

Sectoral Analysis of Investment Dynamics and Economic Growth with Special Reference to India's Infrastructure and Services Sectors

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Abstract

This study examines the relationship between sectoral and regional investment dynamics and economic growth in India during 1995–2022. The study constructs two composite indices—the Sectoral Investment Index (SII) and the Regional Investment Disparity Index (RIDI)—using Principal Component Analysis (PCA) to capture investment patterns across infrastructure and services sectors as well as regional disparities in investment allocation. To analyse the relationship among investment indicators and economic growth, the study employs a multivariate time-series framework including unit root tests, Johansen co-integration analysis, Vector Error Correction Model (VECM), Vector Autoregression (VAR), Granger causality tests, and impulse response functions. The empirical findings reveal the existence of a long-run equilibrium relationship among the variables. However, the adjustment process is relatively weak for GDP, while stronger short-run interactions are observed between regional investment disparities and sectoral investment structures. Granger causality results indicate a significant directional relationship from RIDI to SII, suggesting that regional disparities influence the composition and allocation of sectoral investments over time. The findings suggest that the effectiveness of investment in India depends not only on the volume of investment but also on its regional distribution, allocation efficiency, and institutional implementation. Persistent regional disparities and structural inefficiencies may weaken the investment–growth relationship. The study highlights the importance of balanced and efficient investment strategies for achieving sustainable and inclusive economic development in India.

Introduction

Economic growth and investment dynamics have long been central themes in development economics, particularly in emerging economies such as India. Investment in infrastructure and services sectors is widely regarded as a key driver of productivity,

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employment generation, and long-term economic expansion (Barro, 1990; Romer, 1990). In the Indian context, the post liberalisation period has witnessed a significant increase in both public and private investments, particularly in infrastructure and service-oriented activities, which are expected to stimulate economic growth and structural transformation.

However, the relationship between investment and economic growth is not always straightforward. While traditional economic theories suggest a positive and stable linkage between investment and output growth, recent empirical studies have highlighted the possibility of weak, unstable, or short-term relationships, particularly in developing economies characterised by structural inefficiencies and regional disparities (Ghosh and De, 2017; Dash, 2016). Factors such as delays in project execution, cost overruns, institutional bottlenecks, and uneven regional development may weaken the effectiveness of investments in translating into sustained economic growth.³

In this context, it becomes important to move beyond aggregate investment measures and examine the quality and distribution of investments across sectors and regions. This study introduces two composite indices, namely the Sectoral Investment Index (SII) and the Regional Investment Disparity Index (RIDI), to capture different dimensions of investment dynamics in India. The SII reflects the performance of investments in terms of project additions, completions, and cost variations, while the RIDI captures imbalances through indicators such as stalled, abandoned, and delayed projects. Recent studies such as (Mishra and Yadav, 2025) highlight the role of structural and institutional factors in shaping enterprise outcomes in India, indicating that investment effectiveness depends on broader economic conditions.

The primary objective of this study is to examine whether sectoral and regional investment dynamics have a significant impact on economic growth in India. Unlike conventional approaches that assume a stable long-run relationship, this study empirically tests the nature of the investment–growth linkage using time-series econometric techniques. Given the mixed order of integration among the variables, the Autoregressive Distributed Lag (ARDL) approach is employed to analyse both short-run and long-run dynamics. Additionally, a Vector Autoregression (VAR) model in first differences is used to examine short-run interactions and causal relationships.

The findings of this study reveal that there is no evidence of a stable long-run relationship between investment indicators and economic growth. While sectoral investments exhibit a marginal positive effect in the short run, this effect does not persist in the long run. These results suggest that the investment–growth relationship in India is weak and unstable, highlighting the importance of improving the efficiency and effectiveness of investments rather than merely increasing their volume.

³ These inefficiencies are often reflected in stalled or incomplete projects, which reduce the productivity of capital formation.

The study contributes to the existing literature by providing empirical evidence on the limited long-run impact of investment dynamics in the Indian economy. It also offers important policy insights regarding the need for better investment planning, efficient resource allocation, and reduction of regional disparities to achieve sustainable economic growth.

Objectives of the Study

The study aims to examine the relationship between sectoral investment dynamics and economic growth in India with specific reference to infrastructure and services sectors. The key objectives are as follows:

1. To examine the relationship between economic growth (GDP) and the Sectoral Investment Index (SII).
2. To analyse the impact of regional investment disparities, represented by the Regional Investment Disparity Index (RIDI), on economic growth.
3. To investigate both short-run and long-run dynamics between investment indicators (SII and RIDI) and economic growth using time-series econometric techniques.
4. To assess the direction of causality and dynamic interactions among the variables using Vector Autoregression (VAR) and impulse response analysis.

Review of Literature

The relationship between investment and economic growth has been widely examined in both theoretical and empirical literature. Classical and endogenous growth theories emphasise the role of capital accumulation, technological progress, and infrastructure development in enhancing productivity and long-term economic growth (Romer, 1990; Barro, 1990). In the Indian context, several studies have investigated the investment–growth nexus, particularly with a focus on infrastructure development and sectoral investments. Pradhan, (2011) examined the present status and constraints of infrastructure development in India using factor analysis and regression techniques. The study categorised infrastructure into physical, social, and financial dimensions and found that infrastructure plays a significant role in explaining inter-state development disparities in India. The findings emphasised that unequal infrastructure distribution contributes to regional imbalances in economic development, highlighting the importance of balanced infrastructure provisioning for sustainable growth. A substantial body of empirical literature finds a positive and long-run relationship between infrastructure investment and economic growth. For instance, Ghosh, (2020) construct a composite infrastructure index using principal component analysis and provide evidence of co-integration between infrastructure and GDP in India, suggesting the existence of a stable long-run equilibrium relationship. Similarly, Pradhan, (2013) highlight the growth-enhancing role of transportation infrastructure and find evidence of bidirectional causality between infrastructure development and economic growth. These studies support the conventional view that investment in infrastructure acts as a key driver of economic expansion.

However, recent empirical evidence presents a more nuanced and sometimes contradictory perspective. While several studies confirm the existence of long-run relationships, they also indicate that short-run effects of investment on economic growth are often weak or statistically insignificant. For example, Ghosh, (2020) observe that infrastructure development does not exert an immediate impact on economic growth, pointing towards temporal inconsistencies in the investment–growth relationship. This suggests that the transmission mechanism from investment to growth may not be instantaneous and may depend on structural and institutional factors.

Further, the literature highlights significant heterogeneity in the impact of investment across regions and sectors. Regional-level studies reveal that the contribution of infrastructure to output growth varies considerably across Indian states, depending on their level of development, institutional capacity, and sectoral composition (Bajar, 2014). This implies that aggregate-level analyses may obscure important regional disparities and structural imbalances in investment allocation.

