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Infrastructure, Urbanization and Economic Growth: A Nexus in Indian States

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Abstract
Urbanisation acts as a primary catalyst for economic advancement. By leveraging city externalities, particularly in conjunction with core infrastructure advancements, it becomes possible to propel the growth trajectory. This study empirically examines the impact of infrastructure and urbanization on economic performance across 20 prominent Indian states spanning the years 2005 to 2019. It employs four agglomerating and networking infrastructure dimensions to construct a multidimensional infrastructure index. The research uses fixed-effects model and FMOLS techniques to explore the enduring equilibrium association among infrastructure, urbanization, and economic growth. Furthermore, a causality test is utilized for assessment of the panel data. The empirical outcomes reveal a positive and statistically significant effect of both infrastructure development and urbanization on both long-term and short-term economic growth in Indian states. The results lend support to the paradigm that "growth pays its way". The findings of the study suggest that most Indian states fall under poor to medium infrastructure development which requires considerable attention of policy makers. Indian economic growth needs to be supported by planned urbanization and infrastructure development to create values that can channel cumulative and circular causation processes further fuelling growth.

Keywords: Agglomeration; Network externalities, Spillovers, City density

1. Introduction

The Commission on Population and Development report (2018) foresees a predominantly urban world. Urban areas accommodate 55 per cent of the total global population (World Urbanization Prospects report 2018). Urbanization process, with its direct and indirect consequences, influences economic growth and overall development. Urban areas create and enhance agglomeration externalities by constituting a large knowledge pool by the creation and diffusion of ideas, innovation, and technology (Glaeser 2011). City density also channels network externalities, where value of a network increases by the number of users. The concentration of firms and labour in cities is influenced by agglomeration and network externalities (Henderson 1974; Quigley 2013; Duranton and Puga 2004; Glaeser 2011). According to Marshall (1890), a firm's production costs decline as its industry size grows, owing to improved access to local infrastructure and the sharing of knowledge within the industry. Such localization economies arise due to knowledge spillovers among firms in a single industry as emphasized by Marshall (1890), Arrow (1962) and Romer (1986), popularly referred as MAR spillovers. There also exists Jane Jacobs externalities. Such externalities arise as cities attract industries to co-locate and create inter-industry linkages. Porter externalities arise as industries compete (Gleaser et. al. 1992). All these lead to localization and urbanization economies that create growth with the diversity of economic activity, labour pooling, input

sharing and knowledge spillovers. Zheng (2010) talks about network dynamic externality, which refers to knowledge spillovers from an agglomeration. All these make cities special and distinctive.
India also witnessed a five- fold increase in urban population from 1961-2011 (Census of India 2011) and is projected at an urbanisation level of 43.2 per cent by 2035 (World Cities Report 2022). The level urbanisation in India is 31.1 per cent with an annual growth rate of 2.76 per cent (Census of India 2011) whereas urban areas contribute is 65 per cent to Gross Domestic Product (Planning Commission of India 2011). India is also home to five out of the 33 mega cities worldwide, where Delhi holds the position of the world's second-largest city with a population of 29 million (World Urbanization Prospects 2018). States (such as Delhi, Goa, Puducherry, Tamil Nadu, Gujarat, Karnataka, Kerala and Maharashtra) which showcase the most substantial levels of urbanization, also possess the highest per capita net state domestic product among all Indian states. It is worth noting that India was more urbanized than China in 1950; however, China strategically accelerated its urbanization process, which was instrumental in its industrialization and economic growth (Ravallion 2009; World Bank 2009). During the early 2000s, China directed 12.6 per cent of its GDP toward infrastructure investments, which was over twice the amount allocated by India (Bardhan 2010). Recent observations have highlighted the stark difference in investment between India and China, with Chinese authorities spending seven times more on urban infrastructure compared to their Indian counterparts (Observer 2012). Urbanization ought to be employed as a strategy to realize a seven-fold rise in per capita income within India as more than 70 per cent of India's GDP and the creation of new employment opportunities will originate from urban centres (McKinsey Global Institute Report 2010). This motivates the paper to establish a clear link between urbanisation and growth.
The paper hinges upon twin objectives: Firstly, to construct a multidimensional infrastructure index and rank states as per their infrastructure development. Secondly to analyse the effect of “agglomerating and networking” infrastructure and urbanization on economic expansion for a panel data set from 2005-2019 on 20 major Indian states. The research also delves into exploring the causal connections between infrastructure, urbanization, and economic growth in both the short-run and long-run contexts. This study stands apart from prior research due to its distinctive approach in constructing a multidimensional infrastructure index and its utilization of advanced econometric tools for estimation. The novelty of this paper is two-fold, departing from the existing previous literature, the paper supplements the construction of the infrastructure index by considering four dimensions of infrastructure. Secondly, a state level analysis of India has been done by basing on this dimensional index.
The following paper is structured as follows: Section 2 offers a comprehensive detail on existing literature. Section 3 gives an overview data and variables used in the study. The methodology used is thoroughly detailed in Section 4. The outcomes of the empirical analysis are delineated in Section 5. The paper concludes with Section 6.

