Evaluating the Capital Expenditure and Infrastructure-Led Development in India: A Sectoral ARDL Approach

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by

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CERTIFICATE

This is to certify that we have examined the thesis entitled "**Evaluating the Capital Expenditure and Infrastructure-Led Development in India: A Sectoral ARDL Approach**", submitted by **Aayush Jitendra Kumar** (**20HS20002**) is a record of bonafide work performed by him in the **Department of Humanities and Social Sciences**, Indian Institute of Technology, Kharagpur under my supervision and guidance for partially fulfilling the requirements for the award of the degree of **Integrated MSc** in **Economics**. We hereby accord our approval of it as a study carried out and presented in a manner required for its acceptance in partial fulfilment of the Integrated MSc degree for which it has been submitted. The thesis has fulfilled all the requirements per the Institute's regulations and has reached the standard needed for submission.

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ABSTRACT

This study analyses capital expenditure (capex) trends across Indian ministries from 2000 to 2022, primarily focusing on physical infrastructure sectors such as railways, roads, and telecommunications. Using historical data, econometric modelling, and synthetic data generation, this study identifies direct drivers (internal revenue, centrally sponsored schemes, debt servicing, PSU support) and indirect factors (GDP growth, fiscal deficit, sectoral performance, political cycles) influencing budgetary allocations. The findings reveal significant disparities in capex growth, with physical infrastructure ministries like Railways, Roads, and Telecom leading the expansion, while others remain stagnant. Macroeconomic conditions and election cycles are shown to have a substantial impact on spending decisions. The study offers a practical framework for optimising public investment, emphasising the importance of targeted sectoral spending, fiscal discipline, and strategic alignment to maximise economic and social benefits.

Keywords: Government expenditure · Economic development · Public investment · GDP · Social welfare · Capital expenditure · Macroeconomic conditions · Direct Drivers · Indirect Factors

Contents

1 Introduction

India's fiscal policy serves as a cornerstone of its broader economic strategy, carefully balancing the twin objectives of stimulating economic activity and maintaining fiscal discipline. Over the years, fiscal policy has played a pivotal role in shaping India's developmental path, particularly through its influence on public spending and resource allocation. Among the various forms of government expenditure, capital expenditure stands out for its transformative potential. This category of spending—directed toward building long-term physical and social assets such as infrastructure, industry, transportation networks, and public service facilities—not only delivers an immediate stimulus to the economy but also lays a durable foundation for sustained economic growth, resilience, and national productivity.

Capital expenditure is crucial for a rapidly developing country like India, where the demands of a growing population and evolving economy continuously place pressure on existing infrastructure. Unlike revenue expenditure, which often pertains to operational and short-term costs, capital expenditure has a multiplier effect, influencing both the supply and demand sides of the economy. Investments in infrastructure projects, for example, improve connectivity, create employment opportunities, and attract private sector participation, all of which contribute to improved industrial competitiveness and regional development.

In the context of India's development journey over the past few decades, government spending patterns have expanded significantly, responding to the increasing needs of a diverse and dynamic economic environment. As the economy has grown, so too have public expectations, necessitating investments in everything from highways and railways to digital connectivity and energy infrastructure. At the same time, the allocation of capital expenditure across different ministries and sectors has evolved and been shaped by multiple overlapping forces. These include fluctuations in macroeconomic indicators such as inflation, fiscal deficit, and GDP growth; changes in political leadership and electoral cycles; and shifts in global trade dynamics and geopolitical considerations. As a result, capital spending decisions are not only economic but also deeply influenced by broader political and strategic priorities.

For researchers, policymakers, economists, and development professionals, understanding how capital expenditure is allocated across sectors is critical to evaluating the government's performance and strategic direction. A close analysis of historical and current spending trends reveals whether budgetary allocations reflect long-term development needs or short-term political calculations. Moreover, identifying the primary drivers of budget allocations—whether they are economic (e.g., tax revenue growth, debt servicing capacity, investment needs) or political (e.g., election-year spending patterns, regional development goals)—can provide valuable insights into the effectiveness and impact of past expenditures. Such analysis can also help optimise future investment decisions by ensuring better alignment between fiscal strategy and developmental priorities.

This study focuses specifically on the allocation of capital expenditure in key physical infrastructure sectors, namely railways, roads, and telecommunications. These sectors form the backbone of any modern economy and play a central role in enabling growth across a range of industries. Using a combination of historical expenditure data, econometric modelling, and synthetic data simulation, this research identifies and categorises the direct and indirect determinants of capital allocation across these ministries. Direct factors include internal revenue generation, centrally sponsored schemes, debt servicing commitments, and financial support to public sector undertakings (PSUS). These elements have a direct bearing on the amount and structure of funds that ministries receive in a given fiscal year. Indirect factors include broader macroeconomic indicators such as GDP growth, inflation, fiscal deficit targets, political cycles, and global economic conditions. These variables influence overall fiscal capacity and the prioritisation of sectors in response to evolving national objectives.

Analysing physical infrastructure through this lens is especially important given its close interconnection with supply chain performance. Efficient infrastructure directly translates into lower logistics costs, improved turnaround times, and enhanced competitiveness for key sectors such as manufacturing, construction, heavy industry, and agriculture. For example, investments in highway expansion and railway modernisation facilitate faster and more reliable movement of goods, reducing delays and increasing trade volume. Similarly, investments in digital infrastructure such as telecommunications networks and broadband connectivity support the integration of rural and urban

economies, enabling digital commerce, e-governance, and remote services. All these improvements collectively contribute to more resilient, efficient, and future-ready supply chains that support inclusive economic development.

In summary, capital expenditure is not just a fiscal instrument—it is a strategic lever for achieving long-term developmental goals. This study contributes to the policy discourse by highlighting the economic logic behind capital allocation patterns and underscoring the critical need for targeted investment in physical infrastructure. As India seeks to emerge as a $5 trillion economy, prioritising efficient and equitable capital spending will be vital to unlocking its full potential and ensuring that economic growth is both broad-based and sustainable.

2 Literature Review

2.1. Introduction to Fiscal Policy and Capital Expenditure

The role of fiscal policy in shaping economic development has been widely studied, with government expenditure identified as a key tool for stimulating growth, improving social welfare, and enhancing infrastructure (Easterly & Rebelo, 1993). In particular, capital expenditure—investment in long-term assets like infrastructure and industry—plays a critical role in supporting economic growth by increasing productive capacity and promoting sustainable development (Esfahani & Ramirez, 2003). Compared to other types of government spending, capital expenditure's unique impact lies in its ability to generate future returns and contribute to long-term resilience (Economic Survey, Ministry of Finance, various issues).

Research on fiscal policy highlights the importance of understanding how funds are allocated, as the effectiveness of government spending largely depends on the targeted distribution of resources across sectors (Dutt & Ravallion, 1998). Studies indicate that capital expenditures in developing economies like India are influenced by a range of factors, including economic conditions, political motivations, and global economic pressures (Estache, 2006).