Another important strand of literature distinguishes between public and private investment. Empirical findings suggest that although both types of investment contribute to economic growth, private investment tends to exhibit stronger and more efficient growth effects compared to public investment (Unnikrishnan, 2020). This raises concerns regarding the efficiency of public investment, especially in the presence of issues such as project delays, cost overruns, and governance constraints.

Moreover, recent studies emphasise that the investment–growth relationship is neither linear nor stable over time. Structural bottlenecks, including delays in project implementation, incomplete projects, and institutional inefficiencies, can significantly weaken the effectiveness of investment in generating sustained economic growth. Additionally, macroeconomic trends in India indicate that despite an increase in public capital expenditure, private sector investment remains relatively subdued, which may limit the long-term effectiveness of investment-led growth strategies.

Despite these contributions, several gaps remain in the existing literature. First, most studies rely on aggregate investment measures and fail to capture the qualitative dimensions of investment, such as efficiency, completion rates, and project-level performance. Second, limited attention has been given to regional investment disparities and their interaction with economic growth. Third, the assumption of a stable long-run relationship between investment and growth is often imposed rather than empirically tested. A number of earlier empirical studies in the Indian context further reinforce the importance of infrastructure and sectoral investments in shaping economic growth, although their findings are not entirely uniform.

Sahoo and Dash, (2009) provide one of the earliest comprehensive analyses of the infrastructure–growth nexus in India using a growth accounting framework. Their findings suggest that infrastructure development plays a more significant role in economic growth compared to both public and private investment, thereby highlighting

its central importance in the development process. However, their study assumes a relatively stable relationship between infrastructure and growth, which may not fully capture structural changes in the post-reform period.

Similarly, Ghosh and De, (2017) emphasise the role of infrastructure in influencing interstate development disparities. The study finds that uneven infrastructure development contributes to regional imbalances, suggesting that the growth effects of investment are not spatially uniform. This supports the argument that aggregate-level analyses may overlook critical regional variations.

Expanding the scope beyond traditional infrastructure, Pradhan et al., (2015) examine the role of information and communication technology (ICT) infrastructure in economic growth and financial development across Asian countries, including India. Their findings highlight the growing importance of technological infrastructure, particularly within the services sector, in driving modern economic growth.

Further, Tripathy et al., (2016) analyse both long-run and short-run relationships between infrastructure investment and economic growth in India, providing evidence of dynamic interactions between the two. However, their results also indicate that short-run adjustments are often weak, pointing to delays in the transmission mechanism from investment to growth.

In addition, Paul and Sana, (2018) examine the relationship between gross capital formation and GDP over a longtime horizon and conclude that infrastructure investment remains a key determinant of economic growth. Nevertheless, their study does not explicitly account for efficiency and project-level dynamics, which may influence the effectiveness of investment.

The role of foreign direct investment (FDI) is also highlighted in the work of Jana et al., (2019), who analyse sector-specific impacts of FDI on economic growth in India. Their findings suggest that the impact of investment varies significantly across sectors, reinforcing the need for sectoral-level analysis rather than relying solely on aggregate measures.

Taken together, these studies provide strong evidence that investment in infrastructure and service sectors is a key driver of economic growth in India. However, they also reveal important limitations, including the assumption of stable relationships, insufficient attention to regional disparities, and limited consideration of investment efficiency. These limitations further justify the need for a more comprehensive and disaggregated analysis, as undertaken in the present study. In this context, the present study contributes to the literature in three important ways. First, it constructs composite indices to capture sectoral investment dynamics and regional disparities, thereby moving beyond aggregate measures. Second, it explicitly tests the existence of a long-run relationship using appropriate econometric techniques, rather than assuming it. Third, by combining ARDL and VAR approaches, the study provides a comprehensive analysis of both long-run equilibrium and short-run dynamics.

Unlike a large body of existing literature that finds a stable positive relationship between investment and economic growth, the findings of this study suggest that the relationship is weak and unstable, particularly in the long run. This highlights the importance of focusing on the efficiency, allocation, and effectiveness of investment rather than merely its volume.

Research Gap and Significance of the Study

Research Gap

Despite a substantial body of literature examining the relationship between investment and economic growth, several important gaps remain in the context of India's infrastructure and services sectors.

First, much of the existing literature focuses on aggregate investment trends and does not adequately distinguish the differential role of sector-specific investments in influencing economic growth. Limited empirical attention has been given to the dynamic interaction between infrastructure and services sector investments and their contribution to overall economic performance.

Second, previous studies generally rely on conventional macroeconomic indicators and fail to construct composite measures capable of capturing both sectoral investment performance and regional investment disparities simultaneously. The absence of integrated indices restricts a comprehensive understanding of uneven investment patterns across regions and sectors.

Third, although several studies examine the investment–growth relationship, relatively few employ multivariate time-series frameworks to investigate both long-run equilibrium relationships and short-run dynamic adjustments among sectoral investment indicators and economic growth in India. In particular, limited evidence exists regarding how regional investment disparities interact with sectoral investment structures over time.

Finally, the empirical literature provides insufficient evidence on whether regional investment imbalances influence aggregate growth directly or primarily affect the internal structure and allocation of sectoral investments. This distinction is important for understanding the transmission mechanism between investment distribution and economic performance.

In this context, the present study addresses these gaps by constructing the Sectoral Investment Index (SII) and Regional Investment Disparity Index (RIDI) using Principal Component Analysis (PCA) and by employing co-integration, VECM, VAR, Granger causality, and impulse response analyses to examine the dynamic relationship between sectoral investment patterns and economic growth in India.⁴

⁴ The study explicitly tests for long-run equilibrium relationships rather than assuming the existence of a stable investment–growth linkage.

Significance of the Study

The significance of this study lies in its contribution to understanding the relationship between sectoral investment dynamics and economic growth in India through a comprehensive empirical framework.

First, the study provides a sector-specific perspective by examining the role of infrastructure and services sector investments in influencing economic growth, thereby contributing to the literature on sectoral development and investment allocation in emerging economies.

Second, the study develops two composite indices—the Sectoral Investment Index (SII) and the Regional Investment Disparity Index (RIDI)—using Principal Component Analysis (PCA). These indices provide a more systematic and integrated approach for measuring sectoral investment performance and regional disparities compared to conventional single-indicator approaches.

Third, the study contributes methodologically by applying co-integration analysis, VECM, VAR, Granger causality, and impulse response functions to examine both long-run equilibrium relationships and short-run dynamic interactions among investment indicators and economic growth variables.

Fourth, the study highlights the importance of regional investment disparities in shaping sectoral investment structures and economic outcomes. The findings provide evidence regarding the extent to which regional imbalances influence investment dynamics and growth performance over time.

