Raw and Refined Analysis on Infrastructure Productivity : An Investigation into Indian States

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Abstract

Purpose : The present study attempted to compare the performance of 25 major states in India concerning their infrastructure output. To provide an accurate picture, the infrastructure investment and output of each state were compared using sophisticated analysis to determine the true productivity of the Indian states.

Methodology : Principal component analysis was used for raw analysis of panel data from 25 Indian states, while ordinary least square regression was used for refined analysis. The fields of electricity, building, transportation, and communication were examined in this study conducted in India.

Findings : In raw analysis, states like Maharashtra, Tamil Nadu, Gujarat, Uttar Pradesh, and Karnataka performed well, and states like Goa and north-eastern states like Mizoram, Tripura, Manipur, Nagaland were poor performers. However, after a refined analysis, the actual laggards identified were Jammu and Kashmir, Jharkhand, Uttarakhand, Himachal Pradesh, Haryana, etc. While these states found it difficult to get off the ground despite receiving significant infrastructure funding, the performance of places such as Goa and other northeastern states significantly improved following the more thorough investigation.

Practical Implications : The development of India is concerned with the gap in infrastructure between its states. It was advised that policymakers identify the states whose productivity is below par and come up with strategies to elevate them in order to address this.

Originality/Value : The productivity of Indian states in the infrastructure sector has only been empirically studied in a few studies. It was a fresh notion to analyze infrastructure productivity using both raw and refined information, with infrastructure investment serving as a yardstick, in contrast to previous studies.

Keywords : regional disparity, infrastructure investment, and principal component analysis (PCA)

JEL Classification Codes : C33, H54, O18

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"Unity in Diversity" is evident throughout India in various domains, including social, cultural, and economic ones. India's potential is like a "big sleeping elephant" amidst socio-cultural, urban-rural, and interstate differences because it hasn't yet fully realized its potential (Oda, 2011). The government

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recognized the need for a balanced state development during the period of economic turmoil following independence in order to help the economy recover. Organizations such as the Planning Commission of India developed creative programs, including special investment programs to propel underdeveloped states forward and laws to encourage private investment. Nevertheless, over time, regional inequity grew worse.

Infrastructure has a huge impact on local as well as national development of a country (Mishra et al., 2013). There is innumerable empirical evidence to prove that the productivity of a country is, to a large extent, determined by the infrastructure of that country (Bajar & Rajeev, 2016; Unnikrishnan & Kattookaran, 2020). It has been demonstrated that regional productivity is more strongly correlated with investments made in economic infrastructure (Agarwalla, 2011). Policymakers have prioritized reducing regional disparities and finding strategies to lessen the negative effects of inequality since independence. However, Jose (2019) stated that disparity in infrastructure development within the states has become one of the biggest challenges to India's growth and development. It is one of the prominent factors that resulted in government initiatives not reaching up to the mark (Bordoloi, 2014). The disparity between the states continues to impede the country's progress despite multiple attempts to address it. Even though the 2008 recession impacted the entire country of India, the effects on different states were remarkably varied. This demonstrates the diversity of the nation (Saji, 2016).

Finance is the scarcest resource, especially for a developing country like India. It must be treated like gold dust and should be allocated wisely. Infrastructure needs huge capital and is essential for the development of a country regardless of time. Proper management and supervision of finance are quintessential to creating additional value for infrastructure investment (Longe & Omozuawo, 2013). The productivity of the states in terms of infrastructure investment should be given priority, even though numerous internal criteria determine how much should be allotted by the federal government to each state as infrastructure. It is also important that this should be analyzed empirically in a scientific manner. In India, only a few studies empirically analyzed the productivity of Indian states in the infrastructure sector. Unlike prior studies, analyzing infrastructure productivity using raw and refined analysis by taking infrastructure investment as a yardstick was a novel idea. So, this study attempts to investigate the regional disparity of Indian states in infrastructure productivity with the help of raw and refined analysis. The study tries to draw the attention of policymakers regarding making investment decisions in infrastructure in a country like India with large regional disparity.

Literature Review

Numerous scholars have conducted studies to compare state-by-state infrastructure performance. Bajar and Rajeev's (2016) work was one of the most well-known of them. The most striking feature of their work was that, instead of considering infrastructure investment, infrastructure output of different sectors was taken as the dependent variable. Vidyarthi (2017) used principal component analysis (PCA) to study the role played by bank penetration and infrastructure development on the regional growth of Indian states.

Similar to the study, Sahoo and Acharya (2012) constructed a macroeconomic performance index of the states using data envelopment analysis. The study exposed that performance among different states in the growth rate of gross state domestic product, price stability, and fiscal deficit differed drastically. Using the ordinary least square (OLS) estimator, Sharma (2018) studied the impact of inequality in the labor market based on caste, religion, and gender on the economic performance of states in India. It was also found that inequality of opportunity is a major deterrent to the economic performance of states. Many scholars also did a comparison of states based on areas other than infrastructure. Madan (2014) studied the regional disparity of FDI flows in India and identified the factors behind its uneven distribution. In the study, appropriate indicators were constructed and regression analysis was done. Mundle et al. (2016) also measured the quality of governance of major states in India and the results showed there was considerable stability in the group of good and bad-performing states over the period.

States in the south and west of India leapfrogged ahead of those in the east due to the stark regional disparity among them. Narayan (2015) carried out a study akin to this one, examining inter-district disparities in Haryana's health system. In his study, the districts were ranked and analyzed using three distinct health-related factors.

This paper is truly inspired by a study by Bhandari (2013). The performance of the Indian states was compared in three areas: Infrastructure, education, and health. Indian states' productivity was examined through both a crude and a sophisticated analysis using PCA and regression modeling. By conducting a walkthrough of past literature, it can be found that although innumerable studies analyzed the comparative performance of states in areas like infrastructure, governance, human development, investment climate, etc., a comparative analysis of the productivity of Indian states using raw and refined analysis was not attempted. This study uses infrastructure investment as a benchmark to assess the infrastructure productivity of Indian states, adhering to Bhandari's (2013) methodology. It also looks at how the results differ between the raw and refined analysis.

