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Does economic infrastructure promote economic development in Assam? A comparative study with India based on causality and cointegration approach

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ABSTRACT

This study examines the impact of economic infrastructure and its sub-categories (Power, Rail, and Road) on economic development in Assam from 1990 to 2021, compared to India. The NITI Aayog recently released the SDG report 2023-24, revealing that Assam continues to lag behind other states and the national average in infrastructure development (SDG 9). We constructed the Economic Development Index and Economic Infrastructure Index using Principal Component Analysis (PCA). Johansen's cointegration test and Vector Error Correction Model (VECM) were employed to examine long- and short-term relationships, with Gross Fixed Capital Formation and Population as control variables. Granger causality and Variance Decomposition Analysis further evaluated the direction and significance of effects. Results show that infrastructure positively affects development in Assam in the short and long-term, with a significant role from Gross Fixed Capital Formation. Granger causality confirms a two-way relationship, consistent with Wagner's Law and endogenous growth theory for Assam, while India shows a stronger infrastructure impact. Economic infrastructure plays a critical role in Assam's economic development, highlighting the need for targeted investments. Prioritizing infrastructure, especially Power and Rail, is essential for Assam's sustainable development, helping it to align with national development standards.

Contribution/Originality: This article provides fresh insights into Assam's economic infrastructure-development linkage, comparing it with India and emphasizing region-specific needs. Highlighting the role of Power, Rail, and Road in sustaining economic development, it uses PCA-based indices, VECM, Causality testing and Variance Decomposition to align Assam's development objectives with national goals.

1. INTRODUCTION

The accessibility of infrastructure facilities is a key prerequisite in the development process. It comprises all the facilities and services that support and sustain the income generation potential of an economy (Jayashankar, 2002). One of the main policies for regional development is to raise productivity, which is possible through infrastructure development. Both economic and social infrastructure[1] help in uplifting the level of economic development, but economic infrastructure plays a more pivotal role, as it helps in the formation and smooth conduct of other

[1]Economic infrastructure and social infrastructure are the two categories under which infrastructure is traditionally categorized (Dash & Sahoo, 2010; Kumari & Sharma, 2017).

infrastructural facilities (Palei, 2015). Economic infrastructure directly supports productive activities or facilitates the transportation and distribution of economic goods. It supplies the vital energy and communication networks required for industries to run smoothly, as well as the efficient movement of labor, products, and services through transportation networks like ports, railroads, and roadways. As a result, it directly supports industrial activity. By creating the income and resources required to fund initiatives for human development, a robust economic infrastructure paves the way for further advancements in social infrastructure. Lewis (1955) proposed that the creation of credit, which is driven by the expanding power, banking, and transportation sectors—all of which fall under the category of economic infrastructure—is essential to establishing better working conditions in a labor-surplus economy. Hirschman (1958); Singer (1958); Streeten (1959) and Fleming (1955) emphasized infrastructure development for balanced growth. Aschauer (1989) considered economic infrastructure to increase the productivity of other components and be an essential input used in manufacturing activities (Pandya & Maind, 2017). The effects of Economic Overhead Capital (EOC) on the economy vary between developed and developing countries and are based on the degree of economic development. There can occasionally be a discrepancy between immediate gains and long-term sustainable growth. Despite these differences, the consensus is that economic infrastructure promotes higher productivity and economic development. Economic infrastructure like transport infrastructure, viz., rail, road, freight, and water transport, are essential for fostering economic development (Alam, Li, Baig, Ghanem, & Hanif, 2021). Moreover, Power infrastructure promotes economic development by providing reliable and efficient energy supply, which drives industrial activity, supports businesses, and fuels overall economic growth (Xu, Das, Guo, & Wei, 2021). At the India level, studies by Dadibhavi (1991); Ghosh and De (1998); Nagaraj, Varoudakis, and Véganzonès (2000); Mazumder (2002); Pradhan and Bagchi (2013); Mohmand, Wang, and Saeed (2017) and Kumari and Sharma (2017) found that economic infrastructure promotes economic development. Wagner (1958) however, disagreed with Hirschman (1958) who believed that economic infrastructure will only be needed when there is development. Maparu and Mazumder (2017) also found that economic growth drives the expansion of transport infrastructure at the national level in India. The literature reveals ongoing debate regarding causality between economic infrastructure and development, with inconclusive outcomes needing further investigation. Nagaraj et al. (2000) omitted regression analysis that could reveal short- and long-term infrastructure-development linkages. While Kumari and Sharma (2017) and Maparu and Mazumder (2017) analyzed infrastructure at the national level, they overlooked state-level specifics. Notably, no studies provide a comparative assessment of Assam's infrastructure with India's, despite Assam's emerging role as a critical hub in the India-South Asia trade relationship. Furthermore, these studies did not consider power infrastructure, which enables industries, businesses, and services to operate efficiently, driving productivity and growth.

As per the State Income Statistics published by the Government of Assam, Assam boasts the largest economy among the eight North-Eastern states. A closer investigation of macroeconomic data reveals that Assam's economic performance is not comparable to that of India and other major states[2] of the country. Over the past few decades, the service sector and industry have evolved as a rapidly expanding sector. However, the majority of service and industry sub-sectors cannot favorably impact the state's economy due to a lack of infrastructure development. As per the 11thFinance Commission report, Assam ranked 13th among the 15 major states of India in terms of infrastructure development, which implies the dependency on the government investment by the state for infrastructure development rather than on the private counterpart (Das & Dutta, 2023). Thus, it is essential to assess the causality and long-run relationship between economic infrastructure and development in Assam. This analysis will guide the policymakers in enhancing infrastructure, such as transport networks, energy supply, and communication systems, to attract investment and boost productivity. We also compare Assam's results with India's to better understand the relationship between infrastructure and development at both levels. By identifying Assam's specific needs,

[2] See Thind and Singh (2018); Pandya and Maind (2017) and Varkey and Panda (2018) for the details of Major states considered in a pan-Indian analysis.

policymakers can tailor strategies more effectively. To address possible endogeneity, we included relevant control variables in the model. Moreover, we have considered the sub-categories of economic infrastructure to assess the one-to-one correspondence with economic development. Even though per capita income is considered an essential yardstick of economic development (Alam et al., 2021) here we have constructed a composite index based on development indicators to address the endogeneity issue. Additionally, we applied factor analysis to construct the indices, effectively addressing potential multicollinearity issues.

Five sections comprise this article. The introduction section offers a succinct summary of the crucial theory concerning economic infrastructure and development. Section II contextualizes the empirical literature on the relationship between economic infrastructure and economic development, highlighting an important research question for further investigation in the following section. Section III explores the data and methodology employed, while Section IV examines the nexus between economic infrastructure and economic development for Assam and India, respectively, using time series econometrics. Section V concludes the analysis and provides appropriate policy recommendations based on the study.

2. LITERATURE REVIEW

Numerous studies, conducted at both international and national levels, have examined various categories of infrastructure and their correlation with economic development. We present a synoptic view of the most important and relevant studies here. Dadibhavi (1991) analyzed India's inter-state social infrastructure development from 1970-71 to 1984-85, focusing on healthcare and education. Using PCA to construct a composite indicator, the study found significant regional disparities, with greater variation in health infrastructure. A strong positive correlation emerged between social infrastructure and economic development. However, the study did not examine economic infrastructure, a key component of social infrastructure, nor did it apply robust methods to address potential endogeneity. Queiroz and Gautam (1992) analyzed 98 countries over 40 years (1950-1990), finding a significant correlation between road infrastructure and economic development, measured by per capita income. However, the study's reliance on per capita income as a sole proxy for development overlooked other key determinants, which is a major drawback of this paper. Results indicated that high-income countries consistently showed higher per capita road infrastructure compared to middle- and low-income nations. Ghosh and De (1998) found that physical infrastructure has a positive impact on economic development in India, and variation in physical infrastructure was found to be one of the major reasons for unbalanced development in the country over the period 1961-62 to 1994-95 without due region-specific attention.

Nagaraj et al. (2000) used PCA and panel data to look at how infrastructure affected growth in 17 major Indian states from 1970 to 1994. They found that roads, irrigation, and power were important growth drivers and that there was evidence of conditional convergence. Mazumder (2002) used three methods to look at the infrastructural facilities and economic growth of 15 major Indian states: panel data analysis from 1971 to 1995, cross-sectional research for 1970–71, 1980–81, and 1990–91, and a national-level time series from 1971 to 1995. Composite indices were created using Principal Component Analysis, and the results showed notable variations in state-level infrastructure and economic growth. Fan and Zhang (2004) used the Generalized Methods of Moments to examine whether infrastructure development leads to economic development in rural areas of China. Increased investment in roads and irrigation contributed positively to the growth of the agricultural sector. However, the limitation of the study is that instead of GMM, applying Structural Equation Modelling would have been more appropriate for the study. Cesar and Luis (2008) conducted a panel data analysis of over 100 countries from 1960 to 2005 to examine the causal linkage between infrastructure and economic development, finding a positive relationship. However, the study did not include essential control variables to address endogeneity. Kumari and Sharma (2017) found a significant positive linkage between economic and social infrastructure and economic development in Indian states from 1995 to 2013 using unrestricted VAR and Granger causality tests. However, the study did not evaluate the short- and long-run dynamic relationships among the variables. Das and Dutta (2023) used panel dynamic ordinary least squares estimation and the Dumitrescu–Hurlin panel causality test to look into how public infrastructure and economic growth in Assam were connected from 1999–2000 to 2017–18. Excluding health infrastructure, their results show a long-term correlation between economic growth and public infrastructure indices. However, a drawback of the study is its greater focus on growth over the broader aspects of economic development.