Finally, the study offers policy-relevant insights by emphasising that the effectiveness and distribution of investments across sectors and regions are important determinants of economic performance. The findings may assist policymakers in designing more balanced and efficient investment strategies aimed at promoting sustainable and inclusive economic development.

Overall, the study contributes to the empirical literature on investment and growth in India by integrating composite index construction with dynamic multivariate econometric analysis to better understand the interaction between sectoral investments, regional disparities, and economic growth.

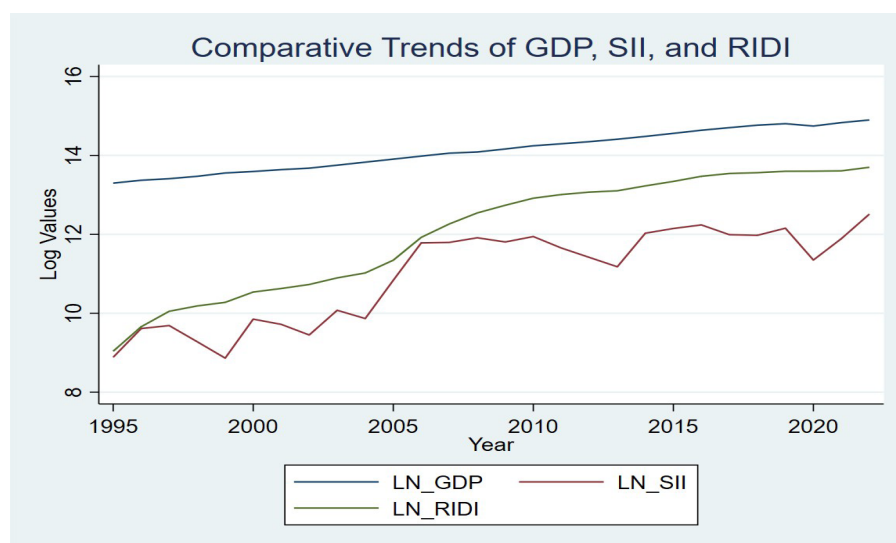
Descriptive Statistics

Table 1 presents the descriptive statistics of the variables employed in the study for the period 1995–2022 based on 28 annual observations. The results indicate substantial variation in Gross Domestic Product (GDP), with a mean value of 1,538,708 USD million and a relatively high standard deviation, reflecting the long-term expansion and structural transformation of the Indian economy during the post-reform period.

The Sectoral Investment Index (SII) and Regional Investment Disparity Index (RIDI), constructed using PCA-based eigenvector loadings, also exhibit considerable variability over time. The mean value of SII is 98,285.5, while RIDI records a comparatively higher mean value of 355,976.7, indicating significant fluctuations in sectoral investment activities and regional investment disparities across the Indian economy. The relatively high dispersion observed in RIDI suggests persistent regional imbalances and uneven allocation of investment resources.

The logarithmic transformations of GDP, SII, and RIDI demonstrate comparatively lower standard deviations, indicating improved distributional stability and reduced heteroscedasticity within the data series. Furthermore, the first-differenced logarithmic variables exhibit moderate variability, supporting their suitability for stationarity testing and advanced time-series econometric analysis (Wooldridge, 2015). Overall, the descriptive statistics provide preliminary evidence of substantial investment and growth dynamics, thereby justifying the application of PCA, unit root testing, co-integration analysis, and Vector Error Correction Model (VECM) estimation in the study.

Figure 1: Comparative Trends of Logarithmic GDP, SII, and RIDI (1995–2022)



Source: Author's calculations based on World Bank database, CMIE CapEx database, and International Financial Statistics (IFS) database.

Note: The figure presents the comparative trends of logarithmic Gross Domestic Product (LN GDP), Sectoral Investment Index (LN SII), and Regional Investment Disparity Index (LN RIDI) over the period 1995– 2022. The SII and RIDI indices are constructed using PCA-based eigenvector loadings. All monetary variables are expressed in USD million terms and transformed into natural logarithmic form to improve comparability and variance stability.

Table 1: Descriptive Statistics of Variables Used in the Study

Variable	Obs	Mean	Std. Dev.	Min	Max
VAR 1RI	28	683024.80	605878.90	15437.55	1720842.00
VAR 2RI	28	3473.46	5438.33	15.39	21102.25
VAR 3RI	28	6726.25	9394.42	0.90	37878.60
VAR 4RI	28	16473.85	21416.38	345.33	68548.06
VAR 5RI	28	7988.40	7061.50	753.28	23710.55
VAR 1SI	28	93935.87	71805.79	6978.88	242240.80
VAR 2SI	28	79449.71	60395.78	6097.82	208552.80
VAR 3SI	28	6271.34	10207.48	0.57	34759.07
VAR 4SI	28	13917.84	16032.58	222.71	61949.95
VAR 5SI	28	17949.59	16794.88	353.13	52626.40
GDP	28	1538708.00	749401.20	596058.80	2954978.00
SII	28	98285.50	76014.30	7060.07	272009.20
RIDI	28	355976.70	316185.80	8405.13	890499.40
LN GDP	28	14.1259	0.5085	13.2981	14.8990
LN SII	28	10.9962	1.1838	8.8622	12.5136
LN RIDI	28	12.0563	1.4722	9.0366	13.6995
D LN GDP	27	0.0593	0.0290	-0.0601	0.0866
D LN SII	27	0.1345	0.4861	-0.8070	0.9882
D LN RIDI	27	0.1727	0.1603	0.0022	0.6209

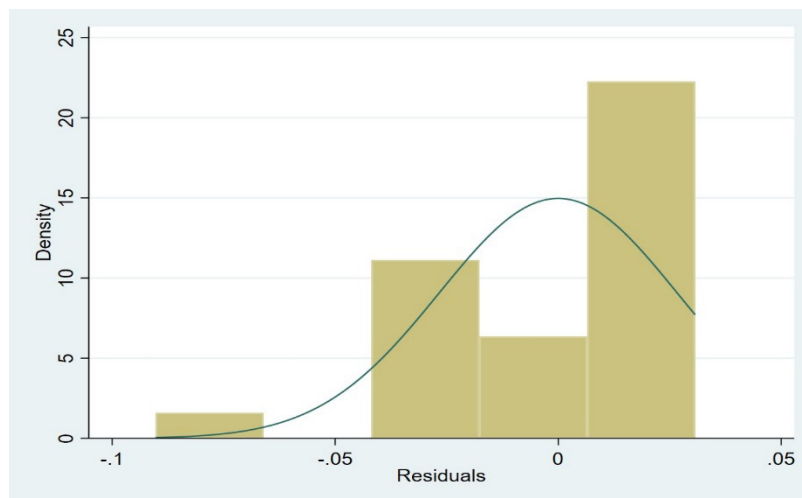
Source: Author's calculations based on the CMIE CapEx database, World Bank database, International Financial Statistics (IFS) database, International Monetary Fund (IMF), and Reserve Bank of India (RBI) statistics.