Research Methodology

The study is both empirical and descriptive. Secondary data was used for analysis. Data analysis was done using SPSS 20.0. Data for 25 major Indian states were collected from the respective department's official databases by the Government of India, namely the Ministry of Power, Ministry of Railways, Ministry of Road Transport and Highways, and Ministry of Communications. State-wise data on infrastructure investment (i.e., total project cost for infrastructure investment made by government, public-private partnership, and private sector) were collected from the Department of Economic Affairs, Government of India. For analyzing the interstate disparity in infrastructure output, variables in the selected sectors were updated up to 2021–2022. State-wise infrastructure investments were updated up to December 2021.

The approach was motivated by a well-known study in this field by Bhandari (2013). PCA was used for raw data analysis, and OLS regression was used for refined data analysis. The Kaiser–Meyer–Olkin Measure of Sampling Adequacy, Bartlett's Test of Sphericity, and component matrix results were analyzed in order to do the raw analysis. OLS regression was analyzed using total variance explained, ANOVA analysis, coefficients of regression, and line of best fit.

Table 1 shows the infrastructure sectors and the corresponding variables (including units) for measuring the infrastructure output of the sectors. The variables and sectors within each sector were chosen according to the state-level data that was available throughout the study period.

Table 1. ***Variables Used in the Study***

Sector	Variables
Electricity Sector	Availability of power (units)
	Installed capacity of power (units)
	Power requirement (units)
Construction Sector	Length of railway route (kilometers)
	Length of national highways (kilometers)
	Length of roads (kilometers)
	Length of state highways (kilometers)
Transport and Communication Sector	Number of telephone subscribers (number)
	Number of post offices (number)
	Number of registered transport vehicles (number)
	Number of registered non-transport vehicles (number)

The fundamental objective behind this study is to find out the relationship between infrastructure input and infrastructure output, in other words, to analyze the interstate variation in the infrastructure productivity of Indian states. Although there are numerous studies conducted to rank the performance of states in India based on indices, analyzing the productivity of states based on an input-output relationship will be a novel thought in this area.

Analysis and Results

Raw Analysis

In this section, a comparison of Indian states on the infrastructure output of three subsectors is carried out. To give appropriate weight during the construction of the index, PCA was used to make the analysis free from personal bias. It helps to present a large set of data in a concise form. The objective here is to identify states that performed well in terms of infrastructure output and states that stayed at the bottom. Table 2 shows the results of the Kaiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity of the three sectors.

Kaiser–Meyer–Olkin test measures sampling adequacy and suitability of both the data and the model for factor analysis. The degree of variation of the variables is measured by it. It is thought that a smaller ratio is more suitable. It is determined to be adequate since the test value in each of the three sectors is more than 0.6. A comparison between an identity matrix and an observed correlation matrix is made using Bartlett's test of

Table 2. ***Kaiser–Meyer–Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity***

Sector	Kaiser–Meyer–Olkin Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
		Approx. Chi-Square	Degree of freedom	Significance
Electricity Sector	0.712	237.73	3	0.000
Construction Sector	0.754	93.22	6	0.000
Transport and Communication Sector	0.696	136.22	6	0.000

Table 3. ***Total Variance Explained***

Sector	Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Electricity Sector	1	2.95	98.44	98.44	2.95	98.44	98.44
	2	0.047	1.55	99.99			
	3	0.000	0.005	100.000			
Construction Sector	1	3.37	84.32	84.32	3.37	84.32	84.32
	2	0.40	10.00	94.32			
	3	0.164	4.09	98.42			
	4	0.063	1.581	100.000			
Transport and	1	3.52	87.93	87.93	3.52	87.93	87.93
Communication Sector	2	0.402	10.05	97.98			
	3	0.056	1.39	99.37			
	4	0.025	0.623	100.000			

sphericity. It is crucial to determine whether the data reduction method can significantly reduce the amount of data before using PCA. In this case, the value is significant across all sectors, and PCA can be performed statistically using the index's creation.

The overall variance explained across the three sectors is displayed in Table 3. Component 1 can be chosen since it has the largest eigenvalue when variances explained by initial eigenvalues and the extracted sum of squared loadings are taken into account. A component is often regarded as statistically valid if its eigenvalue is greater than 1. When a component accounts for a significant amount of the variance, it can be utilized as factor loading in the index construction process. Here, in all sectors, component 1 with eigenvalue explains more than 80% of the total variance in the original variables and the unexplained portion accounts for a meager 20%. Therefore, component 1 can be chosen to be the factor loading for the PCA-based index creation in the sectors. Rotating the loadings was not done because only one component was removed.

Table 4 shows the correlation of variables with component 1. The results show a significant positive correlation (above 0.8), so it can be inferred that the selected component represents all the variables of the model.

Tables 5 and 6 summarize the result of raw analysis by classifying the performance of states into three tiers based on the index and ranks secured by states in the three sectors. A similar classification was also done by Raichoudhury (2020) while comparing the performance of Indian states.

Table 4. ***Component Matrix***

Sector	Variables	Correlation with Component 1
Electricity Sector	Availability of power (units)	0.996
	Installed capacity of power (units)	0.984
	Power requirement (units)	0.996
Construction Sector	Length of railway route (kilometers)	0.870
	Length of national highways (kilometers)	0.970
	Length of roads (kilometers)	0.936
	Length of state highways (kilometers)	0.894
Transport and Communication Sector	Number of telephone subscribers (number)	0.936
	Number of post offices (number)	0.957
	Number of registered transport vehicles (number)	0.877
	Number of registered non-transport vehicles (number)	0.977

Note. One component was extracted.