2.2. Trends in Government Expenditure in India

Over the past two decades, India has experienced significant economic growth, accompanied by increased public spending to address the evolving needs of a growing and diversifying economy (Eberts, 1986). However, the distribution of these funds has varied considerably across sectors and ministries. Several studies point out that economic priorities, political agendas, and socio-economic demands shape the way budgets are allocated across different sectors, from infrastructure to social welfare (Ghosh & De, 2000).

Trend analysis of India’s government expenditure highlights fluctuations in capital spending due to both internal and external factors. For instance, changes in infrastructure funding often align with economic growth cycles, while social welfare expenditures may be influenced by election cycles or shifts in political focus (Garcia-Milà & McGuire, 1992). This variation across sectors reflects a broader trend observed in many developing countries, where capital expenditure allocation is responsive to immediate needs and emerging challenges (Estache, 2004).

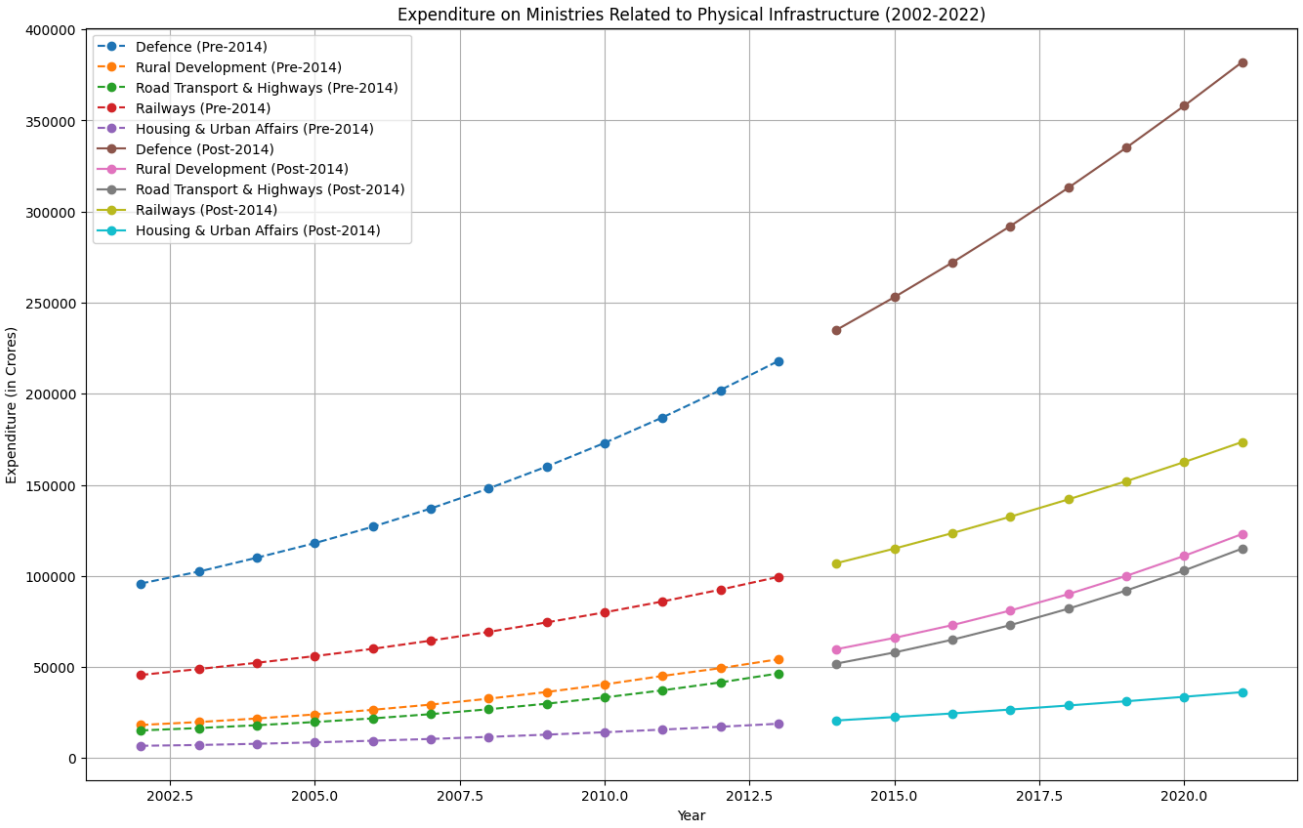

Figure 1: Expenditures ministry-wise

2.3. Determinants of Capital Expenditure

Existing research identifies three broad categories of determinants influencing capital expenditure (capex) allocation:

Economic Factors

GDP Growth: Wagner's law, validated in Nigeria, posits that economic growth drives government spending. In India, capex rose from 2.15% of GDP (2020-21) to 3.3% (2023-24), reflecting GDP-linked fiscal prioritisation.

Sectoral Performance: Infrastructure sectors like roads and railways show strong capex-growth linkages due to their multiplier effects (1.5–3x GDP). Conversely, stagnant sectors (e.g., telecom) face underinvestment despite high growth potential.

Fiscal Factors

Revenue Generation: Internal revenue (e.g., PSU dividends) and CSS funding are critical for capex. However, Indonesian studies found local revenue (PAD) insignificant, suggesting reliance on central transfers.

Debt Servicing: High debt-GDP ratios (e.g., NHAI's ₹3.42 lakh crore debt in 2023) constrain new borrowings, necessitating fiscal reprioritisation.

Political Factors

Election Cycles: Indian states with fragmented governments prioritise populist current expenditures over capex. Pre-election years often see capex surges (e.g., 18% YoY growth in FY19).

Policy Shifts: Landmark reforms (e.g., 1991 liberalisation, GST in 2017) introduced structural breaks in expenditure patterns by altering sectoral priorities.

Macroeconomic Shocks

The 2008 crisis caused breaks in GDP and capex trajectories globally. In India, post-2014 infrastructure pushes created breaks in roads/railways capex.

Policy Interventions

The 1991 reforms induced breaks in India's GDP growth, with capex shifting toward export-oriented sectors.

CSS schemes like PMGSY (rural roads) and Bharatmala (highways) caused abrupt capex spikes in transport ministries.

Political Regime Changes

Changes in ruling parties often reorient capex. For example, the 2004-09 UPA government prioritised rural infrastructure, while post-2014 regimes focused on urban mega projects.

2.4. Sectoral Allocation of Capital Expenditure

Capital expenditure allocation across different ministries reflects the government's priorities in terms of infrastructure, social services, defence, and more. Several studies have shown that infrastructure ministries tend to receive larger portions of capital expenditure due to the high return on investment associated with infrastructure projects (Fedderke et al., 2006). Infrastructure spending is also viewed as a catalyst for growth, as it enables job creation, enhances connectivity, and supports industrial development (Ghosh & De, 2000).

