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Abstract

Globally infrastructure has been found to play a significant role in promoting inclusiveness and growth through various channels. These include reducing the cost and improving the quality of intermediate inputs, enlarging the market size and allowing greater competition, and improving access to public services and economic opportunities. In this paper, we empirically investigate the role played by infrastructure development in improving living standards across major states in India. We explore the role of infrastructure development in four sectors, *viz.* electricity, roads, education and health, in enhancing income growth and facilitating poverty reduction. Instead of focusing on the commonly used infrastructure expenditure as a measure of infrastructure development, we construct infrastructure indexes for each sector using an array of physical indicators for that sector. This helps us overcome the inaccuracies that can arise due to inefficiency, leakage, corruption and weak government procurement policies. We find that infrastructure development across roads, electricity and education sectors, significantly bolster economic growth. On the other hand, infrastructure development across electricity, health and education sectors substantially assist in poverty reduction, even after accounting for the impact of major social welfare schemes. We conclude by highlighting some broad measures to enhance infrastructure investment.

JEL Classification: C3, I15, I25, O11.
Keywords: Infrastructure, Income growth, Poverty, Panel VAR, India.

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1 Introduction

India exhibited impressive growth during the period 2004-05 to 2015-16, growing at an average annual rate of 7.6%. This resulted in per capita income nearly doubling from $903 in 2004 to $1759 in 2015. Furthermore, over this period, India managed to elevate a large number of people out of poverty. The proportion of poor people in the population, based on $1.90 a day (2011 PPP) poverty line, declined from 38.2% to 21.7% between 2004-05 and 2011-12 with the number of poor declining from 430.2 million to 238.7 million.[1] This is in sharp contrast to experience in the earlier decade which saw a marginal increase in the number of poor from 403.7 million to 407.2 million. A similar picture appears with the multidimensional poverty index (MPI), which shows that India was successful in lifting 271 million people out of poverty between 2005-06 and 2015-16.

Several factors have been identified as fostering poverty reduction. First, India witnessed sustained rapid growth during this period, which helped in creating better paying jobs and also raised real wages, both of which in turn raised the household income of the poor and reduced poverty. Higher income also helped these households to gain access to various public health and education services. Lack of financial resources can restrict access to these services, even if they are free, as travel cost to the point of delivery may be prohibitive. Second, introduction of new and expansion of existing social welfare programs like the Mahatma Gandhi National Rural Employment Guarantee (MGNREGA) and the Public Distribution System (PDS) helped improve the purchasing power of the poor.[2] Furthermore, rapid economic growth provided the government with additional resources to spend on these programs. Third, enhanced emphasis on infrastructure, with infrastructure spending as a share of GDP rising from 4.2% in 2001-02 to a peak of over 8.0% in 2010-11, also contributed to poverty reduction. However, since then there has been a moderation in pace of infrastructure spending and it has ranged between 5.0% and 6.0% of GDP.

Globally, infrastructure has been identified as one of the mainstays of inclusive growth. Infrastructure development can foster income generation and poverty reduction directly and indirectly in a variety of ways. Improved infrastructure plays a vital role in promoting economic activity and creating additional jobs, which in turn helps in reducing poverty. A well-developed rail and road network not only facilitates the movement of passengers and freight

[1] In terms of the national poverty lines, the proportion of the people living in poverty declined from 37.2% in 2004-05 to 21.9% in 2011-12, while the number of poor people fell from 418.9 million to 246.6 million.

[2] MGNREGA provides 100 days of wage employment in a financial year to adult member of every rural household. The scheme was piloted in 2006 and subsequently expanded to cover the entire country. Under the PDS the government provides subsidised food and fuel to the poor through a network of shops.

across the country, and thereby promotes efficiency in the economy by minimizing total transportation cost, it also connects remote areas, thereby improving access to health and education and generating new employment opportunities. Similarly, electricity has become essential for most modern manufacturing and good quality of household life. In the absence of good quality and reliable power, businesses and manufacturers are compelled to use more expensive back-up power supplies, often based on greenhouse gas intensive diesel fuel, that add to their costs and undercut competitiveness. Finally, secure water supply and sewage safeguard human health and productivity. Lack of clean water and sanitation often results in high dropout rates among the poorest and most marginalized children, as well as adversely impacting their health.

Apart from promoting economic activities, a well-developed infrastructure system can reduce inequality as infrastructure development can have a differential effect on the income of poor, over and above, the impact on aggregate income. Robust infrastructure facilitates the access of the poor to productive economic opportunities thereby enhancing their livelihoods. Similarly, small and medium enterprises, which are the key generators of employment, benefit disproportionately from improvements in infrastructure, as unlike large enterprises, they are unable to create customized alternatives such as private access roads and captive power plants.

Given these positive externalities, building infrastructure has been a key priority across many emerging markets. In India infrastructure investment increased from an annual average of 5.2% of GDP during 2002-03 to 2006-07 to 7.0% of GDP during 2007-08 to 2011-12. However, infrastructure investment fell to around 5.8% of GDP between 2012-13 and 2016-17 owing to policy and structural bottlenecks. The problem was exacerbated by the twin balance sheet problems, where banks and corporates with stressed balance sheets, were reluctant to finance infrastructure.

Going forward, there are several estimates of finance needed for infrastructure. According to Global Infrastructure Outlook, $4.5 trillion investments are required between 2015 and 2040 to develop infrastructure to improve economic growth and economic well-being. ADB (2017) has estimated that between 2016 to 2020, India's annual infrastructure investment needs range between $230 billion and $261 billion. GOI (2019) points out that India needs to increase infrastructure investment from current levels of $110 billion annually to around $200 billion to become $10 trillion economy by 2032.

In this paper, we investigate the role played by infrastructure development in improving livelihoods *i.e.,* by raising per capita income and lowering poverty rate. We focus on 18 major Indian states over the period 2004-05 to 2015-16.[3] There is a great deal of heterogeneity across Indian states with per capita

[3] The states are chosen on the basis of availability of the data and they account for 90% of output, 93.4% of population, 94.3% of workforce and 93.8% of people living in poverty (Table A.1)

income of Haryana being more than 5 times that of Bihar. Similarly, while only 7.0% of the population lived in poverty in Kerala, the proportion was as high as 40% in Chhattisgarh.

We focus on four sectors, namely, electricity, roads, education and health. We find that infrastructure development across roads, electricity and education sectors, significantly contributes to economic growth. On the other hand, infrastructure development across electricity, health and education reduce the share of population in poverty. Our findings indicate that improved physical and quality of health infrastructure has significant level effect but insignificant growth effect on income and consumption via labour productivity channel in Indian states.

The rest of the paper is organised as follows. Section 2 presents review of the related literature. Section 3 discusses the stylised facts about the relationship between economic growth, poverty and infrastructure. Section 4 outlines the estimation strategy and discusses results of the analysis. Finally, Section 5 concludes the paper with some policy measures to bolster infrastructure investment.

2 Literature Review

A broad strand of literature, both theoretical and empirical, establish infrastructure as a critical factor in bolstering income and reducing poverty. The majority of the theoretical literature explores the role of publicly provided infrastructural inputs in private production of goods. This literature models public infrastructural expenditure, both as stock that can be accumulated over time, as well as flow of infrastructure-related expenditure. The literature broadly argues that publicly provided infrastructure, contributes to the productivity via positive externality effect, and thereby positively affect economic growth in the long run (Agnor, 2008, 2010; Baier and Glomm, 2001; Barro, 1990; Barro and Sala-I-Martin, 1992; Dasgupta, 1999; Futagami, Morita and Shibata, 1993). Incremental public expenditure on infrastructure increases marginal productivity of the non-infrastructural inputs such as labour and capital, attracting employment of more labour and capital and thereby enhancing the aggregate production.

Apart from the endogenous growth paradigm based on Barro-style models, infrastructure can contribute to output growth via innovation of new intermediate inputs and facilitating accumulation of other inputs. In this line, Bougheas, Demetriades and Mamuneas (2000) introduces infrastructure as a technology which reduces fixed cost of producing intermediate inputs in the endogeneous growth framework of Romar (1987). Since final output is increasing in the number of intermediate inputs in this framework, infrastructure enhances economic growth via innovation of new intermediate inputs. For example, transport and telecommunication services facilitate innovation and technological upgrading, fostering economic growth (Calderon and Serven, 2014).