Table 5. ***Consolidated Index and Ranks of Different Sectors of Infrastructure Under Raw Analysis***

States	Electricity Sector		Construction Sector		Transport and Communication Sector	
	Index	Rank	Index	Rank	Index	Rank
Andhra Pradesh	0.52836	8	0.27308	8	0.35542	7
Assam	–0.85858	19	0.07731	12	–0.5744	16
Bihar	–0.49823	14	0.12522	11	0.13341	11
Goa	–0.96318	21	–1.11086	25	–1.10243	22
Gujarat	1.55223	2	0.68403	6	1.18634	4
Haryana	0.07159	11	–0.6262	17	–0.29415	15

Himachal Pradesh	–0.78462	18	–0.78377	19	–0.85949	19
Jammu and Kashmir	–0.6818	16	–0.83834	20	–0.89763	20
Jharkhand	–0.87085	20	–0.53436	16	–0.64609	17
Karnataka	0.77347	5	0.98752	4	0.8999	5
Kerala	–0.50772	15	–0.42352	14	0.20465	10
Madhya Pradesh	0.66068	7	0.89573	5	0.21394	9
Maharashtra	2.51601	1	3.08135	1	2.14271	1
Manipur	–1.02367	23	–0.9676	22	–1.11691	24
Mizoram	–1.03061	25	–1.0423	24	–1.15164	25
Nagaland	–1.02696	24	–0.96345	21	–1.10105	21
Odisha	–0.38508	13	0.19878	10	–0.08867	13
Punjab	0.19484	10	–0.43673	15	0.07603	12
Rajasthan	0.67498	6	1.11958	3	0.6721	6
Tamil Nadu	1.46808	4	0.57399	7	1.66467	3
Telangana	0.32829	9	–0.3628	13	–0.0899	14
Tripura	–0.9828	22	–1.00605	23	–1.10886	23
Uttar Pradesh	1.53301	3	1.53976	2	2.07971	2
Uttarakhand	–0.73719	17	–0.66078	18	–0.84749	18
West Bengal	0.04975	12	0.20042	9	0.24985	8

Table 6. ***Performance of Indian States Under Raw Analysis***

	States	Electricity Rank Index	Construction Index Rank	Transport and Communication Index Rank
First Tier	Maharashtra	1	1	1
	Uttar Pradesh	3	2	2
	Gujarat	2	6	4
	Karnataka	5	4	5
	Tamil Nadu	4	7	3
	Rajasthan	6	3	6
	Madhya Pradesh	7	5	9
	Andhra Pradesh	8	8	7
Second Tier	West Bengal	12	9	8
	Bihar	14	11	11
	Odisha	13	10	13
	Telangana	9	13	14
	Punjab	10	15	12
	Kerala	15	14	10
	Haryana	11	17	15
	Assam	19	12	16
	Jharkhand	20	16	17
	Uttarakhand	17	18	18

Third Tier	Himachal Pradesh	18	19	19
	Jammu and Kashmir	16	20	20
	Nagaland	24	21	21
	Goa	21	25	22
	Tripura	22	23	23
	Manipur	23	22	24
	Mizoram	25	24	25

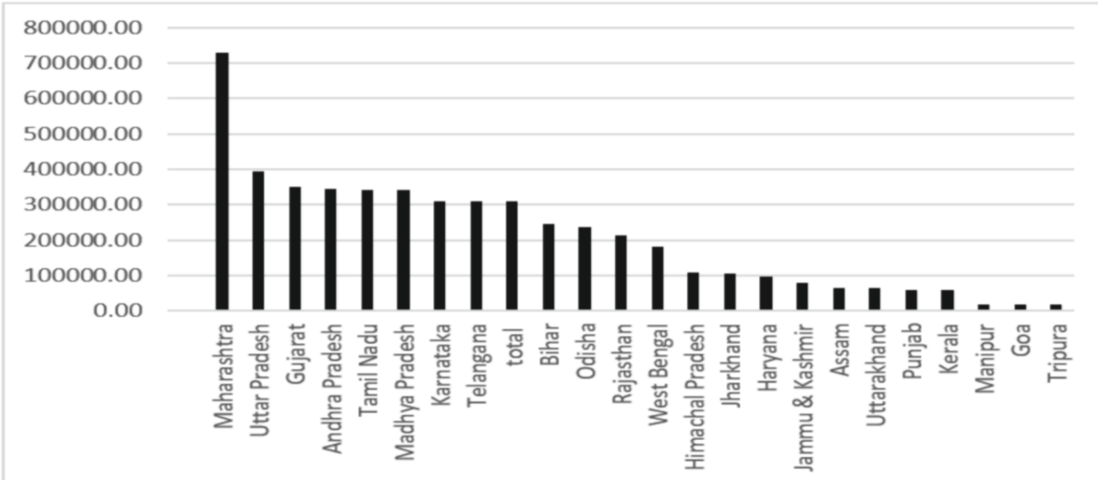
The first-tier states, including Maharashtra, Uttar Pradesh, Gujarat, Karnataka, Tamil Nadu, Rajasthan, Madhya Pradesh, and Andhra Pradesh, are the best performers under the raw analysis. Nevertheless, when examining their performance in specific areas, Madhya Pradesh's performance in the transportation and communication sector was notably subpar. Second-tier states include West Bengal, Bihar, Odisha, Telangana, Punjab, Kerala, Haryana, Assam, Jharkhand, and Uttarakhand. Assam and Jharkhand showed poor performance in the electricity sector when compared with other two sectors. In addition to that, Uttarakhand stands out for its poor performance in all three sectors. The third tier consists of poor performers under raw analysis, including states like Himachal Pradesh, Jammu and Kashmir, Nagaland, Goa, Tripura, Manipur, and Mizoram. It was expected that states such as Goa and certain northeastern states would rank among the worst performers when evaluating infrastructure production without taking into account the population or geographic area of the state as a criterion. However, this limitation can be rectified with the help of refined analysis where infrastructure investment will be considered as a yardstick to measure the productivity of infrastructure output of the Indian states.

Refined Analysis

Raw analysis helps to analyze the performance of states based on the output produced by them in different sectors of infrastructure. The results were expected, meaning that states with smaller inputs of infrastructure would often yield lower outputs of infrastructure. Therefore, a deeper study is required to determine whether the states that were classified as the lowest performers in the raw analysis are actually laggards or just appear to be laggards due to low infrastructure investment. Hence, in this section, a regression analysis of the output of infrastructure sectors with infrastructure investment is done to find the relationship among them. In addition, the goal of this improved analysis is to determine which states—those that fall on the line, those that lie below the regression line, and those that lie above the regression line or line of best fit—are good performers.