The reviewed literature indicates that using Gross Domestic Product as a proxy for development in most studies fails to fully capture the nuances of economic development. Furthermore, these studies have largely overlooked Assam, which is emerging as a business hub between India and South Asia and serves as a leading economy in North-east India. Despite being recognized as the front-runner state in the Sustainable Development Goals Report 2023-24, Assam performs worse in terms of infrastructure development (SDG 9) than all of the BIMARU states combined[3], except Madhya Pradesh. The state's infrastructure is also lagging behind that of multiple northeastern states, which include Mizoram, Manipur, Sikkim, and Nagaland. Furthermore, the Sustainable Development Goals Report, 2023-24, ranks the state sixth from the bottom for SDG 9. Given this context, it would be fascinating to examine how the state's economic infrastructure facilitated economic growth between 1990-1991 and 2020-21, using a time series framework. When compared to panel data, time series are more robust since they consider the unique features of a state. Moreover, the study aims to offer policy recommendations to improve the state's infrastructure to make economic development sustainable, based on the existing findings. The primary aim of the study is to conduct a comparative analysis of the nexus between economic infrastructure and economic development in Assam and India. Additionally, we test the following research question: How does the relationship between economic infrastructure (including rail, road, and power) and economic development differ between Assam and the broader context of India? The answer to this question will assist policymakers in identifying the specific gaps and strengths in Assam's infrastructure in comparison to the national level. It will assist in pinpointing the infrastructure bottlenecks that could be impeding Assam's economic growth, such as inadequate connectivity, insufficient power supply, and poor road conditions. Moreover, these insights will allow policymakers to prioritize investments and reforms in infrastructure development, thereby fostering regional growth in Assam.

3. DATA AND METHODOLOGY

Based on the modes of transport, India's transport system may be broadly classified into four primary categories: air, water, rail, and road. The two most common modes of transportation among them are rail and road. Inland or riverine transport and coastal or marine transport are two other categories for water transport. Still, inland water transport is extremely small, making up only 0.15% of all freight transit within the country (Datt & Mahajan, 2013). Furthermore, we have excluded the time series of air transport and inland water transport data for Assam due to their lack of availability. We collected and compiled secondary and annual time-series data from various sources listed in Table 1 for the present study, spanning from 1990-91 to 2020-21. We select the time period based on the uniform availability of data for all the indicators used to construct the Economic Infrastructure Index, its sub-categorical indices, and the Economic Development Index.

[3]See Sharma (2015) for details on BIMARU states.

Table 1. Selected indicators and source of data.

Variables	Broad indicators	Indicators for composite index construction	Justification for selection of variables	Source of data
Economic infrastructure	Road	a) Total road length per thousand square kilo meters	(i)Total road length per area and population indicates accessibility, while the percentages of national, state, and public works department highways reveal their importance. The surfaced-to-unsurfaced road ratio reflects infrastructure conditions, which are crucial for transportation and economic activity. (ii) For railways, access is measured by the length of the rail route per 1,00,000 population. Area and network efficiency is indicated by the percentages of broad gauge and meter gauge. (iii) In power infrastructure, installed capacity and total generation assess supply, per capita availability indicates access, and electrified village percentages show reach, with transmission losses highlighting efficiency and reliability.	(i)Authors' computation from indiastat database (ii) Infrastructure series of the centre for monitoring Indian economy (CMIE) (iii)Road transport year book (Various issues) (iv) Directorate of economics and statistics, government of India
		b) Total road length per 1,00,000 population		
		c) Percentage of national highways to total road length		
		d) Percentage of State highways to total road length		
		e) Percentage of PWD roads to total road length		
		f) Surfaced roads per thousand population		
		g) Percentage of unpaved road to total road length.		
	Railway	a) Rail route per 1,00,000 population,		
		b) Rail route per 100 square kilometers of area,		
		c) Percentage of broad gauge to total railway length		
		d) Percentage of meter gauge to total railway length.		
	Power	a) Installed capacity of power b) Total generation of electricity		
		c) Per capita availability of power		
		d) Percentage of villages electrified to the total number of villages		
		e) Transmission & distribution lines		
		f) Transmission & distribution losses (In %) as a percentage of power availability		
Economic development	Agricultural development indicators	a) Per capita net state domestic product from agriculture and allied activities at constant prices	(i)Agriculture: Reduce transaction costs, open markets, and foster innovation, enhancing productivity and land use, which boosts economic contributions and underscores the link between agricultural development and infrastructure. (ii)Industry: High-quality infrastructure—covering communication, energy,	(i)Authors computation from handbook of statistics on Indian states (Various issues) (ii) Statistical handbook of assam (Various issues)
		b) Percentage of agriculture from net state domestic product		
		c) Net state domestic product from agriculture per 1000 hectares of gross cropped area		

Variables	Broad indicators	Indicators for composite index construction	Justification for selection of variables	Source of data
		d) Cropping intensity	transportation, and industrial parks—improves productivity, lowers production costs, and supports advanced technology, driving economic development.	(iii) Economic survey of assam (Various issues)
	Industrial development indicators	a) PCNSDP from the secondary sector at constant prices		
		b) Registered factories per 1000 square kilometers of the area		
		c) Percentage of net state domestic product from secondary sector		
		d) Net value added by registered factories per worker		
		e) Productive capital in the registered factories per worker		
		f) Net value added-productive capital ratio in the registered factories per worker		
	Human development indicators	a) Infant survival rate per 1000 infant mortality rate (IMR)	As societies move from high fertility and mortality to lower rates in more developed stages, this lowers both birth and death rates (Demographic transition theory: Thompson (1945)). The cost of raising children increases when economic infrastructure facilitates women's access to education and employment, leading to a decrease in birth rates (Becker, 1960). Improved roads and reliable power make it easier for people to access healthcare, which lowers mortality rates and makes healthcare services run more smoothly (Grossman, 1972).	
		b) Crude death rate		
		c) Crude birth rate		
	Other indicators	a) Per capita net state domestic product at constant prices	Reliable infrastructure is crucial for the tertiary sector, supporting services like banking, information technology, and education that rely on efficient communication and transportation systems.	
		b) Percentage of net state domestic product from tertiary sector		

3.1. Method of Analysis

To form a time series, we use Principal Component Analysis (PCA) to develop indices for economic infrastructure and economic development for each year from 1990-91 to 2020-21. The method's main objective is to determine the variable's weight and its importance (Kaur, Ahmad, & Shakeel, 2023). In this analysis, factor extraction was based on eigenvalues greater than 1 (Malhotra, 2008) and only communalities and factor loadings above 0.5 were retained (Hair, Black, Babin, & Anderson, 2013). Some of the normalization techniques used are z-score, min-max transformation, ranking, and the United Nations Development Programm (UNDP) method to compute the Human Development Index (Basel, Gopakumar, & Prabhakara Rao, 2021; Kumari, Raman, & Patel, 2023). The present study uses the following formula for scale equivalence, Equation 1, following Ohlan (2013).

$$Z_i = \frac{X_{i-}\bar{X}_i}{\sigma_i} \qquad (1)$$

Where X_i refers to the original value of the i^{th} indicator (i=1, 2… n), $\bar{X}_i$ represents the mean of the i^{th} indicator and σ_i the standard deviation of the i^{th} indicator. After the scale equivalence, PCA is deployed to construct the economic infrastructure and economic development indices. Principal components are linear combinations of variables that are orthogonal to one another, which are expressed below:

$$P_1 = a_{11}z_1 + a_{12}z_2 + a_{13}z_3 + \dots\dots\dots + a_{1n}z_n$$
$$P_2 = a_{21}z_1 + a_{22}z_2 + a_{23}z_3 + \dots\dots\dots + a_{2n}z_n$$
$$P_n = a_{n1}z_1 + a_{n2}z_2 + a_{n3}z_3 + \cdots\dots\dots + a_{nn}z_n$$

or

$$P_i = \sum_{j=1}^{n} a_{ij}W_j \qquad (2)$$

Where, a_{1j} represents the correlation between the factor and initial variable and $z_1, z_2, \dots\dots\dots, z_n$ represent the normalized indicators chosen for economic infrastructure or economic development.

The following formula determines the weights of the indicators:

$$W_i = \sum(\mid P_{iw} \mid \times \sum GV_w) \qquad (3)$$

W_i represents the weight of the indicators (i=1,2,….., n), P_{iw} represents the w^{th} components of the i^{th} indicators, and GV_w represents the components' initial Eigen value, which remains constant. The Economic Infrastructure Index (EII) and the sub-categorical infrastructure index viz., Power Infrastructure Index (PII), Road Infrastructure Index (RII), Railway Infrastructure Index (RLYII), and Economic Development Index (EDI), are constructed using the equation given below:

$$Composite\ Index = \frac{\sum(NV_i \times W_i)}{\sum_{i=1}^{10} W_i} \qquad (4)$$

Theoretical frameworks alone cannot adequately determine the relationship between economic infrastructure and development; actual evidence is required to establish the direction of causality for a region under examination. To address the potential endogeneity issue in the infrastructure-development nexus, we have developed two models that particularly target the economic infrastructure sub-indices and a couple of control variables depending on the restrictions of data availability. If stationarity tests such as the Augmented Dickey Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) confirm the same level of integration, we will conduct the Johansen cointegration test to identify long-run relationships. Model I employs Granger Causality and VECM to investigate the causal relationship between economic infrastructure and development, while model II concentrates on the influence of infrastructure subcategories on development.