Few examples of the channel through which infrastructure facilitates accumulation of other inputs are reduction of installation cost of new capital due to improved transport networks, and the decline of cost of human capital generation with improved access to electricity via rise in educational attainment (Agenor, 2011; Calderon and Serven, 2014; Turnovsky, 1996). In presence of this channel, the output effect of infrastructure capital consists of two components: the elasticity of output with respect to the infrastructural capital and the impact on output via accumulation of other inputs. Again, the presence of network effects can lead to non-linearities in marginal productivity of infrastructure. For instance, building road infrastructure can be conducive to economic growth only after it crosses a threshold level, and after completion of the network of roads, building additional road may not contribute to growth (Calderon and Serven, 2014; Fernald, 1999).

The long-standing empirical literature have established support for the theoretical findings (Aschauer, 2000; Bose, Haque and Osborn, 2007; Ligthart and Suarez, 2010; Pereira and Andraz, 2013). The majority of these empirical studies establish the positive role of public investment flow, or accumulation of public capital stock in growth and income distribution. Aschauer (2000) find that during the 1970s and 1980s a one standard deviation increase in public capital stimulate a one-third to one-half standard deviation increase in output per worker in the United States.

Bose, Haque and Osborn (2007) examine the growth effects of government expenditure of 30 developing countries during 1970s and 1980s and conclude that the share of government capital expenditure has a significantly positive impact on growth rate. A disaggregation of public expenditure reveals that only educational expenditure has a significant positive effect on growth rate of the economy.

Ligthart and Suarez (2010) analyse the effect of public capital on private output by undertaking a meta-regression analysis for 55 studies over the period 1973 to 2005, and find that the output elasticity of public capital to be around 0.14. Pereira and Andraz (2013) provides a comprehensive review of the impact on output effect of public capital across a variety of country-specific, cross-country, regional level and industry level studies. The authors observe large and significant positive effect of public capital. While output effect of public capital is found to be relatively low in the regional-level studies, industrial performances seem to respond differently to different components of public capital.

Another strand of literature focus on the role of quantity and quality of infrastructural assets instead of infrastructure expenditure for economic growth (Calderon and Serven, 2004, 2014; Calderon, Moral-Benito and Serven, 2015). This literature highlights that using public expenditure as a proxy for infrastructure can be inaccurate due to a variety of reasons like inefficiency, leakage, corruption and weak government procurement policies. Moreover, the entire public capital may not consist of infrastructure capital. Calderon, Moral-Benito and Serven (2015) estimates the effect of infrastructure assets on output for 88 countries over the period 1960-2000, in a production function framework after controlling for physical and human capital. The long-run elasticity of output with respect to the aggregate infrastructure index, based on the telecommunication sector, power sector and the transportation sector, ranges between 0.07-0.10.

A large strand of literature investigates the role of an individual infrastructure sector in economic performance. Melo, Graham and Brage-Ardao (2013) analyse 563 estimates of output elasticity of transport infrastructure from 33 studies. The contribution of transport infrastructure to output on average ranges from 0.002 and 0.315. Pradhan and Bagchi (2013) find positive role of transport infrastructure (rail and road) for economic growth in India.

Czernich et al. (2011) provides an example of a cross-country analysis of output e ect of telecommunication infrastructure. In a panel of OECD countries during 1996-2007, the penetration of broadband infrastructure is found to increase annual per capita growth by 0.9-1.5%. Pradhan et al. (2016) find telecommunication infrastructure granger cause economic growth in the long run in a sample of G-20 countries for the period 1961-2012.

The findings on the impact of access to electricity vary widely across different empirical studies (Payne, 2010; Wolde-Rufael, 2014). The empirical evidence on this issue can be classified in four paradigms: first, the 'growth hypothesis' postulating increase in electricity consumption leads to economic growth; second, the 'conservation hypothesis' suggesting economic growth induces higher electricity consumption; third, the 'feedback hypothesis' indicating a two-way causality that runs between electricity consumption and economic growth; and fourth, 'neutrality hypothesis' suggesting absence of any causal relationship between electricity consumption and economic growth. Payne (2010) conducts a survey of empirical literature on specific countries and finds that 31.15% of the results supported the neutrality hypothesis; 27.87% the conservation hypothesis; 22.95% the growth hypothesis; and 18.03% the feedback hypothesis. Wolde-Rufael (2014) revisits this issue for 15 transition economies for the period 1975 to 2010, and again finds supports for all the four hypothesis.

Substantial empirical literature highlights poverty reduction via physical infrastructure generation. For instances, the increased coverage of electricity facilities have reduced poverty through growth in Indonesia (Balisacan, Pernia and Asra, 2003), Philippines (Balisacan and Pernia, 2002), and rural areas in Bangladesh and India (Songco, 2002). Better roads and connectivity boost growth, employment and wages, leading to poverty reduction (Ali and Pernia, 2003). These are evident from the results of various studies across different economies (Balisacan and Pernia, 2002; Fan, Zhang and Zhang, 2002; Glewwe, Gragnolati and Zaman, 2000; Jacoby, 1998; Jalan and Ravallion, 2002).

There are strong arguments in favour of positive impacts of improved social infrastructure like access to education and health facilities on reduction of poverty. Literature suggests better education and proper health care have strong positive impact on poverty reduction. There are many channels to reduce poverty by improving social and physical infrastructure. Improved quality of education enhances skills, increases chances to get high paid jobs, and reduce poverty rate. Cuyvers et al. (2011); Sikdar (2016); Vincent (2006) and many other studies showed that better school infrastructure can improve quality of education.

Similarly, better health facilities and health infrastructure can reduce poverty (Cotlear, 2000). Better access to health facilities can improve labour productivity and reduce poverty. The poor patient cannot afford to pay the travel cost to reach the health institutions faraway, and also not be able to buy proper medications. This results in their being vulnerable to diseases, which lower their productivity and the chance of being in the labour force (Douthit and Alemu, 2016).

Ali and Pernia (2003) discuss the channels through which infrastructure investment in rural areas can reduce poverty. Rural infrastructure investment enhances productivity of both agricultural and non-farm activities, raising both agricultural and non-farm wages and employment (direct channel). Increase in productivity and employment in rural activities in turn leads to higher economic growth and supply of commodities, and lower prices, raising the well-being of the poor (indirect channel). Recent empirical studies find similar evidence for Brazil, Sri Lanka and regions in Africa (Akanbi, 2015; Marinho et al., 2017; Sellamuttu et al., 2014).

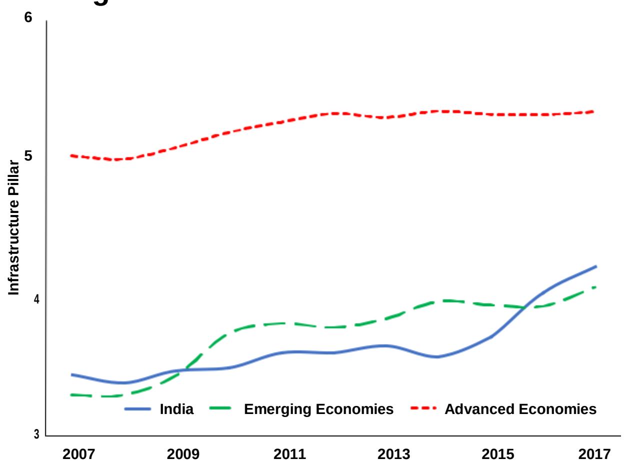
Public infrastructure provision can contribute in lowering the rural poverty by boosting non-farm activities and agricultural productivity (Escobal and Ponce, 2008; Fan, Zhang and Zhang, 2004; Fan, Hazell and Thorat, 2000). Fan, Zhang and Zhang (2004) investigate various effects of government expenditure on production and poverty reduction in the rural People's Republic of China (PRC) through different channels. They find public spending on productive areas like agricultural R&D, irrigation, rural education and infrastructure including roads, electricity and telecommunications, contribute significantly to agricultural productivity growth. Fan, Hazell and Thorat (2000) obtain similar findings for India. Improved roads in rural areas expand opportunities for non-farm activities and thereby lower rural poverty (Escobal and Ponce, 2008).