On the other hand, sectors such as health and education may experience fluctuations in capital budgets depending on the political context and emerging social issues. During periods of social stress or health crises, such as the COVID-19 pandemic, health-related capital expenditure may see a spike (Dutt & Ravallion, 1998). These sector-specific allocations highlight the flexibility of capital expenditure as a tool for addressing both economic and social objectives.

The Kink Regression and Chow Test methods are often applied in the literature to identify structural breaks in budget allocation. These methods show how shifts in expenditure trends correspond with economic events, policy changes, or political cycles (Gramlich, 1994). These econometric tools provide insights into the responsiveness of capital spending to different factors, enabling policymakers to make data-driven adjustments to fiscal policy.

2.5. Impact of Capital Expenditure on Economic Growth and Development

Numerous studies have examined the impact of capital expenditure on economic growth, with findings generally supporting the positive role of targeted investments. Capital expenditure is associated with increased productivity, improved infrastructure, and enhanced social welfare, collectively contributing to sustainable development (Esfahani & Ramirez, 2003). For developing economies like India, capital investments are critical for addressing infrastructure deficits and fostering inclusive growth (Garcia-Milà & McGuire, 1992).

However, some research highlights that the effectiveness of capital expenditure depends on the efficiency of fund allocation and implementation (Easterly & Rebelo, 1993). Misallocation or

inefficient use of funds can reduce the potential economic benefits, underscoring the need for careful analysis of spending patterns and determinants. Studies emphasise the importance of prioritising sectors with high growth potential and ensuring that capital budgets are used optimally to achieve the desired developmental outcomes (Fernald, 1999).

2.6. Previous studies on determinants of infrastructure development in India at the state level

Existing research on infrastructure investment in India highlights a range of factors that shape how and where spending occurs. Notable studies by Mohanty et al. (2017), Pradhan (2017), Rasul and Sharma (2014), Ghate (2008), Pillai (2008), and Umdor & Panda (2007) have explored these dynamics in depth. Ghate (2008), for example, uses theoretical models to demonstrate that differences in infrastructure investment across states can be explained by the fixed costs of accessing modern sectors, the initial level of infrastructure, the wealth of the median voter, and the prevalence of corruption. His findings suggest that reducing access costs, tackling corruption, and enacting supportive credit policies are crucial for attracting more investment to infrastructure.

Mohanty et al. (2017) examine per capita infrastructure spending in 14 major Indian states from 1991 to 2010, finding that resource mobilisation, per capita income, and population density are key determinants of infrastructure levels. They also highlight the importance of public investment, political stability, and the interconnectedness of infrastructure spending among states. Our study builds on and differs from their work by focusing on the stock of infrastructure-physical, social, and financial-rather than just expenditure flows. We construct a composite index using multiple indicators to better capture the real level of infrastructure development and test a broader set of control variables for robust results.

The private sector's role in infrastructure, especially through public-private partnerships (PPPs), has also been the subject of recent research. Anant and Singh (2009) find that wealthier states are more successful in attracting PPPs, particularly for road projects linking major cities, and that better governance further encourages private participation. Kaur & Malik (2020) add that fiscal pressures, a developed financial sector, and strong institutions are important for PPP engagement at the state level, though they find little evidence that political factors play a significant role.

Together, these studies underscore the need for nuanced, region-specific policies to maximise the effectiveness of infrastructure investment and partnerships in India.

3 Research Gap

While there's a substantial amount of research on how government spending can boost economic growth and social welfare, we still lack a detailed understanding of how capital expenditures vary across different ministries in India. Most studies tend to look at government spending as a whole or focus on specific sectors like infrastructure or social services, which doesn't capture the unique spending patterns and needs of each ministry. This leaves an important gap in understanding the specific factors that drive capital budget decisions across different areas of government.

Additionally, much of the existing research emphasises broad economic factors, such as GDP growth or inflation, without exploring how these drivers might impact certain sectors differently. We know that political cycles, economic reforms, and global influences can shape capital spending, but there's little research on how these short- and long-term factors affect capital budgets for individual ministries in distinct ways.

Another gap in the literature is the analysis of structural breaks—the shifts in spending patterns that often happen in response to major economic events or policy changes. Few studies have used advanced econometric tools, like the Chow Test or Kink Regression, to identify these shifts specifically within India's ministry-wise expenditures. This type of analysis is especially important in a country like India, where political priorities and economic conditions can vary significantly across different sectors.

While several studies have explored the determinants of infrastructure development in India at the state level, most have focused on specific factors or relied on descriptive analysis. Research by Ghate (2008) highlights the roles of fixed costs, initial infrastructure levels, voter wealth, and corruption in explaining investment variations across states, while Mohanty et al. (2017) emphasise resource mobilisation, per capita income, and population density as key drivers. Other works, such as those by Pillai (2008), Pradhan (2017), Rasul and Sharma (2014), and Umdor & Panda (2007), further link infrastructure development to governance, planning, and urbanisation. However, these studies often

concentrate on per capita expenditure flows, specific regions, or individual infrastructure categories, and many lack empirical validation or a comprehensive approach that accounts for the stock of infrastructure across multiple dimensions.

Despite the growing importance of public-private partnerships (PPPS) and the recognition that factors like fiscal capacity, institutional quality, and governance influence infrastructure outcomes, there remains a significant gap in the literature. Few studies empirically examine the drivers of differential infrastructure stock development at the state level, especially using composite indices and robust econometric methods. Most prior analyses are either descriptive or limited to case studies, leaving a need for research that systematically identifies and quantifies the determinants of infrastructure stock disparities across Indian states. This gap highlights the necessity for a more holistic and empirically grounded investigation into the factors shaping infrastructure development in India.

4 Research Question

How have the capital expenditure patterns of different Indian ministries evolved over the period 2000-2022? What factors influence these patterns?

4.1. Objectives

- **To investigate Capital Expenditure on transport, electricity consumption and communication infrastructure over 20 years in India:** Examine patterns in transport, Electricity Consumption and communication infrastructure spending from 2000 to 2022, identifying sectoral growth rates and shifts in inter-ministerial allocations.

- **To examine the unobserved factors that determine Infrastructure growth:** Investigate economic (e.g., GDP growth, inflation), political (e.g., election cycles), and structural factors influencing short-run and long-run capital expenditure decisions at the ministry level.

- **To estimate the impact of infrastructural growth on sectoral dynamics:** Assess how infrastructure growth affects sectoral dynamics, particularly in logistics, manufacturing, and communication, using econometric modelling to estimate causal relationships.

- **Recommend Policy for Efficient Capital Allocation:** Provide data-driven recommendations to enhance the effectiveness of public spending, ensuring capital investments align with national development goals and reduce regional disparities.