2. Review of Literature

Urban economies serve as the driving force behind a nation's wealth. (Jacobs 1984). They are strongly connected with the growth generating forces in an economy (Henderson 2003; Rahman et al., 2006). Nakamura (1985) found that multiplying the urban population by a factor of 2 in Japan could lead to a productivity increase of 3.4 per cent In similar lines, United States has a 6 per cent rise in productivity (Ciccone and Hall 1996). Henderson (2003) proposes a robust positive correlation between urbanization and per capita GDP with a correlation coefficient of 0.85. Moomaw and Shatter (1996) state that certain factors like higher GDP per capita, increased industrialization, greater export orientation, and higher levels of foreign assistance; were positively associated with the urban population percentage. Black and Henderson (1999) study revealed a positive association between city sizes and human capital accumulation. Anett Hofmann and Guanghua Wan (2013) estimate that for every 1 per cent increase in economic growth, there is a corresponding 0.9 per cent rise in urbanization. Timilsina et. al (2022) state that urbanisation and economic growth are the major determinants of infrastructure development for Indian states. Tripathi's (2017) study focused on examining India's Class I cities has discovered that enhancing infrastructure facilities might not lead to a significant rise in population concentration (measured by factors such as size, density, and population growth) within these major cities. However, it can considerably enhance the cities' potential contribution to India's national economic growth. The above literature stems from theory that as countries undergo economic development, urbanization tends to occur as a natural progression. This structurally transforms any economy from an agrarian to an "industry-service" based economy (Todaro 1997; Henderson 2003) and thus fuelling growth.