Among more recent studies on India, Chotia and Rao (2015) construct a Composite Infrastructure Index (CII), comprising transport, health education, agriculture and energy, and finds a negative correlation between poverty rate and the CII index for the majority of Indian states. Using primary data from 500 serviced and non-serviced slums interviewed across India, Parikh et al. (2015) find that infrastructure provision significantly improve the well-being of the slum dwellers and particularly of women.

3 Stylised facts: Inclusive Growth and Infrastructure

Given the benefits emanating from infrastructure development we present some key stylized facts. We use the infrastructure pillar of the Global Competitive Index to document the evolution of infrastructure across various economies. This measure encompasses various aspects of physical infrastructure like transport, electricity and communication. A higher value indicates a better quality of infrastructure. A comparison of India with the averages for other emerging markets and advanced economies is outlined in Figure 1.

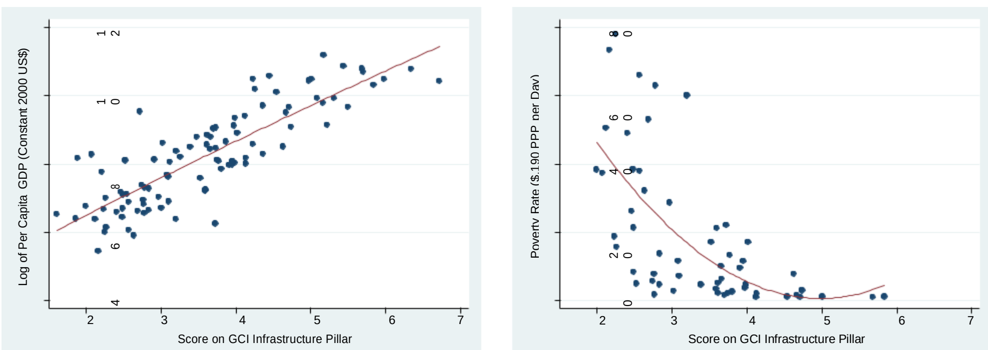
Figure 1: Evolution of Infrastructure



Source: Global Competitiveness Index, World Economic Forum and Authors' Estimates

As expected, the average value of the infrastructure pillar across advanced economies is significantly higher than that of the emerging economies, although it has increased only marginally during the last 10 years. On the other hand, emerging economies have witnessed a larger increase, mainly driven by strong performance by economies like Indonesia, Poland, Russia and Bangladesh. India, where infrastructure quality had stagnated after the Global Financial Crisis, witnessed a strong improvement since 2014, and breached the average for emerging markets.

Figure 2: Relation between Infrastructure and Inclusive Growth across Developing and Emerging Economies

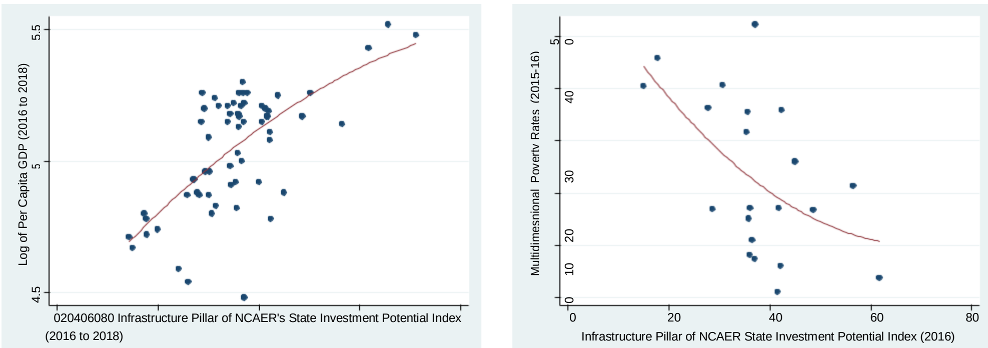


Source: Global Competitiveness Index, World Economic Forum; World Development Indicators, World Bank and Authors' Estimates

Next, we focus on the relationship between infrastructure development and higher and inclusive growth across the various emerging and other developing countries (Figure 2). Expectedly, better quality infrastructure is associated with improved economic outcomes like higher per capita GDP and lower poverty rates. However, this correlation does not indicate the direction of causation as the reverse channel, *i.e.*, richer countries would have resources to develop better quality infrastructure, can also be at play. The impact of building infrastructure on inclusive growth would have to be empirically verified and can differ across periods, countries and type of infrastructure.

A similar relationship can be observed among the Indian states. We use the infrastructure index developed in NCAER's State Investment Potential Index (N-SIPI). The infrastructure index covers 21 states and focuses on diverse metrics like road and rail density, cargo handled in airport and port, availability of ground water, bank branches, power tariff and shortages, readiness of ICT and presence of statutory towns. States, which rank well on the infrastructure index are also states with higher per capita income and lower poverty rates (Figure 3). [4]

Figure 3: Relation between Infrastructure and Inclusive Growth across Indian States



Source: State Investment Potential Index, National Council for Applied Economic Research; Oxford Poverty and Human Development Initiative and Authors' Estimates

Next we empirically evaluate the relationship of various infrastructure sectors *viz.* roads, electricity, education and health, with growth and poverty reduction. We combine the respective indicators for each infrastructure sector using Principal Component Analysis (PCA).[5] We find that the indicators for the electricity sector are non-stationary, hence use their growth rates for our analysis. [6] For the electricity sector, we consider two components that

[4] Given that national poverty rates are available only for 2011-12, we use the Multi- dimensional Poverty Index, which is available for 2015-16 and closer to the time period covered under N-SIPI index, i.e. 2016 to 2018.
[5] The variables used here and in subsequent sections are outlined in Table A.2
[6] Each indicator is normalised as a deviation from the respective minimum value and as a ratio of the deviation of it maximum and minimum values.

explain 73.5% of the variations in the indicators. In the literature, components with eigenvalue greater than 1 are generally retained following Kaiser rule (Nardo et al., 2005). In our analysis, we retain the eigenvalues less than 1 but greater than 0.99 (Table A.3). We find that in the electricity sector, installed capacity and energy sold are summarised into one component and availability of electricity creates another component (Table A.4). We create two sub-indices for this sector, one being the weighted average of installed capacity and energy sold, where the weights being the square of their respective loadings. The availability of electricity builds the second sub-index. Finally these two sub-indices are combined into one index as a weighted average of the two sub-indices, where the respective weights are the proportion of variations explained by the two retained components from the PCA analysis. This final index represents the change in the electricity infrastructure stock over time.

Figure 4 depicts a positive relation between average electricity infrastructures with average GSDP growth, while the top left panel of Figure 8 shows a co-moving relation of the two over time. The co-moving pattern between infrastructure stock and growth rate is further corroborated by high contemporaneous correlation between the two as shown in Table 1.

Figure 4: Relationship between Growth and Electricity Infrastructure

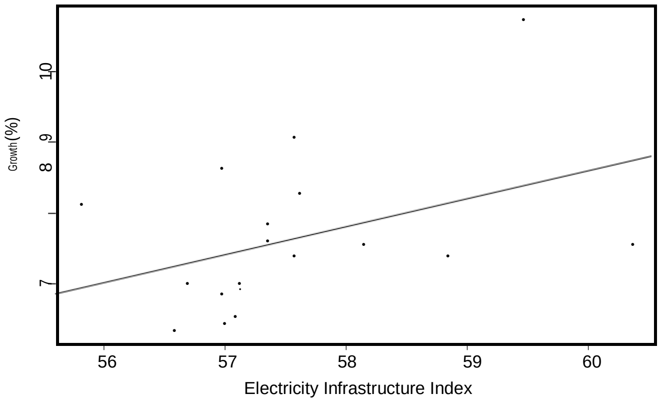
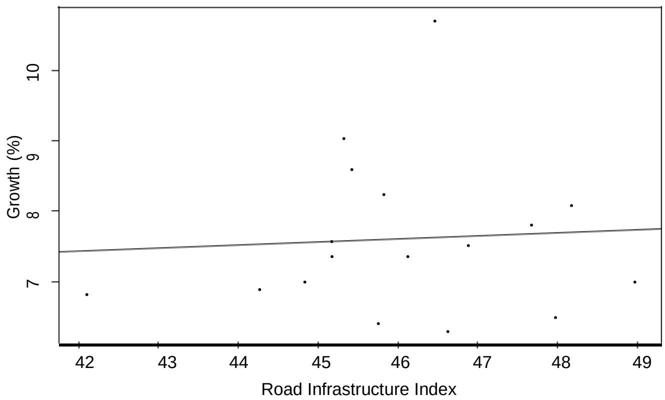


Figure 5: Relationship between Growth and Road Infrastructure



For the road sector also, we conduct PCA on the growth rate of the indicators to ensure stationarity. We retain two components with eigenvalue greater than 1 and explaining 72.3% of the variations in the data (Table A.3). For this sector, we find that national and state highways are summarised into one component, while other roads explain most of the other component (Table A.4). We create two sub-indices and finally combine them into one index using the same methodology described for the electricity sector. A mild positive relation exists between GSDP growth and change in road infrastructure (Figure 5). Road infrastructure is found to be mildly leading economic growth and at the same time also responds to growth with a lag of three years (top right panel of Figure 8 and Table 1).

