3	.001	56.028	.38	.11	.35	.08
	4	.000	112.834	.61	.89	.65	.92
a. Dependent Variable: GDP (USD trillion)							

Table 7 highlights the collinearity diagnostics for the models, revealing that Model 2 manages collinearity most effectively. In this model, the first dimension shows an eigenvalue of 2.757 and a condition index of 1.000, with minimal variance proportions across predictors, indicating that collinearity is relatively well-controlled. The second dimension's condition index of 3.377 suggests some collinearity, but it is not severe, with Transportation Expenditure (USD billion) accounting for only a modest proportion of the variance. The third and fourth dimensions exhibit higher condition indices, reflecting potential multicollinearity concerns, particularly in the context of Transportation

From a theoretical perspective, transportation expenditure can be interpreted as an investment in productive public capital that enhances economic output by expanding network capacity, improving accessibility, and reducing generalized transportation costs. The strong associations observed in the hierarchical regression results are therefore consistent with infrastructure-as-capital arguments, which hold that improved connectivity facilitates labor mobility, market access, and freight efficiency, thereby leading to higher aggregate productivity.

CONCLUSION AND RECOMMENDATIONS

This study provides strong empirical evidence of a close association between transportation infrastructure investment and economic performance, as demonstrated through hierarchical linear regression analysis. The results reveal a consistently strong positive relationship between gross domestic product (GDP) and both total transportation expenditure and passenger transportation expenditure, highlighting the central role of transportation systems in supporting economic activity. Higher-income countries exhibit substantially greater absolute investment in transportation infrastructure, reflecting the strategic importance assigned to transportation in sustaining economic productivity. At the same time, the observed negative relationship between GDP and transportation expenditure as a share of GDP indicates that more affluent economies tend to allocate a smaller proportion of national output to transportation, a pattern that is consistent with efficiency gains and economies of scale in more mature transportation systems.

The regression results further indicate that transportation expenditure is a statistically significant predictor of economic performance, with the baseline model accounting for a very large share of the variation in GDP across countries. The inclusion of additional explanatory variables, such as transportation expenditure relative to GDP and freight transportation, yields only marginal improvements in model performance. Among the alternative specifications, the second model offers the most stable and interpretable results, effectively addressing multicollinearity concerns while preserving explanatory power. These

findings suggest that the core relationship between transportation investment and economic output is robust across model specifications.

From a policy perspective, the results underscore the continued importance of transportation infrastructure investment as a key component of economic development strategies. While wealthier economies may benefit from efficiency gains that reduce the relative investment burden, sustained attention to transportation funding remains essential to maintaining system performance and supporting long-term growth. For developing and emerging economies strategic and well-targeted transportation investments are critical to enhancing connectivity, improving productivity, and fostering durable economic development. Overall, this study highlights the need for a balanced investment approach that combines adequate financial commitment with efficient allocation to maximize the economic returns of transportation infrastructure.

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