The following models were developed to examine the causal relationship between economic infrastructure and economic development:

3.2. Model I

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{i1} Y_{t-i} + \sum_{i=1}^{m} \beta_{1i} A_{t-i} + \sum_{i=1}^{m} \gamma_{1i} B_{t-i} + \sum_{i=1}^{m} \phi_{1i} C_{t-i} + u_t \quad (5)$$

$$A_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{i1} Y_{t-i} + \sum_{i=1}^{m} \beta_{1i} A_{t-i} + \sum_{i=1}^{m} \gamma_{1i} B_{t-i} + \sum_{i=1}^{m} \phi_{1i} C_{t-i} + u_t \quad (6)$$

Here, t= current year, i= 1,2,…,m represents time lag, Y_t= Economic Development, A_t= Economic Infrastructure, B_t=Population and C_t=Gross Fixed Capital Formation and u_t= residual or error term.

3.3. Model II

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{i1} Y_{t-i} + \sum_{i=1}^{m} \beta_{1i} D_{t-i} + + \sum_{i=1}^{m} \beta_{1i} E_{t-i} + \sum_{i=1}^{m} \beta_{1i} F_{t-i} + \sum_{i=1}^{m} \gamma_{1i} B_{t-i} + \sum_{i=1}^{m} \phi_{1i} C_{t-i} + u_t \quad (7)$$

$$D_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{i1} Y_{t-i} + \sum_{i=1}^{m} \beta_{1i} D_{t-i} + + \sum_{i=1}^{m} \beta_{1i} E_{t-i} + \sum_{i=1}^{m} \beta_{1i} F_{t-i} + \sum_{i=1}^{m} \gamma_{1i} B_{t-i} + \sum_{i=1}^{m} \phi_{1i} C_{t-i} + u_t \quad (8)$$

$$E_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{i1} Y_{t-i} + \sum_{i=1}^{m} \beta_{1i} D_{t-i} + + \sum_{i=1}^{m} \beta_{1i} E_{t-i} + \sum_{i=1}^{m} \beta_{1i} F_{t-i} + \sum_{i=1}^{m} \gamma_{1i} B_{t-i} + \sum_{i=1}^{m} \phi_{1i} C_{t-i} + u_t \quad (9)$$

$$F_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{i1} Y_{t-i} + \sum_{i=1}^{m} \beta_{1i} D_{t-i} + + \sum_{i=1}^{m} \beta_{1i} E_{t-i} + \sum_{i=1}^{m} \beta_{1i} F_{t-i} + \sum_{i=1}^{m} \gamma_{1i} B_{t-i} + \sum_{i=1}^{m} \phi_{1i} C_{t-i} + u_t \quad (10)$$

Where, t= current year, i= 1,2,…,m represents time lag, Y_t= Economic Development, D_t= Road Infrastructure, E_t= Railway infrastructure, F_t= Power Infrastructure, B_t=Population and C_t=Gross Fixed Capital Formation and u_t= residual or error term.

To minimize omitted variable bias and more accurately capture the impact of infrastructure improvements on economic development, two control variables were included. We have incorporated Gross Fixed Capital Formation (GFCF) and Population as control variables in our study following Sajjad, Chani, Pervaiz, and Chaudhary (2012); Pradhan and Bagchi (2013); Meersman and Nazemzadeh (2017) and Zhang and Cheng (2023).

4. FINDINGS AND DISCUSSIONS

Since the British era, Assam's economic infrastructure has expanded, initially serving colonial interests in industries like coal, tea, and oil. Post-independence, infrastructure grew with projects like the East-West Corridor, enhancing road, rail, and trade connectivity with India. Key developments included the construction of bridges, power plants, and oil refineries. Recent investments focus on renewable energy, but challenges remain, especially in rural areas (Dikshit & Dikshit, 2014). A comparative analysis with India highlights infrastructure gaps that may hinder Assam's development over the study period. This study's construction of the composite index for economic development represents an improvement over many previous studies, with their limitations already discussed in the literature review. Adding sub-categorial variables to a separate regression analysis is a new way to deal with possible endogeneity problems and get a fuller picture of the relationship between infrastructure and development.

Table 2. Descriptive statistics (Assam).

Indicator/Variables	EDI	EII	PII	RLYII	RII	GFCF	Population
Mean	0.747	0.248	0.765	0.310	0.258	24249.71	31807.06
Median	0.768	0.242	0.740	0.317	0.202	10110.80	31596.13
Maximum	1.390	0.586	1.656	0.557	0.570	192001.0	45192.99
Minimum	0.194	0.009	0.015	0.089	0.0157	1981.800	24066.44
Std. dev.	0.357	0.161	0.436	0.114	0.184	39074.29	5207.338
Skewness	0.160	0.378	0.226	-0.219	0.488	3.003837	0.523
Kurtosis	1.966	2.133	2.159	2.041	1.691	1.478	2.668
Jarque-Bera	1.512	1.312	0.474	0.415	3.445	162.665	1.558

Table 3. Descriptive statistics (India).

Indicator/Variables	EDI	EII	GFCF	Population	PII	RLYII	RII
Mean	1.014	0.349	1693600	686000000	0.871	0.119	0.178
Median	1.010	0.298	799365.9	572000000	0.840	0.081	0.178
Maximum	2.265	0.837	3795876	1510000000	2.201	1.345	0.541
Minimum	0.112	0.068	242925.9	245000000	0.027	0.004	0.006
Std. dev.	0.593	0.215	1369430	390000000	0.553	0.233	0.138
Skewness	0.154	0.759	0.446	0.715	0.573	4.866	0.533
Kurtosis	2.114	2.059	1.464	1.321	1.641	26.102	1.631
Jarque-Bera	1.136	3.054	4.072	3.237	1.863	811.743	1.644

Table 2 and 3 present descriptive statistics for seven variables across 31 observations for Assam and India. The median values for Assam are 0.768 (EDI), 0.243 (EII), and 10110.80 (GFCF), while India's are 1.010 (EDI), 0.299 (EII), and 799365.9 (GFCF). Mean values show a similar pattern with GFCF and the Population having higher skewness and standard deviation. Variables like Population and RLYII show leptokurtic behavior, with extreme outliers. The data for Assam and India display similar characteristics, justifying using a common analysis method. Further, the structural break Test has also been conducted using the Zivot-Andrews Structural breakpoint test (Zivot & Andrews, 2002) and no significant structural break was recorded[4]. The ADF, PP, and KPSS tests are used to check for stationarity in time series data, and the results are presented below (Tables 4 and 5).

Table 4. Result of ADF, PP and KPSS unit root tests (Model I).

Assam						
Variables	**Level**			**First difference**		
	ADF	**PP**	**KPSS**	**ADF**	**PP**	**KPSS**
Ln EDI	-3.97	-2.16	0.25	-8.08***	-8.24***	0.09***
lnEII	-4.23	-1.92	1.77	-4.14***	-4.17***	0.07***
Ln GFCF	-2.91	-2.18	0.21	-4.45***	-20.93***	0.09***
Ln population	-3.90	-3.17	0.32	-2.63***	-2.48***	0.01***
India						
lnEDI	-2.272	-1.23	0.163	-4.42***	-4.30***	0.086***
lnEII	-1.576	-1.357	0.160	-7.432***	-7.421***	0.169***
lnGFCF	-3.81	-2.09	0.122	-5.02***	-5.02***	0.0726***
Ln population	-4.121	-4.231	0.157	-5.51***	-23.51***	0.308***

Note: Significant at ***1%.

The results represent that the null hypothesis of the existence of a unit root is rejected at a 1% level (p-values ≤0.01) for all the variables on their first-order difference (Table 4). This implies all the variables are I (1) processes.

Table 5. Result of ADF, PP and KPSS unit root tests (Model II).

Assam						
Variables	**Level**			**First difference**		
	ADF	**PP**	**KPSS**	**ADF**	**PP**	**KPSS**
lnEDI	-3.18	-4.51	0.23	-3.97***	-2.16***	0.25***
lnGFCF	-4.22	-2.45	0.82	-2.91***	-2.18***	0.21***
Ln population	-2.11	-1.11	0.12	-3.90***	-3.17***	0.32***
lnPII	-3.33	-1.12	0.99	-2.63***	-2.48***	0.09***
lnRLYII	-3.12	-0.88	0.12	-4.45***	-20.93***	0.05***
lnRII	-4.11	-0.89	0.13	-4.25***	-11.93***	0.95***
India						
lnEDI	-2.272	-1.23	0.16	-4.42***	-4.30***	0.09***
lnGFCF	-3.81	-2.09	0.12	-5.02***	-5.02***	0.07***
Ln population	-4.12	-4.23	0.16	-5.51***	-23.51***	0.31***
lnPII	-3.09	-3.05	0.10	-7.34***	-9.48***	0.48***
lnRLYII	-3.17	-3.14	0.17	-5.43***	-15.47***	0.17***
lnRII	-2.87	-2.68	0.78	-4.87***	-19.27***	0.23***

Note: Significant at ***1%.