For the education sector, we conduct PCA for changes in school density and teacher-student ratio in upper primary and secondary schools. We retain the component with eigenvalue greater than 1 explaining 41.8% of the variations in the data (Table A.3). We find that all the indicators explain the estimated component thereby giving a composite indicator of changes in the education infrastructure stock. We obtain a negative relationship between educational infrastructure and GSDP growth, which appears counterintuitive (Figure 6). We do not find any significant cross correlation pattern between the average education infrastructure index and average growth rates (bottom left panel of Figure 8 and Table 1).

Figure 6: Relationship between Growth and Education Infrastructure

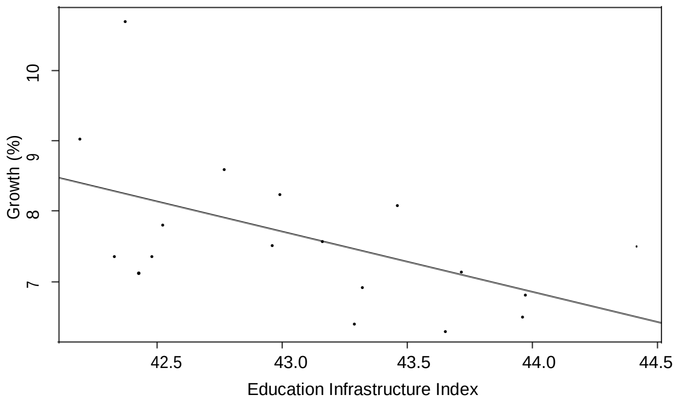
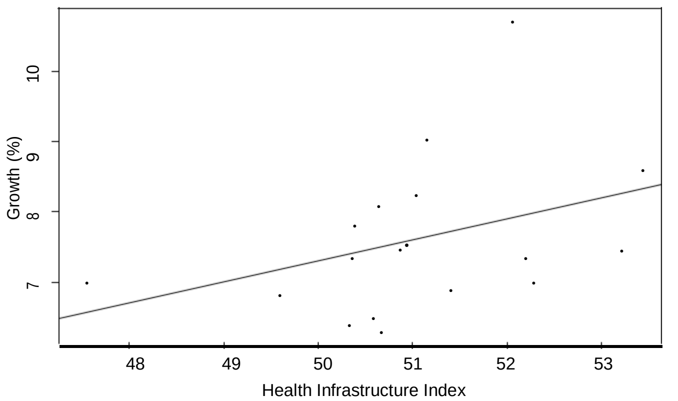
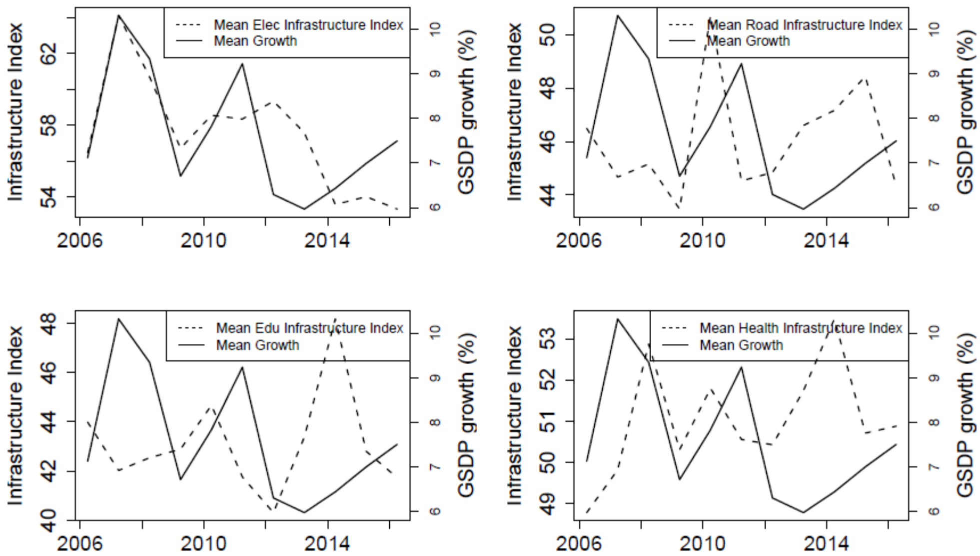


Figure 7: Relationship between Growth and Health Infrastructure



Finally, for the health sector we conduct PCA of Health Sub Centres (SC) density, Primary Health Centres (PHC) density, Community Health Centres (CHC) density, number of government hospitals per 10,000 sq. km (HOSP), number of government doctors available per 100,000 population, average number of people treated per government doctor, number of PHCs available for per 100,000 population and number of CHCs available for per 1 million population to derive a composite infrastructure index for the health sector.

Figure 8: Comovement of Infrastructure Indexes and GDP Growth



We find that SC density, PHC density and number of PHCs available per 100,000 population constitute component 1 (Table A.4). Component 2 is constructed by CHC density, and number of CHCs available per 1 million population; while HOSP density and number of doctors available per 100,000 population constitute component 3. Average number of people treated per government doctor majorly contributes to component 4. We create four sub-indices and finally combine them into one index. Figure 7 depicts a mild positive relation between average changes in the health infrastructure stocks with average GSDP growth. However, we do not find any significant correlation pattern between growth and health infrastructure (bottom right panel of Figure 8). From Table 1, we find that health infrastructure development follows GDP growth at a three period lag.

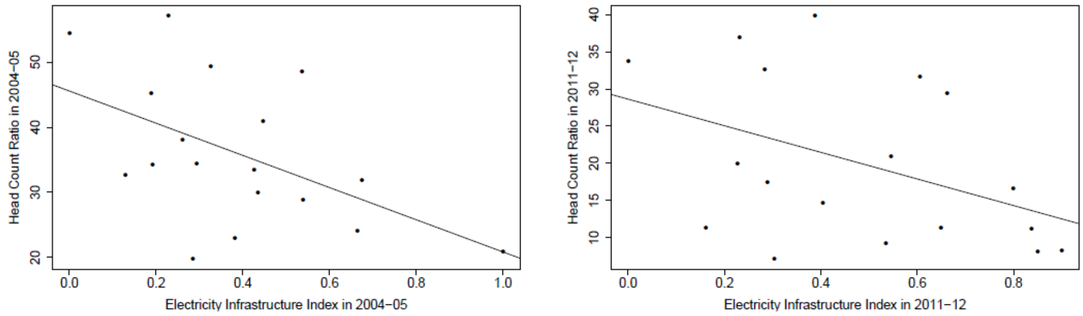
Table 1: Cross Correlation of Infrastructure Index and Economic Growth

Sector	Y(-5)	Y(-4)	Y(-3)	Y(-2)	Y(-1)	Y(0)	Y(+1)	Y(+2)	Y(+3)	Y(+4)	Y(+5)
Electricity	-0.333	0.123	0.103	-0.278	0.127	0.668	0.416	0.296	0.176	0.082	0.013
Road	0.141	-0.039	-0.132	-0.167	0.297	-0.215	-0.561	0.006	0.462	-0.085	-0.158
Education	0.141	-0.039	-0.132	-0.167	0.297	-0.215	-0.561	0.006	0.462	-0.085	-0.158
Health	-0.264	-0.271	0.262	-0.146	-0.399	-0.033	0.018	-0.129	0.400	-0.126	-0.215

Source: Authors' estimates

Next we highlight the relationship between poverty rate (percentage of population living in poverty) and infrastructure indexes. Figures 9, 10, 11 and 12 depict a negative relationship for both 2004-05 and 2011-12, indicating that states with better infrastructure also experienced low poverty rates.