Figure 1 shows the amount of infrastructure investment undertaken throughout Indian states. While analyzing the graph, it is evident that some states in India are lucky enough to attract huge infrastructure investment while some states receive only a meager share. Surprisingly, of India's 28 states, only eight—Maharashtra, Uttar Pradesh, Gujarat, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Karnataka, and Telangana—got more than 60% of the country's infrastructure investment. States at the bottom of the list included Mizoram, Goa, Manipur, Nagaland, and Tripura. The collective investment in infrastructure sectors, including economic and social infrastructure, but not limited to the electricity, construction, transportation, and communication sectors, made by the government, public – private partnership (PPP), and private sector is referred to here as infrastructure investment. However, this aggregate infrastructure investment serves as the common control variable for the energy, construction, transportation, and communication sectors because state-by-state data on investment in specific infrastructure sectors are not accessible. Regression analysis can be used to re-model the productivity of the infrastructure in the Indian states by using this infrastructure investment as a control variable. In the three infrastructure sectors, a semi-log OLS regression was performed between infrastructure output and infrastructure investment.

Figure 1. ***Infrastructure Investment of Indian States****



Note. *Total Project Cost for Infrastructure Investment in India made by the government, public-private partnership, and private sector in ₹ crore.

Table 7. *Model Summary of Regression Between Sector Indices and Infrastructure Investment*

Sector	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate	Durbin–Watson
Electricity Sector	0.783	0.613	0.596	0.63584	1.892
Construction Sector	0.782	0.611	0.594	0.63690	1.688
Transport and Communication Sector	0.801	0.641	0.626	0.61175	2.168

Table 8. *ANOVA Analysis of Regression Between Sector Indices and Infrastructure Investment*

Sector		Sum of Squares	*Df*	Mean Square	*F*	Sig.
Electricity Sector	Regression	14.736	1	14.736	36.449	0.000
	Residual	9.299	23	0.404		
	Total	24.035	24			
Construction Sector	Regression	14.677	1	14.677	36.184	0.000
	Residual	9.330	23	0.406		
	Total	24.007	24			
Transport and Communication Sector	Regression	15.392	1	15.392	41.130	0.000
	Residual	8.608	23	0.374		
	Total	24.000	24			

Table 7 shows the summary of the OLS regression run with sector indices as the independent variable and infrastructure investment as the dependent variable. The *R*-square value, otherwise known as the coefficient of determination, denotes the goodness of fit of the data. Here, the *R*-square values are at a satisfactory level. The standard error of the estimate is also not on the higher side and Durbin–Watson statistics, which measures the heteroscedasticity of data, is also quite satisfactory. Table 8 shows the ANOVA analysis of the three sectors.

Table 9. ***Coefficients of Regression Between Sector Indices and Infrastructure Investment***

Sector	Unstandardized Coefficients		Standardized Coefficients	*T*	Sig.
	B	Std. Error	Beta		
Electricity Sector	(Constant)	–6.858	1.144		–5.995
	Log_infra	0.594	0.098	0.783	6.037
Construction Sector	(Constant)	–6.849	1.146		–5.977
	Log_infra	0.593	0.099	0.782	6.015
Transport and	(Constant)	–7.015	1.101		–6.374
Communication Sector	Log_infra	0.607	0.095	0.801	6.413

F - statistics represent whether the mean of two populations are statistically different or not. The probability value of the *F*-test determines whether the regression model fits into the data. As can be seen from Table 8, the model is deemed adequate overall because the probability value is below the 5% significance limit.

If the beta coefficient is positive, this means that the dependent variable will increase by the beta coefficient for each unit increase in the independent variable. The positive beta coefficient, in this case, as indicated in Table 9, indicates a high positive correlation between sector indices and infrastructure investment.

Figures 2 to 4 show the line of fit between the dependent variable (sector index) and independent variable (infrastructure investment). A linear regression line is fitted into the model to ascertain if examples (in this case, the states of India) lie above, on, or below the regression line. In the electrical sector, states below the regression line close to the origin are the poorest-performing states, whereas states above the regression line and far from the origin are the best-performing states. Table 10 displays an overview of the results.

Figure 2. ***Line of Best Fit in Regression Between Electricity Index and Infrastructure Investment***

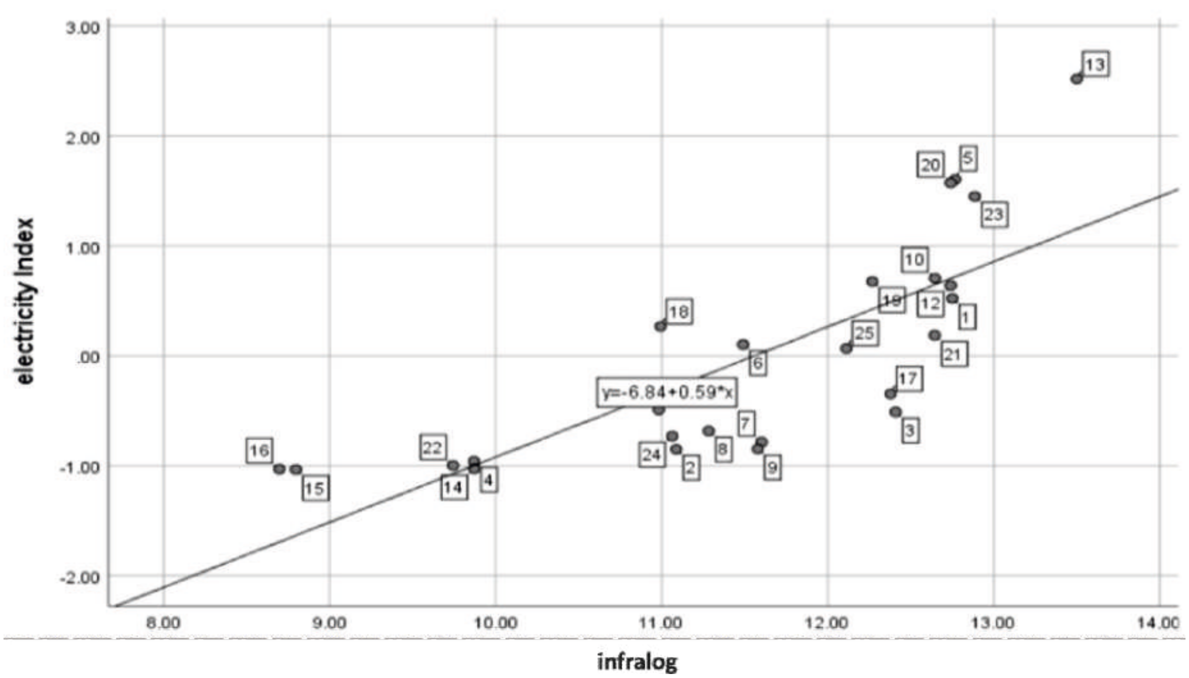


Figure 3. ***Line of Best Fit in Regression Between Construction Index and Infrastructure Investment***