The results represent that the null hypothesis of the existence of a unit root is rejected at a 1% level (p-values ≤0.01) for all the variables on their first-order difference (Table 5). This implies all the variables are I (1) processes. Before carrying out the co-integration test, the relevant variables and appropriate lag need to be identified. Here,

[4]In 2012, we identified a single break. Assam has not experienced any unusual instability this year. To determine the significance of the break, we employed the following model by adding a dummy.: $lnEDI_t = \psi + \lambda lnEII_t + \mu dum + u_t$

VAR-based lag selection criteria have been used, and the appropriate lag length for both Assam and India (Model I) is estimated to be 1 at a 5% level of significance. For Model II, the appropriate lags selected are 1 and 2 for Assam and India, respectively (See Appendix Table 15). Based on the stationarity and co-integration result, whether VECM or VAR will be used in our analysis will be determined. The VAR model will be employed if the variables have different orders of integration. In analyzing economic infrastructure and development, the VAR model does not strictly rely on economic theory (Torrisi, 2010). If the series are co-integrated (given the variables are of the same order of integration), it is more appropriate to use the Vector Error Correction Model (VECM). VECM helps to capture both the short- and long-run relationship between the economic infrastructure and economic development (Zhang & Cheng, 2023). However, before the application of the VECM model, it is necessary to examine whether the variables exhibit any long-run relationship between them, which is examined using the Johansen co-integration test (Tables 6 & 7).

Table 6. Johansen co-integration tests based on trace and eigenvalue (Model I).

Hypothesis	Assam			
	Eigenvalue	Trace statistics	5% CV	p-value
Trace				
None*	0.801	69.940	47.856	0.0001
At most 1	0.458	24.605	29.797	0.176
At most 2	0.159	7.417	15.494	0.529
At most 3*	0.087	2.553	3.841	0.010
Maximum eigenvalue				
None*	0.801	45.334	2758434	0.0001
At most 1	0.458	17.188	21.131	0.163
At most 2	0.159	4.863	14.264	0.759
At most 3*	0.087	2.553	3.841	0.0101
India				
Trace				
None*	0.704	73.000	47.856	0.0001
At most 1*	0.457	38.909	29.797	0.0034
At most 2*	0.398	21.805	15.494	0.0049
At most 3*	0.237	7.584	3.841	0.0059
Maximum eigenvalue				
None*	0.704	34.090	27.584	0.006
At most 1*	0.457	17.103	21.131	0.167
At most 2*	0.398	14.220	14.264	0.051
At most 3*	0.237	7.584	3.841	0.0059

Note: * denotes rejection of the null hypothesis at 5% level of significance.

Table 7. Johansen co-integration tests based on trace and eigenvalue (Model II).

Hypothesis	Assam			
	Eigenvalue	Trace statistics	5% CV	p-value
Trace				
None*	0.895	129.317	95.753	0.000
At most 1	0.675	66.111	69.818	0.095
At most 2	0.379	34.573	47.856	0.470
At most 3	0.309	21.228	29.797	0.343
At most 4	0.216	10.853	15.494	0.220
At most 5*	0.133	4.009	3.841	0.045
Maximum eigenvalue				
None*	0.895	63.206	40.077	0.0000
At most 1	0.675	31.537	33.876	0.0927
At most 2	0.379	1334489	27.584	0.8650
At most 3	0.309	10.375	21.131	0.7088
At most 4	0.216	6.843	14.264	0.5078
At most 5*	0.133	4.009	3.841	0.0452

Hypothesis	Assam			
	Eigenvalue	Trace statistics	5% CV	p-value
India				
Trace				
None*	0.933	187.537	95.753	0.000
At most 1*	0.849	114.288	69.818	0.000
At most 2*	0.594	63.207	47.856	0.0010
At most 3*	0.492	38.816	29.797	0.0035
At most 4*	0.392	20.478	15.494	0.0081
At most 5*	0.228	7.005	3.841	0.0081
Maximum eigenvalue				
None*	0.933	73.249	40.077	0.000
At most 1*	0.849	51.080	33.876	0.000
At most 2	0.594	24.391	27.584	0.121
At most 3	0.492	18.338	21.131	0.117
At most 4	0.392	13.472	14.264	0.066
At most 5*	0.228	7.0054	3.841	0.0081

Note: * denotes rejection of the null hypothesis at 5% level of significance.

The Engle and Granger (1987) cointegration test uses the ADF test on residuals to check for cointegration, with the tau and z-statistics as key measures. However, this single-equation approach treats one variable as dependent and may miss cointegration in small samples or when multiple variables are involved. It also can't estimate multiple cointegrating vectors for more than two variables (Enders, 2014). The Johansen co-integration test has been employed, and the results of trace statistics and maximum eigenvalues are shown in Tables 6 & 7. The results of both tests confirm the long-run equilibrium relationship between the variables for Assam and India. This finding conforms with Pradhan and Bagchi (2013). Estimating a VECM is more appropriate in our case due to the existence of the long-run equilibrium relationship between the variables. The long run co-integration relationship is estimated with the help of the models below:

$$Model\ I: lnEDI_{t-1} = \alpha + \beta_1 lnEII_{t-1} + \beta_2 lnGFCF_{t-1} + \beta_3 lnPopulation_{t-1} + u_t \quad (11)$$

$$Model\ II: lnEDI_{t-1} = \phi + \gamma_1 lnRII_{t-1} + \gamma_2 lnRLYII_{t-1} + \gamma_3\ lnPII_{t-1} + \gamma_4 lnGFCF_{t-1} + \gamma_5\ lnPopulation_{t-1} + u_t \quad (12)$$

Table 8. Long run co-integration relationship (Model I).

Region/Variables	Constant	$lnEDI_{t-1}$	$lnEII_{t-1}$	$lnGFCF_{t-1}$	$lnPOP_{t-1}$
Assam	0.693	1.000	-0.449 (0.273) [-2.177]**	-2.621 (0.284) [-9.239]***	23.592 (12.563) [1.878]**
India	38.789	1.000	-32.202 (12.910) [-2.494]**	5.991 (21.203) [-0.282]	62.960 (98.449) [6.395]***

Note: ***Statistically significant at 1% level, **statistically significant at 5% level. Figure in parentheses is estimated standard errors.

The results in Table 8 show that in the case of Assam, the Economic Development Index (EDI) and the Economic Infrastructure Index (EII) appear to have a positive and significant relationship, according to the long-run cointegrating equation. For Assam, a 1% rise in economic infrastructure increases economic development by 0.449%, and gross fixed capital formation (GFCF) has a strong positive impact. Population growth negatively affects development. For India, a 1% rise in infrastructure boosts development by 32.202%, while population growth negatively impacts development due to resource constraints. Our study's findings align with those of Zhang and Cheng (2023).

Table 9. Long-run co-integration relationship (Model II).

Region/ Variables	Constant	$lnEDI_{t-1}$	$lnPII_{t-1}$	$lnRII_{t-1}$	$lnRLYII_{t-1}$	$lnGFCF_{t-1}$	$lnPOP_{t-1}$
Assam	0.693	1.000	-0.143 (3.373) [-1.235]	-0.955 (0.151) [-6.304]***	-0.073 (0.135) [-0.544]	-0.787 (0.108) [-7.257]***	1.609 (7.373) [0.218]
India	0.222	1.000	-3.273 (0.292) [-11.192]***	-1.498 (0.113) [-13.290]***	-1.543 (0.206) [-7.505]***	-1.653 (0.293) [-5.634]***	4.392 (1.551) [2.833]***

Note: ***Statistically significant at 1% level. Figure in parentheses is estimated standard errors.

For Assam, a 1% increase in road infrastructure leads to a 0.955% improvement in economic development, with a strong positive impact from GFCF, emphasizing the importance of capital investment in long-term growth in model II (Table 9). For India, development is positively and significantly influenced by road, railway, and power infrastructure, as well as GFCF, demonstrating the key role of infrastructure and capital investment, which corroborates the findings of Maparu and Mazumder (2017). In contrast, population growth negatively affects development.

Table 10. Results of vector error correction model (VECM) (Model I).