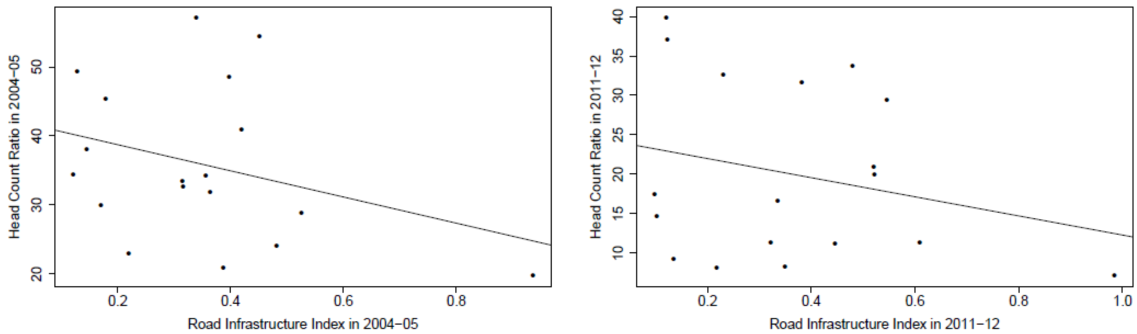
Figure 9: Poverty and Electricity Infrastructure



(a)2004-05 (b)2011-12

Source: Authors' estimates

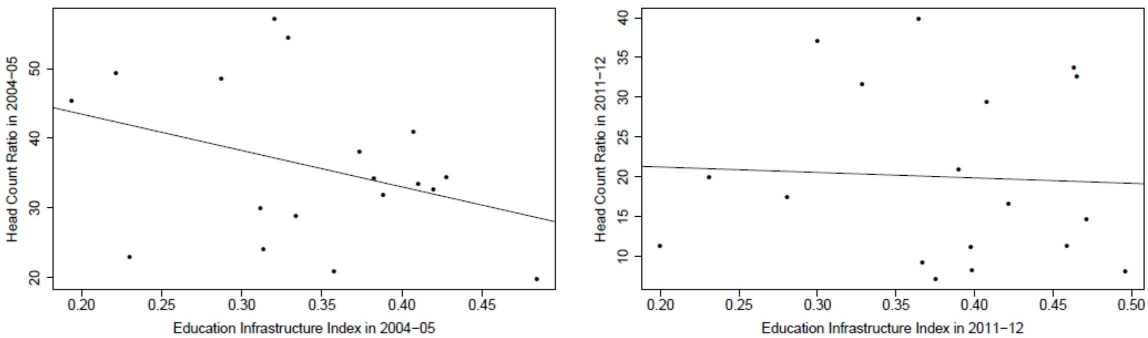
Figure 10: Poverty and Road Infrastructure



(a)2004-05 (b)2011-12

Source: Authors' estimates

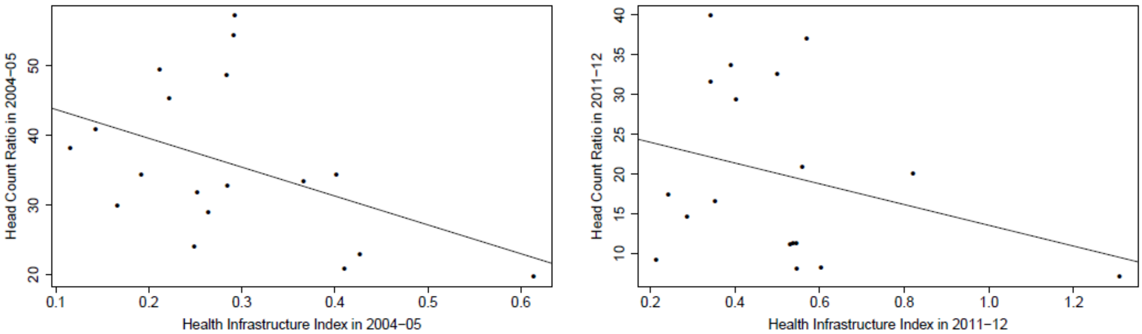
Figure 11: Poverty and Education Infrastructure



(a)2004-05 (b)2011-12

Source: Authors' estimates

Figure 12: Poverty and Health Infrastructure



(a)2004-05 (b)2011-12

Source: Authors' estimates

4 Estimation strategy

4.1 Economic Growth and Infrastructure

In this section we estimate the contribution of infrastructure development to output growth in an infrastructure-augmented aggregate production function framework following Calderon, Moral-Benito and Serven (2015). In this framework, aggregate output is produced using non-infrastructure physical capital, labour and infrastructure. Thus the underlying model of our empirical analysis is a production function of the form:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{1-\alpha-\gamma}Z_{it}^{\gamma} \qquad (1)$$

Where Y and K denote real output and capital stock; L represents labour and Z denotes infrastructure capital stock. Taking first difference of the log on both sides of the equation in per unit labour terms, the model is estimated in following growth form

$$\frac{\delta y_{it}/\delta t}{y_{it}} = \frac{\delta A_{it}/\delta t}{A_{it}} + \alpha\frac{\delta k_{it}/\delta t}{k_{it}} + \gamma\frac{\delta z_{it}/\delta t}{z_{it}} \qquad (2)$$

where y, k and z are respectively the real output, capital stock and infrastructure stock in per unit labour respectively. As the theoretical literature suggests, there can be endogeneity among economic growth and infrastructure capital generation, as higher economic growth allows the state to invest more on infrastructure capital, while that in turn boost economic growth via the positive externality effects. Again, there can be spillover effects of infrastructure development in one on the economic performance of the other states. To take into account the endogeneity and spillover effects, we estimate our model using the Panel Vector Auto Regression (PVAR) model as follows:

$$Y_{it} = A_0 + A(L)Y_{it} + v_i + \epsilon_{it}; \quad i = 1, \dots, N; T = 1, \dots, T_i \qquad (3)$$

where Y_{it} is the vector of endogenous variables as follows:

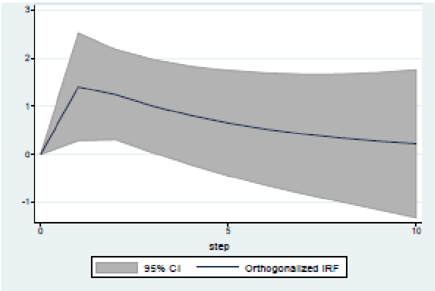
$$\begin{bmatrix} \Delta \log \text{Real GSDP per labour}_{it} \\ \Delta \log \text{Real capital stock per labour}_{it} \\ \Delta \log \text{Real composite infrastructure stock}_{Sit} \end{bmatrix}. \qquad (4)$$

where S ϵ (Electricity; Roads; Education; Health).