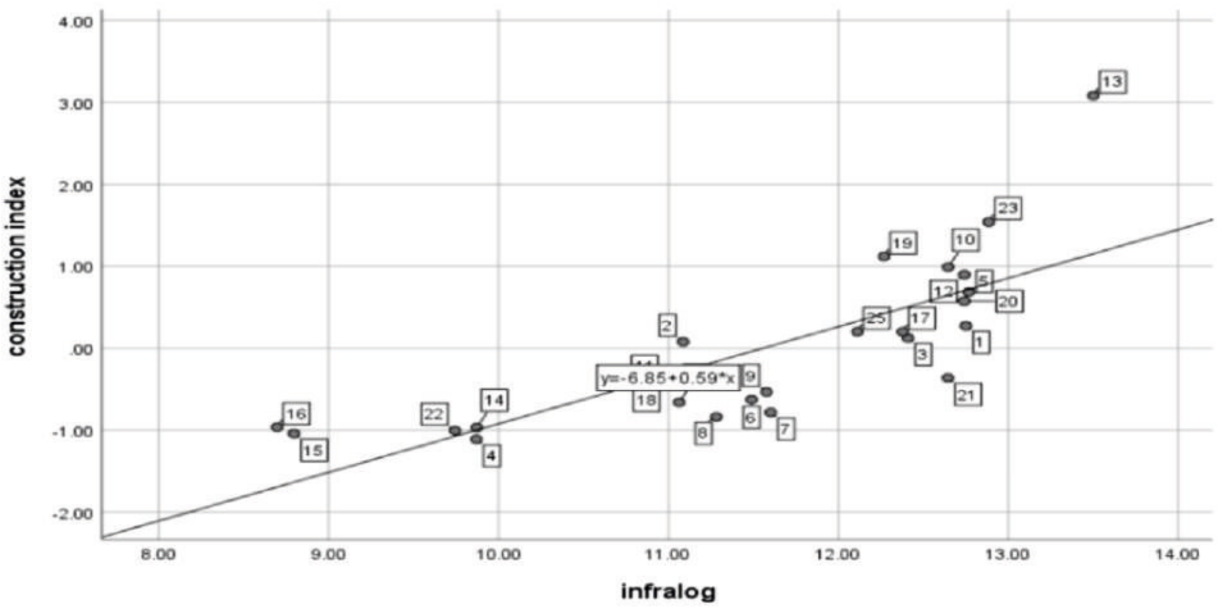


Figure 4. ***Line of Best Fit in Regression of Transport and Communication Index and Infrastructure Investment***

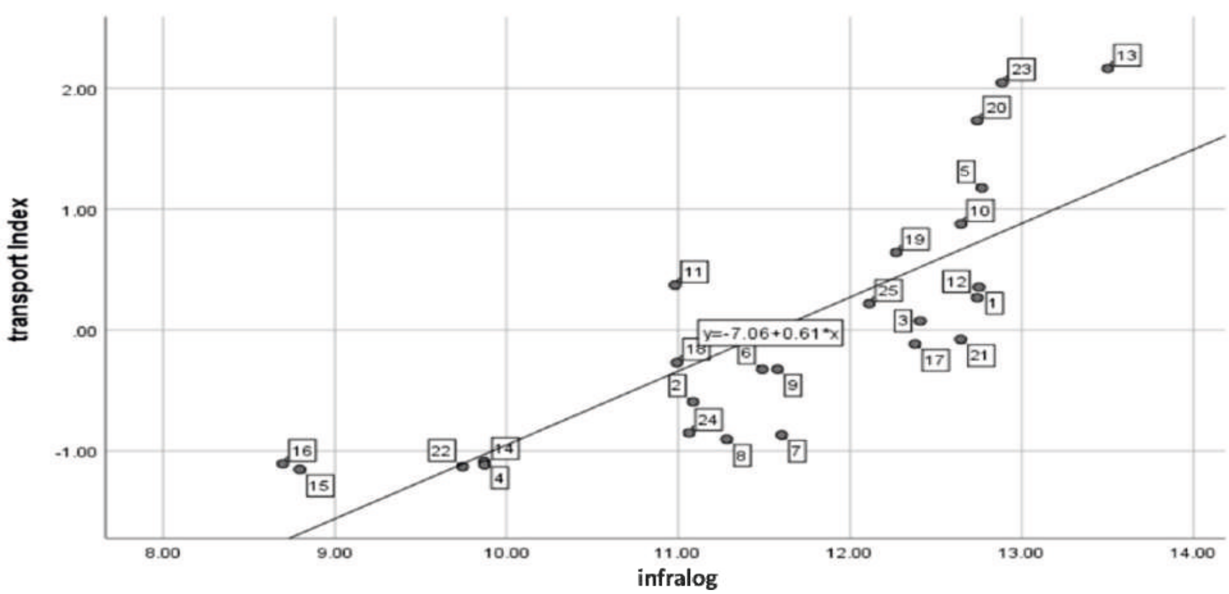


Table 10 analysis allows for the drawing of some conclusions on state productivity in more detail. States that exhibit high productivity in terms of infrastructure input and output are those that are located above the regression line in this instance. In other words, such states make the best use of infrastructure investment available to produce more infrastructure output. States with higher productivity across all sectors are Maharashtra, Uttar Pradesh, Rajasthan, Nagaland, Mizoram, Gujarat, and Tamil Nadu. A state is considered a laggard if it is unable to generate adequate infrastructure output for each investment it receives. Stated differently, the output of their infrastructure