5 Formulation of Infrastructure indices using PCA

5.1. Construction of Physical Infrastructure Index

In empirical research, numerous variables can represent infrastructure, but incorporating all of them in a model often leads to multicollinearity issues. At the same time, omitting key indicators may introduce selection bias. To address this, the study develops a composite index—Physical Infrastructure Index (PINFI)—that captures the essence of infrastructure using principal component analysis (PCA). This approach helps to reduce dimensionality while retaining critical information. The index is constructed using three core indicators: total road density, per capita electricity consumption (in kWh), and total telephone subscriptions per 100 people in India..

Infrastructure Variables	Road Density	Telephone Subscription	Electricity Consumption
Road Density	1		
Telephone Subscription	0.86	1	
Electricity Consumption	0.99	0.92	1

Table 1: Co-relationship between selected infrastructure indicators

Principal Components	Eigen Values	%Variation	% cumulative
PC1	2.85	95.04	95.04
PC2	0.15	4.86	99.90
PC3	0.00	0.1	100.00

Eigen Factors

Infrastructure Variables	PC1	PC2	PC3
Road Density	0.58	-0.56	0.59
Telephone Density	0.56	0.80	0.21
Electricity consumption	0.59	-0.22	-0.78

Table 2: Construction of the Physical Infrastructure Index

6 Methodology: Variables, Data and Techniques

6.1. Data Sources

The main dataset for this research is drawn from the Ministry of Finance, Government of India, which offers detailed records on government spending and budgetary allocations. This data provides a ministry-wise breakdown of capital expenditures across multiple sectors, illustrating how funds have been distributed for various development priorities. The study examines 22 years from 2000 to 2022, allowing for an in-depth analysis of expenditure trends, patterns, and significant structural changes over time.

For the cross-sectional component, the analysis initially focuses on national-level capital allocation to capture overarching trends across the country. In later stages, the research may extend to state-level expenditures, enabling a closer look at how budget priorities vary by region and align with local development needs. The selected timeframe ensures a comprehensive view of long-term shifts, with flexibility to expand the dataset as new information becomes available or project requirements evolve. Additional data sources include the Reserve Bank of India, the Centre for Monitoring Indian Economy, various central ministries, and the 2011 Census. The data will be based on 20 major states and 10 years to form the panel.

6.2. Methodology

The methodology for this study is structured to achieve two main objectives, each addressed through a different analytical approach.

6.2.1. Investigating the Capital Expenditure in India through Trend Analysis

For the first objective, we aim to analyse trends in capital expenditure across ministries and sectors. This analysis will be conducted through both graphical and statistical methods:

1. **Graphical Analysis:** We will visualise expenditure trends over time using line graphs and other visual aids. This approach provides an intuitive view of capital spending patterns, allowing us to observe general trends, cyclical variations, and any apparent shifts in spending priorities.
2. **Structural Break Analysis:** We will employ econometric techniques such as the Chow Test and Kink Regression to identify specific points in time when significant changes in

expenditure patterns occurred.

- **Chow Test:** The Chow Test will detect structural breaks within the time series data. It can pinpoint whether a certain year marked a significant change in the expenditure pattern, likely due to economic events, policy shifts, or political cycles.

$$y_t = x_t'\beta_1 + u_t$$

$$for\ t \leq T_b.$$

$$y_t = x_t'\beta_2 + u_t$$

$$for\ t > T_b.$$

- **CUSUM TEST:** The CUSUM Test detects structural breaks in time series data by examining cumulative sums of residuals. Unlike the Chow Test, it identifies changes without a predefined breakpoint, making it useful for gradual shifts. Stable data keeps the cumulative sum around zero, while significant changes cause it to cross critical bounds, indicating a potential break.

The CUSUM test is based on the recursive least square estimation of the model

$$y_t = x_t'\beta_t + u_t$$

for all $k + 1 \leq t \leq T$. This yields a set of estimates for $\beta, \beta_{k+1}, \beta_{k+2}, \ldots, \beta_T$.

These approaches will provide a comprehensive understanding of capital expenditure trends over time, enabling us to identify gradual and abrupt spending changes.