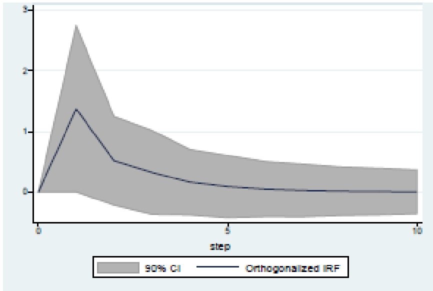
In equation (3), A_0 is a vector of constants, A(L) is a matrix polynomial in lag operator, v_i represents state-specific fixed effects. The idiosyncratic errors ϵ_{it} are assumed to follow white noise properties such that $E[\epsilon_{it}] = 0$;

$$E[\epsilon_{it}' \epsilon_{it}] = \sum; E[\epsilon_{it}' \epsilon_{it}] = 0 \text{ for all } t > s.$$

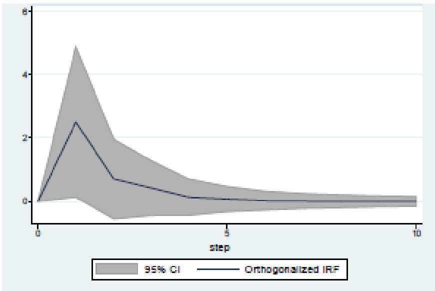
Figure 13: Response of Growth to infrastructure



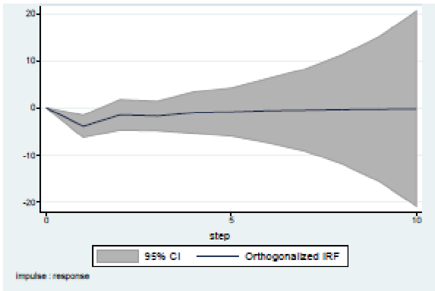
(a)Response of output growth to electricity infrastructure



(b)Response of output growth to road transport infrastructure



(c)Response of output growth to education infrastructure



(d)Response of output growth to health infrastructure

Source: Author's estimates

The model is estimated by system-GMM method using the lags of the endogenous variables as instruments (Holtz-Eakin, Newey and Rosen, 1988), after transforming the variables in the system using the Helmert procedure to remove the state-specific fixed effects (Arellano and Bover, 1995). The Helmert procedure is a forward mean-differencing method where the average of all available future observations is subtracted from the variable to be transformed.

The optimal lag order selection criteria (Moment and Model Selection Criteria or MMSC) for both panel VAR specification and moment condition for GMM models, analogous to standard AIC, BIC and HQIC following Andrews and Lu (2001) suggest a first order PVAR model with three lags for instruments for electricity, roads and health, and four lags for instruments for education (Table A.5). All eigenvalues of the PVAR models estimated for full and sub-samples lie within the unit circle, thus satisfying the stability condition of the models (Figure A.1 in Appendix B).

Figure 13 depicts the results of the impulse response analysis. The results suggests that one standard deviation shock to the yearly changes in infrastructure stock in electricity sector increases output growth by 1.4% immediately. The effect subsides in the subsequent years, but remains significant for a long period of time. One standard deviation shock to the yearly growth in road transport infrastructure increases output growth by 1.5% immediately, however the effect is transitory.

Yearly changes in the education infrastructure capital has the highest impact on output growth. One standard deviation shock to it causes output growth to rise immediately by 1.90%, although the effect is again transitory. We do not find any significant impact of health infrastructure on output growth. Theoretically, health infrastructure increases output growth by enhancing labour productivity (Agnor, 2008). However, empirical evidence on this issue is varied (Bedir, 2016; Ye and Zhang, 2018). In the context of India, both the studies find income growth Granger causes healthcare expenditure. Our work differs from the existing ones as we explore the effects of physical and quality aspects of health infrastructure on growth. A plausible reason for not finding a statistically significant growth rate impact may be that the physical and quality aspects of health infrastructure can enhance labour productivity sufficient to generate a growth rate effect only after a threshold level is attained.

The Forecast Error Variance Decomposition (FEVD) analysis suggests that variations in yearly growth of electricity infrastructure stock explains 11.5% of the variations in output growth after two years of the shock, while the contribution increases to 27.0% in the long run (Table 2). Again variations in output growth contribute 18.0% of the variations in the growth of electricity infrastructure.

Variations in growth of road infrastructure explains 7.0% of the variation in output growth after two years of the shock, and the contribution stabilises to 8.7% after eight years (Table 3). However, output growth does not seem to have significant contribution to growth in road infrastructure.

In the education sector, variations in infrastructure growth explains 17.7% of output variations after two years of the shock, while the effect stabilises at 18.5% after eight years (Table 4). Output growth seems to contribute to the variations in education infrastructure growth by 1.2% in the long run.

Table 2: FEVD Analysis: Model with Electricity Infrastructure

Response variable	Forecast horizon	Impulse variable		
		Real output per labour growth	Real capital per labour growth	Electricity infras-Tructure Growth
Real output per labour growth	1	1	0	0
	2	.8740956	.0106005	.115304
	4	.763674	.0174406	.2188854
	8	.7136655	.0206371	.2656974
	10	.7081222	.0209923	.2708855
Real capital per labour growth	1	.0894901	.9105098	0
	2	.1154214	.7638225	.1207561
	4	.1264846	.6864505	.1870649
	8	.1324128	.6455665	.2220206
	10	.7081222	.0209923	.2708855
Electricity infrastructure Growth	1	.1382354	.0611696	.8005949
	2	.1663224	.0572852	.7763923
	4	.1812977	.0559346	.7627677
	8	.1867533	.0554136	.7578331
	10	.1873179	.0553595	.7573227

Source: Authors' estimates

Table 3: FEVD Analysis: Model with Road Infrastructure

Response variable	Forecast horizon	Impulse variable		
		Real output per labour growth	Real Capital per labour growth	Road transport infrastructure Growth
Real output per labour growth	1	1	0	0
	2	.9189529	.0020959	.0789511
	4	.911456	.0021205	.0864234
	8	.910692	.0021282	.0871798
	10	.910687	.0021283	.0871848
Real capital per labour growth	1	.0875772	.9124228	0
	2	.3100385	.6796955	.010266
	4	.3306476	.6189018	.0504505
	8	.333376	.614899	.0517251
	10	.3333946	.6148747	.0517307
Road transport infrastructure growth	1	.0004265	.0001768	.9993966
	2	.0042384	.0002934	.9954682
	4	.005544	.0002963	.9941597
	8	.0056595	.0002966	.9940439
	10	.0056602	.0002966	.9940432

Source: Authors' estimates

Table 4: FEVD Analysis: Model with Education Infrastructure

Response variable	Forecast horizon	Impulse variable		
		Real output per labour growth	Real Capital per labour growth	Education infrastructure Growth
Real output per labour growth	1	1	0	0
	2	.8232465	6.74e-06	.1767468
	4	.8149635	.0001815	.184855
	8	.8146834	.000186	.1851306
	10	.8146831	.000186	.1851309
Real capital per labour growth	1	.0378239	.9621761	0
	2	.2982891	.6430753	.0586356
	4	.2821641	.5218629	.195973
	8	.2820545	.5191972	.1987483
	10	.2820547	.5191952	.19875
Education infrastructure growth	1	.0023391	.0008496	.9968113
	2	.0105234	.0021438	.9873328
	4	.0120525	.0024707	.9854768
	8	.0121031	.002478	.9854189
	10	.0121032	.002478	.9854189

Source: Authors' estimates

Table 5: FEVD Analysis: Model with Health Infrastructure

Response variable	Forecast horizon	Impulse variable		
		Real output per labour growth	Real Capital per labour growth	Health infrastructure Growth
Real output per labour growth	1	1	0	0
	2	.6766892	.0067305	.3165803
	4	.6316746	.0282149	.3401105
	8	.6157658	.0327495	.3514848
	10	.6146052	.0329829	.352412
Real capital per labour growth	1	.4609979	.5390022	0
	2	.3487112	.3492687	.3020201
	4	.3613759	.3228377	.3157864
	8	.3654425	.3094492	.3251083
	10	.3656762	.3083686	.3259552
Health infrastructure growth	1	.0155547	.0042758	.9801695
	2	.1276915	.0630243	.8092843
	4	.1554708	.0626319	.7818972
	8	.1673613	.0622263	.7704123
	10	.1682715	.0622384	.7694901

Source: Authors' estimates

Finally, in the case of health infrastructure, the FEVD analysis suggests that one standard deviation increase in the stock of composite health infrastructure index contributes to 35.0% of the variations in output growth in the long run, while, output growth contributes to around 17.0% of the variations in generation of health infrastructure in the long run (Table 5).

4.2 Poverty and Infrastructure

We also evaluate the effect of infrastructure generation on poverty reduction. However, given that poverty data in India is available for a limited number of years, we are constrained in our empirical approach. We investigate the relationship between poverty rate and infrastructure development across the four sectors for 2004-05 and 2011-12.[7] Studies like Ravi and Engler (2015) and Dreze and Khera (2013) argue that the introduction and expansion of social protection programs like MGNREGA and PDS have also been identified as reducing poverty by increasing the monthly per capita expenditure. We control for the effect of these two programs by taking in to account the MGNREGA expenditure per rural poor and percentage of household using PDS in the state.