Note: GDP is measured in USD million and sourced from the World Bank database. The Sectoral Investment Index (SII) and Regional Investment Disparity Index (RIDI) are constructed using investment-related variables obtained from the CMIE CapEx database through Principal Component Analysis (PCA)-based eigenvector loadings.

All monetary variables are expressed in USD million terms.

Investment data originally reported in Indian Rupees (INR million) were converted into USD million using the average exchange rate for the year 2015, where 1 USD = 64.15 INR, based on data obtained from the International Financial Statistics (IFS) database and the International Monetary Fund (IMF), World Bank.

VAR 1SI to VAR 5SI denote variables used in constructing the Sectoral Investment Index (SII), whereas VAR 1RI to VAR 5RI denote variables used in constructing the Regional Investment Disparity Index (RIDI). LN variables denote logarithmic transformations,

Figure 2: Distribution of Residuals for the GDP Equation in the model residuals.

D LN variables represent first-differenced logarithmic series employed for stationarity analysis.

Source: Author's computation using Stata 17 based on VECM estimation results.

Note: The figure presents the histogram of residuals obtained from the GDP equation of the VECM estimation along with the normal distribution curve. The residuals appear approximately symmetrically distributed around zero, indicating the absence of severe non-normality

The residual distribution indicates that the estimated model does not suffer from substantial deviations from normality. Most residual values are concentrated around zero, while the fitted normal curve closely follows the observed distribution pattern. This suggests that the model specification is reasonably stable and statistically reliable for analysing the dynamic relationship among sectoral investment, regional investment disparities, and economic growth in India.

Research Methodology

Data and Sources

The study is based on annual time-series data covering the period from 1995 to 2022. The data are collected from secondary sources, including the Centre for Monitoring Indian Economy (CMIE) CapEx database and the World Bank. GDP data are obtained from the World Bank, while investment-related variables are constructed using the CMIE database.

All monetary variables are expressed in USD million. Investment data originally reported in Indian Rupees (INR million) are converted into USD using an average exchange rate of 64.15 INR (International Financial Statistics (IFS) database and the International Monetary Fund (IMF), World Bank) per USD to ensure consistency.

Variables Construction

To examine the relationship between investment dynamics and economic growth in India, the study constructs two composite indices namely the Sectoral Investment Index (SII) and the Regional Investment Disparity Index (RIDI). These indices are developed to capture multidimensional investment patterns associated with the infrastructure and services sectors. Since investment behaviour is influenced by multiple interconnected indicators, the use of composite indices provides a more comprehensive representation of sectoral investment performance and regional investment imbalances.

The indices are constructed using Principal Component Analysis (PCA), which reduces dimensionality and extracts the common variation among correlated variables. The PCA-derived eigenvector loadings from the first principal component (PC1) are utilised as weights in constructing the indices.

Table 2: Principal Component Analysis (PCA) Results for Sectoral Investment Index (SII)

Variables Included in SII	Comp.1	Comp.2	Comp.3	Selected Weight (PC1)
Total Investments Added (VAR 1SI)	0.4783	-0.3362	-0.3276	0.4783
New Investments Captured (VAR 2SI)	0.4625	-0.4289	-0.3683	0.4625
Projects Revived (VAR 3SI)	0.4091	0.6702	-0.3384	0.4091
Projects Completed (VAR 4SI)	0.4476	0.4358	0.3291	0.4476
Variation in Cost (VAR 5SI)	0.4354	-0.2528	0.7309	0.4354

Table 3: PCA Component Selection Statistics for SII

Principal Component	Eigenvalue	Variance Explained (%)	Cumulative Variance (%)	Selection Status
PC1	3.8923	77.85	77.85	Selected
PC2	0.6076	12.15	90.00	Not Selected
PC3	0.3673	7.35	97.34	Not Selected

Source: Author's calculation using Principal Component Analysis (PCA) in Stata.

Note: The first principal component (PC1) was selected for constructing the Sectoral Investment Index (SII) because it explained the maximum proportion of total variance (77.85%) among the included variables. The reported weights represent PCA-derived eigenvector loadings obtained from the first principal component and were used in constructing the composite SII index.

Table 4: Construction of Sectoral Investment Index (SII)

Variable Code	Variable Description	PCA Weight (PC1)
VAR 1SI	Total Investments Added during the Quarter/Year	0.4783
VAR 2SI	New Investments Captured	0.4625
VAR 3SI	Projects Revived	0.4091
VAR 4SI	Projects Completed	0.4476
VAR 5SI	Variation in Cost	0.4354

Source: Author's calculation using Principal Component Analysis (PCA) in Stata.

Note: SII denotes the Sectoral Investment Index constructed using PCA-derived eigenvector loadings obtained from the first principal component (PC1). The selected variables capture multiple dimensions of sectoral investment dynamics including investment expansion, project revival, project completion, and cost variation.

$$SII = (0.4783 \times VAR_{1SI}) + (0.4625 \times VAR_{2SI}) + (0.4091 \times VAR_{3SI}) + (0.4476 \times VAR_{4SI}) + (0.4354 \times VAR_{5SI})$$

The index is computed as:

$$SII = \sum_{i=1}^5 W_i^{SI} \cdot VAR_i^{SI}$$

(1)

where W_i^{SI} represents PCA-based weights and VAR_i^{SI} denotes the respective variables.

Table 5: Principal Component Analysis (PCA) Results for Regional Investment Disparity Index (RIDI)

Variables Included in RIDI	Comp.1	Comp.2	Comp.3	Selected Weight (PC1)
Total Investments Outstanding (VAR 1RI)	0.4994	-0.4021	0.1735	0.4994
Projects Abandoned (VAR 2RI)	0.4638	0.3517	-0.2522	0.4638
Projects Announced & Stalled (VAR 3RI)	0.4286	0.4175	-0.5139	0.4286
Projects with No Information (VAR 4RI)	0.4342	-0.6481	-0.1545	0.4342
Change of Ownership (VAR 5RI)	0.4040	0.3470	0.7864	0.4040

Table 6: PCA Component Selection Statistics for Regional Investment Disparity Index (RIDI)

Principal Component	Eigenvalue	Variance Explained (%)	Cumulative Variance (%)	Selection Status
PC1	3.2504	65.01	65.01	Selected
PC2	0.8432	16.86	81.87	Not Selected
PC3	0.5858	11.72	93.59	Not Selected

Source: Author's calculations using Principal Component Analysis (PCA) in Stata 17.

Note: The first principal component (PC1) was selected for constructing the Regional Investment Disparity Index (RIDI) because it explained the maximum proportion of total variance (65.01%) among the included variables. The reported weights represent PCA-derived eigenvector loadings obtained from the first principal component and were used in constructing the composite RIDI index.

