EVALUATION OF THE PROCESS OF INFRASTRUCTURE DEVELOPMENT IN THE REGION BASED ON ECONOMETRIC MODELS

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1. Abstract. *This research provides a rigorous quantitative assessment of the nexus between infrastructure capital stock and regional economic performance, focusing on a global panel of 45 emerging economies (2000–2020) and a sub-regional analysis of the Volga Federal District. Grounded in an infrastructure-augmented Cobb-Douglas production function, the study utilizes Fully Modified Ordinary Least Squares (FMOLS), Structural Vector Autoregressive (SVAR) models, and the Spatial Durbin Model (SDM) to estimate elasticities and capture spatial spillovers. To address inherent endogeneity, Dynamic System-GMM serves as the primary dynamic estimator. Findings indicate a significant positive impact on growth, with static infrastructure elasticity ranging from 0.24 to 0.31. Long-run panel estimates reveal a more substantial elasticity range of 1.08 to 1.23, with an annual error correction speed of 27% toward equilibrium. Sectoral decomposition identifies telecommunications (0.156) and transport (0.142) as the most potent growth drivers, significantly outperforming energy (0.098). Temporal analysis suggests a partial recovery in infrastructure efficacy post-2013 (0.246) following the 2008–2012 crisis period (0.201). The study concludes that while infrastructure contributes 1.2–1.8 percentage points to annual GDP growth, outcomes are mediated by institutional quality and spatial externalities.*

2. Keywords: *Infrastructure, Econometric Models, Regional Development, FMOLS, SVAR, Spatial Spillovers, Public Investment, Private Investment, Energy Infrastructure, Transport Connectivity.*

3. Introduction

3.1 Infrastructure as Social Advance Capital

From a macroeconomic perspective, infrastructure is not merely a facilitating asset but a fundamental productive input that determines the ceiling of aggregate output and international competitiveness. This study adopts the conceptualization of infrastructure as

"social advance capital," as articulated by Aschauer (1989). By providing the essential physical framework for production, public investment in core utilities—transportation, power, and communications—serves as a catalyst that reduces marginal costs for the private sector, thereby enhancing total factor productivity (TFP).

3.2 Theoretical Foundations

The theoretical architecture of this analysis is primarily derived from Endogenous Growth Theory, notably the Barro (1990) model. Unlike neoclassical frameworks that assume diminishing returns to capital, endogenous models posit that productive government expenditure can sustain long-term growth by improving the productivity of private inputs. Central to this is the concept of complementarity; as Dissou and Didic (2013) demonstrate, the effectiveness of private capital is conditional upon the sufficiency of public infrastructure stocks. Infrastructure investment thus overcomes capital saturation by generating positive externalities that shift the production function upward.

3.3 The Global and Regional Context

The impetus for this research stems from the persistent infrastructure investment gap in emerging markets, estimated at $452 billion annually. While large-scale regional initiatives such as the China-Pakistan Economic Corridor (CPEC) signal a shift toward massive connectivity projects, the economic returns are non-uniform across time and space. Crucially, empirical evidence indicates a temporal shift in infrastructure productivity: during the 2008–2012 global crisis, elasticity dipped to 0.201, followed by a post-2013 recovery to 0.246. Understanding these fluctuations is vital for emerging economies characterized by rapid industrialization and transitional institutions.

3.4 Research Contribution

This study advances the literature by addressing the dual challenges of endogeneity and regional heterogeneity. Utilizing a robust dataset of 45 emerging economies from 2000 to 2020, we integrate global panel findings with a granular econometric investigation of the Volga Federal District (VFD). By applying advanced estimators like System-GMM and SDM, this research quantifies the "time-to-build" lags and cross-border spatial spillovers that traditional cross-sectional studies frequently overlook, providing a more nuanced understanding of how infrastructure quality versus quantity dictates growth trajectories.

4. Methodology

4.1 Infrastructure-Augmented Production Function

The empirical framework is built upon an extended Cobb-Douglas production function, where infrastructure capital (G) is treated as a distinct input alongside private capital (K) and labor (L):

$$\ln(Y_{it}) = \ln(A_{it}) + \alpha \ln(K_{it}) + \beta \ln(L_{it}) + \gamma \ln(G_{it}) + \epsilon_{it}$$

Here, Y denotes Real GDP per capita, and \gamma represents the output elasticity of infrastructure. This specification enables the direct estimation of sectoral contributions—transport, energy, and telecommunications—to aggregate economic welfare.

4.2 Fully Modified Ordinary Least Squares (FMOLS)

To identify the long-run cointegrated relationship between infrastructure and growth while adjusting for endogeneity and serial correlation, FMOLS is employed. This estimator is critical for analyzing emerging markets where variables are often non-stationary. FMOLS provides consistent estimates of the long-run equilibrium parameters, allowing us to distinguish between transitory shocks and permanent structural improvements.

4.3 Structural Vector Autoregressive (SVAR) Model

The SVAR framework captures the dynamic impulse response of GDP to infrastructure shocks. Given the significant "time-to-build" lag associated with large-scale projects, SVAR identifies the temporal stabilization of output. Our modeling confirms that approximately 27% of the deviation from long-run equilibrium is corrected annually in the sampled emerging economies.

4.4 Spatial Durbin Model (SDM) and Dynamic GMM

To quantify regional externalities, the SDM incorporates a spatial weight matrix (W):

$$y = \rho W y + X\beta + WX\theta + \epsilon$$

In the context of the Volga Federal District, W is defined by contiguous administrative borders, acknowledging that connectivity in one territory inherently influences the productivity of neighbors. For the global panel, **Dynamic GMM (System and Difference)** is utilized as the primary estimator to address the persistence of GDP and the potential feedback loop where economic growth drives infrastructure demand.