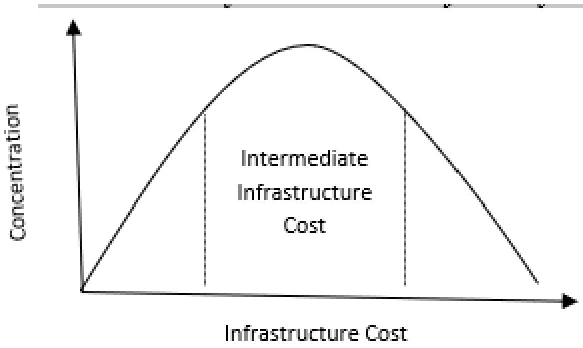
Urbanisation and Economic Growth Nexus

Cities with greater population density yield elevated rates of economic growth (Jedwab & Vollrath 2015). There are several studies that have analysed role of urban expansion on economic growth (Fay and Opal 2000; Henderson 2002; Turok and McGranahan 2013; Chen et al. 2014; Bao and Chen 2015; Liddle and Messinis 2015; Mohanty and Mishra 2015; Li 2017). Studies are divided among urbanisation having a positive impact on growth (Henderson 2003; Hansen 1990; Zi 2017; Nguyen and Nguyen 2017) to having a negative impact on growth as well (Piano et al. 2020; Etokakpan et al. 2021; and Philip et al. 2021). Empirical literature on the direction of causality also runs from urbanisation causing economic growth (Gallup et al.1999; Cheng 2013; Liu, Su and Jiang 2015; Gross and Ouyang 2020) to economic growth causing urbanization (Hofmann and Wan 2013; Pradhan et. al 2014; Zhao and Wang 2015; Arvin et. al 2015; Shaban, Kourtit, Nijkamp 2022) and also a feedback effect existing between the two (Solarin and Shahbaz 2013). Ades and Glaeser (1995), Junius (1999), Davis and Henderson (2003) and Arouri et al. (2014). Davis and Henderson (2003) state that urban population growth rate is a concave increasing pattern of level of income. In the Indian context, Cali (2008) found that as the rate of urbanization increases, the rate of economic growth tends to decrease. Tripathi and Mahey (2017) identified a positive association between urbanization and economic growth, particularly within the context of Punjab. Ghosh and Kanjilal (2014) and Shaban et al. (2022) identified a unidirectional causality in which economic growth influences urbanization. Megeri and Kengnel (2016) investigated the connection between urbanization and economic growth in Indian states, utilizing their Human Development Index (HDI) as a basis for analysis. Their findings revealed that states with an HDI surpassing 0.5 displayed a causal relationship from growth to urbanization, whereas states with an HDI below 0.5 exhibited causality from urbanization to growth. Certain states, irrespective of their HDI levels, demonstrated bidirectional causality between urbanization and economic growth. Shaban (2019) employed cross-sectional data for Indian states in 2013 and illustrated that a 1 per cent increase in the urbanization rate led to an approximate per capita income rise of Rs. 935.

Urbanisation and Infrastructure Nexus

Infrastructure costs hold a pivotal role in influencing the extent of urbanization. When the costs associated with infrastructure are excessively high, economic activity tends to disperse. Conversely, in situations where infrastructure costs are minimal, firms could be distributed randomly, as factors like proximity to markets or suppliers become less relevant. Optimal agglomeration, however, occurs at intermediate infrastructure costs, especially when labour mobility is limited (Lall, Shalizi and Deichmann 2004). This pattern of spatial concentration in relation to infrastructure costs is typically represented by a bell-shaped or inverted U-shaped curve, as shown in Figure 1.

Figure 1
Concentration of Economic Activity and Infrastructure Cost



Source: Lall, Shalizi and Deichmann (2004), Author

The analysis of Pradhan, Arvin, and Nair (2021) unveiled that the sustained economic growth trajectory of G-20 economies is reliant on urbanization, transportation infrastructure, and ICT infrastructure. Rice et al. (2006) established a connection between the pace of urbanization and the commuting time from less developed regions to core city centres in Great Britain. Their results highlighted that the urbanization rate peaks when the commuting time is under 40 minutes. Furthermore, they unearthed that the influence of agglomeration is fourfold more pronounced when the commute time is 30 minutes in comparison to 60 minutes. Alam et al. (2007) contend that swift urbanization can result in diseconomies due to heightened strain on infrastructure. Elevated levels of urbanization generate an increased need for infrastructure amenities, including transportation, power, electricity, water supply, telecommunications networks, schools, and hospitals. Consequently, this calls for escalated infrastructure development (Démurger 2001; Li 2017; Maparu and Mazumder 2021).

Economic Growth and Infrastructure Nexus

Infrastructural is the pre-condition of economic growth (Barro 1991 Barro & Sala-i-Martin 1995; Khadaroo and Seetanah 2008 and Timilsina et al. 2022). Infrastructure not only fosters economic growth but is also impacted by it (Aschauer 1990; Khadaroo and Seetanah 2008; Tripathi and Gautam 2010; Pradhan and Bagchi 2013 and Mohmand et al. 2017). Scholars including Ghani et al. (2013), Sahoo & Dash (2009), Sanchez-Robles (1998), Shah (1992) and Short & Kopp (2005), accentuate the significance of infrastructure for economic development. Tripathi and Gautam (2010) and Pradhan and Bagchi (2013) specifically identify a substantial and positive long-term relationship between infrastructure and economic growth in India. Maparu and Mazumder (2017) find that the long term, transport infrastructure and economic development are cointegrated, with the causality typically flowing from economic development to the distinct sub-sectors of transport infrastructure. Ghosh and Dinda (2022) uncover a bidirectional causality between overall transport infrastructure and economic growth across Indian states.