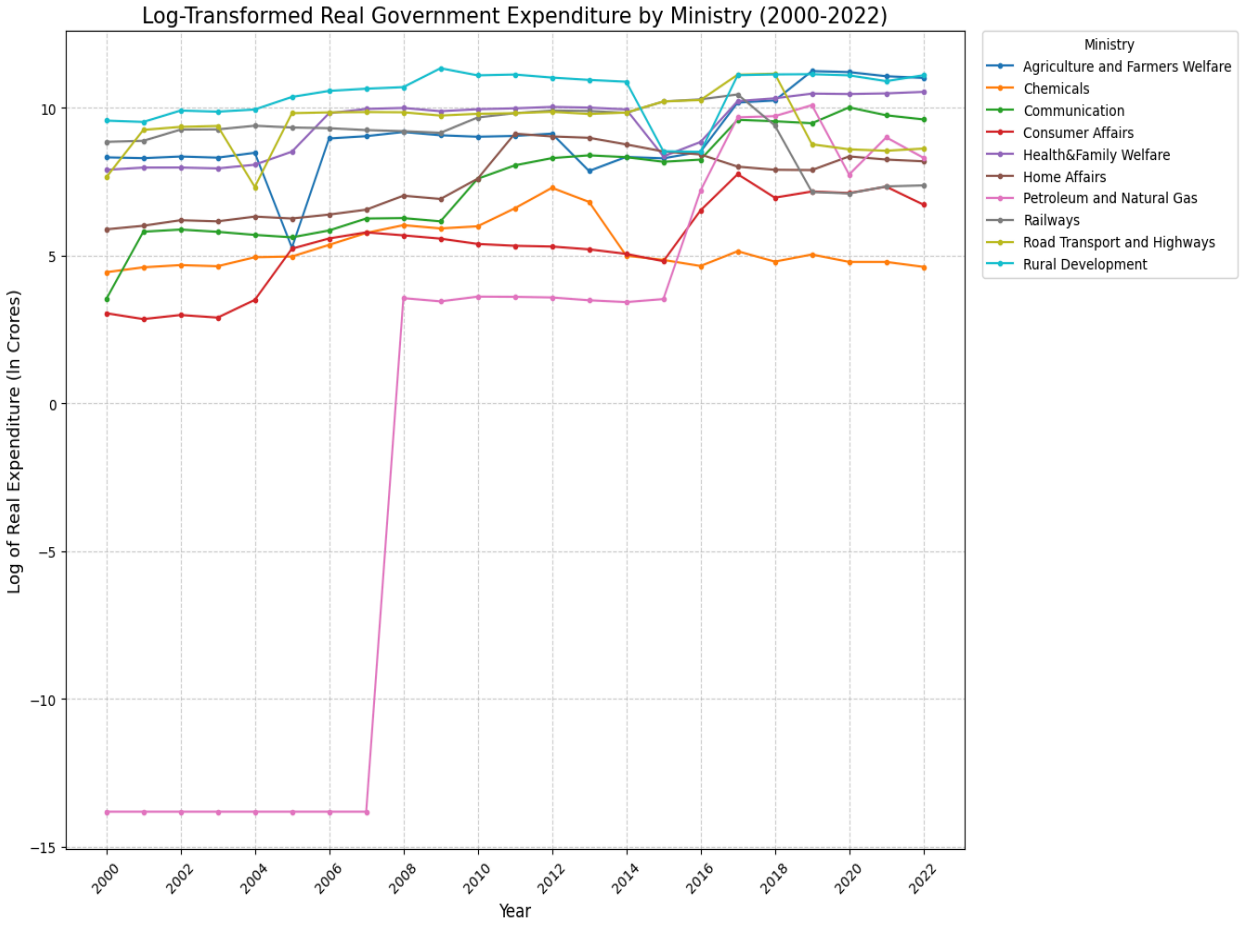

Fig 2: Patterns of Real Capital Expenditure from the year 2000-22

6.2.2. Determinants of Infrastructure Development

The possible determinants of infrastructure development, based on both theoretical and empirical literature, can be broadly categorised as economic, fiscal, demographic, institutional, and political factors. Below, we discuss some of the major determinants.

1. **Economic development (measured by per capita GDP or GSDP)** influences infrastructure development from both the demand and supply sides. Higher income levels increase demand for infrastructure (Wagner's hypothesis), while economic growth boosts government and private revenues, enabling more investment in infrastructure. A favourable business environment and changes in economic structure (e.g., industrial vs. services-led growth) also shape infrastructure composition. The study uses per capita income to assess living standards and GSDP to examine the economy's size with infrastructure development.

2. **Investment Rate (Gross Capital formation as a ratio of GDP)/ Public Capital Expenditure:** directly boosts infrastructure supply and indirectly increases demand via economic multiplier effects. Public capital spending also attracts private investment and helps address regional disparities. Thus, states with greater investment are expected to achieve higher infrastructure development.

3. **Internal debt:** The impact of internal debt-meaning the total government debt held by state governments, infrastructure development can be either positive or negative (Aschauer, 2000; Aizenman et al., 2007). On one hand, higher levels of debt increase debt servicing costs and can drive up interest rates, which may ultimately constrain infrastructure investment (Winter, 2017). On the other hand, if debt is used to finance productive investments, it can foster infrastructure growth within the economy (Aizenman et al., 2007).

4. **Foreign Direct Investment (FDI):** is a key driver of physical infrastructure development in India. FDI brings in capital, advanced technology, and managerial expertise, helping to fund and upgrade essential infrastructure like roads, railways, ports, and telecommunications. By supplementing limited public resources, FDI enables larger and faster infrastructure projects. It also creates a positive feedback loop: improved infrastructure attracts more FDI, while FDI further enhances infrastructure quality. Through public-private partnerships, FDI promotes efficiency and innovation, ultimately supporting economic growth and industrial expansion.

5. **Temperature extremes** and **PM pollution(PM2.5/PM10):** are critical determinants of infrastructure development, driving innovations in materials, urban design, and policy. Addressing these variables ensures infrastructure longevity, public health, and economic efficiency in a warming, urbanising world.

6. **Population growth** is a key driver of physical infrastructure development, as it increases demand for transportation, utilities, housing, and social services. As more people move to

cities or regions expand, governments must invest in new and upgraded infrastructure to prevent congestion and maintain service quality. Rapid population growth requires substantial planning and investment; if infrastructure doesn't keep pace, it can lead to overcrowding and strain on public services. Thus, anticipating population trends is essential for effective infrastructure planning and sustainable development.

6.2.3. Model Specifications

This study employs a two-pronged econometric approach to analyse the determinants of physical infrastructure development in India. For long-run dynamics, we utilise the Autoregressive Distributed Lag (ARDL) model, which accommodates variables with mixed orders of integration (I(0)/I(1)) and provides robust estimates even in smaller samples. The ARDL framework allows us to capture the immediate effects of factors such as population growth, FDI inflows, climate variables (e.g., temperature extremes), and fiscal indicators (debt, CSS allocations) on infrastructure outcomes. To assess short-run equilibrium relationships, we apply the Vector Error Correction Model (VECM), which identifies cointegrating relationships and quantifies the speed of adjustment toward equilibrium. Before estimation, we conduct unit root tests (ADF) to verify stationarity and the bounds test to confirm cointegration. Diagnostic checks, including tests for, ensure the robustness of results. This dual approach provides a comprehensive understanding of both transient and sustained impacts, enabling policymakers to design targeted interventions for infrastructure resilience.

1. Long Run Dynamics: Autoregressive Distributed Lag (ARDL) model

$$PNIFI(t) = \alpha 0 + \beta 1\, PINFI(t-1) + \beta 2\, PINFI(t-2) + \beta 3\, GSDP(t) + \beta 4\, INV(t) + \beta 5 DEBT(t) + \beta 6 FDI(t) + \beta 7 PM10(t) + \beta 8 TEMP(t) + \beta 10 POP + \varepsilon(t)$$

Where **PINFRA** is the log of physical infrastructure index, **GSDP** is the log of gross state domestic product, **INV** is the log of investment as a ratio of GSDP, **POP** is the log of population growth rate, and **Debt** is the internal debt as a ratio of GDP. **FDI** is the log of Foreign Direct Investment, **TEMP** is the log of Temperature, and **PM10** is the log of particulate Matter value

2. Short Run Dynamics: Vector Error Correction Model (VECM)

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \, \Delta y_{t-i} + D_t + \varepsilon_t$$

where:

Δ = operator *differencing*, where $\Delta y_t = y_t - y_{t-1}$,
y_{t-1} = vector variable endogenous with *lag* 1,
ε_t = kx1 vector residuals,
D_t = kx1 vektor constant,
Π = matrix coefficient of cointegration ($\Pi = \alpha\beta^t$; α = vector *adjustment*, kxr matrix and β = matrix cointegration (*long-run parameter*) (k × r))
Γ_i = kxk matrix coefficient the ith variable endogenous.

7 Empirical Analysis

7.1. Unit root tests

Before proceeding with any estimations in time series analysis, it is essential to test for stationarity to prevent misleading or spurious results. Conducting unit root tests is particularly important when using the ARDL model, as it requires that none of the variables be integrated of order two, i.e., I(2). In this study, both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are employed to assess the stationarity of the variables. The results, shown in Table 5, reveal that variables such as GSDP, FDI, DEBT, INV, PM10, and TEMP are stationary at first difference (I(1)), whereas POP is stationary at level (I(0)). Since none of the variables are I(2), the ARDL technique is deemed suitable for further empirical analysis.