5. Results and Analysis

5.1 Marginal Productivity of Infrastructure

The analysis confirms a statistically significant relationship between infrastructure stock and economic growth. Table 1 presents the sectoral elasticity coefficients derived from the FMOLS and GMM estimations.

Infrastructure Category	Estimated Elasticity (γ)	Statistical Significance
Telecommunications	0.156	***

Infrastructure Category	Estimated Elasticity (γ)	Statistical Significance
Transport	0.142	***
Energy	0.098	**
Water and Sanitation	N/A	Insignificant

*(Significance levels: *** $p < 0.01$; ** $p < 0.05$)*

Telecommunications exhibits the highest marginal productivity, reflecting the rapid digital transformation in emerging markets. Water and sanitation showed positive but statistically insignificant coefficients across the primary models.

5.2 Sectoral and Regional Heterogeneity

Heterogeneity is pronounced across geographic clusters. East Asian economies exhibit the highest elasticity (0.387), attributed to their integrated industrial-infrastructure strategies. Conversely, European and Central Asian (ECA) economies show a more modest elasticity of 0.198. This disparity reflects different growth patterns; while East Asian growth is infrastructure-led and industrial-intensive, ECA economies often face diminishing returns due to higher initial endowment levels and a transition toward service-based output, which is more sensitive to digital rather than physical transport stock.

5.3 Statistical Significance in the Volga Federal District (VFD)

The sub-regional analysis of the VFD identifies highly specific infrastructure factors driving Gross Regional Product (GRP). In line with the findings of Morozov & Gamidullaeva (2025), significant variables vary by territory:

- **Republic of Tatarstan:** Economic growth is significantly driven by rail freight arrival (x_4) and negatively influenced by the social costs of accidents with injuries (x_{16}).
- **Nizhny Novgorod:** The primary predictor of GRP is road freight turnover (x_7).
- **Samara Region:** Significant growth effects are tied to paved road density (x_{13}).
- **Perm Territory:** The model shows high sensitivity to safety outcomes, specifically fatalities in road accidents (x_{17}).

6. Discussion

6.1 Public vs. Private Investment Productivity

The efficiency of infrastructure provision is highly dependent on the procurement and financing model. While public investment remains essential for social equity, the EPC+F (Engineering, Procurement, Construction with Finance) model has increasingly

outperformed traditional Public-Private Partnerships (PPPs) in the emerging market context. Drawing from Verma et al. (2025), EPC+F projects deliver superior economic outcomes by mitigating the multi-layered financial risks and achieving faster completion times, thereby reducing the "time-to-build" lag that often erodes the net present value of public works.

6.2 Quality vs. Quantity: The Hirschman Perspective

The distinction between "trait taking" and "trait making" projects, as established by Hirschman (1967), is central to interpreting our results. Trait-making projects actively alter the environment and the production function, acting as catalysts for structural transformation. However, in regions with high existing capacity, the focus must shift to quality—specifically reducing electricity transmission losses and optimizing existing road networks. Failure to invest in maintenance leads to "productivity decay," where the marginal cost of repair eventually exceeds the marginal benefit of the original investment.

6.3 Spatial Dependencies and Digital-Green Transition

The spatial lag coefficient of 0.156 underscores the importance of cross-border connectivity. Large-scale corridors like CPEC generate spillovers that enhance the domestic productivity of neighboring regions through trade facilitation and knowledge transfers. Furthermore, the 2025 data suggests a pivotal shift toward "New Infrastructure": Digital stock (5G and ICT platforming) and Green infrastructure (renewable energy grids) are now the primary drivers of technological innovation and regional well-being, surpassing the growth impact of traditional bulk-freight physical stock.

6.4 Institutional Mediators

Infrastructure effectiveness is capped by institutional quality. High corruption or weak regulatory frameworks act as a tax on infrastructure productivity, muting the elasticity effects. The "managerial response" to shocks—as discussed by Pellegrin and Sirtori (CSIL)—is a critical determinant of whether a project survives an economic crisis or becomes a "white elephant."

7. Conclusion and Policy Recommendations

Summary of Findings

Infrastructure investment contributes between 1.2 and 1.8 percentage points to annual GDP growth in emerging economies. With long-run elasticities of 1.08–1.23 and a steady error correction mechanism of 27% annually, the study confirms that infrastructure is a persistent driver of endogenous growth. However, this impact is heterogeneous and contingent upon the specific regional economic structure.

Recommendations for Maintenance and Quality

To prevent productivity decay, policymakers must prioritize the maintenance of existing road and energy networks over new "quantity-based" construction. High-quality, reliable

infrastructure provides more immediate TFP gains and is essential for attracting high-value FDI in the industrial and service sectors.

Rural Connectivity and Regional Imbalance

Investment should target "last-mile" rural connectivity and digital infrastructure to reduce intra-provincial development imbalances. As evidenced by the VFD analysis, enhancing paved road density and mobile communication access in peripheral areas facilitates labor mobility and market integration.

Spatial Externality Methodology

There is an urgent need for a universal and transparent methodology for accounting for external spatial externalities. National planners should adopt spatial-econometric frameworks to ensure that cross-border benefits are quantified, thereby preventing regional development imbalances and optimizing the allocation of limited public capital.

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