There are only few studies which examine the interconnectedness of economic growth, urbanization, and, specifically, the development of "agglomerating and networking" infrastructure in India. The present study centres on examining the impact of infrastructure and urbanization on economic growth in 20 prominent states of India, setting itself apart from preceding research in various aspects. Firstly, this study constructs a multidimensional infrastructure index to thoroughly assess its influence on economic growth and ranks states as per their infrastructure development. This is a more nuanced approach. Secondly, the study examines the interlinkages among urbanization, infrastructure, and economic growth by utilizing the latest available data. By incorporating up-to-date information, the study provides a current and relevant analysis of these factors. Thirdly, the analysis employs various econometric techniques to ensure the robustness of its findings. By utilizing different methods, the study enhances the credibility and reliability of its results. Moreover, the study offers valuable insights into the effects of infrastructure and urbanization on economic growth across the 20 prominent Indian states.

3. Data and Variables

The study makes use of a yearly panel data set of 20 major Indian States over the period 2005-2019 from the RBI Handbook of Statistics for Indian States. Table 1 describes the variables used in the study. Sarma's (2008) methodology is used to form an infrastructure index using available data on four physical infrastructures: Roads, National Highway, Railway and Power. These are the core infrastructures which create "Agglomerating and Networking" externalities in a city. The dependent variable used in this framework is the natural logarithm of Net State Domestic Product per capita (SDPPC). The independent variables include the Infrastructure Index (Infraindex) and the natural logarithm of the Urbanization Rate (UR).

Table 1
List of Variables for Panel Data Analysis.

1.	SDPPC_{it}	Natural Log of Per capita Net State Domestic Product (Constant Rs.)
2.	UR_{it}	$\text{Natural log of Urbanization} = \frac{\text{Urban Population (in Thousands)}}{\text{Total Population (in Thousands)}} \times 100$
3.	$Infrainde$	• The ratio of the State's total length of Roads to land area (in sq. kms) • The ratio of the State's total length of National Highways to land area (in sq. kms) • The ratio of the State's total Rail Route to land area (in sq. kms) • State-wise per capita availability of power (in kilowatt-hour)

Source: Author

Table 2 offers descriptive statistics of all the variables employed in the analysis, drawing from a balanced panel dataset encompassing the period from 2005 to 2019 and including data for 20 Indian states. The mean values for SDPPC, Infraindex, and UR are 93675.83, 0.2577823, and 37.35652, respectively. The skewness statistics for all variables fall within the range of 1-2, indicating a moderate level of skewness. Moreover, the kurtosis statistics for all variables exceed 3, indicating a heavier tail in the dataset being leptokurtic. This follows that neither of the variables are normally distributed.

Table 2
Descriptive Statistics

Statistics	SDPPC	Infraindex	UR
Mean	93675.83	0.21	37.36

Median	77719.5	0.17	34.77
Standard Deviation	58492.61	0.14	21.18
Maximum	313973	0.67	100.97
Minimum	11734.55	0.05	9.89
Sum	2.81e+07	63.38	11206.96
Skewness	1.38	1.73	1.12
Kurtosis	5.08	5.45	4.21
Observations	300	300	300

Source: Author's estimation

Table 3 depicts the cross-correlation matrix of all the variables under consideration. The results indicate a significant positive linear association between SDPPC and UR at the significance level of 1 per cent. Similarly, a positive correlation is observed between SDPPC and Infraindex, also significant at the 1 per cent level. Furthermore, a positive and significant correlation is found between UR and Infraindex. However, it is important to note that the degree of correlation between infrastructure and urbanisation is higher (0.85) than any other pair.

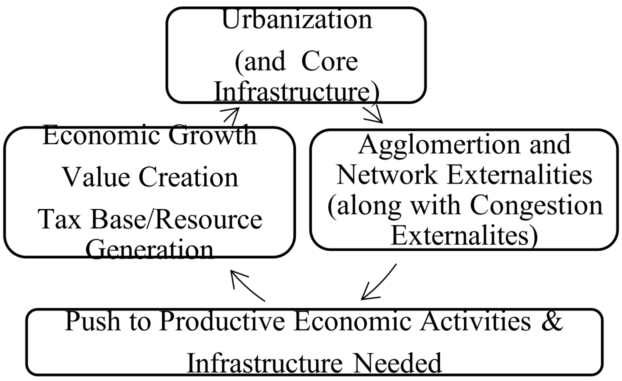
Table 3
Correlation Matrix

Variables	SDPPC	Infraindex	UR
SDPPC	1		
Infraindex	0.57^{***} (0.00)	1	
UR	0.59^{***} (0.00)	0.85^{***} (0.00)	1

Source: Author's estimation

Urbanization provides the breeding ground on which infrastructure compounds the benefits leading to economic growth. This interrelationship between urbanization, infrastructure, and economic growth is illustrated in Figure 2. This analytical linkage shall be econometrically verified in the following section.