	ADF TEST		PP		
Variables	**Level**	**First Difference**	**Level**	**First Difference**	**Decision**
PINFI	-0.43	-5.69***	-0.09	-5.71***	I (1)
	(0.98)	(0.00)	(0.99)	(0.00)	
GSDP	-1.19	-5.13***	-1.19	-5.08***	I (1)
	(0.90)	(0.00)	(0.90)	(0.00)	
INV	-0.96	-5.35***	-0.65	-5.12***	I (1)
	(0.94)	(0.00)	(0.97)	(0.00)	
POP	-2.79	-7.76***	-2.88	-7.74***	I (o)
	(0.21)	(0.00)	(0.18)	(0.00)	
TEMP	-0.47	-5.32	-0.07	-4.69***	I (1)
	(0.84)	(0.00)	(0.79)	(0.00)	
DEBT	-0.76	-4.25***	-0.57	-4.79***	I (1)
	(0.84)	(0.00)	(0.87)	(0.00)	
PM10	-0.63	-4.42	-0.09	-5.57	I (1)
	(0.78)	(0.00)	(0.69)	(0.00)	

Table 3: Results of the Unit Root Test

7.2. Bounds Testing Approach to Cointegration

To determine the existence of long-term relationships among the selected variables, the ARDL bounds testing method is applied. The procedure begins by estimating an Ordinary Least Squares (OLS) regression using the first-differenced forms of both the dependent and independent variables. Following this, the Wald test (F-statistic) is employed to evaluate the combined significance of the lagged level variables included in the model. Specifically, the F-test assesses the null hypothesis that these lagged level coefficients are jointly equal to zero, indicating no long-run association, against the alternative hypothesis that a long-run relationship exists.

Test Statistic	Value	Probability	Reject the Null hypothesis of no cointegration
F-statistic	19.58	0.000	
Chi-square	19.58	0.0001	
Critical Levels			
Critical Bounds	99%	95%	90%
Upper Bound	-5.94	-5.29	-4.96
Lower Bound	-3.96	-3.41	-3.13

Table 4: ARDL Co-integration Test (Wald Test)

7.3. Diagnostic Checks

7.3.1. Breusch-Godfrey Test (Serial Correlation)

This test detects autocorrelation in residuals by regressing residuals on lagged residuals and original model variables. The null hypothesis assumes no serial correlation, while the alternative suggests its presence. The test statistic follows a χ^2 distribution. For the ARDL model, rejecting implies residuals are correlated over time, violating OLS assumptions and biasing standard errors. The study confirmed no serial correlation, ensuring unbiased coefficient estimates.

7.3.2. White Test (Heteroscedasticity)

The White test checks for non-constant error variance by regressing squared residuals on original variables and their cross-products. A significant statistic indicates heteroscedasticity, which inflates standard errors and reduces test reliability. The study's use of this test validated homoscedastic residuals, reinforcing the model's robustness.

7.3.3. Non-Normality Checks

Residual normality is assessed using graphical methods (Q-Q plots) or formal tests (Jarque-Bera). Non-normality skews p-values and confidence intervals. The NIPFP study likely used diagnostic plots or tests to confirm that residuals followed a normal distribution, ensuring valid statistical inference.

Diagnostic Tests	Result of Model
Serial Correlation Test	0.262 [0.772]
Normality Test	0.682 [0.711]
Heteroscedasticity Test	1.352 [0.263]
ARCH Test	1.849 [0.184]
Ramsey Test	0.495 [0.490]

Table 5: Results of diagnostic tests

7.3.4. CUSUM/CUSUMSQ Tests

These tests evaluate parameter stability by plotting cumulative sums (CUSUM) or squared recursive residuals (CUSUMSQ) against confidence bounds. A trajectory within bounds indicates stable parameters, while crossing bounds signals structural breaks. In the study, Figures 3–5 showed CUSUM/CUSUMSQ statistics remaining within 5% significance bands, confirming no structural shifts in the ARDL model over 2002-2022. This stability underscores the model's suitability for long-run analysis.

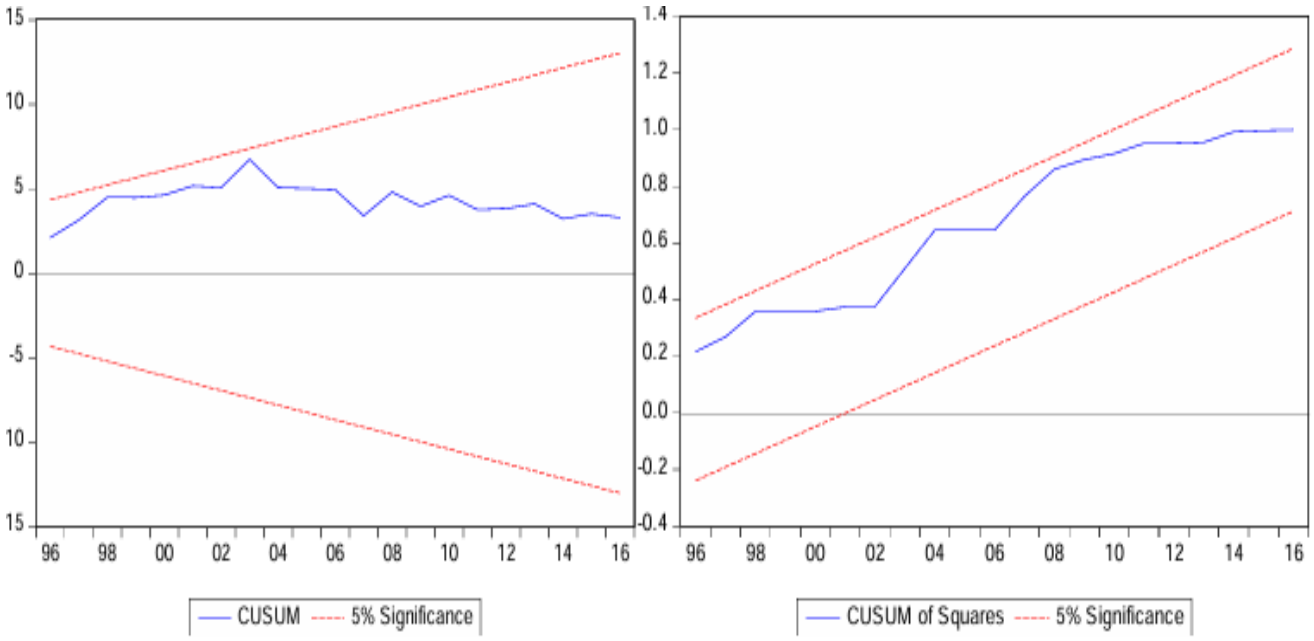

Figure 3: CUSUM and CUSUMQ test of the model

8 Results and Discussion

We extracted key direct and indirect factors influencing the budget allocations of the Ministry of Communications, the Ministry of Railways, and the Ministry of Road Transport and Highways by carefully studying relevant literature and policy documents. Additionally, we analysed structural breaks and trends in budgetary graphs to understand the timing and rationale behind significant changes in expenditure patterns. For each ministry, factors were identified that either directly impact spending (such as capital requirements, pension liabilities, or infrastructure development needs) or indirectly influence it through broader macroeconomic and political considerations.