Table 7: Construction of Regional Investment Disparity Index (RIDI)

Variable Code	Variable Description	PCA Weight (PC1)
VAR 1RI	Total Investments Outstanding at the End of the Quarter/Year	0.4994
VAR 2RI	Projects Abandoned	0.4638
VAR 3RI	Projects Announced & Stalled	0.4286
VAR 4RI	Projects with No Information	0.4342
VAR 5RI	Change of Ownership	0.4040

Source: Author's calculation using Principal Component Analysis (PCA) in Stata.

Note: RIDI denotes the Regional Investment Disparity Index constructed using PCA-derived eigenvector loadings obtained from the first principal component (PC1). The selected variables represent different dimensions of regional investment imbalances, project bottlenecks, investment inefficiencies, and ownership related structural changes within the economy.

$$\begin{aligned}
 RIDI = & (0.4994 \times VAR_{1RI}) \\
 & + (0.4638 \times VAR_{2RI}) \\
 & + (0.4286 \times VAR_{3RI}) \\
 & + (0.4342 \times VAR_{4RI}) \\
 & + (0.4040 \times VAR_{5RI})
 \end{aligned}$$

The index is computed as:

$$RIDI = \sum_{i=1}^5 W_i^{RI} \cdot VAR_i^{RI} \quad (2)$$

where W_i^{RI} denotes the PCA-derived weights and VAR_i^{RI} represents the corresponding variables.

Table 8: Description of Variables Used in SII and RIDI

Variable	Description	Economic Interpretation
VAR_1SI	Total Investments Added	Measures overall investment inflows during the period.
VAR_2SI	New Investments Captured	Indicates new investment opportunities and sectoral attractiveness.
VAR_3SI	Projects Revived	Reflects the revival of previously stalled investment projects.
VAR_4SI	Projects Completed	Represents successfully completed investment activities.
VAR_5SI	Variation in Cost	Captures changes in project implementation costs.
VAR_1RI	Investments Outstanding	Indicates investment commitments remaining outstanding.
VAR_2RI	Projects Abandoned	Reflects discontinued or failed investment projects.
VAR_3RI	Projects Announced & Stalled	Represents investment projects that have been announced but remain stalled.
VAR_4RI	Projects with No Information	Captures gaps in information regarding investment projects.
VAR_5RI	Change of Ownership	Reflects restructuring or changes in project ownership.

Source: Author's compilation based on CMIE CapEx database.

Note: Variables VAR 1SI to VAR 5SI were used in constructing the Sectoral Investment Index (SII), while variables VAR 1RI to VAR 5RI were employed in constructing the Regional Investment Disparity Index (RIDI).

Unit Root Test Results

Table 9 presents the results of the Augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root tests conducted to examine the stationarity properties of the variables used in the study. The results indicate that the logarithmic level series of GDP (LN GDP), Sectoral Investment Index (LN SII), and Regional Investment Disparity Index (LN RIDI) are non-stationary at their level form, as the null hypothesis of unit root cannot be rejected in the ADF and PP tests for most variables. Similarly, the KPSS test statistics further support the presence of non-stationarity in the level series.

However, after applying first differencing, all variables become stationary at conventional significance levels. The first-differenced series, namely D LN GDP, D LN SII, and D LN RIDI, reject the null hypothesis of unit root in both the ADF and PP tests, while the KPSS statistics remain within the critical threshold values, confirming stationarity.

Therefore, the empirical findings indicate that all variables are integrated of order one, I(1). The presence of non-stationary variables at level form and stationarity after first differencing justifies the application of Johansen co-integration analysis and the Vector

Error Correction Model (VECM) framework to examine both the long-run equilibrium relationship and short run dynamics among investment indicators and economic growth.

Table 9: Unit Root and Stationarity Test Results

Variable	ADF	ADF	PP	PP	KPSS	Stationarity
	Statistic	p-value	Statistic	p-value	Statistic	
LN GDP	-0.626	0.8651	-0.800	0.8191	0.130	Non-Stationary
LN SII	-1.040	0.7383	-1.432	0.5667	0.211	Non-Stationary
LN RIDI	-1.145	0.6967	-2.958	0.0390	0.306	Non-Stationary
D LN GDP	-3.771	0.0032	-4.907	0.0000	0.071	Stationary
D LN SII	-4.266	0.0005	-5.448	0.0000	0.048	Stationary
D LN RIDI	-2.939	0.0411	-3.475	0.0087	0.071	Stationary

Source: Author's calculations using Stata 17.

Note: The Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests examine the null hypothesis of unit root (non-stationarity), whereas the KPSS test examines the null hypothesis of stationarity. ADF refers to the Augmented Dickey–Fuller test, PP denotes the Phillips–Perron test, and KPSS represents the Kwiatkowski–Phillips–Schmidt–Shin stationarity test. For the ADF and PP tests, the null hypothesis assumes the presence of a unit root (non-stationarity), whereas for the KPSS test, the null hypothesis assumes stationarity. The results indicate that LN GDP, LN SII, and LN RIDI are non-stationary at level form but become stationary after first differencing, implying that all variables are integrated of order one, I(1).

Econometric Framework

The study employs a comprehensive time-series econometric framework to examine the relationship between investment dynamics and economic growth in India's infrastructure and services sectors. Initially, the Sectoral Investment Index (SII) and Regional Investment Disparity Index (RID) are constructed using Principal Component Analysis (PCA), where PCA-derived eigenvector loadings from the first principal component are used as weights for developing the composite indices.

Subsequently, the stationarity properties of the variables are examined using the Augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root tests to determine the order of integration of the series. The results indicate that the variables are non-stationary at level form but become stationary after first differencing, implying that the variables are integrated of order one, I(1).

Following the stationarity analysis, the Johansen co-integration test is employed to investigate the existence of a long-run equilibrium relationship among economic growth (GDP), the Sectoral Investment Index (SII), and the Regional Investment Disparity Index (RID). Since evidence of co-integration is observed among the variables, the Vector Error Correction Model (VECM) framework is adopted to capture both the short-run dynamics and long-run equilibrium adjustments among the variables.

Furthermore, the VECM framework enables the estimation of the error correction mechanism, which reflects the speed of adjustment toward long-run equilibrium following short-run disequilibrium shocks. Diagnostic and stability tests, including residual autocorrelation tests, normality tests, and stability condition tests, are also conducted to validate the robustness and adequacy of the estimated model.

Finally, the empirical analysis is carried out using Stata software (Version 17), which provides advanced econometric tools suitable for time-series modelling, co-integration analysis, and Vector Error Correction Model estimation.

Research Hypotheses

The study tests the relationship between investment dynamics and economic growth using the following hypotheses:

H0: There is no significant relationship between economic growth (GDP) and investment indicators (SII and RIDI).