Figure 2
Analytical Linkage between Infrastructure, Urbanization and Economic Growth



Source: Author

4. Methodology

4.1 Construction of Index

Sarma's (2008) methodology was employed to construct the infrastructure index. By applying the formula mentioned in Equation 1, a multidimensional infrastructure index was computed for all the dimensions. This index denotes a point within the four-dimensional Cartesian space.

$$d_i = w_i\ [(A_i - m_i)/(\ M_i - m_i)] \qquad (1)$$

In Equation (1), the weight associated with dimension i is denoted as w_i, with a range of $0 \leq w_i \leq 1$; A_i represents the true value of dimension i, while m_i refers to minimum value and M_i stands for maximum value of dimension i, respectively. The value d_i corresponds to the dimension of the infrastructure index i. This equation is derived from empirical observations. The weights assigned to each dimension always fall within the range of 0 to 1, indicating that $0 \leq w_i \leq 1$. A higher value of d_i signifies greater achievement in dimension i. The present situation encompasses four aspects of the infrastructure index, with each state denoted as a coordinate in the four-dimensional Cartesian space. Within this space, the point O = (0, 0, 0, 0) signifies the least favourable state, whereas the point W = (1, 1, 1, 1) represents the pinnacle achievement across all dimensions. To gauge the infrastructure index, it's crucial to examine the placement of the achievement point X relative to both the ideal point W and the worst point O. An elevated level of infrastructure attainment occurs as X moves farther from O and nearer to W. To compute the present index, the measurement entails calculating a basic average of two elements: the Euclidean distance between X and O (designated as X_1) and the reciprocal Euclidean distance between X and W (denoted as X_2). Both distances are then normalized by dividing them by the distance between O and W, ensuring that they fall within the range of 0 to 1. The construction of the indices involves computing the values of X_1 and X_2, and then calculating the index by taking a simple average of these two components. The specific formulae for these calculations are provided below.

$$X_1 = \frac{\sqrt{d_1^2+d_2^2+d_3^2+d_4^2}}{\sqrt{w_1^2+w_2^2+w_3^2+w_4^4}} \qquad (2)$$

$$X_2 = 1 - \frac{\sqrt{(w_1-d_1)^2+(w_2-d_2)^2+(w_3-d_3)^2+(w_4-d_4)^2}}{\sqrt{w_1^2+w_2^2+w_3^2+w_4^4}} \qquad (3)$$

$$\text{Infraindex} = (X_1 + X_2)/2 \qquad (4)$$

Equation (2) quantifies the separation between X and O, whereas Equation (3) assesses the separation between X and W. Subsequent to computing the values of X_1 and X_2, the infrastructure index for distinct states can be computed using Equation (4). The infrastructure index is computed for 20 prominent Indian states spanning the years 2005 to 2019. A greater index value signifies an elevated degree of infrastructure advancement. Accordingly, Indian states can be classified into tiers of infrastructure development—namely, low, medium, and high levels—based on previous categorizations by Sarma (2008) and Yadav et al. (2020). If Index ranges from $0 \leq \text{Index} < 0.25$, it falls under low infrastructure development, $0.25 \leq \text{Index} < 0.5$ range indicates medium infrastructure development and a range of $0.5 \leq \text{Index} \leq 1$ may be considered as high infrastructure development.

The critical objective involves assigning suitable weights to individual dimension indices. Given that each dimension holds equal significance for overall infrastructure, thus study has allocated uniform weights to all four dimensions. In the present analysis, a weight 1 is assigned for roads (d_1), 1 for national highways (d_2), 1 for railways (d_3), and 1 for power (d_4). By using these equations the Infrastructure Index (Infraindex) for the Indian States has been computed.

4.2 Econometric Specification

Prior to conducting the analysis, a unit root test is performed on the data, and the results are stated in Table 4. The Levin-Lin-Chu unit root test, including a time trend, indicates that all variables are stationary at the level at one per cent significance level.