Statistic	Agriculture and Farmers' Welfare	Chemicals	Communication	Consumer Affairs	Health&Family Welfare	Home Affairs	Petroleum and Natural Gas	Railways	Road Transport and Highways	Rural Development
count	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
mean	29848.3	321.47	9032.29	777.23	25150.94	4172.77	7049.68	14061.42	14776.52	52833.34
std	47464.71	406.73	12664.89	1084.49	24124.32	3876.53	13528.0	15196.64	10805.54	45235.75
min	111.82	40.0	16.05	8.5	1277.86	170.7	0.0	2028.0	835.53	6705.0
25%	3032.5	107.0	198.31	135.47	4567.89	335.93	0.0	3415.5	9859.7	10270.0
50%	6900.0	207.67	3418.0	220.0	15580.0	4468.91	40.0	6800.14	11559.75	31500.0
75%	26383.28	284.19	14104.32	1377.51	36504.35	7381.8	5194.93	22000.0	19000.0	89206.56
max	134349.45	1757.0	40756.63	3705.65	77367.43	10500.0	41994.0	55000.0	44007.0	135944.29

Table 6: Descriptive Statistics

8.1. General Trends in Ministry-wise Capital Expenditure

Across the analysed ministries, there was a notable trend of increasing capital expenditure over the years, with distinct peaks and troughs corresponding to economic, political, and policy shifts. Several ministries, particularly those related to infrastructure, social welfare, and economic growth, showed significant growth in spending over the 22 years.

Ministries like Health & Family Welfare, Agriculture and Farmers Welfare, and Rural Development displayed periods of substantial growth, often associated with governmental prioritisation of social welfare programs and rural development initiatives.

8.2. Structural Break Analysis (Chow Test and Kink Regression)

Structural breaks were identified across various ministries using both the Chow Test and Kink Regression methods. These breaks often corresponded to years with major economic changes, budget announcements, or shifts in government priorities.

Specific Structural Breaks by Ministry:

1. Agriculture and Farmers Welfare: **2017, 2019**
2. Chemicals: **2011, 2014**
3. Communication: **2009, 2017, 2020**
4. Consumer Affairs: **2005, 2016, 2018**
5. Health & Family Welfare: **2006, 2014, 2017**
6. Home Affairs: **2011, 2015, 2018**
7. Railways: **2009, 2015, 2017**
8. Road Transport and Highways: **2005, 2014**
9. Rural Development: **2009, 2013, 2017**

These breakpoints typically align with key policy years or economic cycles, providing evidence that government capital expenditure is closely tied to the macroeconomic environment and political agendas.

Ministries involved in social welfare, such as Health & Family Welfare and Rural

Development, experienced breaks during years of policy reforms aimed at improving public health, poverty alleviation, and rural employment. This suggests that public expenditure in these sectors is sensitive to policy shifts and social needs.

8.3. Impact of Direct and Indirect Factors

For the Ministry of Communications, direct factors include support to PSUs like BSNL/MTNL, pension obligations, TSP compensation, and schemes like BharatNet. Indirect influences stem from economic performance, political priorities, global market trends, and revenue from telecom services. Similarly, for the Ministry of Railways, revenue from traffic operations, capital needs, operational costs, and debt servicing shape the direct expenditure, while economic conditions, political priorities, tech upgrades, and competition from other transport modes play an indirect role. The Ministry of Road Transport and Highways faces direct pressure from NHAI financing, road and bridge development, capital investment needs, and debt servicing. Indirectly, GDP growth, fund utilisation efficiency, cess collections, and PPP outcomes influence its budget allocations.

Statistics	PINFI	GSDP	INV	DEBT	FDI	PM10	POP
Maximum	3.82	10.91	10.04	4.06	3.04	91.27	0.95
Minimum	-2.00	9.37	7.36	-2.12	-1.57	70	0.75
Mean	0.00	10.03	8.76	0.92	0.00	105	1.30
Std Dev.	1.71	0.47	0.85	1.23	1.39	9.67	0.18
Skewness	0.84	0.35	0.18	-0.33	0.61	-0.56	0.94
Kurtosis	2.54	1.84	1.67	3.82	1.90	2.53	2.51

Table 7: Descriptive statistics of Determinants

This structured approach enables a deeper understanding of how internal dynamics and external macroeconomic or institutional forces shape the financial planning and resource distribution within key infrastructure ministries in India.

LONG - RUN COEFF	
Variable	**Coeff**
PINFI	0.0156** (2.902)
GSDP	0.034*** (3.380)
INV	0.051*** (3.674)
POP	0.039* (1.812)
TEMP	-0.013*** (-2.438)
DEBT	0.025** (2.674)
PM10	-0.007 (3.544)
C	8.093*** (23.378)
TREND	0.023*** (4.70)

SHORT - RUN COEFF	
Variable	**Coeff**
ΔPINFI	-
ΔGSDP	0.096*** (2.681)
ΔINV	0.006*** (1.616)
ΔPOP	0.072*** (1.766)
ΔTEMP	-0.003*** (-2.438)
ΔDEBT	0.035** (3.520)
ΔPM10	-0.001 (2.424)
C	0.014*** (3.445)
ECMTt-1	-0.618*** (-4.70)

Table 8: Estimation of Long-run and Short-run Coefficients

The development of physical infrastructure in India is primarily driven by economic growth, investment rates, and foreign direct investment (FDI). Higher gross state domestic product (GSDP) and per capita income create a virtuous cycle: economic expansion increases demand for infrastructure (e.g., roads, electricity) while boosting government revenues and private sector capacity to fund projects. For instance, a 1% rise in GDP correlates with a 0.5–0.7% increase in infrastructure investment. Public and private capital formation further amplifies this growth, with targeted spending reducing regional disparities. FDI complements these efforts by introducing advanced technology and efficiency through public-private partnerships, particularly in the energy and transport sectors. Political factors, such as alignment between state and central governments, enhance policy coordination and funding access, while special-category states (e.g., Assam) receive additional fiscal support for infrastructure development.

Other determinants exhibit mixed effects. Population growth and urbanisation drive demand for housing, utilities, and transportation, necessitating proactive planning to avoid service strain. Internal debt has dual impacts: while excessive debt (>25% of GDP) diverts resources from infrastructure to interest payments, strategic borrowing for projects like highways can yield long-term benefits. Environmental challenges (e.g., extreme heat, pollution) strain existing infrastructure but also

incentivise climate-resilient investments, though evidence in the Indian context remains limited.