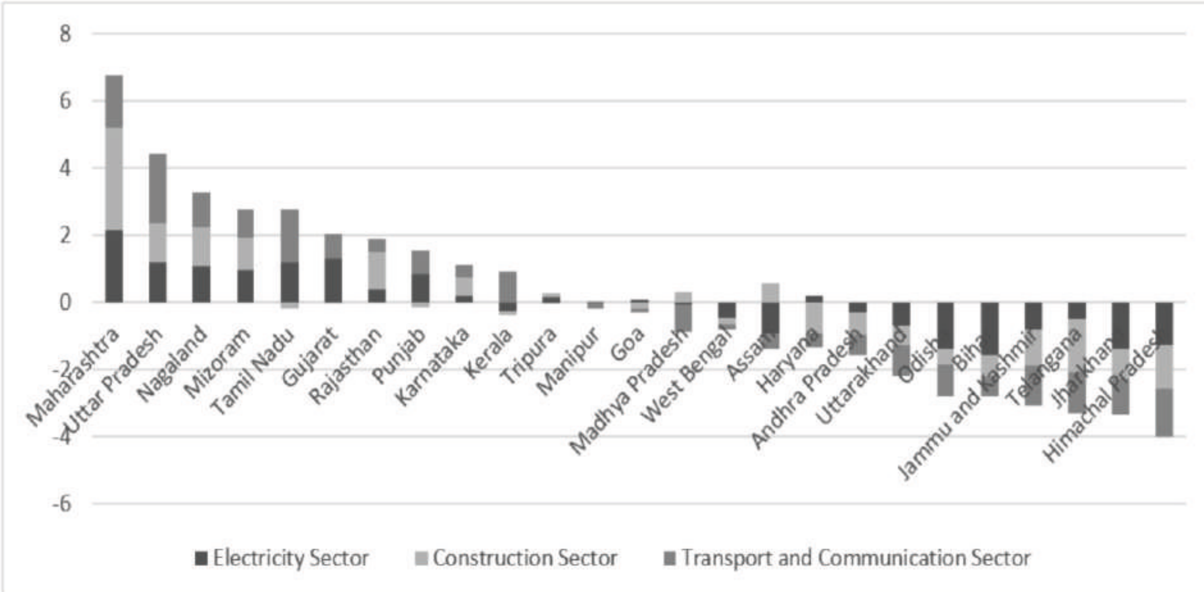
Table 10. *Performance of Indian States Under Refined Analysis*

	Electricity Sector	Construction Sector	Transport and Communication Sector
States Lying Above the Line of Best Fit	Maharashtra (13)	Maharashtra (13)	Maharashtra (13)
	Gujarat (5)	Uttar Pradesh (23)	Uttar Pradesh (23)
	Tamil Nadu (20)	Karnataka (10)	Tamil Nadu (20)
	Punjab (18)	Rajasthan (19)	Gujarat (5)
	Uttar Pradesh (23)	Madhya Pradesh (12)	Karnataka (10)
	Rajasthan (19)	Assam (2)	Rajasthan (19)
	Nagaland (16)	Nagaland (16)	Kerala (11)
	Mizoram (15)	Mizoram (15)	Mizoram (15)
	Tripura (22)		Nagaland (16)
	Haryana (6)		Punjab (18)
States Lying on the Line of Best Fit	Manipur (14)	Tripura (22)	Tripura (22)
	Goa (4)	Gujarat (5)	Manipur (14)
	Karnataka (10)	Manipur (14)	Goa (4)
	Madhya Pradesh (12)	Kerala (11)	
	Kerala (11)		
States Lying below the Line of Best Fit	Jharkhand (9)	Tamil Nadu (20)	Jharkhand (9)
	Bihar (3)	West Bengal (25)	Haryana (6)
	Himachal Pradesh (7)	Odisha (17)	Assam (2)
	Jammu and Kashmir (8)	Bihar (3)	Uttarakhand (24)
	Assam (2)	Telangana (21)	Jammu and Kashmir (8)
	Uttarakhand (24)	Haryana (6)	Himachal Pradesh (7)
	Odisha (17)	Himachal Pradesh (7)	West Bengal (25)
	Telangana (21)	Jammu and Kashmir (8)	Bihar (3)
	Andhra Pradesh (1)	Jharkhand (9)	Madhya Pradesh (12)
	West Bengal (25)	Punjab (18)	Andhra Pradesh (1)
		Goa (4)	Odisha (17)
		Andhra Pradesh (1)	Telangana (21)
		Uttarakhand (24)	

is not commensurate with the investment in infrastructure. These underperforming states in every area include Jharkhand, Bihar, Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Odisha, Telangana, Andhra Pradesh, and West Bengal. Assam also showed poor performance in all sectors except the construction sector. States that generate infrastructure output after making infrastructure investments are considered average performers. The remaining middle-ranking states perform differently in each sector. Nonetheless, Goa, Kerala, Tripura, and Manipur have performed mediocrely in at least two of the three areas examined.

In a regression analysis, the residual is the difference between the dependent variable's observed and anticipated values. The residuals from each state's regression analysis are shown in Figure 5. As we can see, Figure 5 clearly shows states with positive residuals (observed value is greater than predicted value) and negative residuals (observed value is less than predicted value). Although there are variations in the residuals between the

Figure 5. ***Stacking-up of Performance Across States Using Residuals from Regression Analysis***



sectors, piling up of the residuals helps to get the overall performance of the states in all three sectors. State residuals decrease from left to right until they reach negative values. The residuals of each sector's states are listed in Table 11, along with the associated residual-based rankings.