H1: There exists a significant relationship between economic growth (GDP) and investment indicators (SII and RIDI).

Additionally, for econometric estimation:

$$H_0: \beta = 0 \quad (\text{No impact})(3)$$

$$H_1: \beta \neq 0 \quad (\text{Significant impact})(4)$$

Table 10: Johansen co-integration Test Results

Rank	Parameters	Log Likelihood	Eigenvalue	Trace Statistic	5% Critical Value
0	12	79.7311	–	29.5943	29.68
1	17	91.3381	0.5905	6.3803	15.41
2	20	93.6339	0.1619	1.7888	3.76
3	21	94.5283	0.0665	–	–

Source: Author’s calculations using Stata 17.

Note: The Johansen co-integration test was conducted with a constant trend specification and lag length of two. The trace statistic for the null hypothesis of no co-integration was approximately equal to the 5% critical value, indicating evidence of a long-run equilibrium relationship among LN GDP, LN SII, and LN RIDI. Therefore, the Vector Error Correction Model (VECM) framework was employed for subsequent analysis.

Table 11: Vector Error Correction Model (VECM) Results

Variables	D_LN_GDP	D_LN_SII	D_LN_RIDI
Error Correction Term (ECT_{t-1})	-0.0016 (0.458)	-0.0943* (0.001)	-0.0060 (0.400)
LD.LN_GDP	0.0851 (0.732)	5.9389* (0.074)	1.3704* (0.089)
LD.LN_SII	-0.0039 (0.822)	0.0891 (0.703)	0.0043 (0.939)
LD.LN_RIDI	0.0804 (0.389)	3.1777** (0.011)	0.7472** (0.013)
Constant	0.0540*** (0.001)	-0.0005 (0.998)	-0.0062 (0.907)
R-squared	0.8127	0.3880	0.7985
Chi-square	91.1310	13.3148	83.2207
Prob > Chi-square	0.0000	0.0206	0.0000

Source: Author's calculations using Stata 17.

Note: The table reports the estimated Vector Error Correction Model (VECM) results based on one cointegrating equation and lag length of two.

Values in parentheses represent p-values. *, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively. The error correction term (ECT) captures the speed of adjustment toward long-run equilibrium following short-run disequilibrium shocks.

The Johansen co-integration test and VECM estimation provide evidence of a long-run equilibrium relationship among GDP, the Sectoral Investment Index (SII), and the Regional Investment Disparity Index (RIDI). The co-integrating equation was found to be statistically significant, indicating that investment dynamics and regional investment disparities are linked with economic growth in the long run.

The estimated long-run coefficients reveal that the Sectoral Investment Index (SII) exerts a positive influence on economic growth, whereas the Regional Investment Disparity Index (RIDI) exhibits a negative relationship with GDP. These findings suggest that improvements in sectoral investment activities contribute positively toward economic expansion, while regional investment imbalances adversely affect long-run growth performance.

The Vector Error Correction Model (VECM) further indicates that the error correction term associated with the SII equation is negative and statistically significant, implying the existence of an adjustment mechanism toward long-run equilibrium following short-run disequilibrium shocks. Approximately 9.43% of disequilibrium is corrected within each period, reflecting the dynamic role of sectoral investment adjustments in restoring equilibrium conditions.

In the short run, the lagged effects of RIDI on SII and the own lag dynamics of RIDI were found to be statistically significant, indicating that regional investment disparities and project bottlenecks have important short-run implications for investment performance. However, the short-run effects on GDP remain relatively weak, suggesting that investment-related variables primarily influence economic growth through long-run structural channels rather than immediate short-run fluctuations.

Overall, the findings support the existence of meaningful long-run interactions between investment dynamics and economic growth in India, highlighting the importance of balanced sectoral investments and reduced regional disparities for achieving sustainable economic development.

Table 12: VAR Diagnostic and Stability Test Results

Diagnostic Test	Test Statistic	p-value	Inference
LM Test (Lag 1)	4.4546	0.8790	No Serial Correlation
LM Test (Lag 2)	4.4008	0.8831	No Serial Correlation
Jarque–Bera Normality Test (ALL)	27.237	0.0001	Residuals not normally distributed
Stability Condition	Eigenvalues <1	–	Stable VAR Model

Source: Author’s calculations using Stata 17.

Note: The LM test examines the null hypothesis of no serial autocorrelation in the residuals. The Jarque–Bera test examines residual normality. The stability condition is satisfied when all eigenvalues lie inside the unit circle. The estimated VAR model satisfies the stability condition and does not suffer from serial autocorrelation, indicating overall model adequacy.

Granger Causality Results

The diagnostic test results confirm the adequacy and stability of the estimated VAR model. The Lagrange Multiplier (LM) test indicates the absence of serial autocorrelation in the residuals at both lag orders, suggesting that the model residuals are independently distributed. Furthermore, the stability condition test confirms that all eigenvalues lie inside the unit circle, implying that the VAR system is dynamically stable and suitable for impulse response analysis.

Although the Jarque–Bera normality test rejects the null hypothesis of residual normality, such deviations are commonly observed in macroeconomic time-series data with relatively

Table 13: Granger Causality Test Results

Null Hypothesis	Chi-square	p-value	Inference
LN SII does not Granger-cause LN GDP	2.7449	0.253	No Causality
LN RIDI does not Granger-cause LN GDP	4.8026	0.091	Weak Causality
LN GDP does not Granger-cause LN SII	4.0636	0.131	No Causality
LN RIDI does not Granger-cause LN SII	7.8577	0.020	Significant Causality
LN GDP does not Granger-cause LN RIDI	3.6063	0.165	No Causality
LN SII does not Granger-cause LN RIDI	0.7507	0.687	No Causality

Source: Author's calculations using Stata 17.

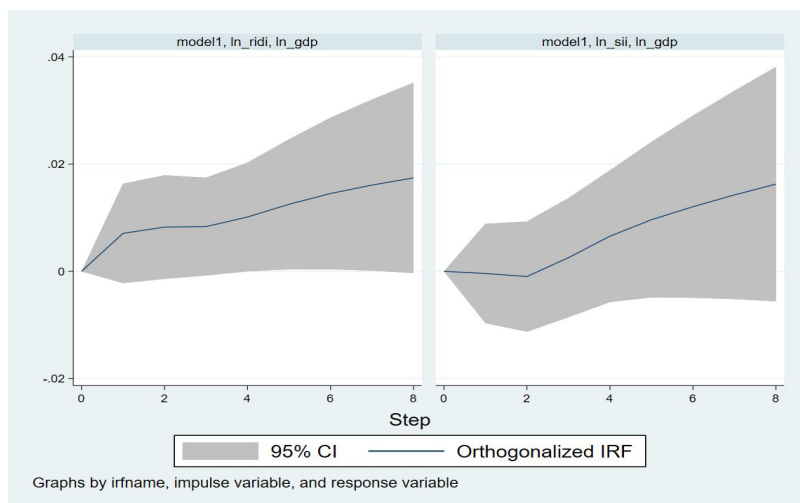
Note: The Granger causality test examines whether past values of one variable help predict another variable. The results indicate that regional investment disparities (LN RIDI) significantly Granger-cause sectoral investment dynamics (LN SII), while weak evidence of causality is observed from LN RIDI to LN GDP at the 10% significance level.

small sample sizes and do not invalidate the overall reliability of the VAR estimates.