In conclusion, the most critical drivers are economic growth, investment, FDI, and political-institutional support, all showing strong positive correlations with infrastructure development. Policymakers should prioritise these factors while managing debt sustainability and integrating climate resilience into planning to address India's infrastructure gaps effectively.

9. Conclusion and Policy Implications with a Focus on Supply Chain Resilience

This study underscores the critical role of infrastructure in long-run economic growth, revealing that physical infrastructure, particularly roads and electricity, yields the most significant returns, contributing up to 7.5% per unit increase in the infrastructure index. Strengthening these components can substantially enhance supply chain performance. Priority should be given to expanding rural electrification, renewable energy networks, and last-mile road connectivity, which are essential for reducing logistics costs, improving trade flow, and ensuring the timely movement of goods across regions.

To build resilient and efficient supply chain networks, the government should expedite multimodal transport integration through initiatives like PM Gati Shakti, Bharatmala, and Sagarmala, aiming to lower logistics costs from 14% to 8% of GDP. Developing industrial corridors and logistics hubs equipped with smart technologies can boost manufacturing efficiency and global competitiveness, particularly in sectors such as electronics and pharmaceuticals.

Furthermore, policies must support supply chain diversification and risk mitigation. Strengthening international partnerships through the Supply Chain Resilience Initiative (SCRI), boosting domestic manufacturing under PLI schemes, and leveraging FDI in logistics infrastructure can help reduce import dependency and enhance self-reliance. Digital logistics platforms (e.g., ULIP) should be scaled to provide real-time tracking, while climate-resilient infrastructure must be integrated into planning to mitigate disruptions from environmental shocks. These coordinated actions will help create a future-ready supply chain ecosystem that is efficient, inclusive, and sustainable, critical for maintaining economic momentum.

References

Sharma, S. (2010). "Government Expenditure and Economic Growth: Evidence from India." South Asia Economic Journal.

Ministry of Finance. (2020). "Economic Survey 2019-2020." Government of India.

Chakraborty, P., & Dash, B. B. (2017). "Fiscal Policy in India: Trends and Trajectories." Indian Council for Research on International Economic Relations.

World Bank. (2019). "World Development Report 2019: The Changing Nature of Work."

Jain, V. (2018). "Political Influences on Public Expenditure in India." Economic and Political Weekly.

Ahluwalia, M. S. (2012). "Planning and the Market in India's Economic Development." Economic Policy.

Dutta, A., & Choudhury, R. (2016). "Fiscal Deficit and Economic Growth: Empirical Evidence from India." Journal of Economic Policy.

Das, K., & Mohanty, S. (2015). "Inflation and Growth in India: A Structural Analysis." Indian Economic Review.

Mukherjee, S. (2019). "Capital Expenditures and Fiscal Deficit in India." Journal of Public Budgeting.

Singh, R., & Bhattacharya, S. (2021). "Economic Reforms and Fiscal Policies in India." Sage Publications.

Dutt, G. and Ravallion, M., 1998. Why have some Indian states done better than others at reducing rural poverty? Economica, 65, 17–38.

Easterly, W. and Rebelo, S., 1993. Fiscal policy and economic growth. Journal of monetary economics,32, 417–458.

Eberts, R.W., 1986. Estimating the contribution of urban public infrastructure to regional growth. In: Federal Reserve Bank of Cleveland, working paper no. 8610. Cleveland, OH: Federal Reserve Bank of Cleveland.

Economic Survey, various issues. Ministry of Finance, Government of India.

Elhance, A.P. and Lakshamanan, T.R., 1988. Infrastructure production system dynamics in national and regional systems: an economic study of the Indian economy. Regional science and urban economics, 18 (4), 511–531.

Esfahani, H.S. and Ramirez, M.T., 2003. Institutions, infrastructure and economic growth. Journal of Development Economics, 70, 443–477.

Estache, A., 2004. Emerging infrastructure policy issues in developing countries: a survey of the recent economic literature. Background paper for the October 2004 Berlin meeting of the POVNET infrastructure working group (processed). Washington, DC: The World Bank.

Estache, A., 2006. Infrastructure: a survey of recent and upcoming issues. Washington, DC: The World Bank.

Fedderke, J.W., Perkins, P., and Luiz, J.M., 2006. Infrastructural investment in long-run economic growth: South Africa 1875–2001. World development, 34, 1037–1059.

Fernald, J., 1999. Assessing the link between public capital and productivity. American Economic Review, 89 (2), 619–638.

Garcia-Mil`a, T. and McGuire, T.J., 1992. The contribution of publicly provided inputs to economies. Regional science and urban economics, 22, 229–241.

Garcia-Mil`a, T., McGuire, T.J., and Porter, R.H., 1996. The effect of public capital in state-level production functions reconsidered. Review of economics and statistics, 78, 177–180.

Ghosh, B. and De, P., 2000. Infrastructure, economic growth and trade in SAARC. BIISS journal, 21(2), 212–225.

Gramlich, E., 1994. Infrastructure investment: a review essay. Journal of Economic Literature, 32,1176–1196

Holtz-Eakin, D., 1994. Public-sector capital and the productivity puzzle. The review of economics and statistics, 76 (1), 12–21.

Anant, T. C. A., & Singh, R. (2009). Distribution of highways public-private partnerships in India: Key legal and economic determinants. Centre on Democracy, Development, and the Rule of Law Working Papers, (100).

Arellano, M., and S. Bond. 1998. Dynamic panel data estimation using DPD98 for Gauss: A guide for users. Mimeo Aschauer, David. (2000). Do States Optimise? Public Capital and Economic Growth. The Annals of Regional Science. 34. 343-363.

Aizenman, J., K. Kletzer and B. Pinto (2007), Economic growth with constraints on tax revenues and public debt: implications for fiscal policy and cross-country differences, NBER Working Paper 12750.

Allen, F., Carletti, E., Cull, R., Qian, J. Q., Senbet, L., Valenzuela, P., 2014. The African financial development and financial inclusion gaps. Journal of African Economies, 23(5), 614-642.

Ari, A., Bartolini, D., Boranova, V., Di Bella, G., Dybczak, K., Honjo, K., ... & Topalova, P. (2020). Infrastructure in Central, Eastern, and South-eastern Europe: Benchmarking, Macroeconomic Impact, and Policy Issues, IMF

Ari, H., & Toivanen, O. (2005). Do financial constraints hold back innovation and growth? Evidence on the role of public policy. Research Policy, 34(9), 1385–1403.

Arimah, B. C. (2005). What drives infrastructure spending in cities of developing countries? Urban Studies, 42(8), 1345-1368.

Bajar, S. (2014), “The Infrastructure-output Nexus: Regional Experience from India”, Working paper 319, The Institute for Social and Economic Change,

Bajar, Sumedha. & Meenakshi Rajeev (2016). The Impact of Infrastructure Provisioning on Inequality in India: Does the Level of Development Matter?, Journal of Comparative Asian Development, 15:1, 122-155.

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