Assam				
Variables	$\Delta lnEDI_t$	$\Delta lnEII_t$	$\Delta lnPop_t$	$\Delta lnGFCF_t$
Cointegration	-0.0320 (0.03012) [-1.965]**	-0.228 (0.110) [-2.078]**	-0.005 (0.004) [1.23]*	-0.689 (0.136) [5.044]***
$\Delta lnEDI_{t-1}$	-0.504 (0.175) [-2.874]***	0.106 (0.641) [0.166]	0.036 (0.024) [1.512]**	-0.268 (0.797) [-0.336]
$\Delta lnEII_{t-1}$	0.021 (0.033) [1.668]*	-0.888 (0.12386) [-7.174]***	-0.002 (0.004) [-0.507]	-0.187 (0.153) [-1.22]
$\Delta lnPop_{t-1}$	-4.267 (2.255) [-1.891]*	-23.029 (8.242) [-2.794]***	-0.209 (0.309) [-0.678]	16.314 (10.238) [1.593]
$\Delta lnGFCF_{t-1}$	-0.046 (0.045) [-1.035]**	-0.358 (0.165) [-2.169]	0.009 (0.006) [1.515]*	0.171 (0.205) [0.833]
Constant	0.007 (0.038) [1.183]*	-0.133 (0.140) [-1.949]***	0.0032 (0.005) [0.617]	-0.0256 (0.174) [-0.14711]
R-squared	0.781	0.766	0.457	0.797
Adj. R-squared	0.520	0.699	0.391	0.739
India				
Variables	$\Delta lnEDI_t$	$\Delta lnEII_t$	$\Delta lnPop_t$	$\Delta lnGFCF_t$
Cointegration	-0.199 (0.002) [-1.679]*	-0.001 (0.004) [0.153]	-0.003 (0.001) [6.157]***	-0.006 (0.002) [2.842]
$\Delta lnEDI_{t-1}$	0.084 (0.224) [0.375]	0.023 (0.488) [0.047]	0.039 (0.058) [0.669]	0.001 (0.253) [0.004]
$\Delta lnEII_{t-1}$	0.919 (0.079) [1.166]*	0.679 (0.171) [3.952]***	0.041 (0.020) [2.002]	0.154 (0.089) [1.728]*
$\Delta lnPop_{t-1}$	-0.376 (0.817) [-0.460]	-0.503 (1.777) [-0.283]	-0.347 (0.214) [1.619]	-1.377 (0.923) [1.491]
$\Delta lnGFCF_{t-1}$	-0.046 (0.184) [-1.852]*	0.131 (0.401) [0.327]	0.022 (0.048) [0.474]	0.317 (0.208) [1.520]
Constant	-0.006 (0.047) [-0.128]	0.173 (1.103) [1.768]*	0.002 (0.012) [0.189]	0.098 (0.053) [1.652]*
R-squared	0.618	0.768	0.797	0.689
Adj. R-squared	0.492	0.687	0.750	0.581

Note: ***statistically significant at 1% level, **statistically significant at 5% level, *statistically significant at 10% level. (Estimated standard errors are in parenthesis).

The long-term co-integration coefficient for Assam is -0.032, which is significant at 5%. This means that the state is slowly adjusting (3.2%) from short-term dynamics to long-term equilibrium between development and economic infrastructure (Table 10). Past higher growth leads to slower future growth. The lagged term for economic infrastructure (Δlnecoinfra-1) has a coefficient of 0.021, significant at 10%, showing a short-term impact after two or more years. For India, the long-run coefficient is -0.199, significant at 10%, with a 1.99% adjustment speed. The lagged term (Δlnecoinfra-1) has a coefficient of 0.919, also significant at 10%, showing short-term effects. These suggest that a significant short-term impact of economic infrastructure on economic development is evident after two or more years. This finding corroborates the findings of Pradhan and Bagchi (2013). Many studies have, however, highlighted the negative impact of transport infrastructure projects (Cantarelli, Flyvbjerg, Molin, & Van Wee, 2010; Locarelli, Invernizzi, & Brookes, 2017). According to them, transport infrastructure projects require huge investments but fail to deliver the benefits. However, in our study, we found a positive association between the transportation infrastructure variable and economic development for both Assam and India.

Table 11. Results of vector error correction model (VECM) (Model II).

Variables	**Assam**					
	$\Delta lnEDI_t$	**$\Delta lnRII_t$**	**$\Delta lnRLYII_t$**	**$\Delta lnPII_t$**	**$\Delta lnPop_t$**	**$\Delta lnGFCF_t$**
Cointegration	-0.210 (0.060) [-3.449] ***	-0.329 (0.335) [-0.982]	-0.741 (0.187) [3.952]***	-0.116 (0.295) [0.392]	-0.020 (0.009) [2.101]**	-1.577 (0.343) [4.592]***
$\Delta lnEDI_{t-1}$	-0.327 (0.156) [-1.090]	-0.169 (0.041) [0.496]	0.306 (0.482) [0.634]	0.876 (0.761) [1.152]	0.035 (0.025) [1.404]	1.110 (0.883) [1.257]
$\Delta lnPIIr_{t-1}$	0.057 (0.029) [-1.982]*	-0.292 (0.160) [-1.824]*	0.178 (0.089) [1.989]**	-0.524 (0.142) [-3.698]***	-0.001 (0.004) [-0.292]	0.104 (0.165) [0.633]
$\Delta lnRLYII_{t-1}$	0.011 (0.060) [1.781]*	-0.009 (0.330) [-0.029]	-0.092 (0.085) [-1.084]***	-0.047 (0.291) [-0.162]	0.0094 (0.009) [0.987]*	1.556 (0.338) [4.596]***
$\Delta lnRII_{t-1}$	0.024 (0.028) [1.977]**	-0.726 (0.152) [-4.77]	-0.099 (0.185) [-1.084]	0.0811 (0.134) [0.603]***	0.010 (0.004) [2.328]**	-0.118 (0.156) [-0.760]
$\Delta lnPop_{t-1}$	3.252 (1.709) [1.203]	13.761 (9.401) [1.464]	3.839 (5.266) [0.729]	38.315 (8.302) [4.615]***	-0.474 (0.273) [-1.738]*	-11.426 (9.637) [-1.186]
$\Delta lnGFCF_{t-1}$	-0.103 (0.031) [-3.299]***	-0.132 (0.171) [-0.773]	0.218 (0.096) [2.275]***	0.132 (0.152) [0.876]	0.012 (0.005) [2.333]**	-0.213 (0.176) [-1.208]
Constant	-0.0105 (0.029) [-2.004]**	0.022477 (0.160) [0.142]	0.007 (0.088) [0.088]	-0.0009 (0.139) [-0.007]	0.003 (0.004) [0.665]	0.0002 (0.162) [0.001]
R-squared	0.656	0.609	0.679	0.644	0.431	0.826
Adj. R-squared	0.536	0.573	0.567	0.520	0.232	0.765
India						
Variables	$\Delta lnEDI_t$	$\Delta lnRII_t$	$\Delta lnRLYII_t$	$\Delta lnPII_t$	$\Delta lnPop_t$	$\Delta lnGFCF_t$
Cointegration	-0.169 (0.061) [-2.784]***	-0.731 (0.512) [1.428]	-0.536 (0.387) [1.387]	-0.544 (0.138) [3.951] ***	-0.044 (0.027) [1.601]	-0.155 (0.100) [1.543]
$\Delta lnEDI_{t-1}$	0.276 (0.252) [1.094]	0.797 (0.587) [1.358]	-2.037 (1.608) [-1.266]	0.270 (0.573) [0.472]	-0.226 (0.114) [-1.989]*	-0.512 (0.418) [-1.227]
$\Delta lnPIIr_{t-1}$	0.397 (0.102) [3.876]***	0.172 (0.866) [0.199]	-0.219 (0.653) [-0.335]	0.831 (0.232) [3.572] ***	0.042 (0.046) [0.899]	0.191 (0.169) [1.127]
$\Delta lnRLYII_{t-1}$	0.094 (0.060)	0.338 (0.508)	0.379 (0.383)	0.516 (0.137)	0.055 (0.027)	0.035 (0.099)

Variables	Assam					
	ΔlnEDI_t	ΔlnRII_t	ΔlnRLYII_t	ΔlnPII_t	ΔlnPop_t	ΔlnGFCF_t
	[2.353]**	[0.666]	[0.991]	[3.777] ***	[2.022]**	[0.356]
$\Delta lnRII_{t-1}$	0.105 (0.045) [2.353]**	0.122 (0.378) [0.325]	0.022 (0.286) [0.079]	0.458 (0.102) [4.502]***	-0.061 (0.020) [-2.998]***	0.108 (0.074) [1.449]
$\Delta lnPop_{t-1}$	-0.725 (0.471) [-1.539]	1.633 (3.980) [0.410]	0.376 (3.004) [0.125]	1.280 (1.070) [1.196]	-0.601 (0212) [-2.829]***	-1.109 (0.780) [-1.421]
$\Delta lnGFCF_{t-1}$	0.332 (0.184) [-1.806]*	0.009 (1.553) [0.006]	0.024 (1.172) [0.020]	0.546 (0.418) [1.308]	0.079 (0.082) [0.951]	0.006 (0.304) [0.021]
Constant	0.018 (0.038) [0.205]**	0.095 (0.324) [0.293]	0.004 (0.245) [0.018]	0.012 (0.087) [0.148]	0.001 (0.017) [0.009]	0.001 (0.064) [0.021]
R-squared	0.754	0.705	0.959	0.778	0.849	0.954
Adj. R-squared	0.557	0.436	0.953	0.519	0.675	0.901

Note: *statistically significant at 1% level, **statistically significant at 5% level, ***statistically significant at 10% level. (Estimated standard errors are in parenthesis).