The Granger causality results reveal that the Regional Investment Disparity Index (LN RIDI) significantly influences the Sectoral Investment Index (LN SII), indicating that regional investment imbalances play an important role in shaping sectoral investment dynamics in India. In addition, weak evidence of causality is observed from LN RIDI to economic growth (LN GDP), suggesting that regional investment disparities may exert short-run predictive influence on economic performance.

Impulse Response Analysis

Figure 3: Orthogonalized Impulse Response Functions: Response of GDP (LN GDP) to Shocks in SII (LN SII) and RIDI (LN RIDI)



Source: Author's calculations based on VAR estimation using Stata 17.

Note: The figure presents orthogonalized impulse response functions (OIRFs) illustrating the dynamic response of economic growth (LN GDP) to one-standard-deviation shocks in the Sectoral Investment Index (LN SII) and Regional Investment Disparity Index (LN RIDI). The responses are derived from the estimated VAR model with two lags. The results indicate that investment shocks generate relatively short-run fluctuations in GDP, with the responses gradually converging toward equilibrium over time, confirming the stability of the VAR system.

Model Specification

The relationship between economic growth and investment dynamics is expressed as a functional relationship between Gross Domestic Product (GDP), the Sectoral Investment Index (SII), and the Regional Investment Disparity Index (RIDI):

$$GDP_t = f(SII_t, RIDI_t)(5)$$

For empirical estimation, the variables are transformed into logarithmic form to reduce heteroskedasticity and improve interpretability of the estimated coefficients:

$$\ln GDP_t = \beta_0 + \beta_1 \ln SII_t + \beta_2 \ln RIDI_t + \varepsilon_t(6)$$

where:

- represents the logarithm of Gross Domestic Product,
- denotes the logarithm of the Sectoral Investment Index,
- denotes the logarithm of the Regional Investment Disparity Index,
- is the intercept term,
- and are slope coefficients,
- is the stochastic error term.

Johansen Co-integration Framework

Since the variables are integrated of order one, $I(1)$, the Johansen co-integration approach is employed to examine the existence of a long-run equilibrium relationship among the variables. The Vector Autoregressive (VAR) system of order p can be represented as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_p Y_{t-p} + \varepsilon_t(7)$$

where:

$$Y_t = \begin{bmatrix} \ln GDP_t \\ \ln SII_t \\ \ln RIDI_t \end{bmatrix} \quad (8)$$

The Johansen methodology transforms the VAR system into a Vector Error Correction representation:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (9)$$

where:

- Δ denotes the first-difference operator,
- Π captures the long-run co-integration relationships,
- Γ_i represents short-run adjustment coefficients,
- ε_t is the vector of white-noise disturbances.

Vector Error Correction Model (VECM)

Given the presence of co-integration among the variables, the Vector Error Correction Model (VECM) is estimated to capture both long-run equilibrium adjustments and short-run dynamics.

The VECM specification is represented as:

$$\begin{aligned} \Delta \ln GDP_t = & \alpha_1 + \lambda_1 ECT_{t-1} + \sum_{i=1}^p \beta_{1i} \Delta \ln GDP_{t-i} + \sum_{i=1}^p \gamma_{1i} \Delta \ln SII_{t-i} \\ & + \sum_{i=1}^p \delta_{1i} \Delta \ln RIDI_{t-i} + \varepsilon_{1t} \end{aligned} \quad (10)$$

$$\begin{aligned} \Delta \ln SII_t = & \alpha_2 + \lambda_2 ECT_{t-1} + \sum_{i=1}^p \beta_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^p \gamma_{2i} \Delta \ln SII_{t-i} \\ & + \sum_{i=1}^p \delta_{2i} \Delta \ln RIDI_{t-i} + \varepsilon_{2t} \end{aligned} \quad (11)$$

$$\begin{aligned} \Delta \ln RIDI_t = & \alpha_3 + \lambda_3 ECT_{t-1} + \sum_{i=1}^p \beta_{3i} \Delta \ln GDP_{t-i} + \sum_{i=1}^p \gamma_{3i} \Delta \ln SII_{t-i} \\ & + \sum_{i=1}^p \delta_{3i} \Delta \ln RIDI_{t-i} + \varepsilon_{3t} \end{aligned} \quad (12)$$

where:

- ECT_{t-1} represents the lagged error correction term,
- λ_i measures the speed of adjustment toward long-run equilibrium,
- β_{ij} , γ_{ij} , and δ_{ij} represent short-run dynamic coefficients.

Granger Causality Test

To examine the direction of causality among the variables, the Granger causality framework is employed. The null hypotheses are specified as follows:

$H_0 : \ln SII$ does not Granger-cause $\ln GDP$ (13)

$H_0 : \ln RIDI$ does not Granger-cause $\ln GDP$ (14)

$H_0 : \ln RIDI$ does not Granger-cause $\ln SII$ (15)

The rejection of the null hypothesis indicates the presence of predictive causality between the variables.

The study employs a log-linear specification to capture elasticities and reduce heteroskedasticity. The ARDL model is used to examine both short-run and long-run relationships, while the VAR model captures dynamic interactions among the variables in the absence of co-integration. Impulse response functions (IRFs) and Granger causality tests are further used to analyse the direction and magnitude of dynamic effects.

Table 14: Definition of Variables and Symbols

Symbol	Variable	Unit	Description
GDP_t	Gross Domestic Product	USD million	Proxy for economic growth in India.
SII_t	Sectoral Investment Index	USD million	Composite index representing sectoral investment activities and project performance.
$RIDI_t$	Regional Investment Disparity Index	USD million	Composite index capturing regional disparities in investment patterns.
$\ln GDP_t$	Logarithm of GDP	–	Natural logarithm transformation of GDP.
$\ln SII_t$	Logarithm of SII	–	Log-transformed Sectoral Investment Index.
$\ln RIDI_t$	Logarithm of RIDI	–	Log-transformed Regional Investment Disparity Index.
Δ	First Difference Operator	–	Represents changes in variables over time.
ECT_{t-1}	Error Correction Term	–	Measures speed of adjustment toward long-run equilibrium.
ε_t	Error Term	–	Random disturbance term in the econometric model.
α, β, γ	Model Coefficients	–	Parameters estimated in the econometric models.
Y_t	Endogenous Variable Vector	–	Vector containing GDP, SII, and RIDI variables.