Table 11. ***Consolidated Residuals from Regression Analysis and Corresponding Ranks of Infrastructure Sectors Under Refined Analysis***

States	Electricity Sector		Construction Sector		Transport and Communication Sector	
	Residual	Ranks	Residual	Ranks	Residual	Ranks
Andhra Pradesh	–0.29161	16	–0.68216	20	–0.6052	17
Assam	–0.91802	21	0.55769	6	–0.47365	16
Bihar	–1.59702	25	–0.59684	19	–0.62934	18
Goa	0.06703	12	–0.17563	14	–0.12843	12
Gujarat	1.31579	2	–0.05328	11	0.73697	7
Haryana	0.17638	10	–0.9212	22	–0.41526	15
Himachal Pradesh	–1.28799	22	–1.27317	24	–1.45201	25
Jammu and Kashmir	–0.82258	20	–1.06152	23	–1.19679	23
Jharkhand	–1.40192	24	–0.8592	21	–1.07887	22
Karnataka	0.19589	9	0.53645	7	0.38938	10
Kerala	–0.26149	15	–0.1301	12	0.90609	5
Madhya Pradesh	–0.07262	14	0.30423	8	–0.82709	19
Maharashtra	2.151	1	3.0281	1	1.57329	2
Manipur	–0.03135	13	0.04685	10	–0.15469	14

Mizoram	0.9753	6	0.93033	5	0.8576	6
Nagaland	1.07435	5	1.14582	3	1.03834	4
Odisha	–1.38848	23	–0.45277	17	–0.96214	21
Punjab	0.84246	7	–0.16099	13	0.6848	8
Rajasthan	0.39663	8	1.09477	4	0.39166	9
Tamil Nadu	1.20789	3	–0.20087	15	1.54645	3
Telangana	–0.50834	18	–1.58143	25	–1.22814	24
Tripura	0.15438	11	0.1054	9	–0.0145	11
Uttar Pradesh	1.17414	4	1.1807	2	2.08186	1
Uttarakhand	–0.70302	19	–0.57883	18	–0.89685	20
West Bengal	–0.44679	17	–0.20235	16	–0.14349	13

Table 12 shows that certain states' performance increased significantly across all three sectors, indicating strong productivity, when we compare the ranks before and after more in-depth analysis. However, some states have risen, which is a sign of good productivity. While states like Andhra Pradesh, Telangana, Odisha, Madhya Pradesh, West Bengal, and Bihar showed poor performance after refined analysis, states like Goa, Manipur, Mizoram, Nagaland, Punjab, and Tripura improved their performance in refined analysis. Tamil Nadu has remained at the top of the rankings, with the exception of the construction industry, where there has been a noticeable decline in performance. However, subsequent in-depth examination revealed a significant improvement in Kerala's performance, particularly in the transportation and communication sectors. To conclude, there are wide fluctuations in the rankings of the state under raw analysis and refined analysis. These results show how important it is to research state-level infrastructure productivity as opposed to depending only on infrastructure production.

Table 12. ***Comparison of Performance of States Under Raw Analysis and Refined Analysis***

State	Ranks in the Electricity Sector		Ranks in the Construction Sector		Ranks in the Transport and Communication Sector	
	Raw Analysis	Refined Analysis	Raw Analysis	Refined Analysis	Raw Analysis	Refined Analysis
Andhra Pradesh	8#	16#	8#	20#	7#	17#
Assam	20#	21#	12*	6*	16@	16@
Bihar	15#	25#	11#	19#	11#	18#
Goa	21*	12*	25*	14*	22*	12*
Gujarat	2@	2@	6#	11#	4#	7#
Haryana	11*	10*	17#	22#	15@	15@
Himachal Pradesh	18#	22#	19#	24#	19#	25#
Jammu and Kashmir	16#	20#	20#	23#	20#	23#
Jharkhand	19#	24#	16#	21#	17#	22#
Karnataka	5#	9#	4#	7#	5#	10#
Kerala	14#	15#	14*	12*	10*	5*
Madhya Pradesh	7#	14#	5#	8#	9#	19#
Maharashtra	1@	1@	1@	1@	1#	2#
Manipur	23*	13*	22*	10*	23*	14*

Mizoram	25*	6*	24*	5*	25*	6*
Nagaland	24*	5*	21*	3*	21*	4*
Odisha	13#	23#	10#	17#	14#	21#
Punjab	9*	7*	15*	13*	12*	8*
Rajasthan	6#	8#	3#	4#	6#	9#
Tamil Nadu	3@	3@	7#	15#	3@	3@
Telangana	10#	18#	13#	25#	13#	24#
Tripura	22*	11*	23*	9*	24*	11*
Uttar Pradesh	4@	4@	2@	2@	2*	1*
Uttarakhand	17#	19#	18@	18@	18#	20#
West Bengal	12#	17#	9#	16#	8#	13#

Note. # Rank rises after refined analysis.
@Rank remains the same after refined analysis.
*Rank falls after refined analysis.

Conclusion

The current study compares the performance of 25 major states in India concerning their infrastructure output in electricity, construction, transport, and communication sectors. Raw analysis is carried out to understand the performance level of the states of India regarding the infrastructure output of various sectors. The results, after conducting the raw analysis, are as follows. The first-tier states comprise good performers, which include Maharashtra, Uttar Pradesh, Gujarat, Karnataka, Tamil Nadu, Rajasthan, Madhya Pradesh, and Andhra Pradesh and the second-tier of average-performing states comprises West Bengal, Bihar, Odisha, Telangana, Punjab, Kerala, Haryana, Assam, Jharkhand, and Uttarakhand. The third tier consists of poor performer states like Himachal Pradesh, Jammu and Kashmir, Nagaland, Goa, Tripura, Manipur, and Mizoram. States like Andhra Pradesh, Telangana, Odisha, Madya Pradesh, West Bengal, and Bihar demonstrated low productivity after carrying out more thorough research, but states like Goa, Manipur, Mizoram, Nagaland, Punjab, and Tripura demonstrated increased productivity. States with the largest infrastructure investment typically have the highest infrastructure output. However, states like Andhra Pradesh, Telangana, Odisha, Madhya Pradesh, West Bengal, and Bihar are still having difficulty getting off the ground even after receiving a sizable amount to invest in infrastructure, whereas Goa and many northeastern states rapidly rose to the top of the rankings.

Policy Implications

It is difficult for both developed and developing nations to secure financing for infrastructure (Malik & Kaur, 2021). India has limited financial resources, like gold dust, literally. The only practical method to guarantee that the economy is headed for greatness is to make wise use of these resources. Understanding the infrastructure productivity of a state makes it easier to allocate resources wisely. The Government should bring infrastructure development programs that cater to the needs of the underdeveloped states and should be one of the key focus areas. Infrastructure regional inequalities have resulted in the lop-sided growth of India to a great extent (Bhatnagar & Sharma, 2016).