For Assam, the long-run co-integration coefficient is -0.210, which is significant at 10%. This indicates a 21.01% speed of adjustment from short-run dynamics to long-run equilibrium between economic infrastructure and development. This suggests slower future growth after periods of higher growth (Table 11). Lagged terms for power, railway, and road infrastructure show significant short-term impacts on development, with coefficients of 0.057, 0.011, and 0.024, respectively, indicating effects after two or more years. For India, the long-run coefficient is -0.169, significant at 10%, with a 16.9% adjustment speed, suggesting a similar pattern of slower growth following high past growth. Lagged terms for power, railway, and road infrastructure show significant short-term impacts on development, with coefficients of 0.397, 0.094, and 0.105, significant at various levels, highlighting the strong influence of infrastructure on growth. Our findings conform to Dash and Sahoo (2010) and Ghosh (2020). Assam Power Sector Enhancement Investment Program, Project under NERSIP, etc., are some of the major power infrastructure projects in operation contributing towards the overall economic development via contributing towards the generation of income and employment opportunities and raising labor productivity (Kessides, 1996; Patnaik, 2013).

In order for the VECM to be stable and produce accurate forecasts, the roots of the VECM must be inside the unit circle. This indicates that the model is stationary and the long-term relationships between variables are genuine. Most previous studies by Pradhan and Bagchi (2013); Maparu and Mazumder (2017) and Ghosh (2020) did not perform a stability test following VECM estimation, a gap that this study addresses.

The result of VECM is found stable as per AR roots graph (See Appendix Figure 5). Table 12 presents the results of the VECM post diagnostics tests, demonstrating that both models for Assam and India exhibit no serial correlation, heteroscedasticity, or a normal distribution, with statistical significance at the 5% level.

Table 12. VECM post-diagnostic tests.

Region	Test	Model I (Test statistics)	Model II (Test statistics)
Assam	Breusch-Pegan Lagrange multiplier test	34.867	18.321
	VEC residual normality test	10.648	14.099
	White's Heteroscedasticity test	296.632	75.584
India	Breusch-Pegan Lagrange multiplier test	20.092	52.004
	VEC residual normality test	11.316	17.346
	White's heteroscedasticity test	103.331	110.652

The Granger causality test has further examined the direction of the causality between economic infrastructure and economic development. The results of the Granger causality tests are presented in Tables 13 & 14.

Table 13. Granger causality test (Model I).

Null hypothesis	Assam			India	
	Observations	F-statistics	p-value	F-statistics	p-value
DLGFCF does not granger causes DLNEDI	29	0.128	0.0675*	0.0127	0.0022***
DLNEDI does not granger causes DLGFCF	29	0.833	0.685	1.563	0.775
DLNPOPU does not granger causes DLNEDI	29	0.634	0.432	0.083	0.925
DLNEDI does not granger causes DLNPOPU	29	0.833	0.369	0.0089	0.2561
DLNEII does not granger causes DLNEDI	29	4.752	0.0012***	4.293	0.0557**
DLNEDI does not granger causes DLNEII	29	5.125	0.0005***	5.946	0.0338**

Note: ***Significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 14. Granger causality test (Model II).

Null hypothesis	Observations	F-statistics	p-value	F-statistics	p-value
DLGFCF does not granger causes DLNEDI	29	0.188	0.6675	0.148	0.703
DLNEDI does not granger causes DLGFCF	29	0.168	0.685	0.575	0.454
DLNPOPU does not granger causes DLNEDI	29	0.634	0.432	0.0158	0.900
DLNEDI does not granger causes DLNPOPU	29	0.833	0.369	0.0127	0.911
DLNPII does not granger causes DLNEDI	29	5.423	0.0253**	1.343	0.0469**
DLNEDI does not granger causes DLNPII	29	1.524	0.228	10.528	0.0032***
DNRII does not granger causes DLNEDI	29	5.674	0.0317**	0.989	0.109*
DLNEDI does not granger causes DNRII	29	0.373	0.546	0.140	0.711
DLNRLYII does not granger causes DLNEDI	29	11.740	0.0020***	0.492	0.489
DLNEDI does not granger causes DLNRLYII	29	0.446	0.510	0.088	0.769

Note: ***Significant at 1% level, ** significant at 5% level,* significant at 10% level.

Table 13 shows two-way causality between economic infrastructure and economic development and one-way causality between GFCF and economic development for Assam, similar to India. Table 14 reveals the one-way causality between power, road, and railway infrastructure and economic development in Assam. In India, two-way causality exists between power infrastructure and development, while road infrastructure has a one-way causal link. Improved transportation infrastructure reduces transaction costs, and growing travel demand boosts investment in transportation infrastructure. This finding aligns with Mazumder (2002). The inability of the Granger causality method to evaluate the relative strength of causal linkages between variables outside of the chosen time frame is a significant drawback, undermining the validity of the results (Shahbaz, 2012). To solve this problem, we measured the degree of causal links between economic infrastructure, its sub-indices, and economic development using the generalized forecast error variance decomposition analysis (VDA) inside a vector autoregressive (VAR) system. The disparity between Assam and India, as explained by VDA, lies in the differing contributions of economic infrastructure to economic development. In Assam, EII plays an important role, with its contribution to economic development accounting for 3.049%, which is higher when compared to India (2.381%), while population growth becomes more significant over time for Assam (See Appendix, Table 16, Model I). Moreover, variance explained by PII, RII, and RLYII in economic development was found to be greater for Assam (See Appendix, Table 17, Model II). This finding conforms with Kadyraliev et al. (2022). Furthermore, the impulse response analysis reveals that shocks primarily influence economic development, exhibiting strong initial effects that gradually diminish over time (Figures 1, 2, 3, and 4). Railway and power infrastructure have positive impacts on development, while road infrastructure has a small, short-term negative effect. Shocks in the power infrastructure contribute positively but with a much smaller magnitude, while shocks in the road infrastructure index initially have a small negative effect that fades over time. Road aging, changes in market conditions, lack of maintenance, etc. may have slowly reduced its effect (Zhang & Cheng, 2023). Shocks from infrastructure and capital formation contribute positively, though they stabilize in the long run, emphasizing the need for policymakers to prioritize long-term infrastructure projects with awareness of diminishing benefits over time.

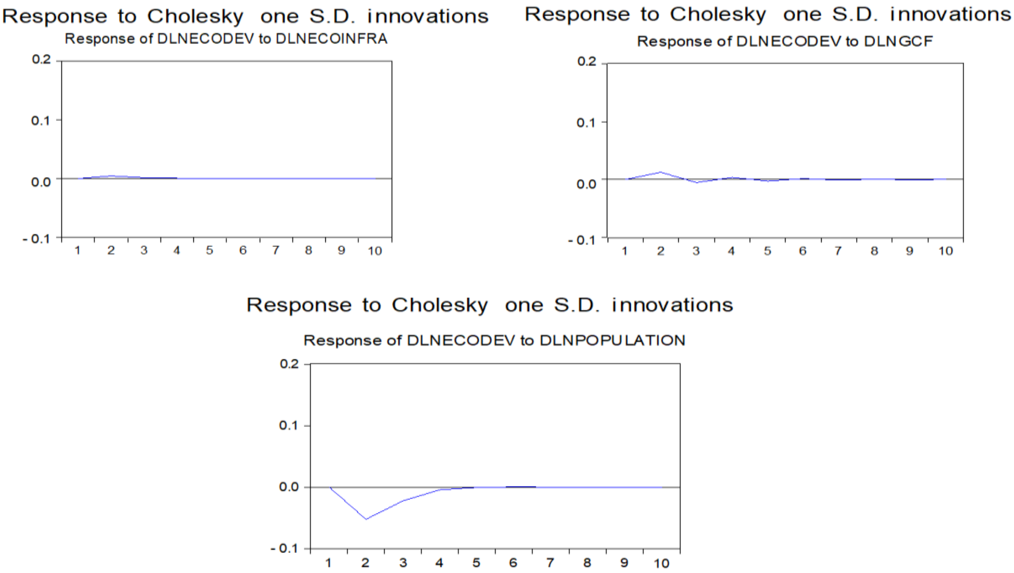

Figure 1. Response of economic development to innovations to endogenous variables (Assam) (Model I).

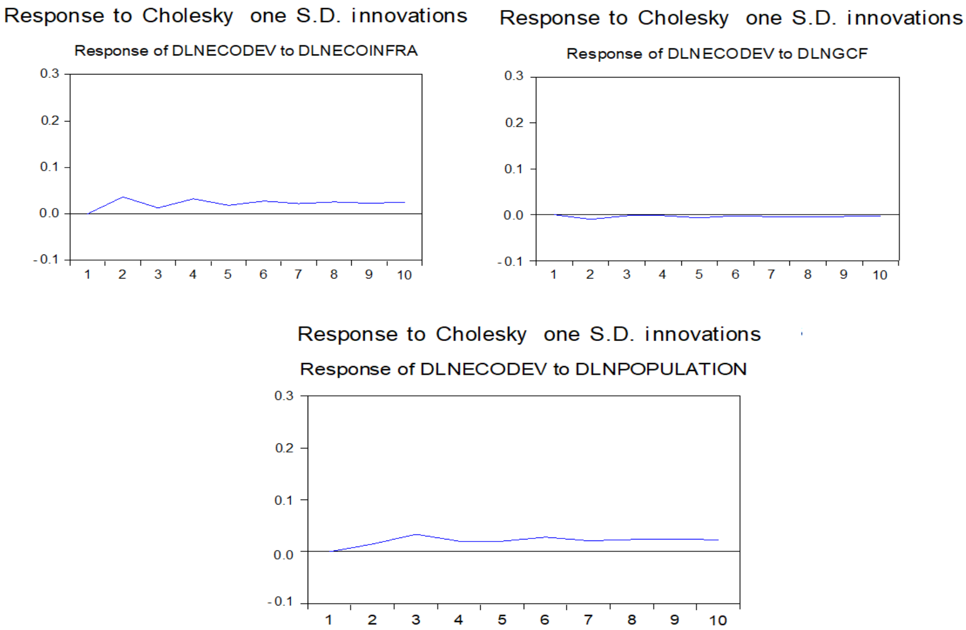

Figure 2. Response of economic development to innovations to endogenous variables (India) (Model I).