Source: Author’s compilation based on model specifications and CMIE CapEx database.

The Granger causality test results reveal limited causal interactions among the variables. The null hypothesis that $\ln SII$ does not Granger-cause $\ln GDP$ cannot be rejected, indicating that sectoral investment dynamics do not exert statistically significant predictive influence on economic growth during the study period. Similarly, the null hypothesis that $\ln GDP$ does not Granger-cause $\ln SII$ is also accepted.

However, the results indicate that $\ln RIDI$ Granger-causes $\ln SII$ at the 5% significance level, suggesting that regional investment disparities significantly influence sectoral investment dynamics in India. In addition, weak evidence of causality is observed from $\ln RIDI$ to $\ln GDP$ at the 10% significance level, implying that regional investment imbalances may exert limited short-run predictive influence on economic growth.

Overall, the findings suggest that investment disparities across regions play a more important role in shaping sectoral investment behaviour than directly influencing aggregate economic growth.

Discussion of Findings

The empirical findings reveal that the relationship between investment dynamics and economic growth in India is relatively weak and unstable, particularly in the long run. Although the Johansen co-integration test confirms the existence of a long-run equilibrium relationship among GDP, SII, and RIDI, the estimated Vector Error Correction Model (VECM) indicates weak adjustment dynamics in the GDP equation. The error correction term associated with economic growth is statistically insignificant, suggesting that deviations from long-run equilibrium are not rapidly corrected through changes in GDP.

The short-run dynamics further indicate that sectoral and regional investment indicators exert limited direct influence on economic growth. While the Regional Investment Disparity Index (RIDI) significantly affects the Sectoral Investment Index (SII), its impact on GDP remains weak and statistically insignificant at conventional significance levels. Similarly, the Granger causality analysis reveals only weak evidence of predictive causality from regional investment disparities to economic growth.

These findings partially deviate from conventional growth theories, which generally emphasise a strong positive relationship between investment and economic growth. The results suggest that the effectiveness of investment depends not only on the volume of investment but also on its efficiency, allocation, implementation quality, and regional distribution.

In the Indian context, structural constraints such as project delays, cost overruns, stalled projects, administrative inefficiencies, and uneven regional allocation of investments may weaken the transmission mechanism between investment and output growth. The persistence of regional investment disparities further indicates that investment benefits remain concentrated in relatively developed regions, limiting the broader growth impact across the economy.

Therefore, the findings imply that merely increasing investment expenditure may not be sufficient to achieve sustained economic growth. Greater emphasis must be placed on improving project execution, institutional efficiency, balanced regional allocation, and effective monitoring of investment activities to enhance the overall productivity and developmental impact of investments in India.

Conclusion

This study examined the relationship between sectoral and regional investment dynamics and economic growth in India over the period 1995–2022 using the Sectoral Investment Index (SII) and the Regional Investment Disparity Index (RIDI). Both indices were constructed using Principal Component Analysis (PCA) based on investment-related variables obtained from the CMIE CapEx database. The empirical analysis employed unit root tests, Johansen cointegration analysis, Vector Error Correction Model (VECM), Granger causality tests, impulse response analysis, and VAR diagnostic tests to investigate both long-run and short-run relationships among the variables.

The results of the Johansen co-integration test confirm the existence of one co-integrating relationship among GDP, SII, and RIDI, indicating the presence of a long-run equilibrium association. However, the VECM estimates reveal that the error correction term in the GDP equation is statistically insignificant, suggesting weak long-run adjustment of economic growth toward equilibrium. In contrast, the error correction term in the SII equation is negative and statistically significant, implying that sectoral investment dynamics adjust to restore long-run equilibrium.

The short-run dynamics indicate limited direct influence of investment indicators on economic growth. Although regional investment disparities significantly affect sectoral investment behaviour, their direct effect on GDP remains weak. The Granger causality analysis further reveals significant causality running from RIDI to SII, while only weak evidence of causality is observed from RIDI to GDP.

The impulse response analysis demonstrates that shocks in sectoral and regional investment indicators generate only short-lived fluctuations in GDP, with the responses gradually converging toward equilibrium over time. Furthermore, the VAR diagnostic tests confirm that the estimated model is stable and free from serial autocorrelation, supporting the reliability of the empirical findings.

Overall, the findings suggest that the relationship between investment dynamics and economic growth in India is relatively weak, unstable, and heavily influenced by structural factors. The results imply that the effectiveness of investment depends not merely on the volume of investment expenditure but also on the efficiency of project implementation, institutional quality, regional allocation, and governance mechanisms.

The study highlights the importance of addressing structural bottlenecks such as project delays, cost overruns, stalled investments, and regional imbalances in order to improve the developmental impact of investment activities. Therefore, policy efforts

should focus on enhancing investment efficiency, strengthening institutional capacity, and ensuring balanced regional investment distribution to achieve more sustainable and inclusive economic growth in India.

Policy Implications

The empirical findings of the study provide several important policy implications for investment planning and economic development in India.

First, although the Johansen co-integration results indicate the existence of a long-run relationship among GDP, SII, and RIDI, the weak significance of several long-run coefficients and adjustment terms suggests that merely increasing investment volumes may not be sufficient to generate sustained economic growth. Policymakers should therefore focus on improving the efficiency, productivity, and implementation quality of investments rather than emphasising investment expansion alone.

Second, the significant influence of the Regional Investment Disparity Index (RIDI) on the Sectoral Investment Index (SII), as observed from the VECM and Granger causality results, highlights the importance of reducing regional investment imbalances. Uneven investment distribution may distort sectoral development and weaken overall economic performance. Accordingly, targeted regional development policies, improved infrastructure connectivity, and greater investment incentives for underdeveloped regions are necessary to ensure balanced growth.

Third, the impulse response analysis indicates that shocks in sectoral and regional investment dynamics generate only short-run fluctuations in GDP, with effects gradually dissipating over time. This finding implies that investment policies should be accompanied by complementary structural reforms, including technological advancement, institutional strengthening, skill development, and financial sector efficiency, to achieve stronger and more sustainable growth effects.

Fourth, the persistence observed in regional investment disparities suggests the need for stronger institutional coordination and monitoring mechanisms. Enhancing project governance, reducing delays in project execution, improving transparency, and strengthening public-private partnerships (PPPs) can improve investment outcomes and reduce inefficiencies.

Finally, the results emphasise that the relationship between investment and economic growth is multidimensional and depends not only on investment quantity but also on investment allocation, regional balance, institutional quality, and economic absorptive capacity. Therefore, a comprehensive policy framework integrating regional planning, sectoral prioritisation, and institutional reforms is essential for promoting sustainable and inclusive economic growth in India.

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