Table 4
Unit Root Test

Variables	At level with time trend
SDPPC	-3.87***
Infraindex	-2.20**
UR	-29.59***

Source: Author's estimation
*** Stationary at significance level of 1 per cent.
** Stationary at significance level of 5 per cent.

The following model is econometrically examined by applying Pooled Ordinary Least Squares (OLS), Fixed Effects Regression and Random- Effects Regression. The anticipated sign of the coefficients for the independent variables being positive.

Model: $SDPPC_{it} = \alpha + \beta_1 Infraindex_{it} + \beta_2 UR_{it} + \varepsilon_{it}$ (5)

for i = 1,2, ..., N and t = 1,2, ..., T.

where:

N = number of individuals or cross section

T = the number of time periods.

To empirically validate the models, diverse econometric techniques are employed. The presence of cross-sectional dependence across the units is assessed using the LM adjusted test introduced by Pesaran, Ullah, and Yamagata (2008). Within the panel regression analysis, Breusch-Pagan tests and Hausman Tests are employed to choose between random- effects, fixed- effects or pooled regression models. To address the concern of autocorrelation in fixed-effect models, the standard error procedure advanced by Driscoll and Kraay (1998) is implemented. Lastly, the panel causality test introduced by Dumitrescu and Hurlin (2012) is utilized as a diagnostic check for the long-run equilibrium relationship.

5. Empirical Findings

5.1 Infrastructure Index and Analysis for Indian States

Table 5 furnishes an overview of infrastructure development across Indian states for the year 2019. Delhi stands as the leading state in terms of infrastructure advancement. Out of the 20 states under consideration, 7 fall into the medium infrastructure development category, namely Goa, Gujarat, Haryana, Maharashtra, Puducherry, Punjab, and Tamil Nadu. The remaining states, including Andhra Pradesh, Assam, Bihar, Chhattisgarh, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and West Bengal, are classified as having low infrastructure development.

Table 5
State of Infrastructure Development in Indian States (2019)

Sl. No.	State	Infraindex	Low/Medium/High
1	Andhra Pradesh	0.21	Low

2	Assam	0.2	Low
3	Bihar	0.21	Low
4	Delhi	0.67	High
5	Goa	0.44	Medium
6	Chattisgarh	0.13	Low
7	Gujarat	0.25	Medium
8	Haryana	0.36	Medium
9	Himachal Pradesh	0.21	Low
10	Karnataka	0.18	Low
11	Kerala	0.24	Low
12	Madhya Pradesh	0.14	Low
13	Maharashtra	0.25	Medium
14	Odisha	0.14	Low
15	Puducherry	0.43	Medium
16	Punjab	0.36	Medium
17	Rajasthan	0.16	Low
18	Tamil Nadu	0.26	Medium
19	Uttar Pradesh	0.19	Low
20	West Bengal	0.21	Low

Source: Author's estimation

5.2 Results of Pooled OLS, Fixed effects and Random Effects Models

Table 6 exhibits the results derived from three regression models: Pooled OLS Model, Fixed Effects Model, and Random Effects Model. In the pooled regression model, all variables demonstrate significance at the 1 per cent level. Both the coefficient of Infraindex and the coefficient of UR are positively oriented. Likewise, within both the Fixed Effects model and the Random Effects model, all variables demonstrate significance at the 1 per cent level. The coefficients of Infraindex and UR remain positive, mirroring the findings of the Pooled OLS results.

Table 6
Results of pooled OLS, Fixed effects and Random Effects Models

Variables	Pooled OLS	Fixed Effects Model	Random Effects Model
Infraindex	0.95^{***}	0.27^{***}	4.12^{***}
UR	0.41^{***}	0.15^{***}	1.25^{***}
Constant	9.63^{***}	0.48^{***}	6.06^{***}
R-Square	0.31	R^2= 0.77	R^2= 0.77
F Statistic	F (2,297)= 66.34	F(2,278)=478.48	Wald chi2(2) = 711.39
Prob>F	0.0000	0.0000	0.0000
DF	299	299	299
N	300	300	300

Source: Author's estimation

*** 1 per cent level of significance.

5.3 Selecting between Regression Models

The Breusch-Pagan Lagrangian Multiplier Test for Random Effects in Table 7 suggests the existence of a panel effect, favouring the utilization of a random effects model, as evidenced by the statistically significant probability value at the 1 per cent level.