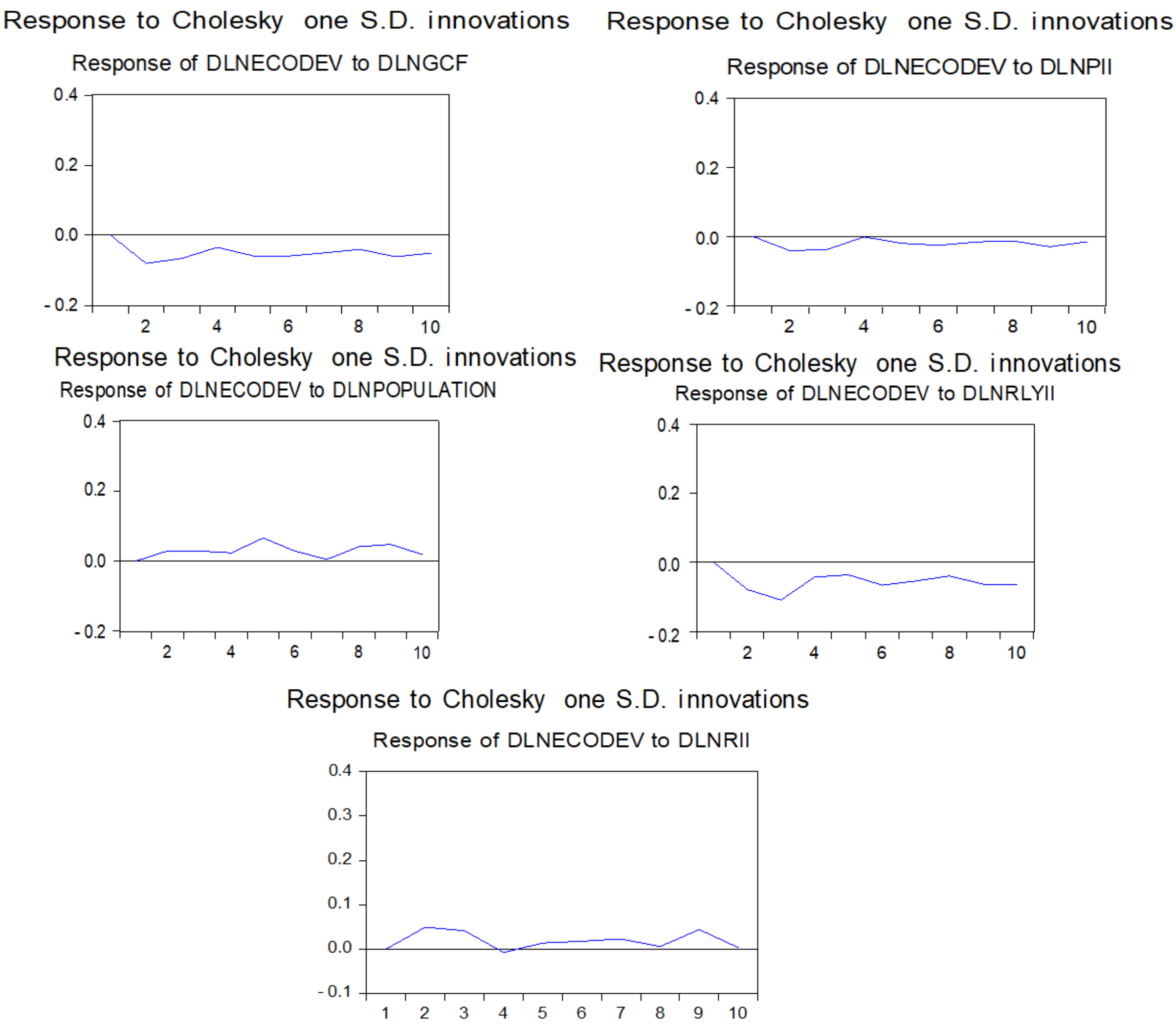

Figure 3. Response of economic development to innovations to endogenous variables (Assam) (Model II).

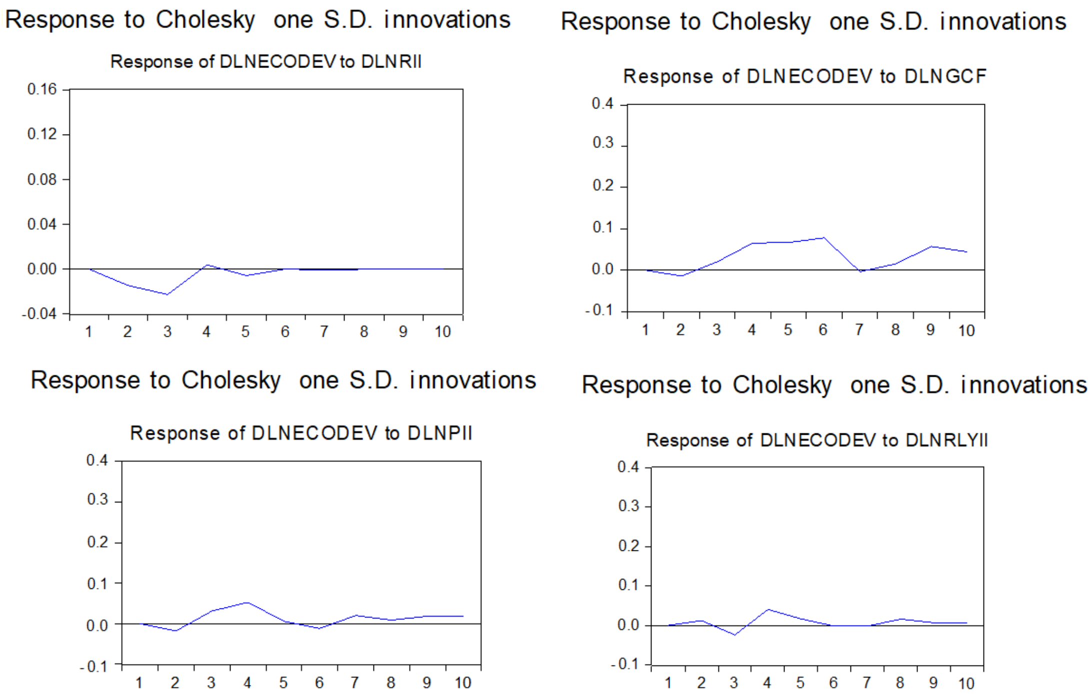

Figure 4. Response of economic development to innovations to endogenous variables (India) (Model II).

5. CONCLUSION AND POLICY IMPLICATIONS

This study highlights the critical link between economic infrastructure and development in Assam relative to India. The findings from the Johansen co-integration tests confirm a long-run relationship between economic infrastructure, specifically roads, railways, and power—and economic development in both regions. The VECM results indicate significant positive short- and long-run effects of economic infrastructure on development, with Assam experiencing greater contributions from its sub-sectors, consistent with the findings of Maparu and Mazumder (2017). To leverage infrastructure's positive impact on development, Assam should prioritize targeted investments in high-impact sub-sectors like transportation and energy. Enhancing road and rail connectivity in underserved areas could foster growth by improving access to markets and services. Additionally, Kaldor (1966) views industrial expansion as an engine of growth, and bolstering energy infrastructure can support it. Granger causality tests reveal a bi-directional relationship between economic infrastructure and development in Assam, supporting Wagner's Law and endogenous growth theory, while India demonstrates similar trends with even stronger impacts from infrastructure. The bi-directional relationship suggests Assam should increase infrastructure spending to stimulate development (endogenous growth theory) while using economic growth to sustainably finance further infrastructure (Wagner's Law). Encouraging public-private partnerships and targeted investments can create a reinforcing cycle of development and infrastructure expansion. The implications of this study extend beyond Assam, providing valuable lessons for other regions seeking to bolster economic development through infrastructure enhancements. Policymakers should prioritize a comprehensive infrastructure strategy that addresses the maintenance of roads, modernization of railways, and investment in renewable energy. Such strategies can foster sustainable economic growth and resilience in various contexts. Additionally, efficient transportation networks are essential for improving access to healthcare, particularly in rural areas. They ensure reliable supply chains for medical supplies and facilitate quicker access to hospitals, thereby significantly impacting health outcomes, including crude birth and death rates. Better access to healthcare, family planning, education, and economic opportunities is a direct result of improved roads, railroads, and power infrastructure. For regions facing similar challenges, this study underscores the importance of adopting integrated infrastructure development policies that not only enhance economic productivity but also address social needs. By leveraging best practices in infrastructure planning and investment, regions can create robust systems that promote economic growth while ensuring equitable access to services, ultimately contributing to the achievement of Sustainable Development Goal 9. Implementing such policies in a timely manner will be crucial for sustaining positive economic momentum and fostering long-term development.