Improved performance of north-eastern states was a result of several development programs like the Comprehensive Scheme for Strengthening of Transmission and Distribution Systems (CSST & DS), Comprehensive Telecom Development Project (CTDP) for the North-Eastern Region (NER), Special Accelerated

Road Development Program for North East (SARDP-NE), North Eastern Region Power System Improvement Project (NERPSIP), etc., which provided a much-needed boost to their respective economies. Such beneficial programs should also be implemented in other backward states to improve their performance.

Interstate disparity in infrastructure is an issue that rings alarm bells. To address this, policymakers need to pinpoint the lowest-performing states and come up with strategies to elevate them. India's regional disparities are becoming much more pronounced (Kumar, 2015). A country can only develop when there is minimal regional disparity among its states. Developing and executing strategies that assist the states that are falling behind is crucial and will contribute significantly to the nation becoming a superpower.

Limitations of the Study and Future Research Directions

One weakness of the study is that, given its analysis of the vast and intricate Indian economy, it is possible that external variables could also affect the productivity of state infrastructure. The research can be extended by incorporating more sectors and variables of infrastructure, especially soft infrastructure sectors. The study's focus on interstate variations in India's infrastructure investment productivity is another flaw. However, further research may be done to determine the causes of states' strong or poor performance. Furthermore, researchers can use the same process of both raw and refined analysis to evaluate the performance of Indian states using metrics other than infrastructure.

Authors' Contribution

Dr. Nishija Unnikrishnan gave the idea for this paper. Data were collected and the numerical computations were done by Dr. Nishija Unnikrishnan using SPSS 20.0. The manuscript was written with the assistance of Drs. Thomas Paul Kattookaran and Biju John M.

Conflict of Interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript

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References

Agarwalla, A. (2011). *Estimating the contribution of infrastructure in regional productivity growth in India* (Working Paper No. 2011-05-01). Indian Institute of Management, Ahmedabad. https://www.iima.ac.in/sites/default/files/rnpfiles/10162392592011-05-01.pdf

Bajar, S., & Rajeev, M. (2016). Contribution of infrastructure to output growth in India. *Emerging Economy Studies*, *2*(2), 240–252. https://doi.org/10.1177/2394901516661093

Bhandari, P. (2013). *Refining state level comparisons in India* (Working Paper Series 2012). Planning Commission, Government of India.

Bhatnagar, G., & Sharma, S. (2016). Inter-state disparities in higher education: Affecting economic development in India. *Arthshastra Indian Journal of Economics & Research*, *5*(1), 8–21. https://doi.org/10.17010/aijer/2016/v5i1/87838

Bordoloi, R. (2014). Formulation and implementation of government policies and programmes with reference to Assam. *Arthshastra Indian Journal of Economics & Research*, *3*(1), 40–47. https://doi.org/10.17010/aijer/2014/v3i1/55963

Jose, A. (2019). India's regional disparity and its policy responses. *Journal of Public Affairs*, *19*(4), e1933. https://doi.org/10.1002/pa.1933

Kumar, S. (2015). Regional disparities in per capita GSDP/NSDP in the seven sister states in India: Convergence and divergence. *Arthshastra Indian Journal of Economics & Research*, *4*(2), 31–46. https://doi.org/10.17010/aijer/2015/v4i2/65544

Longe, J. B., & Omozuawo, M. B. (2013). The management and adequacy of road infrastructure expenditure for economic growth in Nigeria. *Prabandhan: Indian Journal of Management*, *6*(6), 5–15. https://doi.org/10.17010/pijom/2013/v6i6/60001

Madan, P. (2014). Foreign direct investment: Governance and infrastructure - A study across Indian states. *Arthshastra Indian Journal of Economics & Research*, *3*(4), 17–31. https://doi.org/10.17010/aijer/2014/v3i4/55984

Malik, S., & Kaur, S. (2021). Rationales and advantages of financing infrastructure through public – private partnerships: A systematic literature review. *Indian Journal of Finance*, *15*(10), 28–43. https://doi.org/10.17010/ijf/2021/v15i10/166510

Mishra, A. K., Narendra, K., & Kar, B. P. (2013). Growth and infrastructure investment in India: Achievements, challenges, and opportunities. *Economic Annuals*, *58*(196), 51–70. https://doi.org/10.2298/EKA1396051M

Mundle, S., Chowdhury, S., & Sikdar, S. (2016). *Governance Performance of Indian States: 2001-02 and 2011-12* (Working Paper No. 164). National Institute of Public Finance and Policy. https://doi.org/10.13140/RG.2.1.3855.0646

Narayan, L. (2015). Inter-district disparities in health in Haryana. *Arthshastra Indian Journal of Economics & Research*, *4*(5), 7–22. https://doi.org/10.17010/aijer/2015/v4i5/82901

Oda, H. (2011). Infrastructure, economic growth and interstate disparity in India. In H. Oda, & Y. Tsujita (eds.), *Inclusiveness in India: A strategy for growth and equality* (pp. 35–61). Palgrave Macmillan. https://doi.org/10.1057/9780230304956_2

Raichoudhury, A. (2020). Major determinants of financial inclusion: State-level evidences from India. *Vision*, *24*(2), 151–159. https://doi.org/10.1177/0972262920923882

Sahoo, B. K., & Acharya, D. (2012). Constructing macroeconomic performance index of Indian states using DEA. *Journal of Economic Studies*, *39*(1), 63–83. https://doi.org/10.1108/01443581211192116

Saji, T. G. (2016). Recession to resilience: The Indian experience in a regional perspective. *Arthshastra Indian Journal of Economics & Research*, *5*(5), 11–25. https://doi.org/10.17010/aijer/2016/v5i5/105146

Sharma, C. (2018). *Inequality of opportunity and economic performance: Empirical evidence from Indian states*. Available at SSRN. https://ssrn.com/abstract=3184427

Unnikrishnan, N., & Kattookaran, T. P. (2020). Impact of public and private infrastructure investment on economic growth: Evidence from India. *Journal of Infrastructure Development*, *12*(2), 119–138. https://doi.org/10.1177/0974930620961477

Vidyarthi, H. (2017). Banking outreach, infrastructure development, and regional growth: Empirical evidence from Indian states. *World Journal of Entrepreneurship, Management and Sustainable Development*, *13*(2), 114–127. https://doi.org/10.1108/WJEMSD-11-2016-0054

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