Table 7
Breusch and Pagan Lagrangian Multiplier Test

	Var	sd= sqrt(Var)
SDPPC	0.38	0.62
e	0.15	0.12
u	0.26	0.51
Test: Var(u) = 0 chibar2(01) = 1439.28 Prob > chibar2 = 0.0000		

Source: Author's estimation

The application of the Hausman Test aimed to establish the better fit between the fixed effects model and the random effects model for the analysis. The findings of which in Table 8 suggests the fixed effects model is selected as the more suitable choice.

Table 8
Hausman Specification Test Results

Variables	Fixed Effects Model (b)	Random Effects Model (B)	Difference (b-B)	S.E.
Infraindex	3.80	4.12	-0.32	.
UR	1.83	1.25	0.58	0.05
b = consistent under Ho and Ha; obtained from xtreg B = inconsistent under Ha, efficient under Ho; obtained from xtreg Test: Ho: difference in coefficients not systematic $Chi^2(2)$ = (b-B)'[(V_b-V_B)^(-1)](b-B) = 139.95 Prob>chi2 = 0.00 (V_b-V_B is not positive definite)				

Source: Author's estimation

5.4 Diagnostic Tests

Panel data models frequently demonstrate cross-sectional dependency, particularly when interconnected states within a country are influenced by shared shocks and latent factors that contribute to the error terms. In order to assess the presence of cross-sectional dependency in my dataset, the study performed the Cross Sectional Independence test proposed by Pesaran (2004). The outcomes of this test are presented in Table 9. The null hypothesis of cross-sectional independence is rejected for all variables at the 1 per cent significance level. This implies the presence of cross-sectional dependency among the entities within the cross-sections.

Table 9
Results of Pesaran (2004) Cross Sectional Independence Test

Pesaran's (2004) test of cross sectional independence =	10.51, Pr = 0.00
Average absolute value of the off-diagonal elements =	0.56

Source: Author's estimation

To gauge the robustness of the regression models, a series of diagnostic tests were performed. These tests encompass the Breusch-Pagan/Cook-Weisberg test to identify heteroskedasticity (Table 10) and the Variance Inflation Factor (VIF) test to assess multicollinearity (Table 11), The findings of the tests reveal that there is no substantial heteroskedasticity issue, as the p-values are not significant at the 1 per cent level. Also, the VIF values are all below 10, indicating the absence of significant multicollinearity problems in the models.

Table 10
Breusch-Pagan / Cook-Weisberg test for Heteroskedasticity

Ho: Constant variance Variables: fitted values of SDPPC
chi2(1) = 0.69 Prob > chi2= 0.41

Source: Author's estimation

Table 11
Variance Inflation Factor test for Multicollinearity

Variable	VIF	1/VIF
Infraindex	1.90	0.53
UR	1.90	0.53
Mean VIF	1.90	

Source: Author's estimation

Subsequently, Wooldridge Test for Autocorrelation (Table 12) have also been tested. The test yielded notable probabilities at the 1 per cent level, signalling the existence of autocorrelation issues within the model.

Table 12
Wooldridge Test for Autocorrelation

H_0: No first-order Autocorrelation
F(1, 19) = 52.44 Prob > F = 0.00

Source: Author's estimation

5.5 Results of Driscoll and Kraay Standard Errors

Based on the aforementioned findings, the study utilizes the Driscoll and Kraay (1998) standard errors to address the concerns of autocorrelation and dependence. This approach is known for its autocorrelation consistency and robustness against various forms of cross-sectional and temporal dependence, as highlighted by Hoechle (2007). The outcomes of the fixed-effect panel regression with the Driscoll and Kraay (1998) standard errors adjustment for the model are outlined in Table 13.