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Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by the corresponding author.
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APPENDIX

Table 15. Lag length selection based on VAR (Model I).

Region	Models	Lag	LogL	LR	FRE	AIC	SC	HQ
Assam	Model I	0	-64.759	NA	0.0013	4.742	4.931	4.801
		1	33.235	162.197*	4.78e-06*	0.913*	0.030*	-0.617*
		2	39.445	8.565	1.01e-05	0.238	1.459	0.294
	Model II	0	-138.719	NA	0.0139	9.912	10.147	9.986
		1	-66.456	114.624*	0.0005*	6.652	8.067*	7.095*
		2	-48.21221	22.648	0.001	7.112	9.711	7.930
India	Model I	0	-70.144	NA	0.0019	5.113	5.302	5.172
		1	65.146	223.929*	5.30E-07	-3.114	-2.171*	-2.818*
		2	83.129	24.803	4.96e-07*	-3.250*	-1.553	-2.719
	Model II	0	-160.731	NA	0.0039	11.499	11.782	11.587
		1	-9.225	229.871	1.46e-06	3.533	5.513*	4.153
		2	47.854	62.983*	4.86e-07*	-2.079*	5.757	3.231*

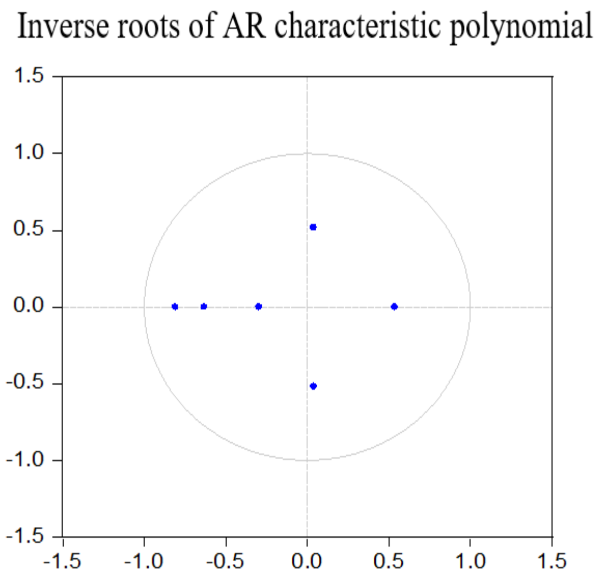
Note: *Indicates lag order selected by the criterion.
LR: Sequential modified LR test statistic (Each test at 5% level).
FPE: Final prediction error.
AIC: Akaike information criterion.
SC: Schwarz information criterion.
HQ: Hannan-Quinn information criterion.

Table 16. Variance decomposition for economic development (Model I).

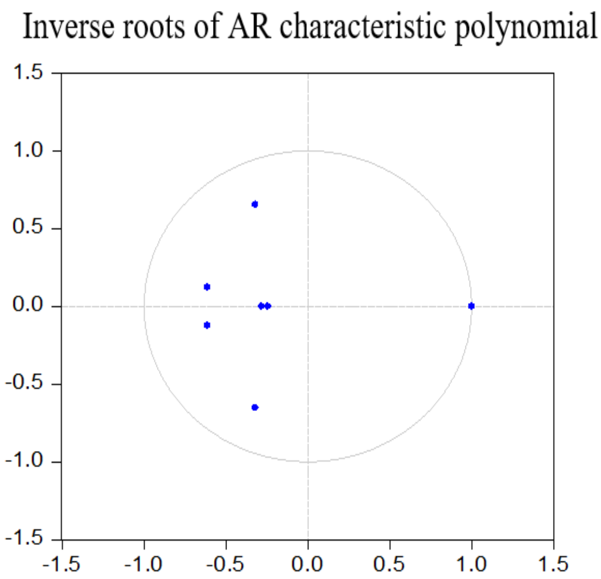
Assam					
Period	**S.E.**	**ΔlnEDI**	**ΔlnEII**	**ΔlnPOP**	**ΔlnGFCF**
1	0.189	100.00	0.000	0.000	0.000
2	0.208	93.250	2.044	4.342	0.361
3	0.209	92.162	2.048	5.372	0.416
4	0.209	92.097	2.048	5.408	0.445
5	0.209	92.084	2.048	5.408	0.458
6	0.209	92.078	2.048	5.408	0.464
7	0.209	92.076	3.049	4.408	0.466
8	0.209	92.076	3.049	4.408	0.467
9	0.209	92.075	3.049	4.408	0.467
10	0.209	92.075	3.049	4.408	0.467
India					
Period	S.E.	ΔlnEDI	ΔlnEII	ΔlnPOP	ΔlnGFCF
1	0.246	100.00	0.000	0.000	0.000
2	0.393	97.222	1.073	1.139	0.564
3	0.480	94.531	1.686	3.066	0.714
4	0.539	93.664	1.545	3.947	0.842
5	0.581	93.975	1.481	3.702	0.840
6	0.618	92.968	2.466	3.803	0.762
7	0.653	93.342	2.437	3.454	0.765
8	0.705	93.134	2.431	3.770	0.663
9	0.748	93.217	2.407	3.783	0.591
10	0.783	93.220	2.381	3.848	0.549

Table 17. Variance decomposition for economic development (Model II).

Period	Assam						
	S.E.	ΔlnEDI	ΔlnPII	ΔlnRLYII	ΔlnRII	ΔlnPOP	ΔlnGFCF
1	0.159	100.00	0.000	0.000	0.000	0.000	0.000
2	0.218	61.140	14.174	0.073	0.007	19.418	0.043
3	0.234	53.829	11.098	0.096	2.123	47.420	0.312
4	0.237	53.254	9.714	0.148	10.208	45.654	0.630
5	0.240	52.029	9.199	0.671	15.611	42.433	0.732
6	0.242	51.544	9.156	0.797	17.205	41.463	0.793
7	0.243	51.091	9.137	0.828	17.785	41.301	0.844
8	0.243	50.907	9.103	0.834	18.155	41.206	0.885
9	0.244	50.779	9.077	0.844	18.428	41.091	0.911
10	0.244	50.714	9.065	0.850	18.582	41.017	0.927
India							
Period	S.E.	ΔlnEDI	ΔlnPII	ΔlnRLYII	ΔlnRII	ΔlnPOP	ΔlnGFCF
1	0.196	10.000	0.000	0.000	0.000	0.000	0.000
2	0.360	84.047	1.278	4.756	4.756	0.639	4.967
3	0.462	79.689	1.419	8.471	8.471	0.763	5.060
4	0.528	80.305	1.087	7.139	7.139	0.777	4.306
5	0.568	79.142	1.056	6.579	6.579	2.023	4.796
6	0.607	78.457	1.095	6.923	6.923	1.978	5.135
7	0.646	78.882	1.029	6.820	6.820	1.754	5.144
8	0.689	79.531	0.937	6.319	6.319	1.893	4.861
9	0.728	78.989	1.004	2.126	6.431	2.126	5.076
10	0.762	79.001	0.955	1.995	6.543	1.995	5.068



Assam (Model I)



Assam (Model II)

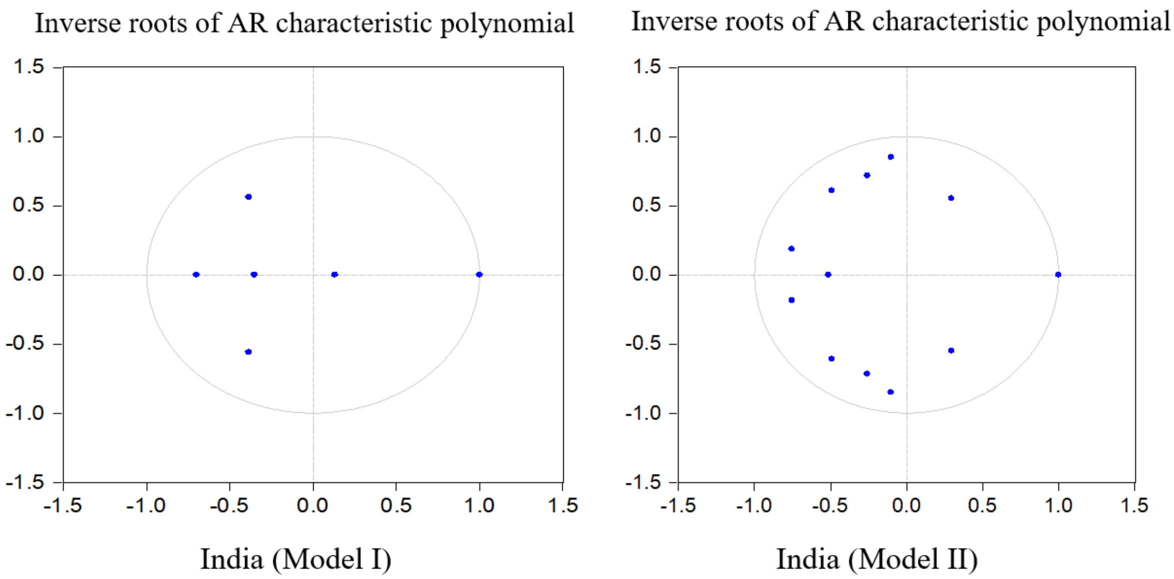


Figure 5. VECM stability: AR roots graph.