The following model is estimated

$$Y_{it} = \alpha + \beta\Gamma_{it}^{j} + \alpha\theta_{it}^{k} + \epsilon_{it} \quad (5)$$

where y_{it} denotes poverty rate of i^{th} state in year t. Here Γ_{it}^{j} denotes the infrastructure index in j^{th} sector, in i^{th} state in year t, where j ϵ (Electricity; Road; Education; Health). θ_{it}^{k} denotes k^{th} welfare program in i^{th} state in year t where k ϵ (MGNREGA; PDS).

Table 6 outlines the results. Columns (I) to (IV) highlight the extent to which individual infrastructure indexes impact poverty rate while controlling for MGNREGA expenditure and households covered by PDS. In Column (V) we include all four infrastructure indexes. When considered individually, electricity index and health index have a strong negative effect on the poverty rate indicating that building electricity and health infrastructure can significantly contribute to poverty reduction. Education infrastructure has a weaker effect on poverty reduction with the effect being significant only at 15%. We do not find any significant impact of road infrastructure development on poverty reduction. MGNREGA expenditure per rural poor is also an important factor in reducing poverty although the effect is not very strong across all specifications. Similarly, while a rise in percentage of households assists in poverty reduction the effect is relatively weak. In Column (V) we look at the combined effect of the different infrastructure indexes. Electricity and health infrastructure continue to strongly aid poverty reduction while education has a weak affect.

[7] State level poverty rates based on national poverty lines is available for 2004-05, 2009-10 and 2011-12. However, since 2009-10 is recognized as a drought year, poverty rates are unlikely to be accurately captured in that year.

The impact of the two social welfare indicators turns insignificant in this specification.

Table 6: Relationship between Poverty Rate and Infrastructure Stock

	I	II	III	IV	V
Constant	44.203***	38.843***	46.983***	42.375***	58.815***
	[8.964]	[7.267]	[5.963]	[9.376]	[7.134]
Electricity Index	-19.665**				-21.279***
	[-2.304]				[-2.685]
Road Index		-4.066			10.375
		[-0.349]			[0.937]
Education Index			-28.971+		-27.786+
			[-1.403]		[-1.475]
Health Index				-19.372*	-28.610***
				[-1.902]	[-2.642]
MNREGA Expd. per Rural Poor	-0.002* [-1.806]	-0.003** [-2.120]	-0.003** [-2.256]	-0.002+ [-1.410]	-0.001 [-0.677]
Percentage of Household Availing PDS	-0.145+ [-1.503]	-0.184* [-1.788]	-0.156+ [-1.549]	-0.133 [-1.320]	-0.081 [-0.891]

Note: z-statistics in brackets; *** p<0.01, ** p<0.05, * p<0.1, + p<0.15
Source: Authors' estimates

One of our key finding is that health infrastructure significantly reduces the poverty rate. Thus improved physical and quality of health infrastructure enhances labour productivity to raise level of income and consumption that is sufficient to transit from below to over the poverty line.

5 Conclusion

India experienced one of the fastest pace of economic growth since 2004. This period also witnessed a sharp drop in poverty rates with the absolute number of poor people declining by close to 200 million. During this period, the ratio of infrastructure investment to GDP increased steadily, peaking at over 8.0% in 2010-11. In this paper, we evaluate the role played by infrastructure development in raising economic growth and facilitating poverty reduction by focusing on infrastructure development across electricity, roads, health and education sectors in 18 major Indian states. We find that development of electricity, roads and education infrastructure has a positive and significant impact on economic growth. While education infrastructure has the strongest impact on economic growth, the impact of electricity infrastructure is more persistent. The impact of health infrastructure on growth is insignificant, which can be due to the fact health infrastructure is able to enhance labour productivity sufficient to generate a growth rate effect only after a threshold level is attained. Our analysis of the linkage between building infrastructure and poverty reduction indicates that improvement in health and electricity infrastructure has a strong impact on poverty reduction. While developing education infrastructure aids poverty reduction, the impact is significant only at 15% level.

Given our finding that infrastructure augments economic growth and helps in poverty reduction, it would be imperative for India to bridge the infrastructure deficit as it strives to become a $10 trillion economy and eliminate poverty. This would require a multi-pronged approach. Efforts would have to be undertaken to increase finance available for infrastructure, ease regulatory burden that constrain infrastructure investment and improve the capacity at the planning and implementation level.

In India, public investment will remain a major source of infrastructure finance given the massive need for infrastructure investment in geographically remote and backward locations and social sectors, where private participation is difficult to be realized. However, public investment remains constrained by resources, thereby necessitating the need to raise more revenue and encourage private investment or public-private partnerships (PPP) wherever possible. India's tax to GDP ratio remains relatively low compared to other countries with similar per capita income. Thus there is a possibility of raising this ratio by (a) improving compliance; (b) rationalizing the tax structure; (c) reducing exemptions and (d) widening the tax base. This is likely to provide additional fiscal space to enhance infrastructure spending. Given the federal structure in India, it is also imperative to mobilize resources at the subnational level by improving efficiency of tax collection and collecting financially viable user charges. More municipal bodies should be encouraged and strengthened to float bonds to raise funds for infrastructure investment. Various credit rating agencies can rate municipalities in a transparent manner for investor satisfaction. Furthermore, strengthening of capital markets is a prerequisite for greater market-based financing, given the current stress in the Indian banking system.

Even after improving the quality of expenditure and generating additional fiscal space, the public sector is unlikely to have resources that would bridge the large infrastructure gap. Hence it is necessary for the private sector to step in, especially in sectors like toll roads, telecom, airports etc. where it is feasible to recover infrastructure investment costs through user charges. For this, the government needs to facilitate an ecosystem that is conducive for PPPs. Measures to revive and accelerate private infrastructure investment can include (a) adoption of a wider array of PPP models with nuanced risk sharing, (b) encouraging states to right-price infrastructure services, and (c) preparing a pipeline of bankable projects.

In addition to improving the availability of funds, there is a need to alleviate the regulatory constraints that impede infrastructure projects. Land acquisition remains a major roadblock for infrastructure development due to poorly planned rehabilitation packages and time and cost overrun in acquiring land. A transparent, balanced and consistent land-acquisition process is essential for a healthy infrastructure market. Slow and cumbersome environmental and forest clearance processes have also delayed infrastructure development. A complex and protracted procedures, for securing approvals across different stage of the project cycle from multiple layers of the government, also create serious disincentives for developers. Thus, there is a need for policies that can fasten these processes ensuring adequate safeguards for the various stakeholders.

Finally, weak institutional capacity at the project designing level results in few bankable projects being available. The problem is exacerbated with the lack of capacity at the level of implementation, which results in sub-optimal outcomes and low returns on investment. Thus, there is a need to re-skill project developers at the local levels.