Table 13
Fixed Effects Model with Driscoll and Kraay Standard Errors

Variables	**Coefficient**	**Driscoll-Kraay Std. Error**	**p-value**
Infraindex	3.80	0.64	0.00
UR	1.83	0.19	0.00
Constant	4.11	0.51	0.00
R^2	0.77		
F-stat	F(2, 19) = 2325.74		0.00
Observations	300		

Source: Author's estimation

The fixed-effects regression model yields the most substantial influence on economic growth, infrastructure, and urbanization. The findings reveal a positive and statistically significant correlation between economic growth and all the variables, signified by a significance level of 1 per cent.

5.6 Fully Modified OLS (FMOLS)

In order to evaluate the stability of the parameters with respect to their signs, significance levels, and magnitudes, the Fully Modified Least Square (FMOLS) estimation method, as proposed by Christopoulos and Tsionas (2004), is utilized. FMOLS is particularly useful when addressing serial correlation issues and provides more reliable results. The FMOLS results in Table 14 are indicative of the fact that, there are no significant changes in the signs, significance levels, or magnitudes of the coefficients. Furthermore, the FMOLS results confirm that infrastructure provision and urbanization have a strong impact on economic outcome or growth.

Table 14
FMOLS Results

Variables	Coefficient	p-value
Infraindex	4.25	0.00
UR	1.67	0.00
R-squared	0.97	
Adjusted R-squared	0.96	

Source: Author's estimation

5.7 Panel Causality

To examine the presence of a long-run equilibrium relationship among the variables of economic growth, infrastructure, and urbanization Dumitrescu and Hurlin (2012) Panel Causality Test is employed and the results are depicted in Table 15.

Table 15
Dumitrescu & Hurlin (2012) Granger non-causality Test

Sl. No.	Null Variable	W-stat	Z-bar stat	p-value
1.	H_0: SDPPC does not Granger-cause Infraindex H_1: SDPPC does Granger-cause Infraindex for at least one panel (code).	2.90	5.99	0.00
2.	H_0: Infraindex does not Granger-cause SDPPC. H_1: Infraindex does Granger-cause SDPPC for at least one panel (code).	2.69	5.35	0.00
3.	H_0: SDPPC does not Granger-cause UR. H_1: SDPPC does Granger-cause UR for at least one panel (code).	6.39	17.06	0.00
4.	H_0: UR does not Granger-cause SDPPC. H_1: UR does Granger-cause SDPPC for at least one panel (code).	6.80	18.33	0.00
5.	H_0: Infraindex does not Granger-cause UR H_1: Infraindex does Granger-cause UR for at least one panel (code).	4.18	10.05	0.00
6.	H_0: UR does not Granger-cause Infraindex. H_1: UR does Granger-cause Infraindex for at least one panel (code).	12.51	36.41	0.00

Source: Author's estimation

Table 15 reports that bi-directional causal relationships exist between SDPPC & Infraindex; SDPPC & UR; and UR & Infraindex in Indian States all significant at 1 per cent level. The findings of which make a competing case for infrastructure and urbanisation led economic development.

6. Conclusion

The paper offers an empirical analysis of the impact of infrastructure and urbanization on economic performance across 20 prominent Indian states spanning the years 2005 to 2019. It employed four agglomerating and networking infrastructure dimensions to construct a multidimensional infrastructure index. The research employs fixed-effects and FMOLS techniques to explore the enduring equilibrium association among infrastructure, urbanization, and economic growth. Furthermore, the Dumitrescu-Hurlin causality test is utilized for causal assessment of the panel data. This paper empirically establishes that urbanisation together with agglomerating and networking infrastructure is a growth generating force for Indian states. The results lend support to the paradigm that "growth pays its way".

In the long run, Indian states should harness the growth potential of productive urbanization through the implementation of inventive financing mechanisms. Cities hold a pivotal role in generating economic growth, which in turn generates revenue that can be earmarked for investment in infrastructure that supports urban agglomeration and networking. This investment in infrastructure further enhances the productivity of cities, leading to sustained growth and increased tax revenues derived from various sources such as income, goods and services, and land-based taxes. Establishing self-financing city infrastructure requires effective partnerships between the central, state, and local governments. China's significant commitment to investing in urban infrastructure has resulted in productive urbanization, leading to improved living standards. In contrast, India's urbanization has displayed a significant concentration of both population and economic activities in major cities, leading to a 'top-heavy' urbanization pattern. This pattern of unplanned urbanisation and undernourished infrastructure outweighs the positive externalities which necessitates policy attention.

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