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A Appendix A

Table A.1: Selected States and Share in Output, Population and Number of Poor

States	Share in Output (Constant Prices) 2015-16	Share in Output (Current Prices) 2015-16	Share in Population 2011	Share of Population in Poverty 2011-12	Share in Workforce 2015-16
Andhra Pradesh	8.6%	8.5%	7.0%	2.9%	8.6%
Bihar	2.7%	2.6%	8.6%	13.3%	7.2%
Chhattisgarh	1.7%	1.7%	2.1%	3.9%	2.8%
Gujarat	7.5%	7.9%	5.0%	3.8%	5.0%
Haryana	3.6%	3.6%	2.1%	1.1%	2.0%
Himachal Pradesh	0.8%	0.8%	0.6%	0.2%	0.5%
Jharkhand	1.5%	1.5%	2.7%	4.6%	3.2%
Karnataka	7.6%	7.3%	5.0%	4.8%	5.9%
Kerala	4.1%	4.0%	2.8%	0.9%	2.8%
Madhya Pradesh	3.9%	3.7%	6.0%	8.7%	5.2%
Maharashtra	14.3%	14.5%	9.3%	7.3%	10.0%
Odisha	2.4%	2.6%	3.5%	5.1%	3.6%
Punjab	2.8%	2.9%	2.3%	0.9%	2.0%
Rajasthan	4.9%	5.0%	5.7%	3.8%	5.8%
Tamil Nadu	8.5%	8.5%	6.0%	3.1%	7.2%
Uttar Pradesh	8.3%	8.0%	16.5%	22.2%	13.9%
Uttarakhand	1.3%	1.3%	0.8%	0.4%	0.7%
West Bengal1	5.8%	5.4%	7.5%	6.9%	8.0%
Total (18 States)	90.2%	89.8%	93.4%	93.8%	94.3%

Source: Handbook of Statistics on Indian States, Reserve Bank of India; National Sample Survey Organisation (Various Surveys); Labour Bureau and Authors' Estimates

Table A.2: Key Data and Sources

Variable	Source
Gross State Domestic Product (Constant Prices)	Handbook of Statistics on Indian States, Reserve Bank of India (Various Issues)
Gross State Domestic Product (Current Prices)	Handbook of Statistics on Indian States, Reserve Bank of India (Various Issues)
Stock of Physical Capital	Handbook of Statistics on Indian States, Reserve Bank of India (Various Issues)
GDP De ator	Handbook of Statistics on Indian States, Reserve Bank of India (Various Issues)
Labour Force	61st, 66th and 68th round Survey on Employment and Unemployment, National Sample Survey Organisation
Workforce	61st, 66th and 68th round Survey on Employment and Unemployment, National Sample Survey Organisation
Population	Registrar General of India
Poverty Rates	Planning Commission
Installed Energy Capacity (Mega Watt)	TERI Energy and Environment Data Directory and Yearbook (Various Issues)
Availability of Electricity (Million Unit)	TERI Energy and Environment Data Directory and Yearbook (Various Issues)
Energy Sold to Consumer (Giga Watt Hours)	TERI Energy and Environment Data Directory and Yearbook (Various Issues)
Length of National Highways (Km)	Handbook of Statistics on Indian States, Reserve Bank of India (Various Issues)
Length of State Highways (Km)	Handbook of Statistics on Indian States, Reserve Bank of India (Various Issues)
Other Roads (Km)	Handbook of Statistics on Indian States, Reserve Bank of India (Various Issues)
Number of Schools	Department of Higher Education, Government of India
Number of Teachers in Upper Primary Schools	Department of Higher Education, Government of India
Number of Students in Upper Primary Schools	Department of Higher Education, Government of India
Number of Teachers in Secondary Schools	Department of Higher Education, Government of India
Number of Students in Secondary Schools	Department of Higher Education, Government of India
Number of Health Sub Centres	Rural Health Statistics in India (Various Issues) and CEIC Databases
Number of Primary Health Centres	Rural Health Statistics in India (Various Issues) and CEIC Databases
Number of Community Health Centres	Rural Health Statistics in India (Various Issues) and CEIC Databases
Number of Government Hospitals	Rural Health Statistics in India (Various Issues) and CEIC Databases
Number of Registered Government Doc tors	Rural Health Statistics in India (Various Issues) and CEIC Databases

Table A.3: Results from PCA Analysis: Eigenvalues and Contribution in Variations

Sector	Component	Eigen value	Proportion of variation explained	Cumulative proportion of variation explained
Electricity	Comp1	1.207946	0.3908	0.3908
	Comp2	.997744	0.3444	0.7352
	Comp3	.7943102	0.2648	1.0000
Road transport	Comp1	1.13634	0.3788	0.3788
	Comp2	1.03139	0.3438	0.7226
	Comp3	.832263	0.2774	1.0000
Education	Comp1	1.25434	0.4181	0.4181
	Comp2	.911134	0.3037	0.7218
	Comp 3	.834524	0.2782	1.0000
Health	Comp 1	2.84791	0.3560	0.3560
	Comp 2	1.52909	0.1911	0.5471
	Comp 3	1.05832	0.1323	0.6794
	Comp 4	.994829	0.1244	0.8038
	Comp5	.8646	0.1081	0.9118
	Comp6	.516814	0.0646	0.9764
	Comp7	.131617	0.0165	0.9929
	Comp8	.056817	0.0071	1.0000

Source: Authors' Estimates

Table A.4: Scoring Coefficients for Orthogonal Varimax Rotation Sum of Squares (column-loading) = 1

Sector	Variable	Comp1	Comp2	Comp3	Comp4
Electricity	Installed capacity	0.7634	0.2056		
	Availability	0.0283	0.9364		
	Energy sold	0.6453	-0.2843		
Road transport	Other roads	-0.0055	0.9168		
	National highways	0.7155	-0.2753		
	State highways	-0.6986	-0.2892		
Education	School density	0.5711			
	Up prim teacher-student ratio	0.5309			
	Sec teacher-student ratio	-0.6261			
Health	SC density	0.4849	0.0345	-0.2557	-0.0173
	PHC density	0.5482	-0.1810	0.0356	-0.0158
	CHC density	-0.0764	0.6551	-0.0179	0.0023
	HOSP density	-0.1477	-0.1474	0.7355	-0.1231
	Share of doctors in POP	0.2815	0.2270	0.6229	0.1615
	POP treated/Doctor	-0.0140	-0.0174	-0.0118	0.9758
	PHC availability	0.5969	0.0435	0.0614	-0.0519
	CHC availability	0.0304	0.6793	-0.0130	-0.0579

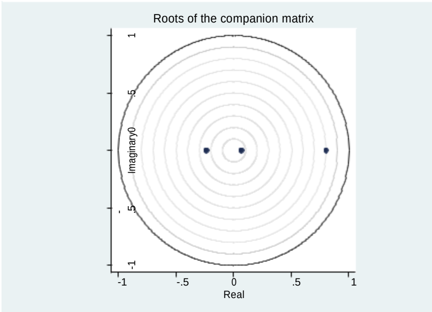
Source: Authors' Estimates

Table A.5: Results of lag order selection test

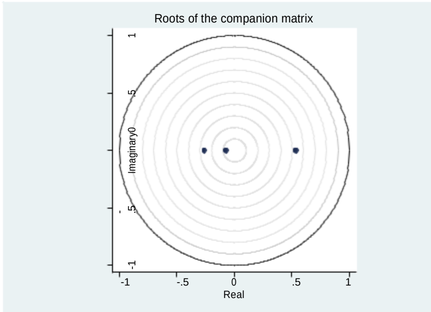
	Electricity		Road transport		Education		Health	
Statistic	Lag 1	Lag 2	Lag 1	Lag 2	Lag 1	Lag 2	Lag 1	Lag 2
MBIC	-59.998	-26.974	-65.797	-34.623	-73.081	-34.811	-93.739	-63.805
MAIC	-8.945	-1.447	-14.744	-9.096	-22.028	-9.285	21.321	-15.526
MQIC	-29.687	-11.818	-35.485	-19.467	-42.770	19.656	-50.684	-35.101

Source: Authors' Estimates

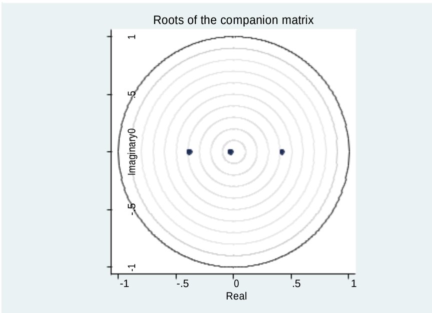
Figure A.1: Stability of estimated PVAR models



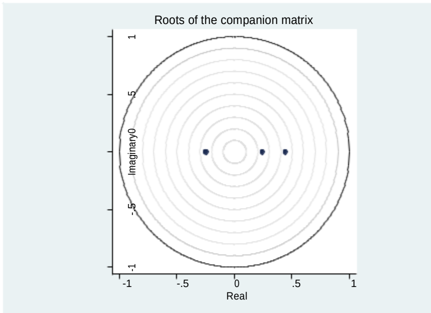
(a)Stability condition for model with Electricity infrastructure



(b)Stability condition for model with Road transport infrastructure



(c)Stability condition for model with Education infrastructure



(d)Stability condition for model with Health infrastructure

Source: Authors' Estimates

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